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Research Report

Forest condition in Europe: 2011 technical report of ICP Forests and FutMon

Work Report, No. 2011/1

Provided in Cooperation with:
Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries

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International Co-operative Programme on
Assessment and Monitoring of Air Pollution
Effects on Forests (ICP Forests)

Further development and implementation of
an EU-level Forest Monitorng System
(FutMon)

Forest Condition
in Europe

2011 Technical Report of ICP Forests and FutMon

Work Report of the:

Johann Heinrich von Thünen-Institute
Institute for World Forestry

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Forest Condition in Europe

2011 Technical Report of ICP Forests and FutMon

Richard Fischer, Martin Lorenz (eds.)

Work report of the Institute for World Forestry 2011 / 1

Hamburg, June 2011

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

Further development and implementation of an EU-level Forest Monitorng System (FutMon)
www.futmon.org

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www.futmon.org

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Cover photos: Dan Aamlid (landscape, top), Richard Fischer (middle) Silvia Stofer (bottom)

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Preface

Forests provide a wealth of benefits to the society but are at the same time subject to numerous natural and anthropogenic impacts. For this reason several processes of international environmental and forest politics were established and the monitoring of forest condition is considered as indispensable by the countries of Europe. Forest condition in Europe has been monitored since 1986 by the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in the framework of the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). The number of countries participating in ICP Forests has meanwhile grown to 41 including Canada and the United States of America, rendering ICP Forests one of the largest biomonitoring networks of the world. ICP Forests has been chaired by Germany from the beginning on. The Institute for World Forestry of the Johann Heinrich von Thünen-Institute (vTI) hosts the Programme Coordinating Centre (PCC) of ICP Forests.

Aimed mainly at the assessment of effects of air pollution on forests, ICP Forests provides scientific information to CLRTAP as a basis of legally binding protocols on air pollution abatement policies. For this purpose ICP Forests developed a harmonised monitoring approach comprising a large-scale forest monitoring (Level I) as well as a forest ecosystem forest monitoring (Level II) approach laid down in the ICP Forests Manual. The participating countries have obliged themselves to submit their monitoring data to PCC for validation, storage, and analysis. The monitoring, the data management and the reporting of results used to be conducted in close cooperation with the European Commission (EC). EC co-financed the work of PCC and of the Expert Panels of ICP Forests as well as the monitoring by the EU-Member States until 2006.

While ICP Forests - in line with its obligations under CLRTAP - focuses on air pollution effects, it delivers information also to other processes of international environmental politics. This holds true in particular for the provision of information on several indicators for sustainable forest management laid down by Forest Europe (FE). The monitoring system offers itself for being further developed towards assessments of forest information related to carbon budgets, climate change, and biodiversity. This is accomplished by means of the project “Further Development and Implementation of an EU-level Forest Monitoring System” (FutMon). FutMon is carried out from January 2009 to June 2011 by a consortium of 38 partners in 23 EU-Member States, is also coordinated by the Institute for World Forestry of vTI, and is co-financed by EC under its Regulation “LIFE+”. FutMon revises the monitoring system in close cooperation with ICP Forests. It establishes links between large-scale forest monitoring and National Forest Inventories (NFIs). It increases the efficiency of forest ecosystem monitoring by reducing the number of plots for the benefit of a higher monitoring intensity per plot. This is reached by means of a higher number of surveys per plot and newly developed monitoring parameters adopted by ICP Forests for inclusion into its Manual. Moreover, data quality assurance and the database system are greatly improved.

Given the current cooperation between ICP Forests and FutMon, the present Technical Report is published as a joint report of both of them.

Part I

INTRODUCTION

1. Background, set-up and current state of the ICP Forests and FutMon monitoring system

Martin Lorenz[1] *and Oliver Granke*[1]

1.1 Background

Forest monitoring in Europe has been conducted for 26 years according to harmonised methods and standards by the International Cooperative Programme on Assessment and Monitoring of Air Pollution effects on Forests (ICP Forests) of the Convention on Long-range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). The monitoring results meet the scientific information needs of CLRTAP for clean air policies under UNECE. According to its strategy for the years 2007 to 2015, ICP Forests pursues the following two main objectives:

1. To provide a periodic overview of the spatial and temporal variation of forest condition in relation to anthropogenic and natural stress factors (in particular air pollution) by means of European-wide (transnational) and national large-scale representative monitoring on a systematic network (monitoring intensity Level I).
2. To gain a better understanding of cause-effect relationships between the condition of forest ecosystems and anthropogenic as well as natural stress factors (in particular air pollution) by means of intensive monitoring on a number of permanent observation selected in most important forest ecosystems in Europe (monitoring intensity Level II).

The complete methods of forest monitoring by ICP Forests are described in detail in the “Manual on methods and criteria for harmonised sampling, assessment, monitoring and analysis of the effects of air pollution on forests” (ICP Forests 2010). For many years forest monitoring according to the ICP Forests Manual was conducted jointly by ICP Forests and the European Commission (EC) based of EU-cofinancing under relevant Council and Commission Regulations. The monitoring results are also delivered to processes and bodies of international forest and environmental policies other than CLRTAP, such as Forest Europe (FE), the Convention on Biological Diversity (CBD) the UN-FAO Forest Resources Assessment (FRA), and EUROSTAT of EC. In order to better meet the new information needs with respect to carbon budgets, climate change, and biodiversity, the forest monitoring system was further developed in the years 2009 to 2011 within the project “Further Development and Implementation of an EU-level Forest Monitoring System” (FutMon) under EU-cofinancing. The following chapters describe briefly the selection of sample plots and the surveys on the revised Level I and Level II monitoring networks.

1.2 Large-scale forest monitoring (Level I)

The large-scale forest monitoring grid consists of more than 7500 plots. The selection of Level I plots is within the responsibility of the participating countries, but the density of the plots should resemble that of the previous 16 x 16 km grid. For this reason, the number of

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plots in each country should be equal to the forest area of the country (in km^2) divided by 256. For each country the number of those Level I plots on which crown condition was assessed within the last years is provided in Table 3-1 of Chapter 3. The spatial distribution of those plots is shown in the map in Annex I of Chapter 3.

Of all countries participating in ICP Forests, 23 EU-Member States participated in FutMon. One of the aims of FutMon was fostering synergies between Level I and other large-scale grids, mainly the National Forest Inventories (NFIs). By the end of FutMon in June 2011, 58% of the Level I plots in the EU-Member States were coincident with NFI plots. No coincidence with NFI plots was given for 29% of the plots. It is expected, however, that a number of countries will merge these plots with NFI plots at a later date. For the remaining plots no information was made available (Fig. 1-1).

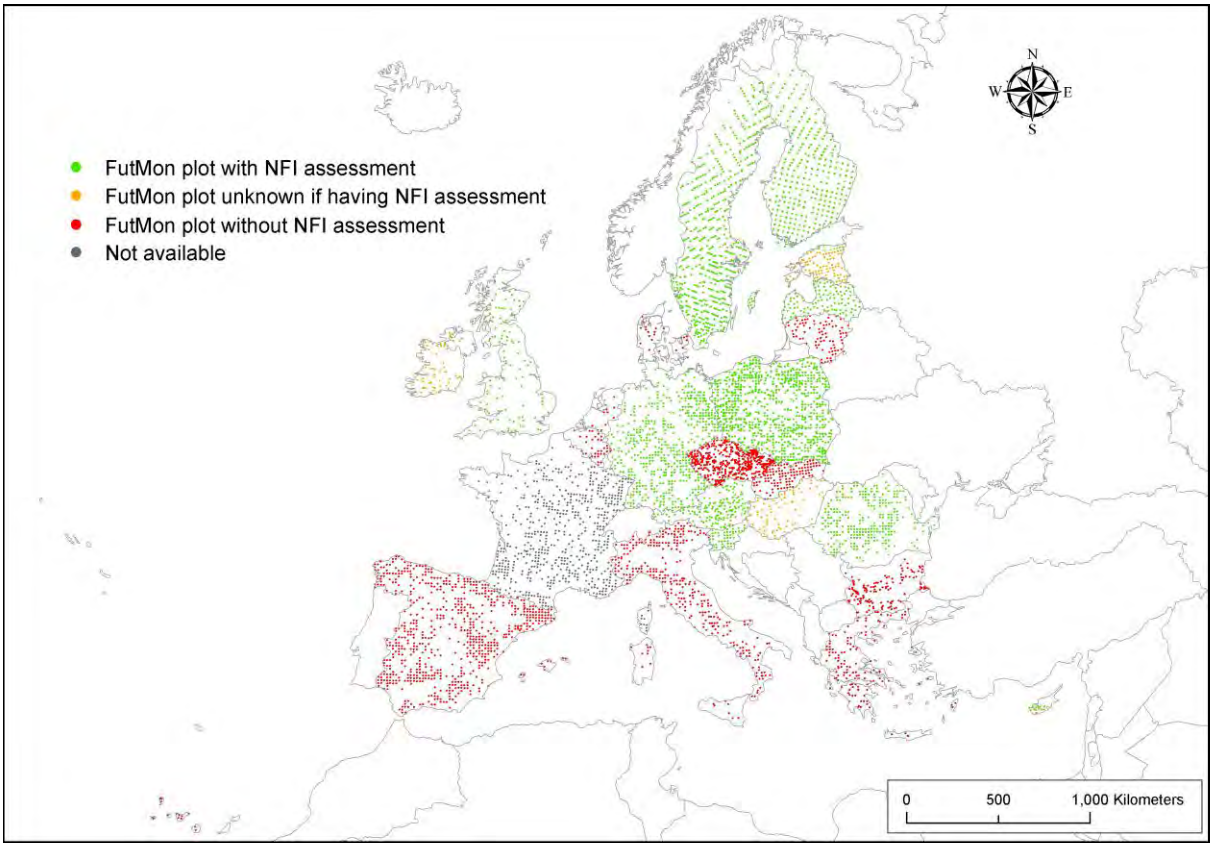

Figure 1-1: Spatial distribution of the large-scale plots under FutMon. Green colour implies a coincidence with NFI plots.

On most of the Level I plots tree crown condition is assessed every year. In 1995, element contents in needles and leaves were assessed on about 1500 plots and a forest soil condition survey was carried out on about 3500 plots. The Level I soil condition survey was repeated on about 5300 plots in 2005 and 2006 and the species diversity of forest ground vegetation was assessed on about 3400 plots in 2006 under the Forest Focus Regulation of EC within the BioSoil project (Fig. 1-2).

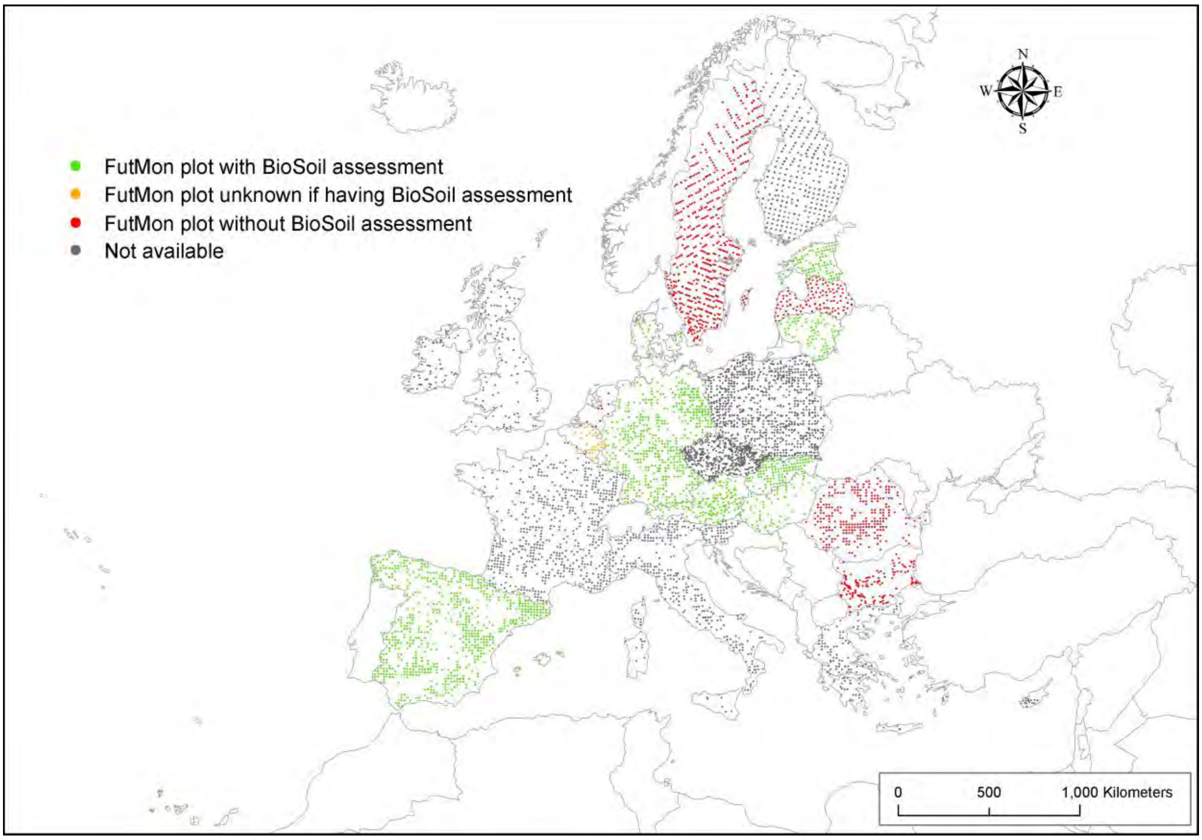

Figure 1-2: Spatial distribution of the large-scale plots under FutMon. Green colour implies inclusion in the BioSoil project under the Forest Focus Regulation of EC.

1.3 Intensive forest monitoring (Level II)

Intensive monitoring in 2009 comprised up to 17 surveys on different numbers of Level II plots depending on the survey (Tab. 1-1). Of these surveys many are not conducted continuously or annually, but are due only every few years. Moreover, on most plots only part of the surveys can be conducted. The fragmentary coverage of the plots by important surveys constituted a major problem for data analyses.

One of the aims of FutMon was to bundle resources and to reduce the number of Level II plots for the benefit of higher numbers of surveys per plot. For each survey Table 1-1 shows the number of plots from which data were submitted in 2009. Installed plots comprise ethose from which data are available in the data base. The map in Figure 1-3 shows those plots on which crown condition was assessed in 2009, coming close to the total of all Level II plots assessed in 2009. Moreover, the map indicates the locations of Level II plots of previous years.

Table 1-1: Surveys, numbers of Level II plots and assessment frequencies in 2009

Survey	Data submitted for 2009	Plots installed	Assessment frequency
Crown condition	559	938	Annually
Foliar chemistry	308	859	Every two years
Soil condition	68	753	Every ten years
Soil solution chemistry	196	338	Continuously
Tree growth	256	820	Every five years
Deposition	287	654	Continuously
Ambient air quality (active)	28	46	Continuously
Ambient air quality (passive)	167	377	Continuously
Ozone induced injury	123	188	Annually
Meteorology	210	327	Continuously
Phenology	188	240	Several times per year
Ground vegetation	169	815	Every five years
Litterfall	162	276	Continuously
Nutrient budget of ground vegetation	83	83	Once
Leaf Area Index	107	107	Once
Soil Water	46	46	Once
Extended Tree Vitality	115	115	Annually/ Continuously

Within FutMon Action “Intensive Monitoring 1” an increased set of surveys was bundled on so-called “IM1 plots”. Based on the experiences and outcome of FutMon the ICP Forests manual update 2010 refers to and explicitly specifies variables to be assessed on Level II standard plots. With a few changes and amendments Level II standard plots comprise the set of “IM1” surveys. Table 1-2 identifies the surveys conducted on those 252 “IM1” plots as well as the numbers of plots installed in each country. On part of these plots FutMon conducted demonstration actions D1, D2 and D3. For each of these demonstration actions Table 1-2 identifies the respective additional surveys. The ICP Forests manual update 2010 refers to and explicitly specifies variables to be assessed on Level II core plots. With a few changes and amendments Level II core plots comprise the set of “IM1+D1+D2+D3” surveys. There are approximately 100 plots on which all three demonstration actions are carried out. The plots largely corresond to Level II core plots.

In summing up, about 100 Level II core plots comprise practically all surveys and constitute a subsample of 252 Level II standard plots. The standard plots have an increased set of surveys and constitute a subsample of the total of more than 900 Level II plots. The remaining of those more than 900 plots have smaller sets of surveys with different combinations.

Figure 1-3: Level II plots with crown condition assessments in 2009. Also shown are plots with other surveys and of previous years.

Table 1-2: Numbers of plots in each country with FutMon intensive monitoring (IM1) and demonstration actions D1, D2 and D3 during the FutMon project period (2009-2011)

Country	2009-2011			
	IM1*	D1**	D2^{+}	D3^{++}
Austria	15	6	6	6
BE-Flanders	5	5	5	5
Bulgaria	3		3	
Cyprus	2			
Czech Republic	14	4	10	10
Denmark	6	3	6	6
Estonia	7		5	
Finland	18	18	18	18
France				
Germany	44	37	44	36
Greece	4	3	3	3
Hungary	8	8	2	
Ireland	3	3	3	
Italy	22	5	22	5
Latvia	1			
Lithuania				
The Netherlands	5			
Poland	12			
Romania	4	4	4	4
Slovakia	8	4	4	4
Slovenia	10	6	2	6
Spain	13	13	13	7
Sweden	12		12	
United Kingdom	10	4	6	4
Total	252	140	195	124

* Assessments within IM 1 (Intensive Monitoring 1) include:
Crown condition
growth (once)
Foliar chemistry (once)
Ground vegetation (once)
Deposition
Ambient air quality
Visible ozone injury;
Soil (unless already assessed under BioSoil)
Meteorology

** Assessments within D1 (demonstration project 1) include:
Intensified crown condition assessments
growth (continuous)
Litterfall (foliage and fruiting compartments)
Phenology
Leaf area index (new)

$^{+}$ Assessments within D2 (demonstration project 2) include:
Litterfall (mass and element concentrations)
Soil solution
Intensified foliar surveys (new)
Nutrient budgets of ground vegetation (new)

$^{++}$ Assessments within D3 (demonstration project 3) include:
soil volumetric water content (new)
matrix potential (new)
stand precipitation (new)
leaf area index (new)
soil temperature (new)
determination of water retention functions in the lab (new)

2. Quality Assurance and Quality Control within the monitoring system

Marco Ferretti[1], Nils König[2], Oliver Granke[3], Nathalie Cools[4], John Derome(†)[5], Kirsti Derome[5], Alfred Fürst[6], Friedhelm Hosenfeld[7], Aldo Marchetto[8], Volker Mues[3]

2.1 The overall quality assurance perspective

The need for a comprehensive Quality Assurance (QA) programme in ecological monitoring has been reported several times (e.g. Crumbling, 2002; Ferretti, in press; Ferretti, 2009). Since 2007 a concept for a new QA perspective has been developed and implemented within the ICP Forests (Ferretti et al., 2009). This concept includes four main pillars: (i) the revision and harmonization of the Standard Operative Procedures (SOPs, i. e. the Manual); (ii) a new set of Data Quality Requirements (DQRs), explicitly incorporated in the SOPs; (iii) an extended series of training sessions and (iv) inter-comparison rounds. The SOPs have been revised in 2009 and 2010 with the support of the Life+ FutMon project, and this process has resulted in the comprehensive revision of the ICP Forests Manual (ICP-Forests 2010). One of the main aims of this revision process was to identify DQRs for a series of key monitoring variables covering all the investigations carried out within the ICP Forests. For such variables, DQRs have been identified in terms of Measurement Quality Objectives (MQOs) and Data Quality Limits (DQLs). MQO is the expected level of precision/accuracy for individual observations; DQL is the minimum acceptable frequency of observation that should be within the MQOs.

This comprehensive QA approach resulted in a much higher share of variables for which data quality requirements have been specified (Fig. 2-1). ICP Forests measurements cover approximately 260 different variables. Prior to the FutMon project and the manual revision, the share of variables covered by DQRs was 33%. Afterwards, the coverage was extended to 66% of the variables. In practical terms, it means that it is now possible to document and report on data quality for 2/3 of the variables measured within the ICP Forests. It is worth noting that – besides laboratory measurements that were traditionally given more attention with respect to data quality (see below) – field measurements like tree condition, ground vegetation, litterfall, ozone injury, tree growth and phenology are now covered by explicit DQRs.

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[8] National Research Council, Insitute for Ecosystem Study, Largo Tonolli 50, I-28922, Verbania, Italy

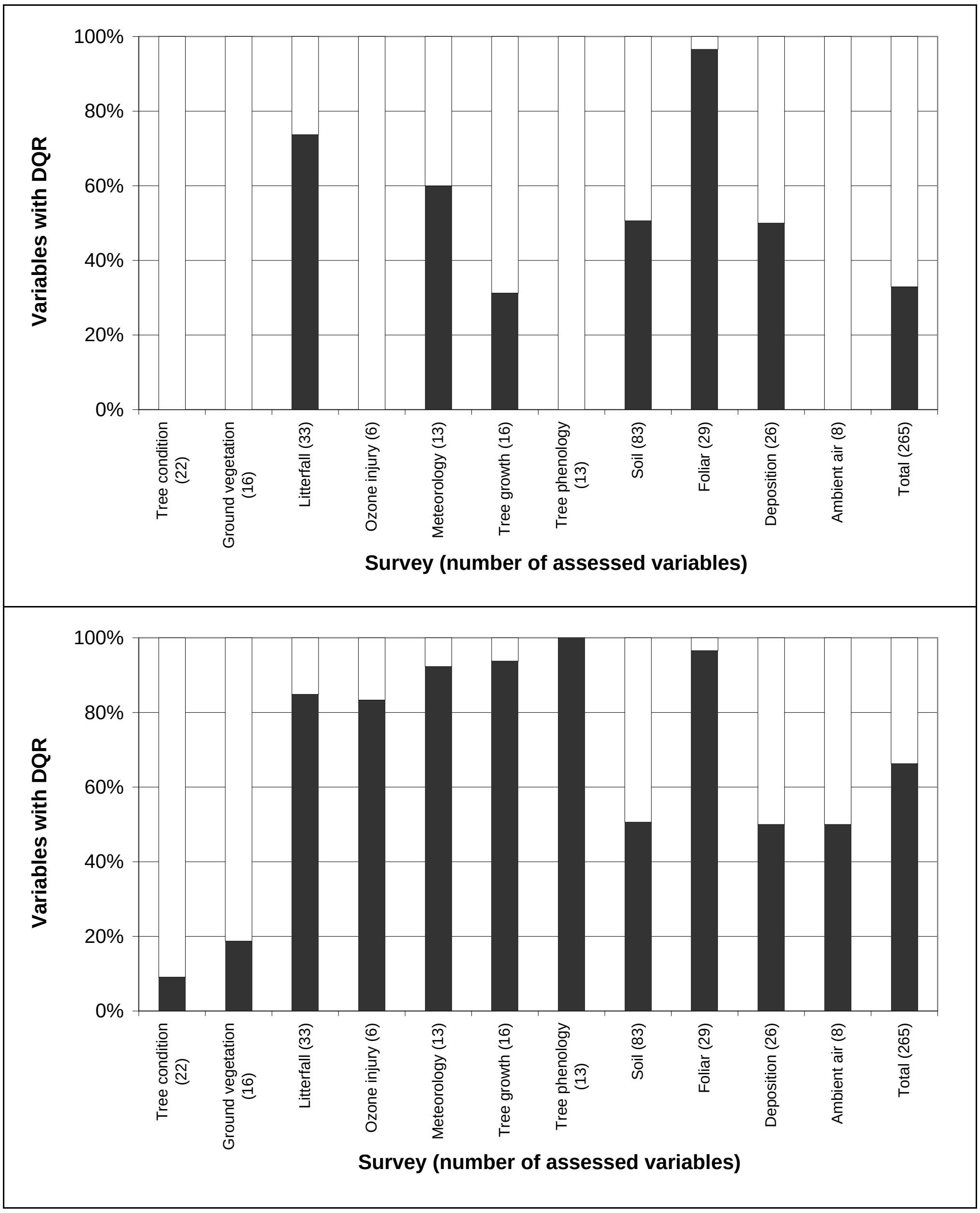


Figure 2-1: Frequency (%) of variables with (black) and without (white) DQRs before (top) and after (bottom) the development of the new QA approach and the revision of the ICP Forests Manual carried out within the FutMon project.

However, a sound data quality concept must go beyond the metrological quality of the data (i.e. the quality of measurements, which is of course important – see below) and should address all the steps before and after the measurements (Crumbling, 2002). While the steps after the measurements are being considered by the database managers, quality issues related to sampling in the field need to be tackled in the near future. This will be a further, major step ahead in promoting the overall data quality within the ICP Forests.

2.2 Quality improvement in the laboratories

The Working Group on Quality Assurance and Quality Control in Laboratories was installed within the ICP Forests in the year 2004 in order to improve the comparability and evaluability of the analytical data of the ICP Forests program and later also of the FutMon project. The aims of this group are

- the evaluation of analytical methods used in terms of their comparability and acceptability and the elimination of unqualified methods
- the amendment of the ICP Forests Manuals with information on methods for sample pretreatment and analysis
- the development and introduction of new methods for quality control in the laboratories
- the organization of practical help for laboratories with analytical problems and
- the organization of ring tests to control the development of quality in the laboratories.

After several years of work the analytical parts of the ICP Forests manual have been totally revised and unqualified methods have been eliminated. A review of possible checks and other helps for quality assurance and control in laboratories has been compiled and published. Two meetings of the heads of the laboratories have been organized to exchange analytical knowledge and discuss analytical problems and possible solutions. A helping program for laboratories with problematic ring test results has been organized with bilateral visits of the laboratories and active help. In the meantime 10 laboratories have made use of this possibility with great success. The use of reference methods, different quality checks like control charts or ion balance calculations and the participation in ring tests has become mandatory within the ICP Forests program and the FutMon project. Nowadays, each laboratory involved in the program has to send filled quality forms with information on methods used, on quantification limits, use of control charts and ring test results when submitting analytical data to the ICP Forests database.

The most important step to improve quality assurance and control was the introduction of regular ring tests for water, soil and plant samples. It is worth noting that, before the installation of the Working Group, such ringtests had been conducted only on an irregular basis. In the meantime 6 soil, 4 water and 12 foliar ring tests have been organized within the ICP Forests program and the FutMon project. The results of these ring tests show the development of data quality in the laboratories. In water ringtests, the percentage of results outside the tolerable limits has been reduced from 20-60% to 5-30% over 8 years (Fig. 2-2). A similar improvement can be seen for the results of the last 4 soil ring tests (Fig. 2-3): the coefficient of variation (CV in %) for the results of all participants has been reduced from 15-65% to 10-35% over 7 years. For the foliar ring tests (Fig. 2-4) only 3-10% of the results were beyond the tolerable limits already in 2005. This excellent level has been maintained in the following five tests.

Ring test results suggest a lower comparability and quality of the soil analysis data as compared to water and plant analysis data. One reason may be that soil analyses are regularly carried out in much longer intervals; another reason is that the soil matrix is much more complex to analyse. In contrast to water and foliar analysis, element analyses do not concern total analyses but fractions, which are much more difficult to measure accurately. And the soil analyses mostly are of two steps (e.g. digestion or extraction and measurement) which in turn double possible mistakes. But it is obvious that as well the quality of water analyses can still be improved. Therefore regularly ring tests are still important for the improvement of the quality of analyses in the ICP Forests programme.

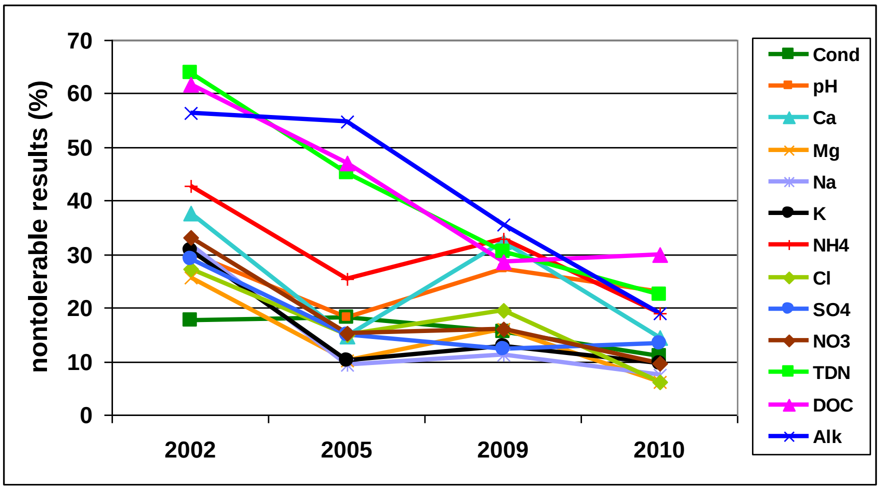


Figure 2-2: Development of the non tolerable results of the ICP Forests/FutMon water ring tests 2002 – 2010 for all evaluated parameters

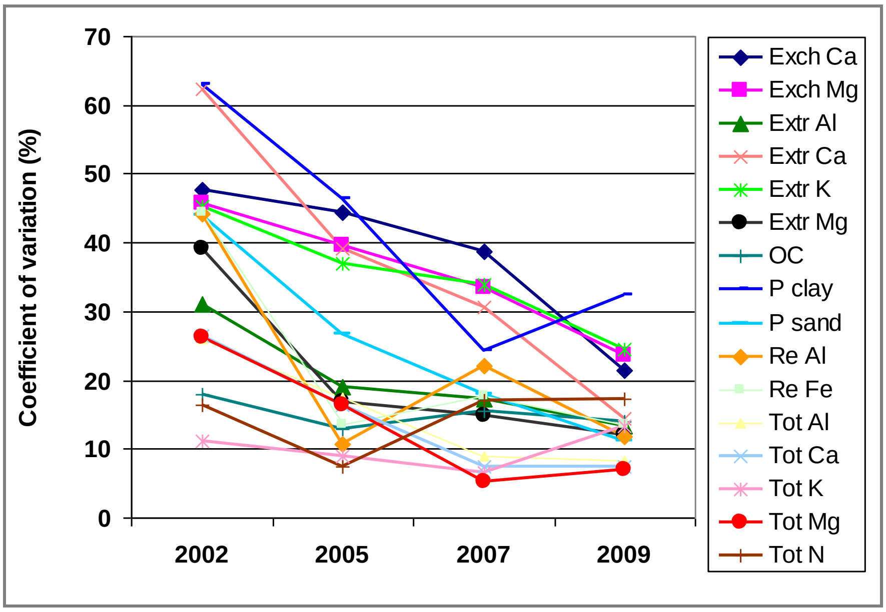


Figure 2-3: Development of the coefficient of variation (CV, in%) for selected parameters of the ICP Forests/FutMon soil ring tests (RT) 2002 – 2009

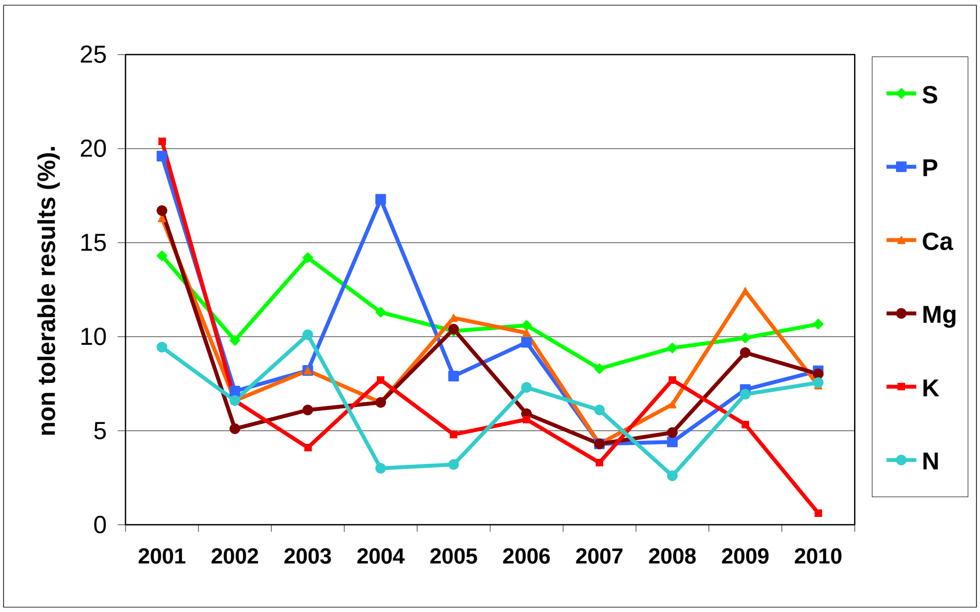


Figure 2-4: Development of the non tolerable results of the ICP Forests/FutMon foliar ring tests 2001 - 2010 for the mandatory parameters (foliage samples)

2.3 Quality control in the data base

Co-financed by the FutMon project, a new web-based system for data submission, storage, dissemination and evaluation was set up in the years 2009 and 2010. Central data management is an essential tool to control and document data quality. Only by means of comprehensive validations and consistency checks improved data quality can be achieved and fully documented: this facilitates extensive and effective data evaluations for project partners and third parties. A wide range of validation rules help to control data compliance and conformity using online and real-time checks. In addition, the newly designed system offers an administration area including functions to monitor data submission processes, to inspect and compare the managed data using tables, digital maps as well as diagrams.

In the database, three modules support data analysis and checks after import. These are compliance, consistency and uniformity checks which are subsequently applied (Fig. 2-5) (Durrant Houston and Hiederer, 2009).

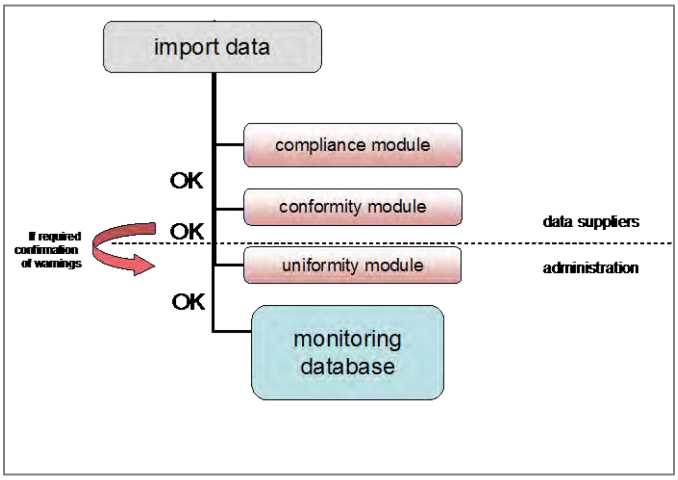


Figure 2-5: Subsequent application of data checks

2.3.1 Compliance checks

The compliance module analyses file structure based on data type, field lengths, mandatory information as well as completeness of the file. In real-time, data suppliers receive pdf test reports documenting results of the checks. Errors need to be corrected offline and only after successful resubmission the data submission process can be continued by the user.

2.3.2 Conformity checks

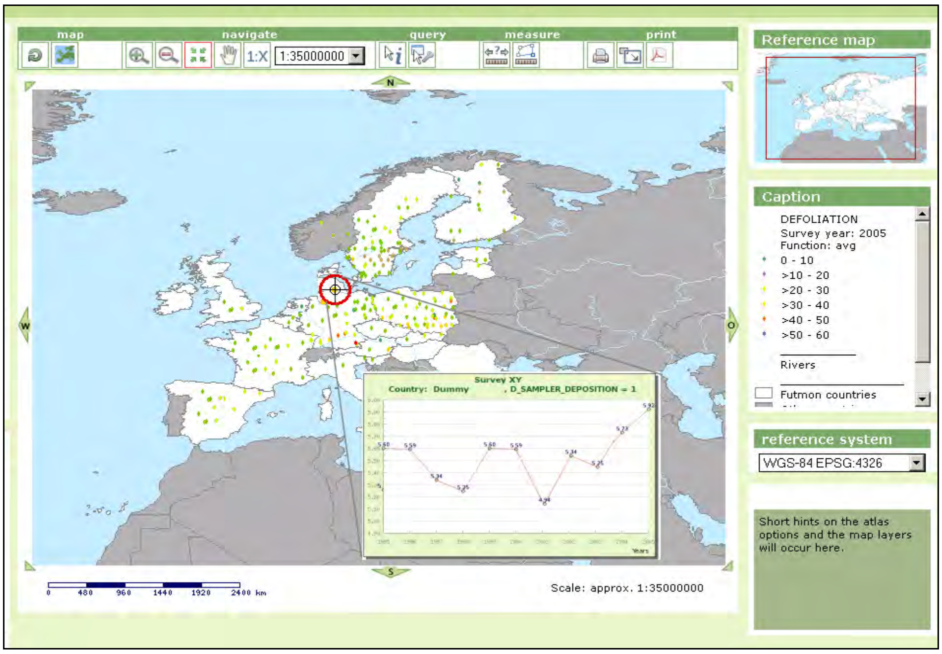
In a second step, data are checked for conformity by a number of additional tests. This module is currently based on 682 defined data rules.

- Primary key properties check for data gaps or duplicates.
- Simple range checks are defined by lower and upper limits that may not be exceeded by single parameters.
- Multiple parameter checks analyse parameters with regard to contradictions or implausibility. These checks can be based on parameters within the same data submission file as well as on parameters from different files and even different surveys.
- Temporal consistency checks compare data with values of previous years.
- Spatial comparisons check whether the spatial details of the plots are defined according to pre-defined specifications.
- Additional parameter specific rules can be applied for checks that are not covered by the previous ones.

Also for these tests results are automatically documented in a pdf report and submission can only be continued if no more errors occur.

2.3.3 Uniformity checks

When data submission is complete for single years and countries, various uniformity analyses are performed by the data managers. This includes plausibility checks for spatial and temporal consistency. Dynamically generated tables, diagrams and digital maps support these steps. A WebGIS module offers dynamic spatial evaluations complemented by time series diagrams (Fig. 2-6). In the current version, data managers can select from 866 dynamic maps. The combination of spatial and time-based visualization enables the identification and further analysis of implausible values. Problematic data records can require re-submission of the affected data files or manual correction of single values.



DEFOLIATION
Survey year: 2005
Function: avg
0 - 10
>10 - 20
>20 - 30
>30 - 40
>40 - 50
>50 - 60
Rivers
Futmon countries

WGS-84 EPSG:4326

Short hints on the atlas options and the map layers will occur here.

Scale: approx. 1:35000000

Figure 2-6: WebGIS module

2.3.4 Experience with improved data base system

Within the monitoring programme the acceptance by the users was very high so that data acquisition and data quality could be improved. Immediate feedback from compliance and conformity checks has proven essential in order to fix data errors promptly and to increase the motivation of data suppliers. Time necessary for data transmission has been considerably reduced. With the new system, legacy data from previous monitoring years were checked as well and numerous inconsistencies in existing legacy data were detected and corrected.

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Part II

TREE HEALTH AND VITALITY

3. Tree crown condition and damage causes

Stefan Meining[1] *and Richard Fischer*[2]

3.1 Abstract

The study presents results of the 2010 forest health and vitality survey carried out on the representative net of Level I plots of ICP Forests and the FutMon project. The survey was based on over 7 500 plots and 145 000 trees in 33 participating countries, including 26 EU member states. It was thus the most comprehensive survey that has ever been carried out on the Level I network.

Defoliation results show slightly higher mean defoliation for broadleaves as compared to the conifers assessed. Deciduous temperate oaks had the highest mean defoliation (24.8%), followed by the south European tree species groups. *Picea abies* and *Pinus sylvestris* showed lowest mean defoliation with 17.0% and 17.4% respectively. The Mediterranean coast in southern France and northern Spain was a hot spot with specifically high defoliation in several species groups.

Over the last five years, temporal defoliation trends show some recuperation for evergreen oaks and a continuously increasing defoliation of *Pinus sylvestris*. For the other species/-goups there is no pronounced trend in the most recent years. After the heat and drought in central Europe in 2003 defoliation clearly increased for most tree species. This points to the value of the data as basis of an early warning system for tree health under changing environmental conditons.

For the first time, forest damage assessments were evaluated based on newly introduced assessments that had started in 2005. In 2010, damage causes were assessed with harmonized methods on 6 413 plots in 32 different countries across Europe. Insects and fungi were the most widespread agents occurring on 27% and 15% of the trees within the survey. The occurrence of these factors shows clear regional trends like plots with high insect occurrence in north-eastern Spain, Italy or Hungary or high occurrence of trees with fungal infestations in Estonia.

3.2 Large scale tree crown condition

3.2.1 Methods of the surveys in 2010

The annual transnational tree crown condition survey was carried out on 7 503 plots in 33 participating countries, including 26 EU member states. It was thus the most comprehensive survey that has ever been carried out on the Level I network. Due to co-financing through the FutMon project Austria, Greece, The Netherlands, Romania and United Kingdom again conduted the survey after one or several years without assessments. Montenegro participated for the first time. The assessment was carried out under national responsibilities according to harmonized methods laid down in ICP Forests (2010). Data were compiled and checked for consistency by the participating countries and submitted online to the European Coordinating Centre at the Institute for World Forestry in Hamburg, Germany.

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Aditional data quality checks were carried out in the context of the online data submission (Chapt. 2).

Table 3-1: Number of sample plots assessed for crown condition from 1998 to 2010

Country	Number of sample plots assessed												
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austria	130	130	130	130	133	131	136	136	135				135
Belgium	29	30	29	29	29	29	29	29	27	27	26	26	9
Bulgaria	134	114	108	108	98	105	103	102	97	104	98	159	140
Cyprus				15	15	15	15	15	15	15	15	15	15
Czech Republic	116	139	139	139	140	140	140	138	136	132	136	133	132
Denmark	23	23	21	21	20	20	20	22	22	19	19	16	17
Estonia	91	91	90	89	92	93	92	92	92	93	92	92	97
Finland	459	457	453	454	457	453	594	605	606	593	475	886	932
France	537	544	516	519	518	515	511	509	498	504	508	500	532
Germany	421	433	444	446	447	447	451	451	423	420	423	412	411
Greece	93	93	93	92	91			87				97	98
Hungary	59	62	63	63	62	62	73	73	73	72	72	73	71
Ireland	21	20	20	20	20	19	19	18	21	30	31	32	29
Italy	177	239	255	265	258	247	255	238	251	238	236	252	253
Latvia	97	98	94	97	97	95	95	92	93	93	92	207	207
Lithuania	67	67	67	66	66	64	63	62	62	62	70	72	75
Luxemburg	4	4	4		4	4	4	4	4	4	4		
The Netherlands	11	11	11	11	11	11	11	11	11			11	11
Poland	431	431	431	431	433	433	433	432	376	458	453	376	374
Portugal*	149	149	149	150	151	142	139	125	124				
Romania	235	238	235	232	231	231	226	229	228	218		227	239
Slovak Republic	109	110	111	110	110	108	108	108	107	107	108	108	108
Slovenia	41	41	41	41	39	41	42	44	45	44		44	44
Spain**	465	611	620	620	620	620	620	620	620	620	620	620	620
Sweden	764	764	769	770	769	776	775	784	790			789	830
United Kingdom	88	85	89	86	86	86	85	84	82	32			76
EU	4751	4984	4982	5004	4997	4887	5039	5110	4938	3885	3478	5147	5455
Andorra							3		3	3	3	3	3
Belarus	416	408	408	408	407	406	406	403	398	400	400	409	410
Croatia	89	84	83	81	80	78	84	85	88	83	84	83	83
Moldova	10	10	10	10									
Montenegro													49
Norway	386	381	382	408	414	411	442	460	463	476	481	487	491
Russian Fed.												365	288
Serbia						103	130	129	127	125	123	122	121
Switzerland	49	49	49	49	49	48	48	48	48	48	48	48	48
Turkey												563	555
Total Europe	5701	5916	5914	5960	5947	5933	6152	6235	6065	5020	4617	7227	7503

* including Azores, **including Canares

3.2.1.1 Assessment parameters

For the monitoring year 2010, the following stand and site characteristics are reported from transnational plots: *country, plot number, plot coordinates, altitude, aspect, water availability, humus type*, and *mean age of dominant storey*. Besides *defoliation* and *discolouration*, the tree related data reported are *tree numbers, tree species* and *identified damage types*. (Tab. 3-2). Also recorded is the *date of observation*.

Table 3-2: Stand and site parameters given within the crown condition data base.

Registry and location	country	state in which the plot is assessed [code number]
	plot number	identification of each plot
	plot coordinates	latitude and longitude [degrees, minutes, seconds] (geographic)
	date	day, month and year of observation
Physiography	altitude [m a.s.l.]	elevation above sea level, in 50 m steps
	aspect [°]	aspect at the plot, direction of strongest decrease of altitude in 8 classes (N, NE, ... , NW) and "flat"
Soil	water availability	three classes: insufficient, sufficient, excessive water availability to principal species
	humus type	mull, moder, mor, anmor, peat or other
Forest type	Forest type	14 forest categories according to EEA (2007)
Stand related data	mean age of dominant storey	classified age; class size 20 years; class 1: 0-20 years, ..., class 7: 121-140 years, class 8: irregular stands
Additional tree related data	tree number	number of tree, allows the identification of each particular tree over all observation years
	tree species	species of the observed tree [code]
	identified damage types	treewise observations concerning damage caused by game and grazing, insects, fungi, abiotic agents, direct action of man, fire, known regional pollution, and other factors

Nearly all countries submitted data on water availability, humus type, altitude, aspect, and mean age (Tab. 3-3).

Table 3-3: Number of sample plots assessed for crown condition and plots per site parameter

Country	Number of plots	Number of plots per site parameter				
		Water	Humus	Altitude	Aspect	Age
Austria	135	135	135	135	135	135
Belgium	9	9	9	9	9	9
Bulgaria	140	140	140	140	140	140
Cyprus	15	15	15	15	15	15
Czech Rep.	132	132	53	132	132	132
Denmark	17	17	17	17	17	17
Estonia	97	97	97	97	97	97
Finland	932	932	923	932	932	932
France	532	497	497	532	532	532
Germany	411	411	345	411	411	411
Greece	98	98	98	98	98	98
Hungary	71	71	39	71	71	71
Ireland	29	29	17	29	29	29
Italy	253	253	253	253	253	253
Latvia	207	207		207	207	207
Lithuania	75	75	75	75	75	75
Netherlands	11	11	11	11	11	11
Poland	374	374	374	374	374	374
Romania	239	239	239	239	239	239
Slovak Rep.	108		108	108	108	108
Slovenia	44	44	44	44	44	44
Spain	620	620	620	620	620	620
Sweden	830	830	785	830	830	830
United Kingdom	76	73	62	76	76	76
EU	**5455**	**5309**	**4956**	**5455**	**5455**	**5455**
Percent of EU plot sample		**97.3%**	**90.9%**	**100.0%**	**100.0%**	**100.0%**
Andorra	3	3	3	3	3	3
Belarus	410	410	410	410	410	410
Croatia	83	83	83	83	83	83
Montenegro	49	49	49	49	49	49
Norway	491		481	491	491	491
Federation	288			288	288	288
Serbia	121	121	39	121	121	121
Switzerland	48	47	46	48	48	48
Turkey	555	538	524	555	555	555
Total Europe	**7503**	**6560**	**6591**	**7503**	**7503**	**7503**
Percent of total plot sample		**87.4%**	**87.8%**	**100.0%**	**100.0%**	**100.0%**

3.2.1.2 Defoliation

On each sampling point, sample trees were selected according to national procedures. On 52.8% of the plots sample tree number per plot was between 20 and 24 trees. On 22.5% of all plots less than 10 sample trees were observed (Fig. 3-1).

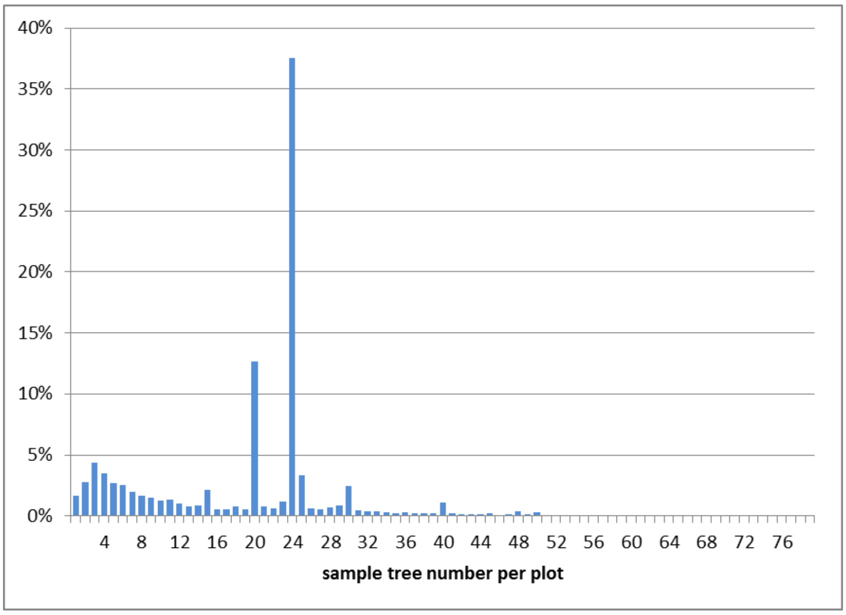

Figure 3-1: Percentage of sample tree number per plot

Due to harmonisation with plot designs of national forest inventories, the variation of numbers of trees per plot has been increasing in comparison to previous years. Predominant, dominant, and co-dominant trees (according to the system of Kraft) of all species qualify as sample trees, provided that they have a minimum height of 60 cm and that they do not show significant mechanical damage.

The variation of crown condition is mainly the result of intrinsic factors, age and site conditions. Moreover, defoliation may be caused by a number of biotic and abiotic stressors. Defoliation assessment attempts to quantify foliage missing as an effect of stressors including air pollutants and not as an effect of long lasting site conditions. In order to compensate for site conditions, local reference trees are used, defined as the best tree with full foliage that could grow at the particular site. Alternatively, absolute references are used, defined as the best possible tree of a genus or a species, regardless of site conditions, tree age etc. depicted on regionally applicable photos, e.g. photo guides. Changes in defoliation and discolouration attributable to air pollution cannot be differentiated from those caused by other factors. Consequently, defoliation due to factors other than air pollution is included in the assessment results. Trees showing mechanical damage are not included in the sample. Should mechanical damage occur to a sample tree, any resulting loss of foliage is not counted as defoliation.

In 2010, 145 323 trees were assessed (Tab. 3-4). Defoliation scores were available for 144 724 trees (Tab. 3-6). Table 3-4 shows the total number of trees assessed in each participating country since 1998. The figures in the table are not necessarily identical to those published in previous reports as re-submission of older data is possible in case of reorganisation of national observation networks.

63.4% of the plots assessed in 2010 were dominated by conifers and 36.6% by broadleaves (Annex I). Plots in mixed stands were assigned to the species group which comprised the majority of the sample trees. On almost 90% of the plots assessed in 2010, only one to three different tree species occurred. On 9.1% of plots four to five species and on 1.8% of plots six to ten tree species occurred (Annex II)

The total number of species within the tree sample was 133. Most abundant were *Pinus sylvestris* (23.6%) followed by *Picea abies* (15.5%), *Fagus sylvatica* (8.4%), *Betula pendula* (4.7%), and *Pinus nigra* (3.8%). In the following evaluations a number of tree species are groupd into species groups:

- **Deciduous temperate oak:** (*Quercus robur* and *Q. petraea*) accounting together for 6.7% of the assessed trees,
- **Mediterranean lowland pines:** (*Pinus brutia, P. pinaster, P. halepensis* and *P. pinea*) accounting together for 6.1% of the assessed trees,
- **Deciduous (sub-) temperate oak:** (*Quercus frainetto, Q. pubescens, Q. pyrenaica* and *Q. cerris*) accounting together for 5.5% of the assessed trees,
- **Evergreen oak:** (*Quercus coccifera, Q. ilex, Q. rotundifolia* and *Q. suber*) accounting together for 3.9% of the assessed trees.

Table 3-4: Number of sample trees from 1998 to 2010 according to the current database

Country	Number of sample trees												
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Austria	3577	3535	3506	3451	3503	3470	3586	3528	3425				3087
Belgium	692	696	686	682	684	684	681	676	618	616	599	599	216
Bulgaria	5349	4344	4197	4174	3720	3836	3629	3592	3510	3569	3304	5560	4929
Cyprus				360	360	360	360	361	360	360	360	362	360
Czech Rep.	2899	3475	3475	3475	3500	3500	3500	3450	3425	3300	3400	3325	3300
Denmark	552	552	504	504	480	480	480	528	527	442	452	384	408
Estonia	2184	2184	2160	2136	2169	2228	2201	2167	2191	2209	2196	2202	2348
Finland	8758	8662	8576	8579	8593	8482	11210	11498	11489	11199	8812	7182	7946
France	10740	10883	10317	10373	10355	10298	10219	10129	9950	10074	10138	9949	10584
Germany	13178	13466	13722	13478	13534	13572	13741	13630	10327	10241	10347	10088	10063
Greece	2204	2192	2192	2168	2144			2054				2289	2311
Hungary	1383	1470	1488	1469	1446	1446	1710	1662	1674	1650	1661	1668	1626
Ireland	441	417	420	420	424	403	400	382	445	646	679	717	641
Italy	4939	6710	7128	7350	7165	6866	7109	6548	6936	6636	6579	6794	8338
Latvia	2326	2348	2256	2325	2340	2293	2290	2263	2242	2228	2184	3911	3888
Lithuania	1616	1613	1609	1597	1583	1560	1487	1512	1505	1507	1688	1734	1814
Luxemburg	96	96	96		96	96	96	97	96	96	96		
Netherlands	220	225	218	231	232	231	232	232	230			247	227
Poland	8620	8620	8620	8620	8660	8660	8660	8640	7520	9160	9036	7520	7482
Portugal*	4470	4470	4470	4500	4530	4260	4170	3749	3719				
Romania	5637	5712	5640	5568	5544	5544	5424	5496	5472	5232		5448	5736
Slovak Rep.	5094	5063	5157	5054	5076	5116	5058	5033	4808	4904	4956	4944	4831
Slovenia	984	984	984	984	936	983	1006	1056	1069	1056		1056	1052
Spain**	11160	14664	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880	14880
Sweden	11044	11135	11361	11283	11278	11321	11255	11422	11186			2207	2742
Kingdom	2112	2039	2136	2064	2064	2064	2040	2016	1968	768			1803
EU	110275	115555	115798	115725	115296	112633	115424	116601	109572	90773	81367	93066	100612
Andorra							72		74	72	72	73	72
Belarus	9896	9745	9763	9761	9723	9716	9682	9484	9373	9424	9438	9615	9617
Croatia	2066	2015	1991	1941	1910	1869	2009	2046	2109	2013	2015	1991	1992
Moldova	234	259	234	234									
Montenegro													1176
Norway	4069	4052	4051	4304	4444	4547	5014	5319	5525	5824	6085	6014	6330
Russian Fed.												11016	8958
Serbia						2274	2915	2995	2902	2860	2788	2751	2786
Switzerland	868	857	855	834	827	806	748	807	812	790	773	801	795
Turkey												13219	12985
Total Europe	127408	132483	132692	132799	132200	131845	135864	137252	130367	111756	102538	138546	145323

* including Azores, ** including Canares

3.2.1.3 Scientific background for the defoliation data analysis

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

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

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

3.2.1.4 Classification of defoliation data

The results of the evaluations of the crown condition data are presented in terms of mean plot defoliation or the percentages of the trees falling into 5%-defoliation steps. In previous presentations of survey results, partly the traditional classification of both defoliation and discolouration had been applied, although it is considered arbitrary by some countries. This classification (Tab. 3-5) is a practical convention, as real physiological thresholds cannot be defined.

Table 3-5: Defoliation and discolouration classes according to UNECE and EU classification

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

In order to discount background perturbations which might be considered minor, a defoliation of >10-25% is con-sidered 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 with 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". The most important results have been tabulated separately for all countries having participated (called "all plots") and for the 26 participating EU-Member States.

3.2.1.5 Mean defoliation and temporal development

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

The temporal development of defoliation is expressed on maps as the slope, or regression coefficient, of a linear regression of mean defoliation against the year of observation. It can be interpreted as the mean annual change in defoliation. These slopes were considered as "significant" only if there was at least 95% probability that they are different from zero.

Besides the temporal development, also the change in the results from 2009 to 2010 was calculated (Annex V). In this case, changes in mean defoliation per plot are called "significant" only if the significance at the 95% probability level was proven in a statistical test.

3.2.1.6 National surveys

National surveys are conducted in many countries in addition to the transnational surveys. The national surveys in most cases rely on denser national grids and aim at the documentation of forest condition and its development in the respective country. Since 1986, densities of national grids with resolutions between 1 x 1 km and 32 x 32 km have been applied due to differences in the size of forest area, in the structure of forests and in forest policies. Results of crown condition assessments on the national grids are presented in Chapter 11. 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.

3.2.2 Results of the transnational crown condition survey in 2010

In 2010 crown condition was assessed on 7 503 plots (Tab. 3-3) comprising 144 724 sample trees with defoliation scores (Tab. 3-6). Of these, 80 709 conifers and 64 015 deciduous trees were investigated.

Mean defoliation of all assessed trees in Europe was 19.0%. Deciduous trees showed a mean defoliation of 20.1%, slightly higher than that of conifers (18.1%). Annex IV shows a map of mean plot defoliation for all species.

A share of 19.5% of the assessed trees was evaluated as damaged, i.e. had a defoliation of more than 25% (Tab. 3-6). The share of damaged broadleaves (21.9%) exceeded that of damaged conifers (17.6%). In Annex III the percentages of damaged trees are mapped for each plot.

Because of the different numbers of participating countries, the defoliation figures from 2010 are not comparable to those from previous reports. The development of defoliation over time is derived from tree and plot samples from defined sets of countries (Chapt. 3.2.4.1).

Table 3-6: Percentages of trees in defoliation classes and mean defoliation for broadleaves, conifers and all species

		Percentage of trees in defoliation class							Defoliation		No of trees
	Species type	**0-10**	**>10-25**	**0-25**	**>25-60**	>60	**dead**	>25	**mean**	**median**	
EU	broadleaves	28.5	46.5	75.0	22.1	2.1	0.7	25.0	21.7	20	45623
	conifers	35.5	43.7	79.3	18.5	1.3	0.9	20.7	19.4	15	54400
	all species	32.3	45.0	77.3	20.1	1.7	0.8	22.7	20.4	15	100023
Total Europe	*Fagus sylvatica*	35.9	43.7	79.6	19.0	1.2	0.3	20.4	18.9	15	12140
	Deciduous temperate oak	19.2	46.6	65.8	31.3	2.2	0.6	34.2	24.8	20	9674
	Deciduous (sub-) mediterranean oak	26.0	47.5	73.5	23.4	2.6	0.5	26.5	22.3	20	8010
	Evergreen oak	18.2	61.7	80.0	17.6	1.7	0.7	20.0	21.8	20	4762
	broadleaves	34.2	43.9	78.1	19.2	2.0	0.7	21.9	20.1	15	64015
	Pinus sylvestris	38.2	47.4	85.6	12.8	0.8	0.7	14.4	17.4	15	34210
	Picea abies	47.3	32.2	79.5	18.5	1.5	0.5	20.5	17.0	15	22449
	Mediterranean lowland pines	19.6	60.6	80.1	16.5	1.6	1.8	19.9	22.3	20	8917
	conifers	38.8	43.6	82.4	15.5	1.2	0.9	17.6	18.1	15	80709
	all species	36.8	43.7	80.5	17.1	1.6	0.8	19.5	19.0	15	144724

The frequency distribution of the sample trees is shown in 5% classes for broadleaves, conifers, and all species (Fig. 3-2). Dead trees are indicated by defoliation values of 100%.

More than 50% of all trees exhibit defoliation of 10 to 20%. The proportion of conifers is higher in defoliation classes of up to 15%, whereas it was found that deciduous trees showed higher shares in defoliation classes above 15%.

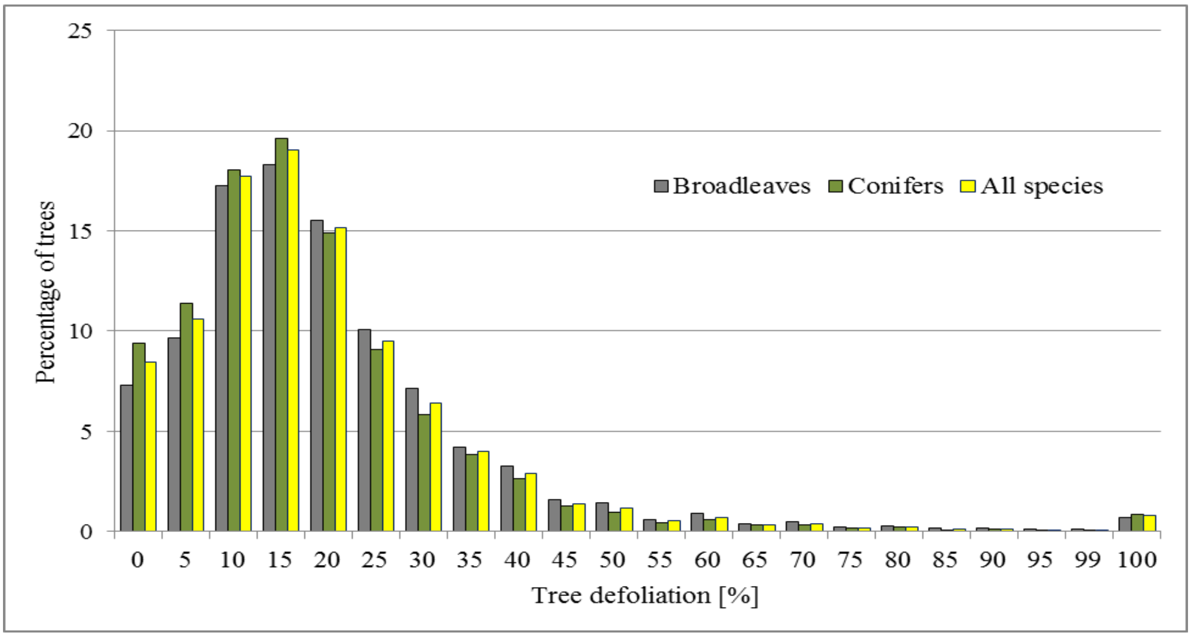

Figure 3-2: Frequency distribution of all trees assessed in 2010 in 5%-defoliation steps

Figures 3-3 to 3-9 show maps of mean plot defoliation for *Pinus sylvestris*, *Picea abies, Fagus sylvatica*, and for the species groups deciduous temperate oak, deciduous (sub-) mediterranean oak, evergreen oak and Mediterranean lowland pines. The maps partly reflect the differences in crown condition between species seen in Table 3-5.

Deciduous temperate oaks had the highest value of mean defoliation (24.8%) on the assessed plots. The spatial distribution on the maps shows clusters of plots with high defoliation concentrated in central Europe. The mean defoliation of deciduous (sub-) mediterranean oaks (22.3%) was higher than the defoliation of the evergreen oaks (21.8%). *Fagus sylvatica* showed a mean defoliation of 18.9%.

From the evaluated conifers Mediterranean lowland pines had the highest mean defoliation (22.3%). In contrast, the mean defoliation of *Pinus sylvestris* and *Picea abies* was lower. Of all the evaluated tree groups *Picea abies* showed the lowest mean defoliation (16.9%).

Clusters of plots with mean defoliation of *Pinus sylvestris* and *Picea abies* above 30% are located in central Europe. Specifically for *Pinus sylvestris* mean defoliation was lower on plots in boreal and hemiboreal regions.

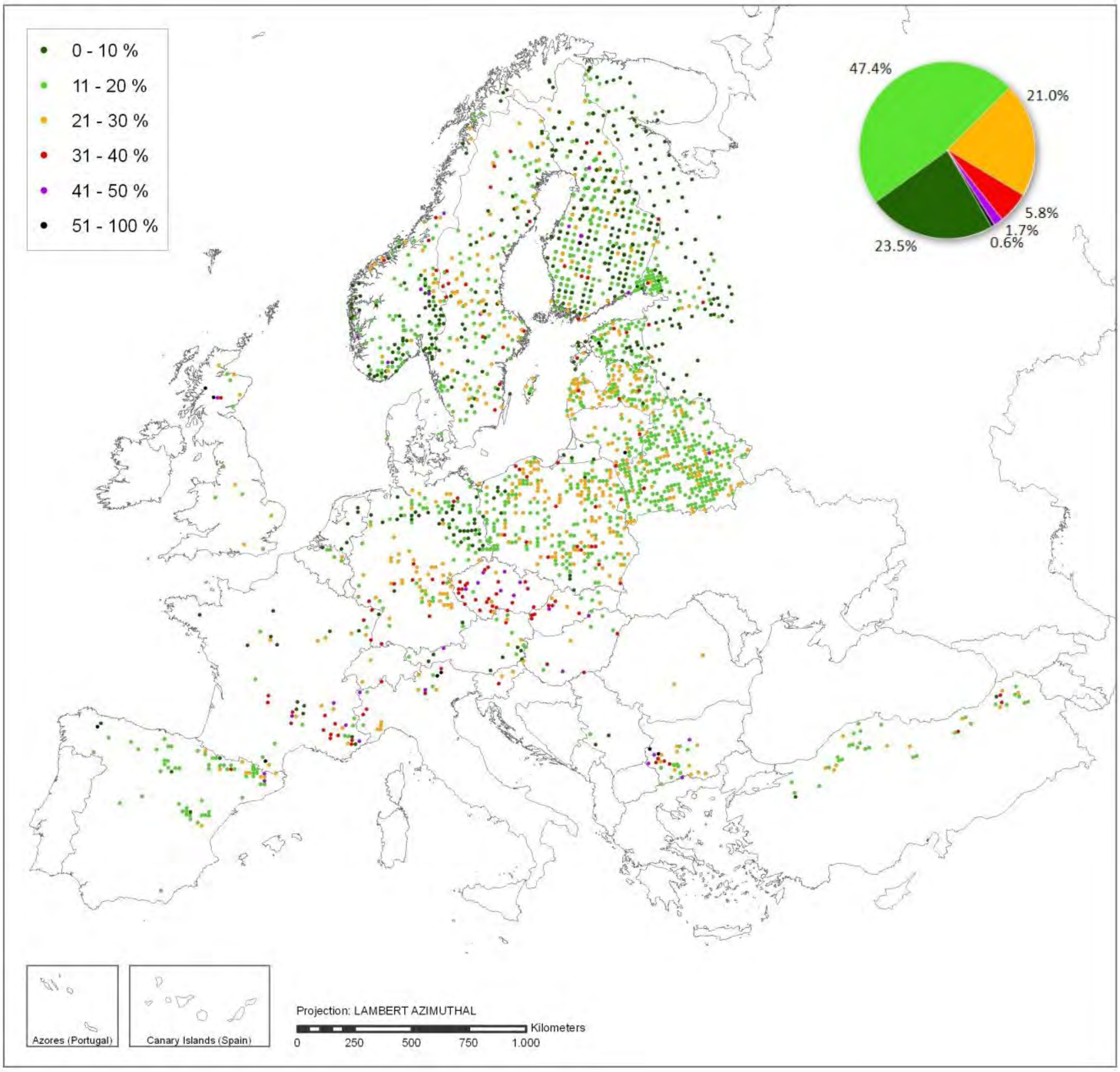

Figure 3-3: Mean plot defoliation for *Pinus sylvestris,* 2010

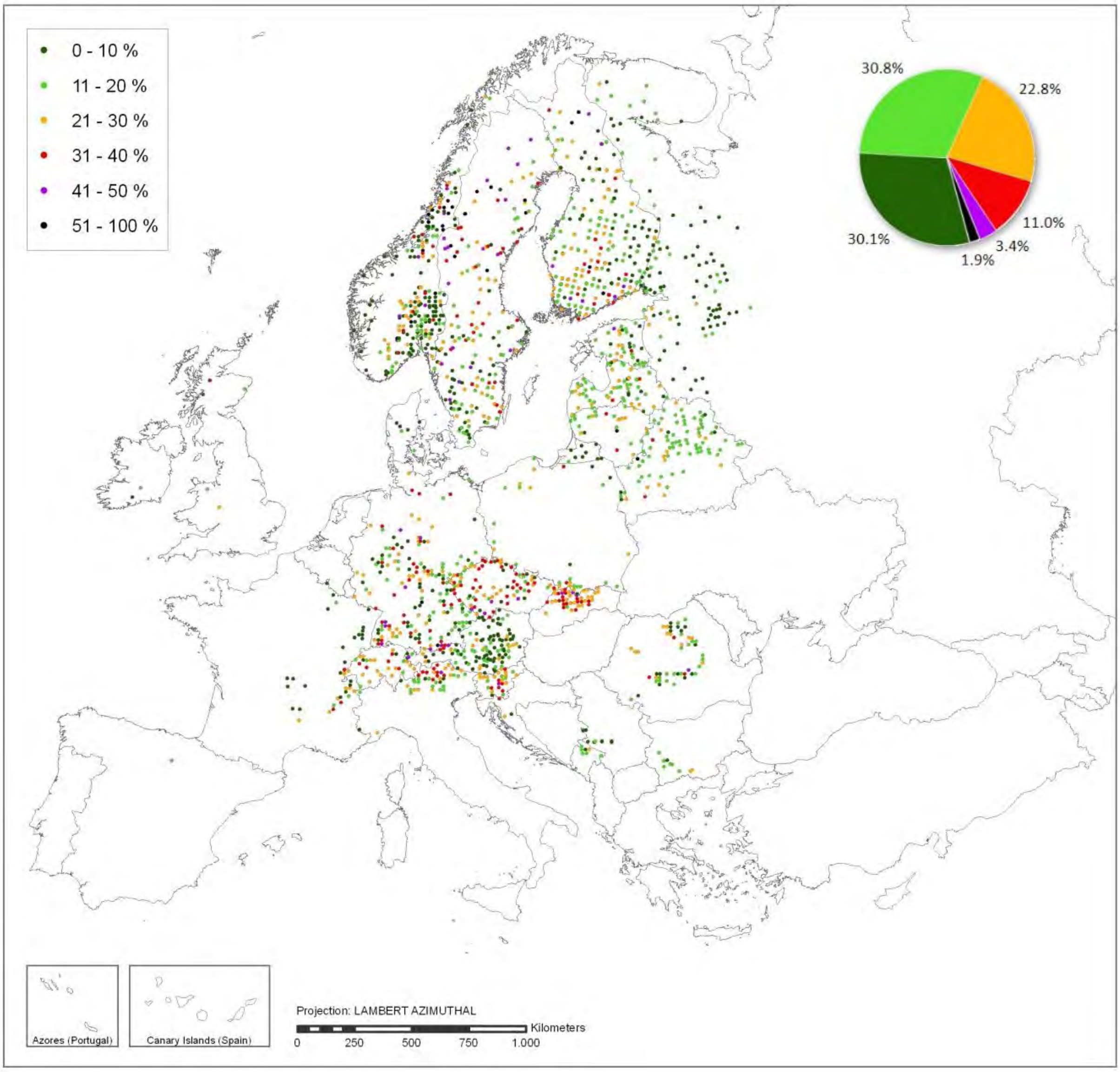

Figure 3-4: Mean plot defoliation for *Picea abies,* 2010

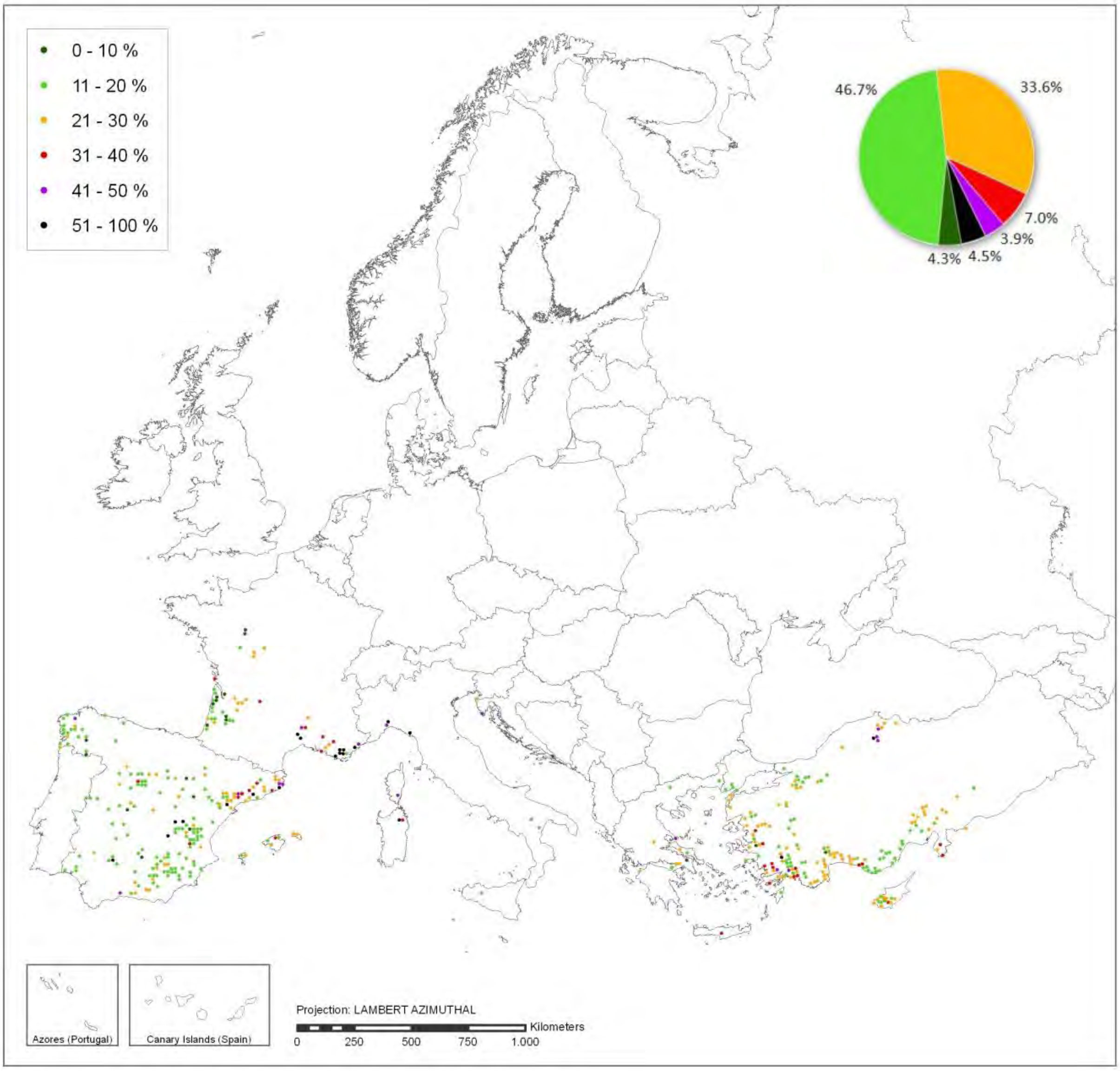

Figure 3-5: Mean plot defoliation for Mediterranean lowland pine (*Pinus brutia, Pinus halepensis, Pinus pinaster, Pinus pinea)*, 2010

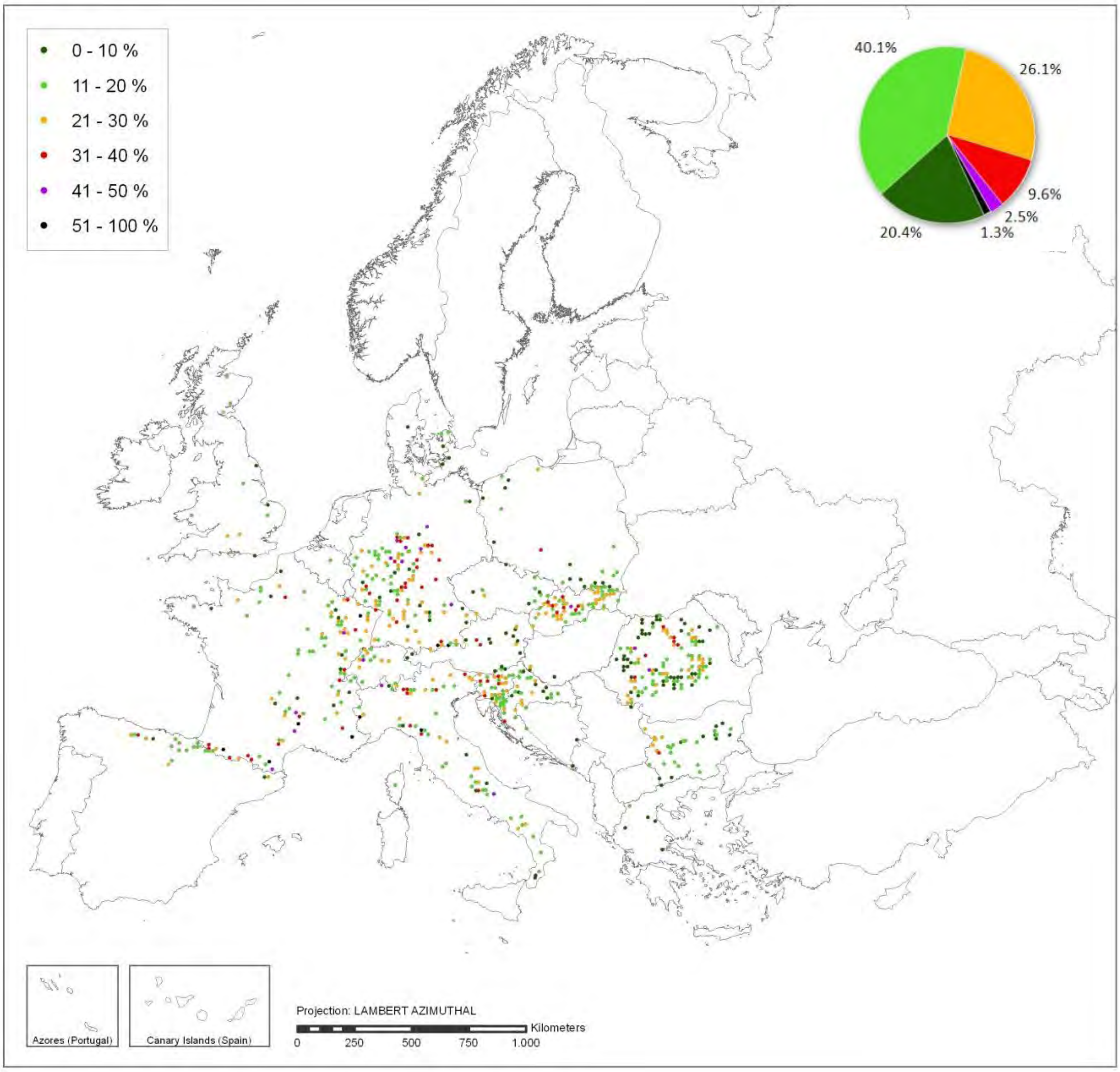

Figure 3-6: Mean plot defoliation for *Fagus sylvatica,* 2010

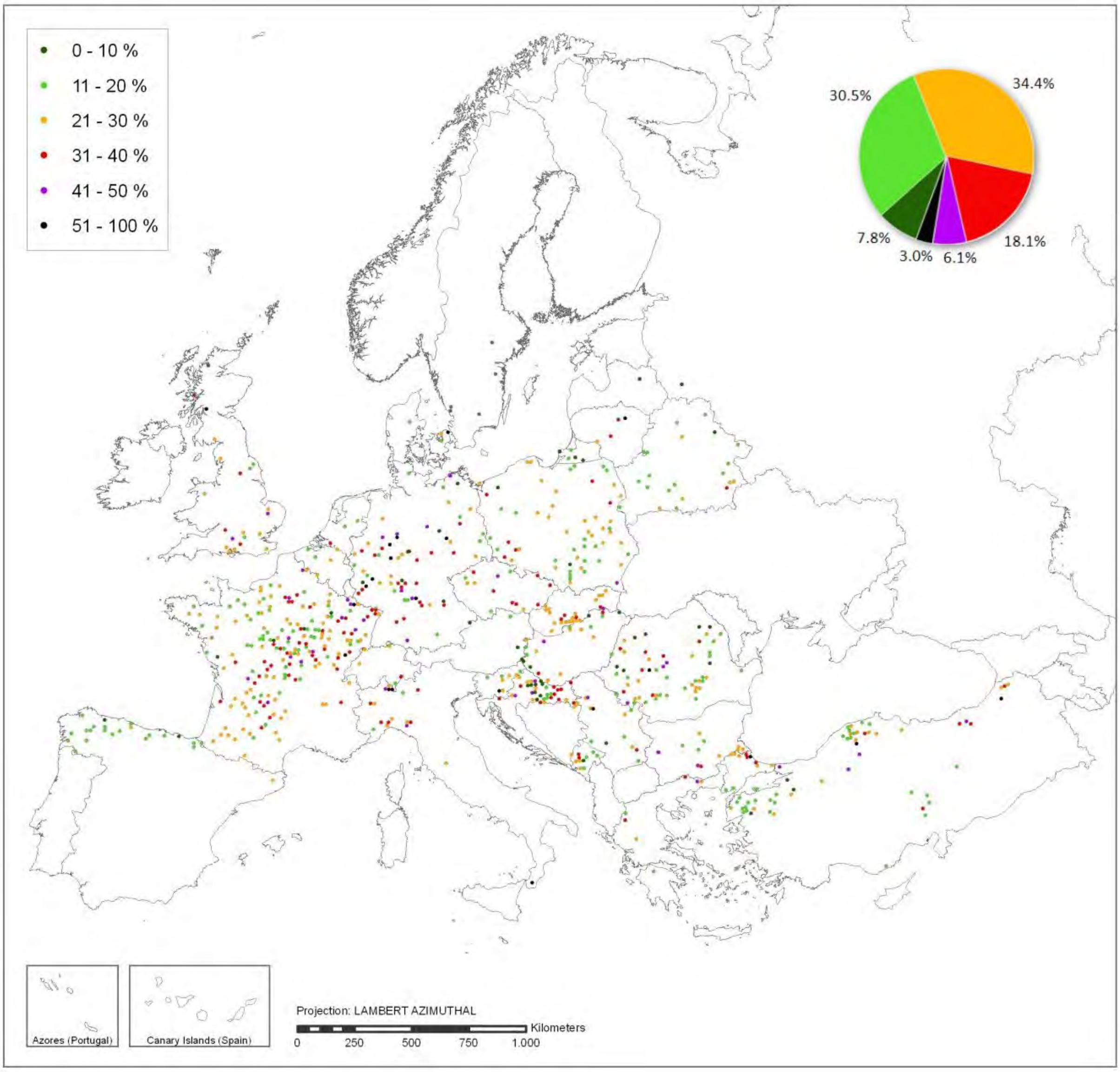

Figure 3-7: Mean plot defoliation for deciduous temperate oak (*Quercus petraea and Quercus robur*), 2010

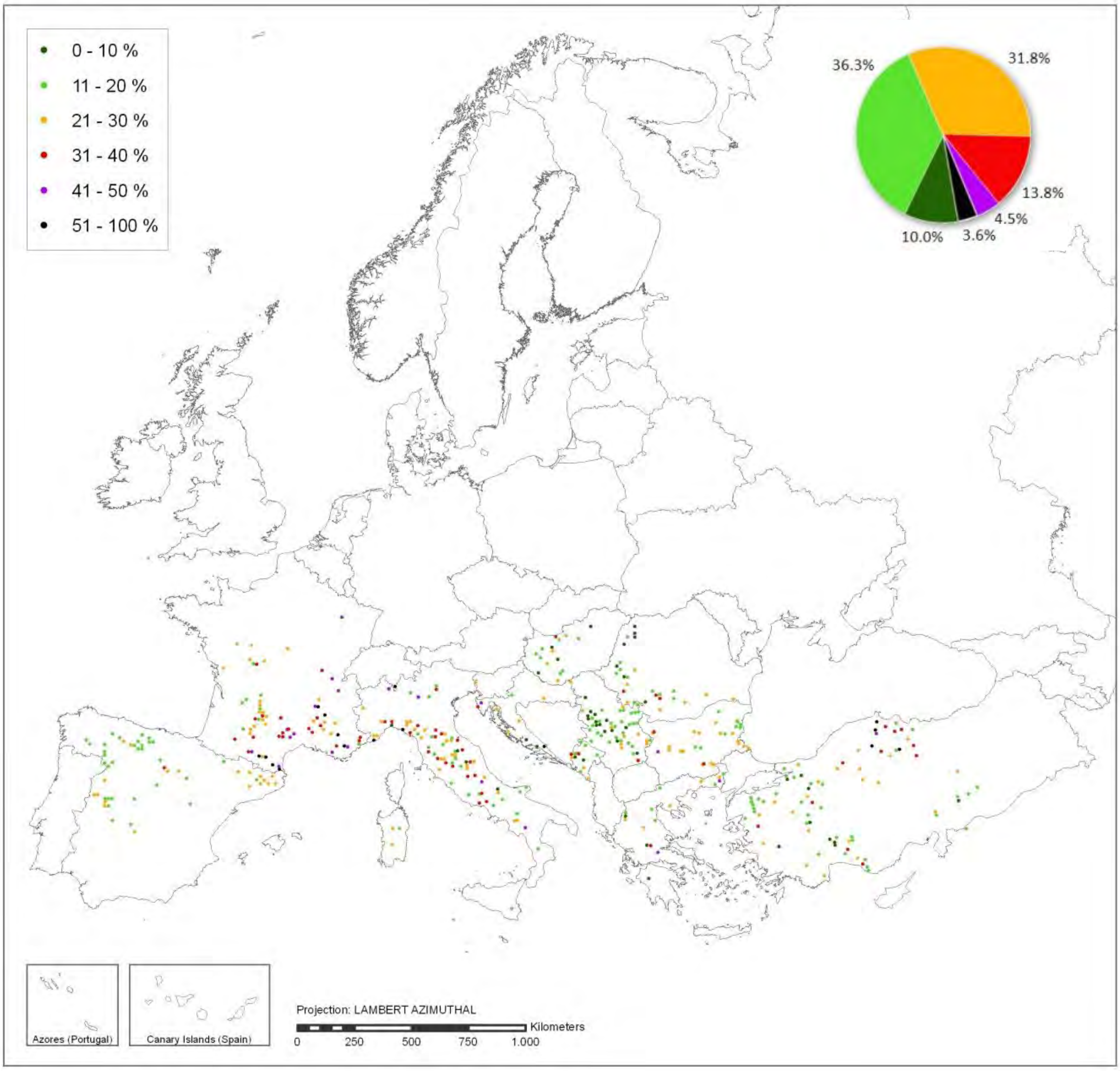

Figure 3-8: Mean plot defoliation for Deciduous (sub-) Mediterranean oak (*Quercus cerris, Quercus frainetto, Quercus pubescens, Quercus pyrenaica*), 2010

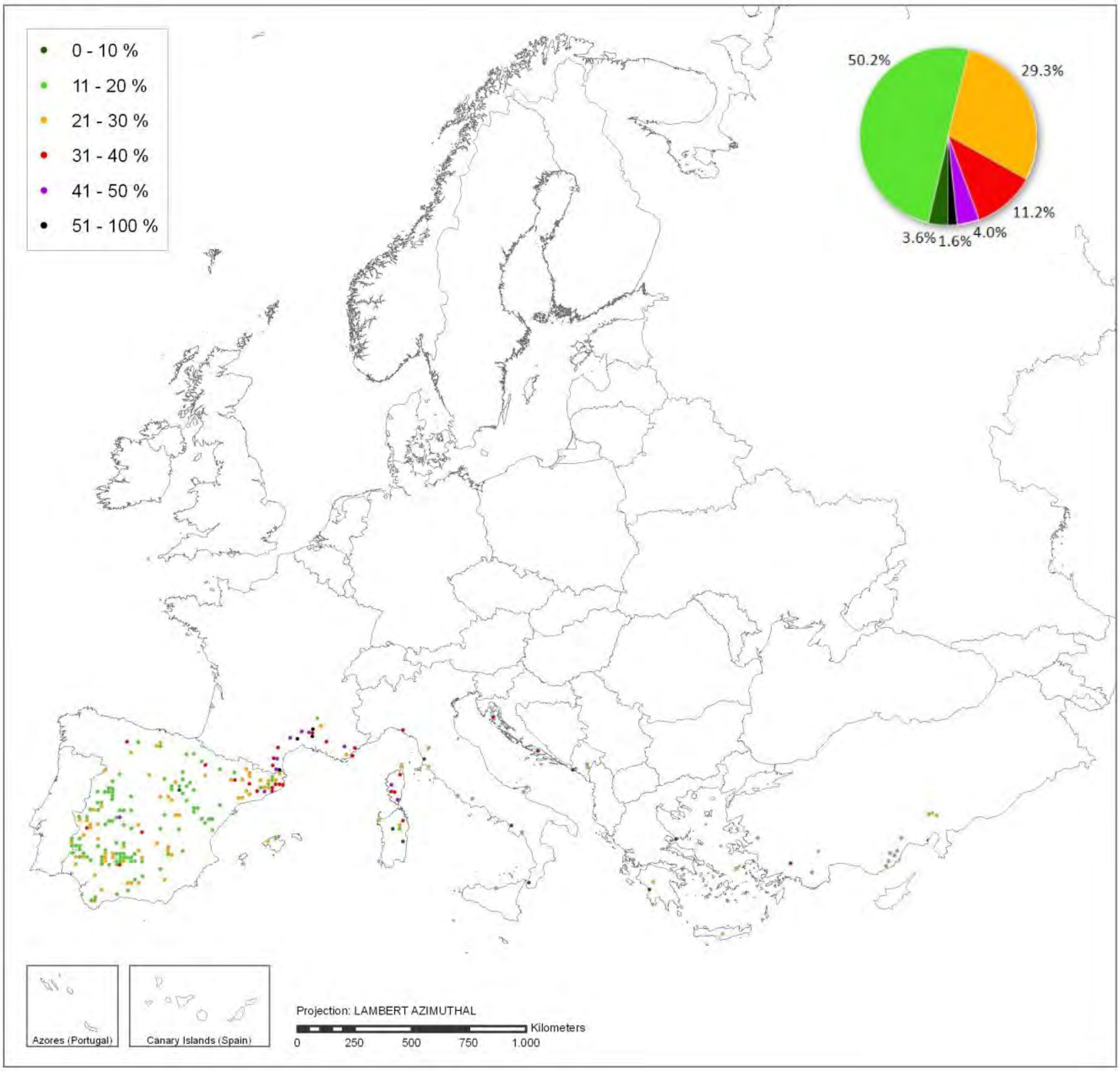

Figure 3-9: Mean plot defoliation for evergreen oak (*Quercus coccifera, Quercus ilex, Quercus rotundifolia, Quercus suber*), 2010

3.2.3 Defoliation trends

3.2.3.1 Approach

The development of defoliation is calculated assuming that the sample trees of each survey year represent forest condition. Studies of previous years show that the fluctuation of trees in this sample (due to the exclusion of dead and felled trees as well as 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 three time periods and the following countries were selected for tracing the development of defoliation:

- **Period 1991-2010 ("long term period")**: Belgium, Czech Republic, Denmark, Finland, France[1], Germany, Hungary, Ireland, Italy, Latvia, Poland, Slovak Republic, Spain, and Switzerland.
- **Period 1997-2010 ("many countries"):** Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Slovak Republic, Spain, and Switzerland.
- **Period 2002-2010 ("short term period used to calculate the trend of the mean plot defoliation"):** Belarus, Belgium, Bulgaria, Croatia, Czech Republic, Cyprus, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, Italy, Latvia, Lithuania, Norway, Poland, Slovak Republic, Spain, and Switzerland.

Several countries could not be included in one of the three time periods because of changes in their tree sample sizes, their assessment methods or missing assessments in certain years. Development of defoliation is presented for the periods 1991-2010 and 1997-2010 in graphs and in tables. Graphs show the fluctuations of mean defoliation and shares of trees in defoliation classes over time.

The maps depict trends in mean defoliation from 2002-2010. Whereas all plots of the countries mentioned above are included for the two respective time periods in graphs, the maps of the trend analysis only represent plots within these countries that were included in all of the surveys. In the last years plots were shifted within Finland and parts of northern Germany (Brandenburg). These plots are not depicted in the maps but the countries are included in the time series calculation.

The spatial pattern of the changes in mean defoliation from 2009 to 2010 across Europe is shown in Annex I-5. On 84.8% of the plots between 2009 and 2010 there was no statistical significance of the differences in mean plot defoliation detected. The share of plots with increasing defoliation was 6.9%, the share of plots with a decrease was 8.3%.

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[1] Methodological changes in the first years of the assessments

3.2.3.2 All tree species

For all species depicted, the two time series show very similar trends for mean defoliation due to the fact that the countries included in the short time series were also included in the evaluation of the long time series (Fig. 3-10 and Fig. 3-11). For *evergreen oak* and *Mediterranean lowland pines* there was hardly any difference in sample sizes on which evaluations of the different time series were based. The largest differences occurred for *Pinus sylvestris* and *Picea abies* the sample sizes for the long time series being 70% smaller than that of the shorter time series.

Since 1991 mean defoliation of the evaluated tree species developed very differently. With the exception of *Picea abies* and *Pinus sylvestris*, all tree species showed a sharp rise in mean defoliation in the first years of the study. Mean defoliation of *Picea abies*, *Fagus sylvatica* and the deciduous temperate oaks peaked after the extremely dry and warm summer in 2003. In all samples studied, deciduous temperate oaks and deciduous (sub-) mediterranean oaks exhibited the highest mean defoliation over the last decade. In contrast, *Pinus sylvestris* clearly showed the lowest mean defoliation from all evaluated species.

Trends in mean plot defoliation for all tree species for the period 2002-2010 are mapped in Figure 3-12. The share of plots with distinctly increasing defoliation (16.8%) surmounts the share of plots with decreasing defoliation (10.0%). Plots showing deterioration are scattered across Europe, but their share is particularly high in southern France, at the eastern edge of the Pyrenean Mountains, Czech Republic, and northeastern Italy.

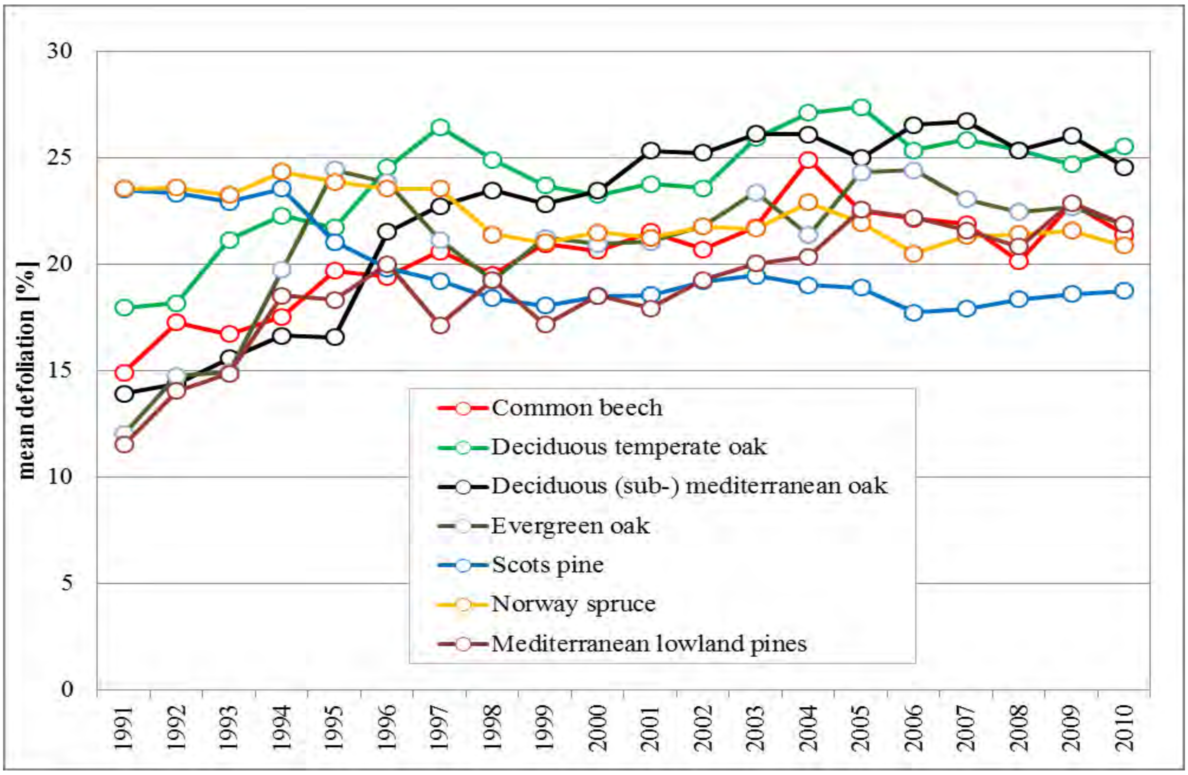

Figure 3-10: Mean defoliation of main species 1991 - 2010

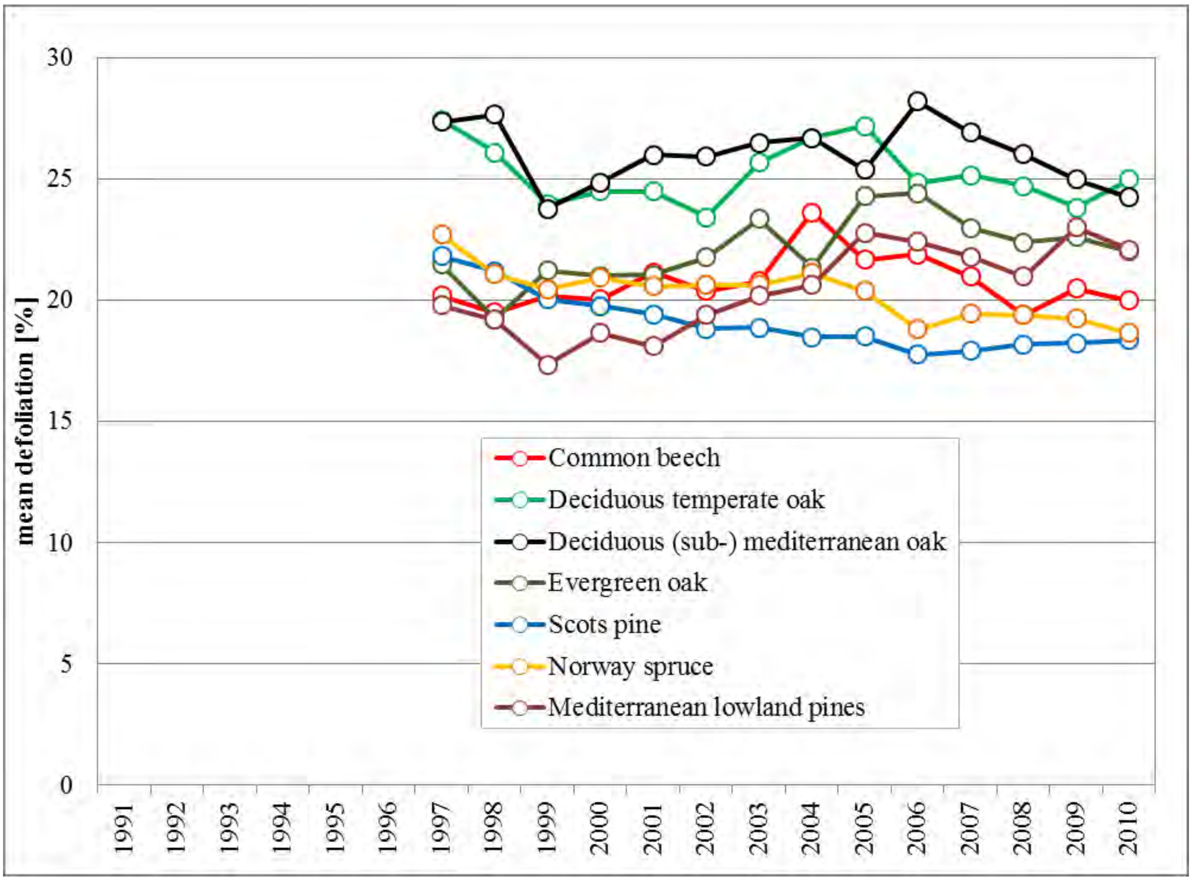

Figure 3-11: Mean defoliation of main species 1997 - 2010

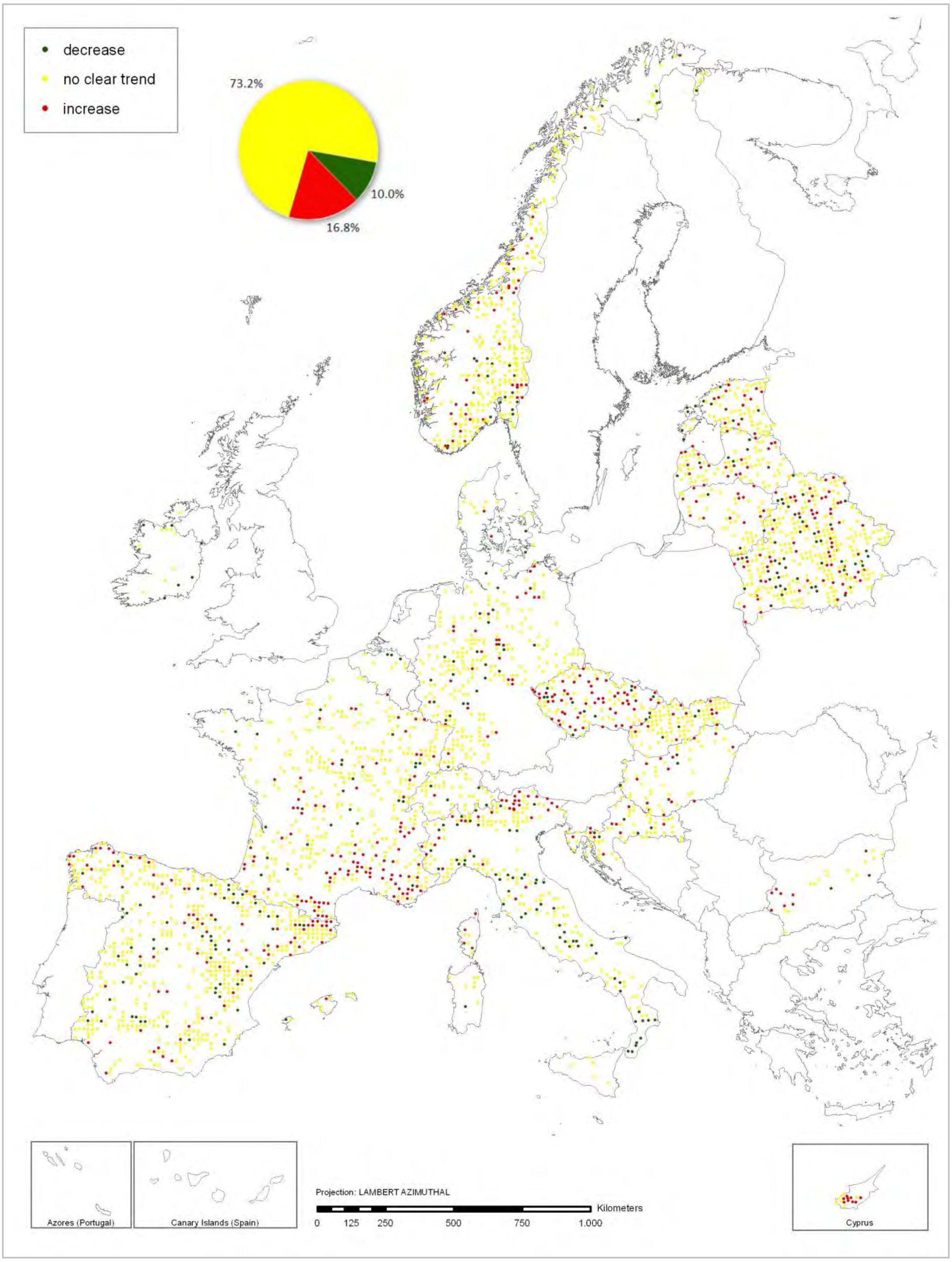

Figure 3-12: Development of mean plot defoliation (slope of linear regression) of all species over the years 2002 – 2010

3.2.3.3 Pinus sylvestris

Pinus sylvestris is by far the most common tree species in the sample. It covers most regions in Europe and occurs on Level I plots from northern Scandinavia to the Mediterranean region. Due to the large sample number and its occurrence throughout Europe, regional differences in the development of crown condition are leveled off in the aggregated results (Tab. 3-7).

Over the long time period, a decrease in the mean defoliation was noticed. In recent years, however, almost no change in crown condition was seen. Throughout both time periods, the share of healthy pines (0-10%) increased and the share of the damaged pine trees (>25%) decreased (Tab. 3-7, Fig. 3-13, Fig. 3-14).

Plots showing a deterioration are scattered across Europe (Fig. 3-15). Most plots show no clear trend from 2002 to 2010. Ths share of plots with increasing defoliation (16.9%) is larger than the share of plots with decresing defolaiton (9.2%).

	N Trees	0-10%	>10-25%	>25%
1991	17768	27.1	37.4	35.5
1992	17193	28.4	36.3	35.4
1993	17224	27.6	38.5	33.9
1994	16570	26.8	37.0	36.2
1995	18751	33.4	37.3	29.3
1996	18788	35.2	40.8	24.0
1997	18824	34.8	42.9	22.3
1998	19205	35.9	45.0	19.1
1999	19468	36.1	46.2	17.7
2000	19455	34.5	47.5	18.0
2001	19571	33.4	49.1	17.5
2002	19495	31.2	50.1	18.6
2003	19486	29.9	51.4	18.7
2004	21101	33.2	48.0	18.8
2005	21279	34.5	46.3	19.2
2006	18654	38.1	45.5	16.4
2007	19254	35.6	48.8	15.6
2008	17696	33.9	49.4	16.7
2009	16979	33.7	48.3	18.0
2010	17122	33.5	49.1	17.5
	N Trees	0-10%	>10-25%	>25%
1997	29838	27.7	44.6	27.7
1998	30196	29.2	45.8	25.0
1999	30148	30.6	47.6	21.8
2000	29855	30.2	49.9	19.9
2001	29967	30.4	51.3	18.3
2002	29798	32.0	51.6	16.4
2003	30077	31.6	52.0	16.5
2004	31593	35.2	48.3	16.6
2005	31722	35.5	47.6	16.9
2006	28990	37.4	48.1	14.6
2007	29570	34.8	50.9	14.2
2008	28046	32.5	52.7	14.8
2009	27662	32.6	52.0	15.4
2010	27851	33.0	51.9	15.1

Table 3-7: Shares of trees in different defoliaton classes

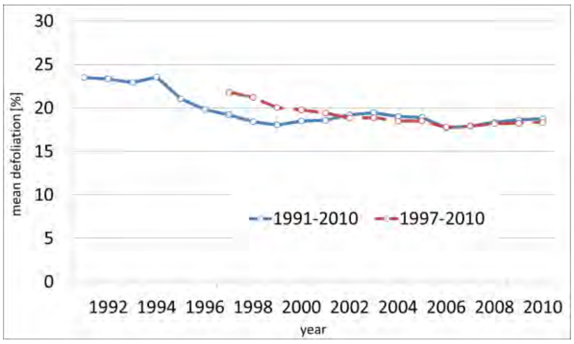

Figure 3-13: Mean defoliation in two periods (1991-2010 and 1997-2010)

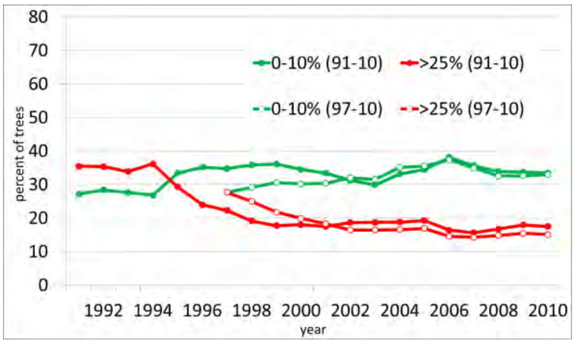

Figure 3-14: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

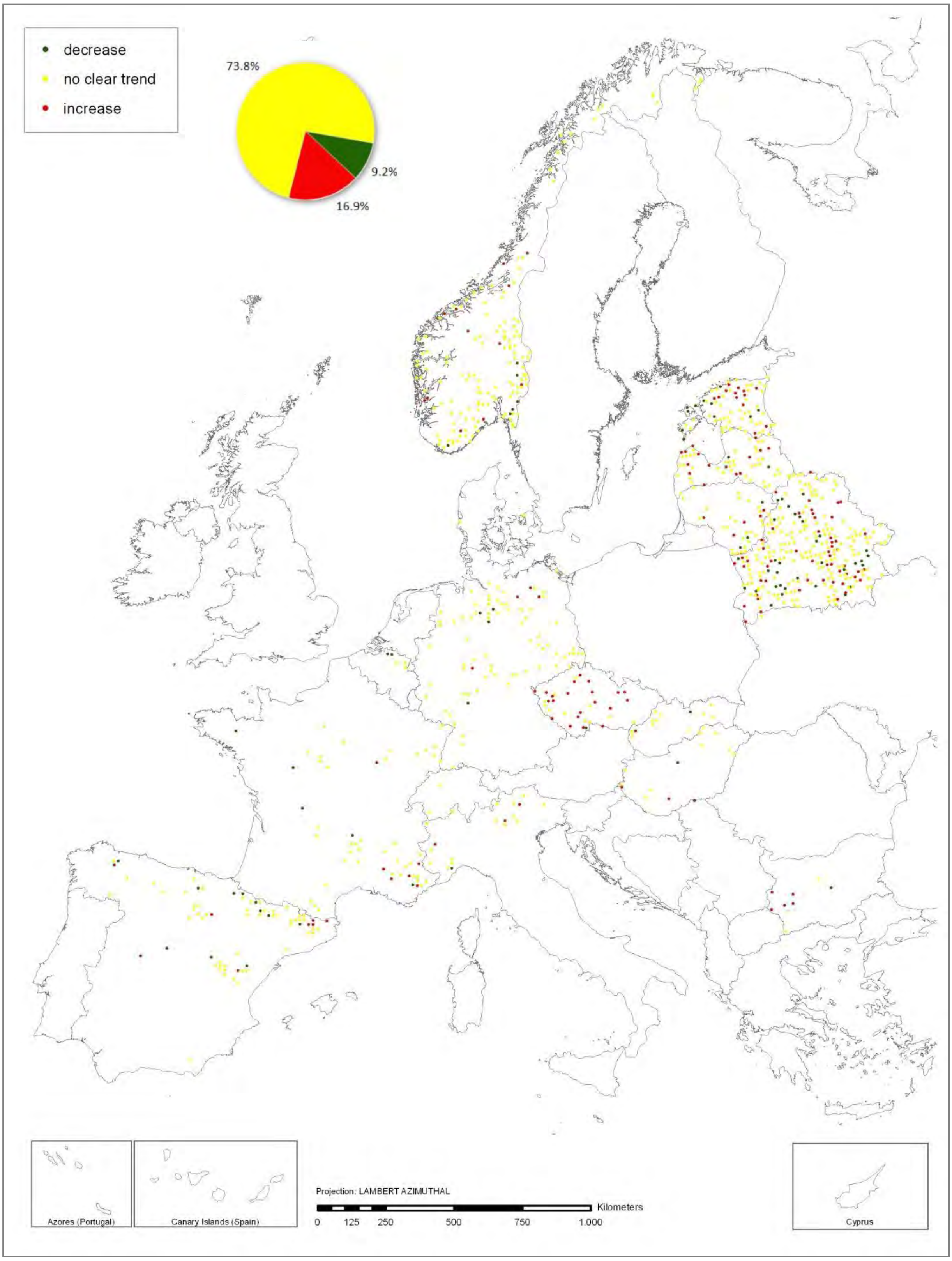

Figure 3-15: Development of mean plot defoliation (slope of linear regression) of *Pinus sylvestris* over the years 2002 – 2010

3.2.3.4 Picea abies

Picea abies is the second most frequently occurring tree species in the large scale tree sample. Its range extends mainly from Scandinavia to northern Italy.

The crown condition of *Picea abies* slightly improved over the course of both observation periods. Due to the extreme weather conditions in central Europe in summer 2003, mean defoliation peaked in this year. Until 2006 a regeneration phase was observed. Since then, the crown condition has remained more or less unchanged (Tab. 3-8, Fig. 3-16, Fig. 3-17).

Since 1991, the share of healthy trees (0-10%) increased slightly. In the same period the share of more damaged spruce (>25%) decreased slightly. A significant improvement in the crown condition of spruce was observed in 1998 and 2006.

From 2003 to 2010, a total of 19.4% of all plots showed an increase of mean defoliation; a significant decrease in crown damage was only observed on 9.2%. In particular, decreasing trends of defoliation were determined in Belarus and southern Norway (Fig. 3-18).

	N Trees	0-10%	>10-25%	>25%
1991	15090	26.0	37.4	36.6
1992	12298	26.8	37.4	35.8
1993	12473	28.1	37.6	34.4
1994	12812	26.3	35.7	38.0
1995	14480	28.9	33.7	37.4
1996	14437	29.4	31.9	38.7
1997	14234	27.0	33.9	39.1
1998	13729	32.2	36.6	31.3
1999	14129	33.2	36.8	30.1
2000	14174	31.3	38.0	30.7
2001	13898	30.3	39.7	30.0
2002	13935	29.3	39.4	31.3
2003	13928	28.7	40.8	30.5
2004	14364	27.1	38.3	34.6
2005	13913	28.1	40.3	31.6
2006	11916	33.9	37.2	29.0
2007	11385	30.5	39.5	30.0
2008	10991	30.6	39.2	30.2
2009	10664	30.4	39.4	30.2
2010	10991	32.2	39.3	28.5
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	17982	30.0	34.2	35.8
1998	17465	34.0	36.1	29.9
1999	17862	35.1	36.7	28.3
2000	17833	33.1	38.3	28.6
2001	17574	32.6	39.4	27.9
2002	17630	33.2	39.1	27.7
2003	17736	32.6	40.3	27.1
2004	18272	32.8	37.4	29.8
2005	17749	33.9	38.5	27.6
2006	15845	39.2	36.3	24.5
2007	15538	37.2	37.5	25.2
2008	15325	37.4	37.3	25.3
2009	15274	38.0	37.4	24.6
2010	15683	40.1	36.5	23.4

Table 3-8: Shares of trees in different defoliaton classes

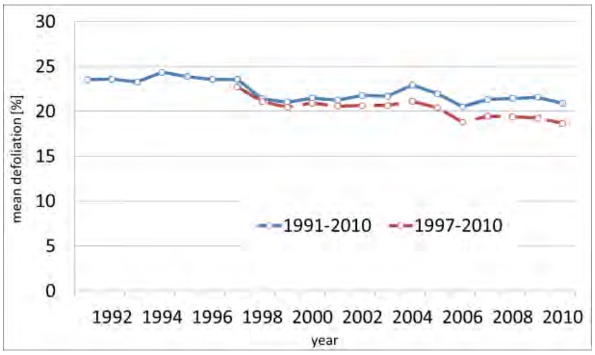

Figure 3-16: Mean defoliation in two periods (1991-2010 and 1997-2010)

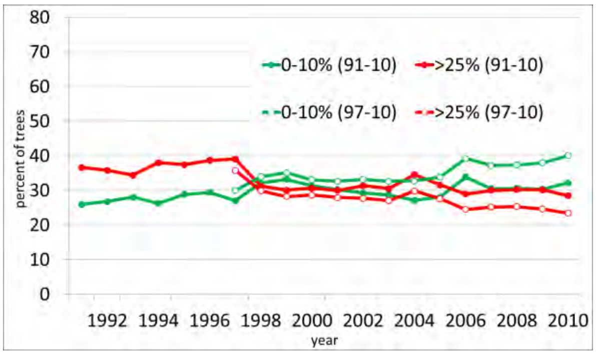

Figure 3-17: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

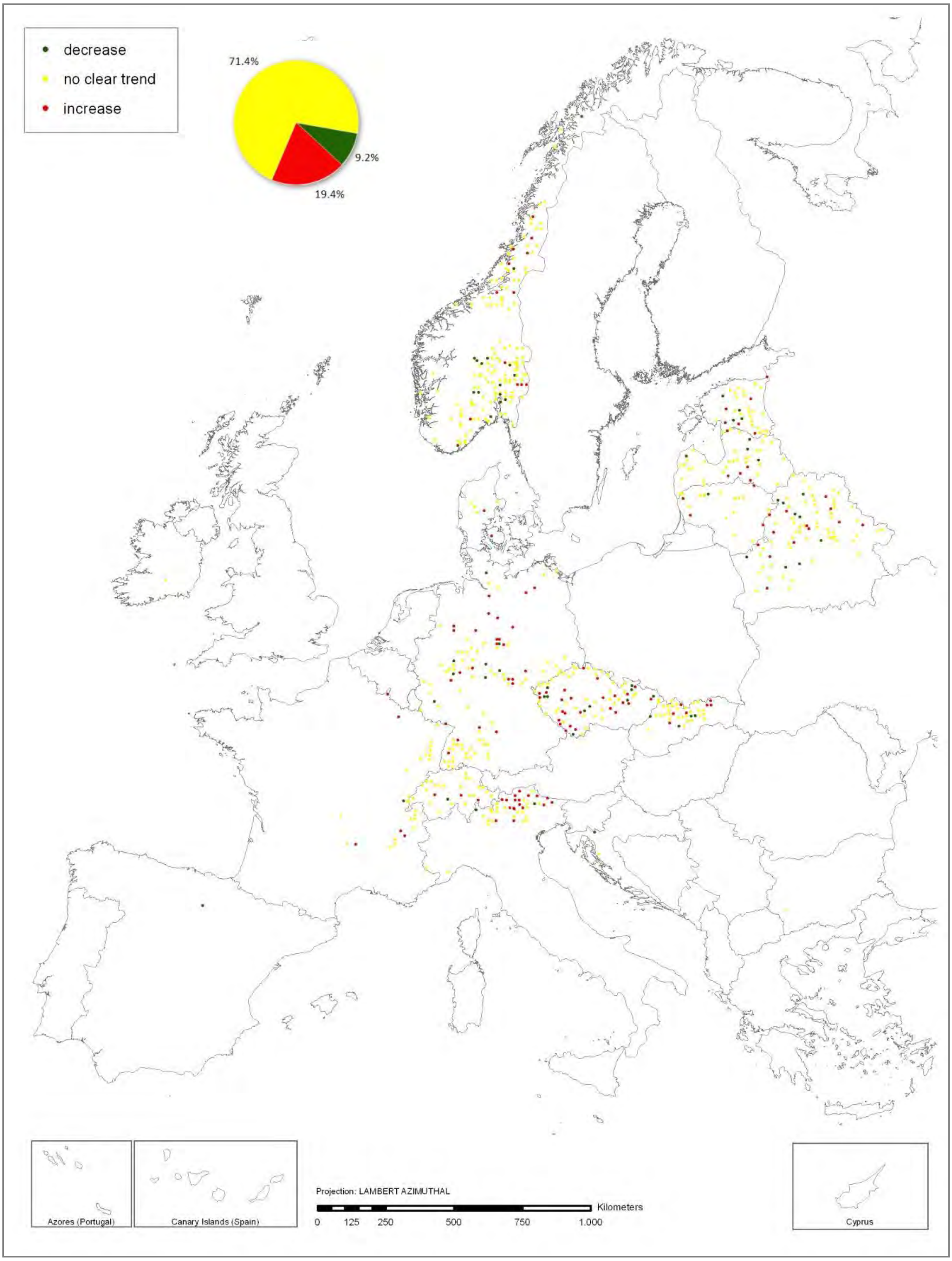

Figure 3-18: Development of mean plot defoliation (slope of linear regression) of *Picea abies* over the years 2002 – 2010

3.2.3.5 Mediterranean lowland pines

The group of Mediterranean lowland pines is composed of *Pinus brutia*, *P. pinaster*, *P. halepensis* and *P. pinea*. Their occurrence is limited to the Mediterranean region. The results for different time periods observed are similar because the two time periods included almost identical countries.

Crown condition of this tree species group is characterized by a considerable increase in mean defoliation of the pine trees since 1991. The share of healthy trees (0-10%) has decreased from 72.9% in 1991 to 23.2% in 2010. In contrast, the share of the damaged Mediterranean lowland pines (>25%) peaked in 2005, decreased thereafter and fluctuated since then (Tab. 3-9, Fig. 3-19, fig. 3-20).

The worsening trend is also reflected in the share of plots showing a significant increase in mean plot defoliation. Mean plot defoliation increased on 20.4% of the plots from 2002 to 2010. These plots are mainly located along the Mediterranean coast in France and in northern Spain (Fig. 3-21).

	N Trees	**0-10%**	**>10-25%**	**>25%**
1991	3758	72.9	20.9	6.1
1992	3866	63.9	24.3	11.8
1993	3891	60.3	27.1	12.6
1994	3802	50.3	32.7	17.0
1995	3823	39.2	43.8	17.0
1996	3815	36.6	45.4	17.9
1997	3769	40.3	48.3	11.5
1998	3827	37.1	47.3	15.6
1999	5202	40.8	47.6	11.6
2000	5279	39.1	48.6	12.2
2001	5287	34.0	54.6	11.5
2002	5280	29.6	55.8	14.7
2003	5215	27.3	56.6	16.1
2004	5235	28.7	55.2	16.1
2005	5198	20.7	56.0	23.3
2006	5201	21.3	56.6	22.1
2007	5240	22.9	57.0	20.1
2008	5248	21.2	60.5	18.3
2009	5105	18.1	61.0	20.8
2010	5085	23.2	58.7	18.1
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	3944	38.5	46.4	15.1
1998	3940	37.5	46.5	16.0
1999	5314	40.1	47.6	12.3
2000	5368	38.6	48.6	12.8
2001	5376	33.5	54.3	12.2
2002	5345	29.3	55.5	15.2
2003	5280	27.0	56.2	16.8
2004	5348	28.1	54.7	17.3
2005	5289	20.4	55.3	24.3
2006	5290	21.0	55.8	23.1
2007	5305	22.6	56.6	20.7
2008	5313	21.0	60.2	18.8
2009	5170	17.9	60.5	21.6
2010	5150	23.1	58.2	18.7

Table 3-9: Shares of trees in different defoliaton classes

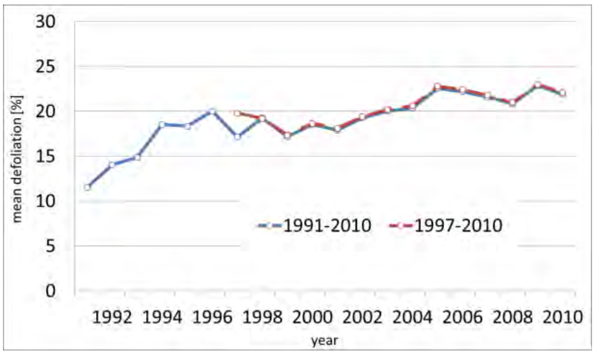

Figure 3-19: Mean defoliation in two periods (1991-2010 and 1997-2010)

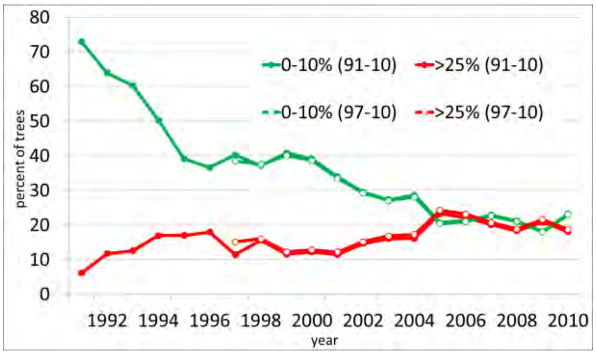

Figure 3-20: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

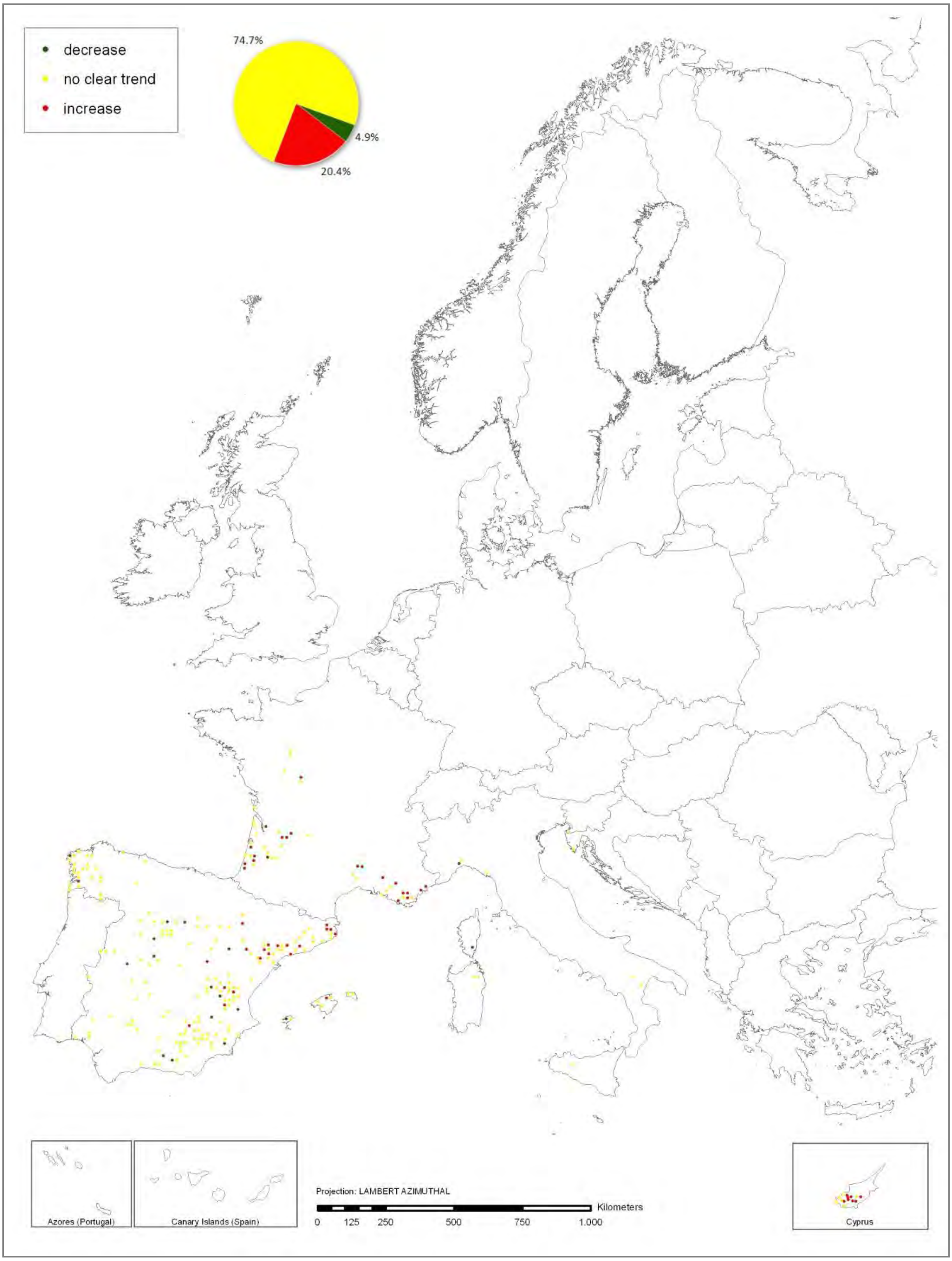

Figure 3-21: Development of mean plot defoliation (slope of linear regression) of *Mediterranean lowland pines* over the years 2002 – 2010

3.2.3.6 Fagus sylvatica

Fagus sylvatica is the most common deciduous tree species occurring on Level I plots. It ranges from southern Scandinavia to Sicily and from the northern coast of Spain to Bulgaria.

Since the beginning of the study in 1991, mean defoliation of this species slightly increased. Defoliation peaked in the year after the hot and dry summer in central Europe in 2003. Recuperation has been observed since then. The increase in defoliation in 2009 has been explained by, widespread fructification (Tab. 3-10, Fig. 3-22, Fig. 3-23).

The share of healthy trees (0-10%) steadily decreased from 49.6% in 1991, to 18.3% in 2004. In 2010, the share of healthy trees increased to 26.6%. The share of the damaged trees (> 25%) was 25.6% in 2010.

Temporal trends of mean defoliation from 2003 – 2010 show an increase in mean defoliation of *Fagus sylvatica*, especially on plots in France and Croatia. Decreasing trends were detected for plots in Italy and western Germany (Fig. 3-24).

	N Trees	0-10%	>10-25%	>25%
1991	6524	49.6	34.0	16.5
1992	6254	43.7	35.5	20.8
1993	6368	45.1	34.7	20.2
1994	6401	41.7	37.3	21.0
1995	6480	35.2	38.7	26.1
1996	6458	33.1	45.4	21.4
1997	6309	29.7	46.9	23.4
1998	6588	32.9	45.1	22.0
1999	7244	26.2	49.5	24.3
2000	7266	29.6	46.7	23.7
2001	7328	25.3	48.0	26.7
2002	7337	26.3	50.4	23.3
2003	7299	23.7	50.2	26.1
2004	7386	18.3	47.3	34.4
2005	7448	24.0	47.7	28.3
2006	6940	26.4	44.9	28.7
2007	7106	23.2	50.6	26.2
2008	7128	29.1	49.1	21.8
2009	6985	24.8	44.2	31.0
2010	7305	26.6	47.8	25.6
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	7792	33.1	44.5	22.4
1998	8176	35.6	43.3	21.0
1999	8454	30.7	46.9	22.4
2000	8668	33.9	44.0	22.1
2001	8664	29.3	45.4	25.4
2002	8772	30.3	47.5	22.1
2003	8666	28.1	48.4	23.5
2004	8613	21.9	47.3	30.8
2005	8760	28.6	45.9	25.5
2006	8315	30.3	43.4	26.3
2007	8577	28.4	48.1	23.5
2008	8533	32.8	47.6	19.6
2009	9041	32.6	42.2	25.2
2010	9187	31.8	45.8	22.4

Table 3-10: Shares of trees in different defoliaton classes

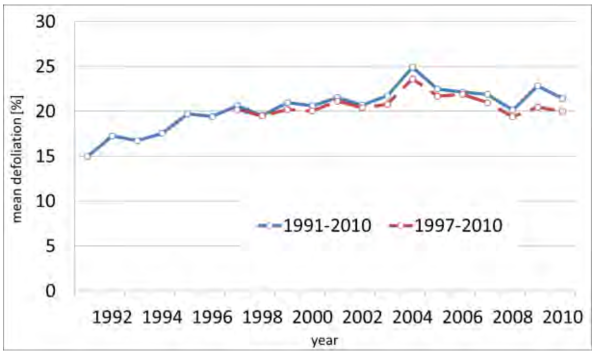

Figure 3-22: Mean defoliation in two periods (1991-2010 and 1997-2010)

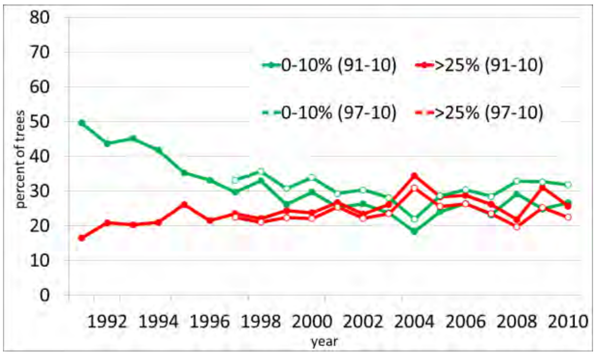

Figure 3-23: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

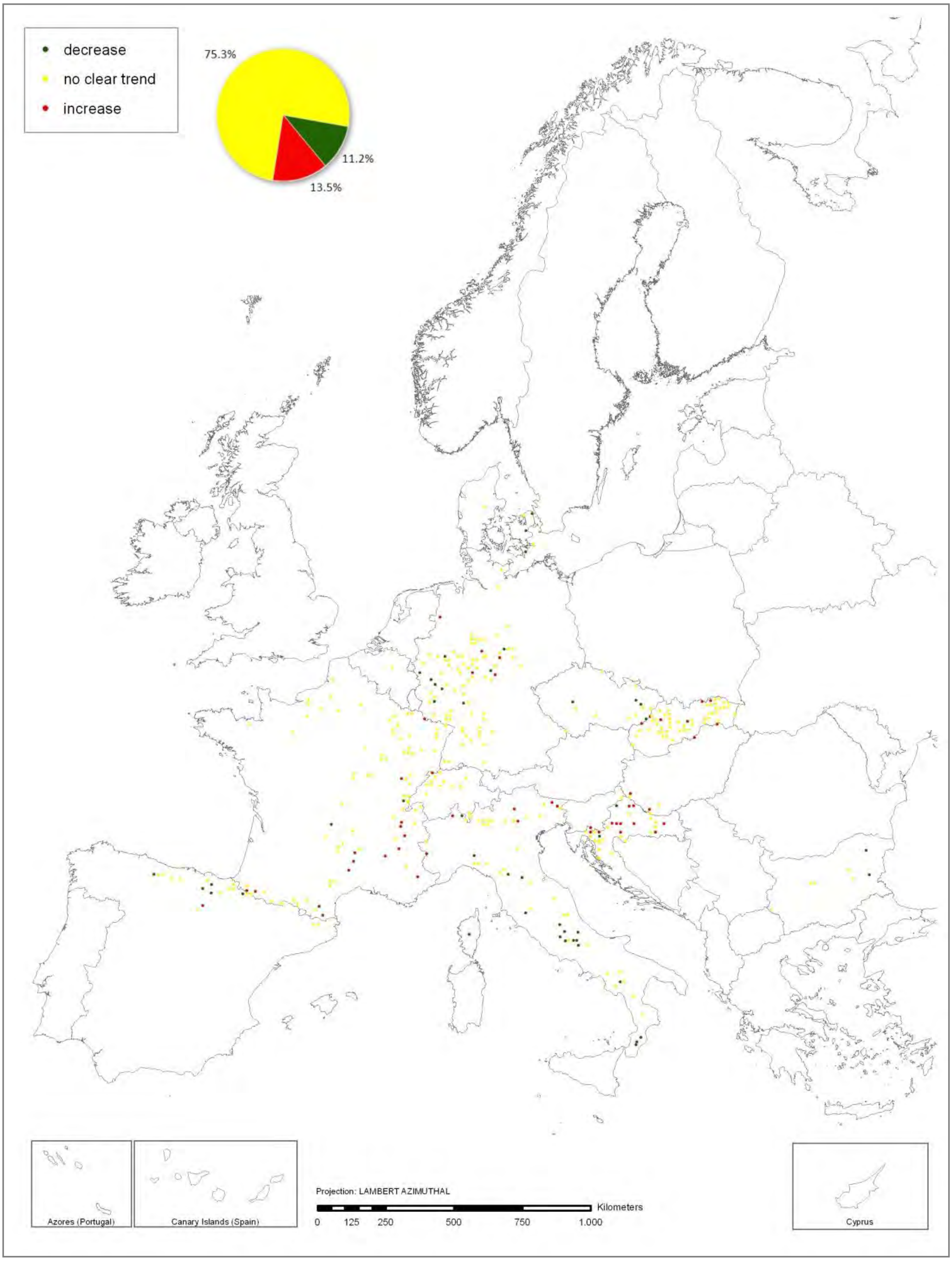

Figure 3-24: Development of mean plot defoliation (slope of linear regression) of *Fagus sylvatica* over the years 2002 – 2010

3.2.3.7 Deciduous temperate oak

The group of decidious temperate oaks includes two species: *Quercus robur* and *Q. petraea*. These species are occuring throughout central Europe.

Defoliation of deciduous temperate oaks has been characterized by two peaks in 1997 and 2005 with a slight recuperation in the subsequent years. In 2010, mean defoliation again increased to slightly over 25%.

The share of healthy oaks has decreased by more 50% since 1991. Consequently, the share of damaged oaks increased over this time period (Tab. 3-11, Fig. 3-26, Fig. 3-26).

An increasing trend of defoliation was observed on 12.9% of the plots from 2002 to 2010. On 9.8% of all plots, a decreasing trend of mean plot defoliation was identified. No clear spatial trends for the development of defoliation were detected for the deciduous temperate oaks (Fig. 3-27).

	N Trees	0-10%	>10-25%	>25%
1991	5730	45.0	32.2	22.8
1992	5295	42.5	35.0	22.5
1993	5377	36.9	33.0	30.1
1994	5593	34.1	31.8	34.1
1995	5449	33.0	36.4	30.6
1996	5422	24.6	39.0	36.4
1997	5435	16.3	42.6	41.1
1998	5589	20.5	42.5	37.0
1999	5708	20.4	47.8	31.7
2000	5737	21.0	48.3	30.7
2001	5738	18.9	49.6	31.5
2002	5750	18.2	51.0	30.8
2003	5750	14.5	47.3	38.2
2004	5852	14.7	44.7	40.5
2005	5863	13.3	43.7	43.0
2006	5373	16.9	46.2	37.0
2007	5475	15.6	47.1	37.2
2008	5646	15.7	48.0	36.2
2009	5579	17.9	46.6	35.5
2010	5639	16.1	47.6	36.3
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	6548	16.5	41.9	41.6
1998	6760	20.1	41.6	38.3
1999	6791	21.0	47.4	31.6
2000	6882	20.2	46.6	33.2
2001	6811	18.9	48.4	32.6
2002	6654	18.8	50.8	30.4
2003	6659	15.3	47.6	37.1
2004	6780	16.2	44.5	39.4
2005	6849	14.6	43.5	41.9
2006	6348	19.2	45.6	35.2
2007	6475	17.5	47.6	34.9
2008	6642	17.2	48.8	34.0
2009	6928	19.3	48.1	32.7
2010	6817	17.7	47.3	35.0

Table 3-11: Shares of trees in different defoliaton classes

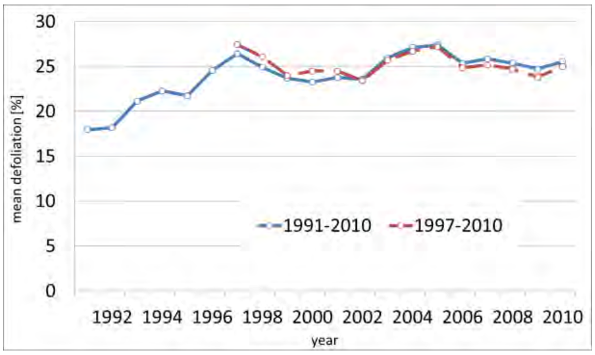

Figure 3-25: Mean defoliation in two periods (1991-2010 and 1997-2010)

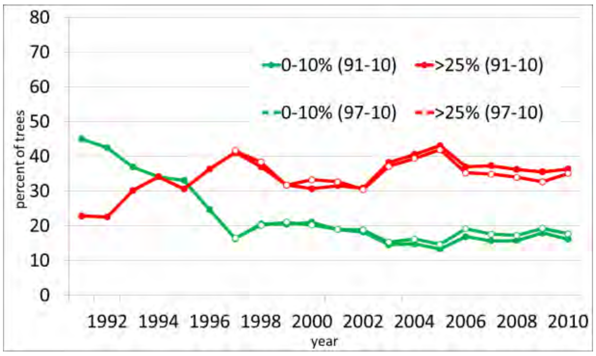

Figure 3-26: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

Figure 3-27: Development of mean plot defoliation (slope of linear regression) of deciduous temperate oak *(Quercus robur, Quercus petraea)* over the years 2002 – 2010

3.2.3.8 Deciduous (sub-) mediterranean oak

The group of deciduous (sub-) Mediterranean oak is composed of *Quercus cerris*, *Q. pubescens*, *Q. frainetto* and *Q. pyrenaica*. These species are occurring on plots in southern European countries.

Crown condition of these oaks declined drastically until the end of 1990s. For the first time in 1996, mean defoliation of this group increased to more than 20%. Since then, no prolonged phases with recuperating crown condition have been observed.

The share of healthy trees (0-10%) decreased by more than 50% since 1991. Accordingly, the proportion of damaged oaks rose to over 30% (Tab. 3-12, Fig. 3-28, Fig. 3-29).

The spatial distribution clearly shows a trend of deterioration of crown condition of deciduous (sub-) Mediterranean oaks since 2002, mainly in areas of southern France. In contrast, plots with an improving trend of mean plot defoliation were found in other areas, such as central Italy (Fig. 3-30).

	N Trees	0-10%	>10-25%	>25%
1991	3113	57.4	30.3	12.4
1992	3156	54.3	32.8	12.8
1993	3154	53.0	31.8	15.2
1994	3123	49.5	32.8	17.7
1995	3170	47.4	34.9	17.7
1996	3218	30.5	43.7	25.8
1997	3056	27.1	42.5	30.4
1998	3084	26.1	41.8	32.1
1999	3678	24.8	46.1	29.1
2000	3648	22.5	46.8	30.6
2001	3686	20.2	45.0	34.8
2002	3599	18.4	46.0	35.6
2003	3519	16.7	46.2	37.0
2004	3625	16.2	48.8	35.0
2005	3580	18.5	48.5	32.9
2006	3583	17.5	46.1	36.4
2007	3588	14.9	49.3	35.8
2008	3606	16.3	50.1	33.6
2009	3608	16.2	50.1	33.6
2010	3967	19.3	48.9	31.8
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	4037	23.4	40.0	36.6
1998	4392	21.7	39.9	38.3
1999	4628	24.4	45.2	30.4
2000	4530	20.4	45.5	34.1
2001	4704	19.0	44.7	36.3
2002	4599	15.9	48.6	35.4
2003	4376	14.2	48.0	37.8
2004	4468	14.3	48.6	37.1
2005	4409	17.1	49.7	33.2
2006	4577	15.8	47.2	37.0
2007	4387	13.6	50.7	35.7
2008	4390	14.9	51.4	33.7
2009	4832	15.8	53.1	31.1
2010	5112	18.0	51.3	30.7

Table 3-12: Shares of trees in different defoliaton classes

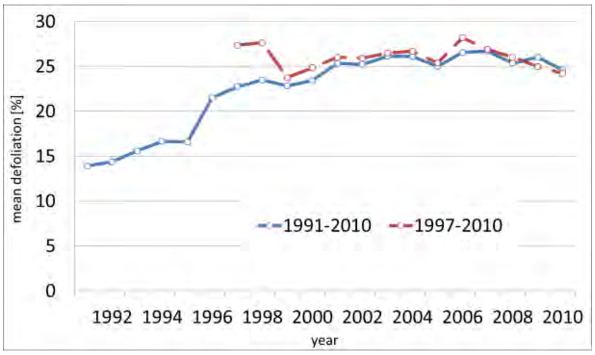

Figure 3-28: Mean defoliation in two periods (1991-2010 and 1997-2010)

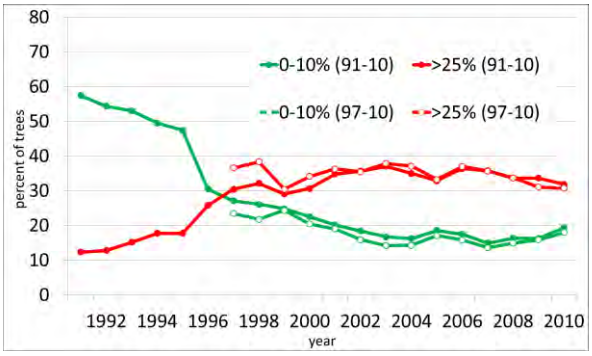

Figure 3-29: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

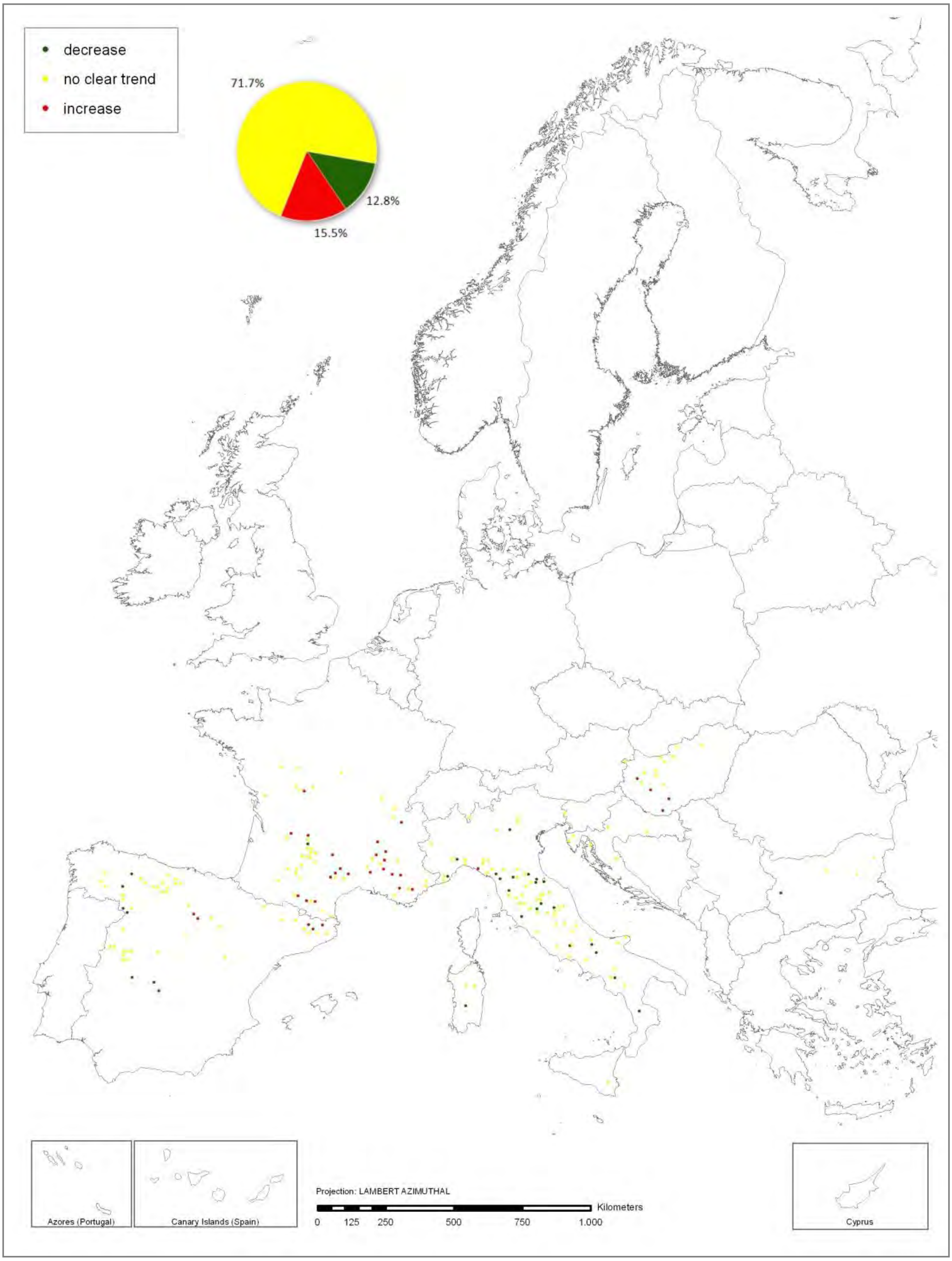

Figure 3-30: Development of mean plot defoliation (slope of linear regression) of deciduous (sub-Mediterranean oak *(Quercus cerris, Quercus frainetto, Quercus pubescens, Quercus pyrenaica*) over the years 2002 – 2010

3.2.3.9 Evergreen oak

The group of evergreen oaks includes *Quercus coccifera*, *Q. ilex*, *Q. rotundifolia* and *Q. suber*. The results for the different time periods shown in the graph are similar because of only marginal differences in the composition of countries represented by the figures.

At the beginning of the study in the early 1990s, mean defoliation of evergreen oak trees was relatively low – less than 15%. Accordingly, the share of healthy trees (0-10%) was high. The first peak (with just under 25% mean defoliation) was recorded in 1995, the second one in 2005 and 2006. Since then, a slight recovery of the crown condition has been recorded (Tab. 3-13, Fig. 3-31, Fig. 3-32).

14.7% of all plots showed a decreasing trend and 13.8% an increasing trend of mean plot defoliation of evergreen oaks from 2002 to 2010. In southern France there are clusters of plots with an increasing trend, while in the continental areas of Spain more plots with a decreasing trend can be identified (Fig. 3-33).

	N Trees	0-10%	>10-25%	>25%
1991	3224	59.9	35.7	4.3
1992	3362	47.4	44.4	8.2
1993	3315	41.5	51.0	7.5
1994	3288	31.4	52.4	16.2
1995	3329	19.2	48.5	32.3
1996	3307	18.1	53.6	28.4
1997	3306	22.3	58.1	19.6
1998	3264	28.6	56.0	15.4
1999	4232	21.7	57.0	21.3
2000	4308	19.3	60.4	20.4
2001	4324	19.9	62.6	17.5
2002	4311	16.2	62.8	21.0
2003	4218	14.0	62.3	23.6
2004	4280	17.7	63.5	18.8
2005	4229	9.8	62.3	27.9
2006	4233	8.8	63.9	27.3
2007	4318	10.1	67.5	22.5
2008	4336	11.6	67.2	21.2
2009	4345	11.0	67.0	22.0
2010	4446	17.3	62.2	20.5
	N Trees	**0-10%**	**>10-25%**	**>25%**
1997	3354	22.1	57.7	20.2
1998	3288	28.4	56.1	15.5
1999	4256	21.6	57.1	21.2
2000	4332	19.2	60.2	20.6
2001	4348	19.8	62.7	17.4
2002	4335	16.1	63.0	20.9
2003	4242	14.0	62.5	23.5
2004	4328	17.5	63.8	18.6
2005	4277	9.8	62.3	27.9
2006	4281	8.8	63.8	27.4
2007	4366	10.3	67.3	22.4
2008	4360	11.9	67.0	21.1
2009	4369	11.3	66.8	21.9
2010	4494	17.4	61.9	20.8

Table 3-13: Shares of trees in different defoliaton classes

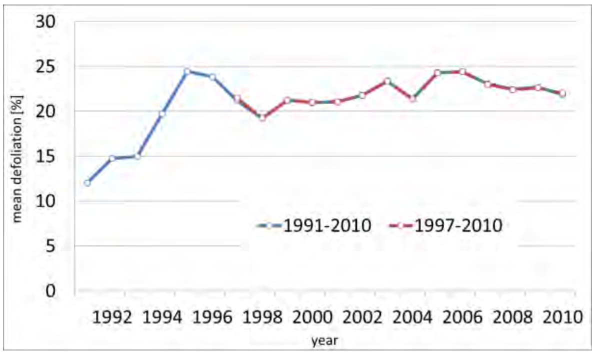

Figure 3-31: Mean defoliation in two periods (1991-2010 and 1997-2010)

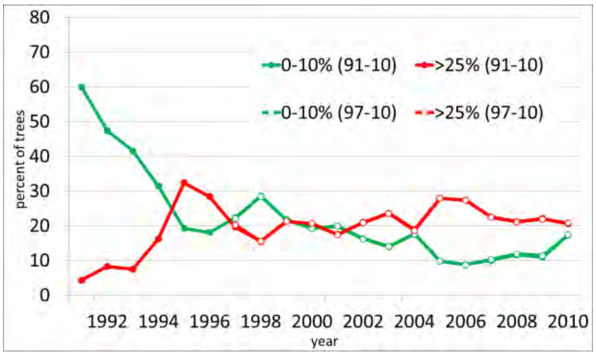

Figure 3-32: Shares of trees of defoliation 0-10% and >25% in two periods (1991-2010 and 1997-2010)

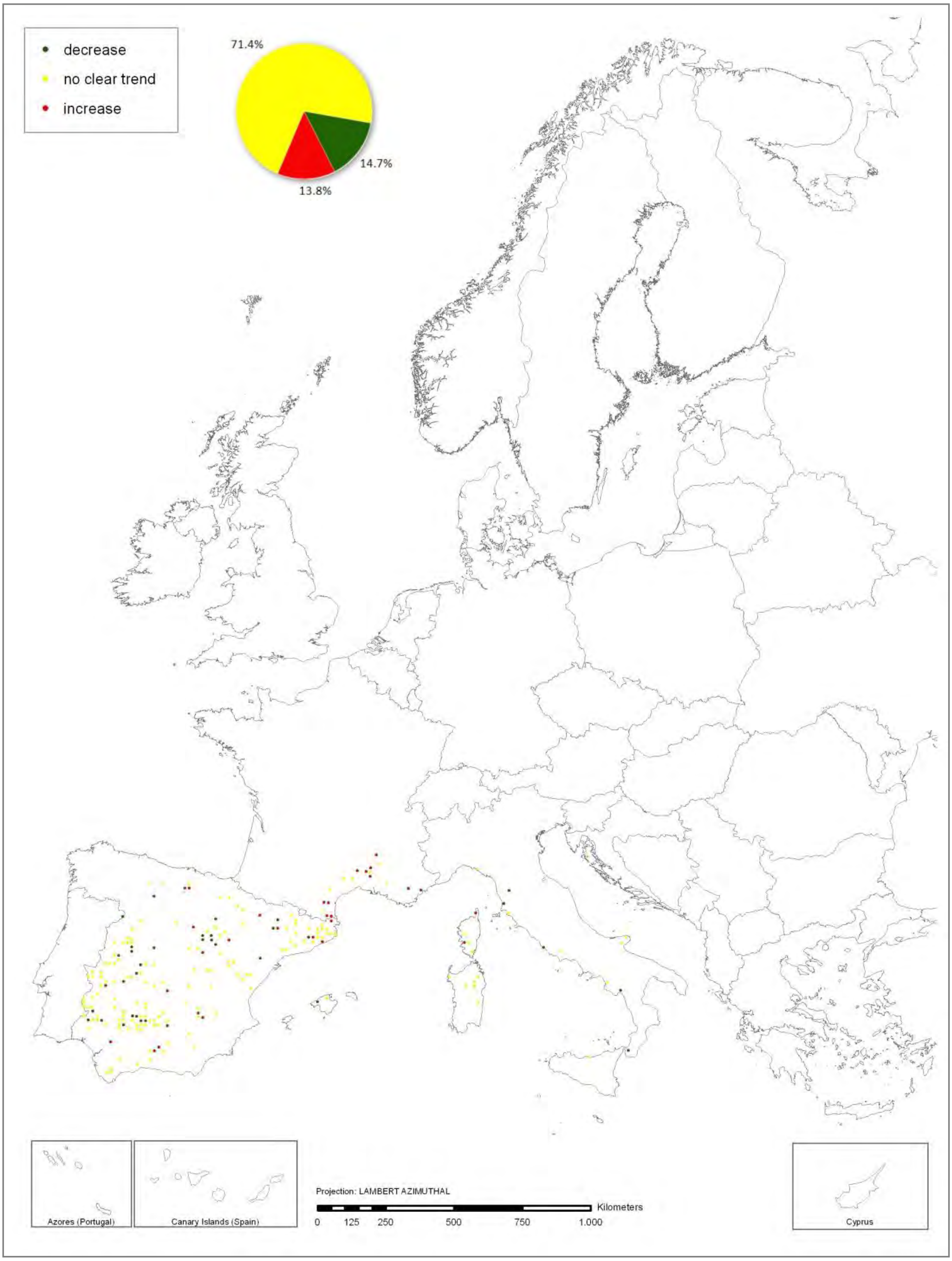

Figure 3-33: Development of mean plot defoliation (slope of linear regression) of evergreen oak *(Quercus coccifera, Quercus ilex, Quercus rotundifolia, Quercus suber)* over the years 2002 – 2010

3.3 Damage Cause Assessment

3.3.1 Background

Crown condition is the most widely applied indicator for forest-health and vitality in Europe. In order to interpret the crown condition accurately, it is necessary to assess tree parameters that have an influence on tree vitality. Parameters assessed in addition to crown condition include discolouration and damages caused by biotic and abiotic factors. Through the assessment of damage and its influence on the crown condition, it is possible to draw conclusions on cause-effect mechanisms. Since 2005, tree crowns on Level I plots have been examined based on an amended method for damage assessment, which allows to obtain more information on injury symptoms, possible causes of damage, and extent of the injury.

The aim of the damage cause assessment is to collect as much information as possible on the causal background of tree damages in order to enable a differential diagnosis and to better interpret the unspecific parameter “defoliation”.

3.3.2 Methods of the Surveys in 2011

3.3.2.1 Selection of sample plots

Assessment of damage causes is part of the visual assessment of crown condition. All trees included in the crown condition sample (Level I plots) are required to be regularly assessed for damage causes.

In 2010, damage causes were assessed on 6 413 plots in 32 different countries across Europe (Fig. 3-34, Tab. 3-14). This is the highest number of assessed plots since the start of the extended damage cause assessment in 2005. The increase in plotnumbers with damage cause assessment from 2009 to 2010 is partly due to the first assessments on plots in Turkey in 2010.

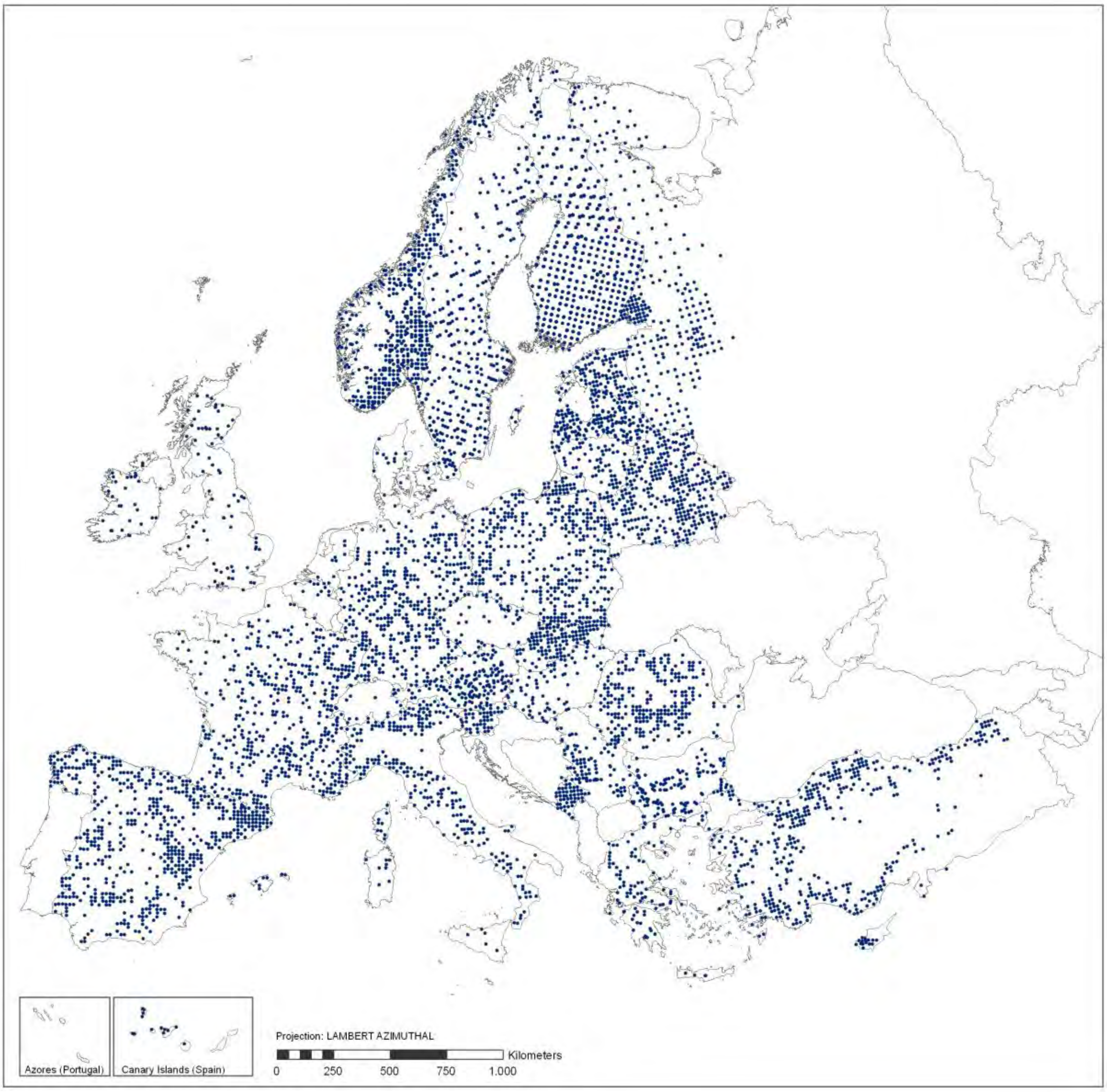

Figure 3-34: Plots with damage cause assessment 2010

Table 3-14: Number of sample plots assessed

Country	Number of sample plots assessed					
	2005	2006	2007	2008	2009	2010
Austria	136	135				135
Belgium	21	25	27	25	23	9
Bulgaria	96	96	100	54	134	132
Cyprus	15	15	15	15	15	15
Czech Rep.	138		40	35	38	43
Denmark					16	17
Estonia	85	81	64	76	92	97
Finland	605	606	518	423	886	932
France	464	498	450	459	459	489
Germany	208	235	255	238	412	389
Greece	79				97	98
Hungary	73	73			73	71
Ireland	17	15		31	32	29
Italy	236	250	238	235	251	253
Latvia	65	93	93	92	169	173
Lithuania	48	50	49	54	63	69
Luxembourg	4	4	2	4		
Netherlands	9	11			11	11
Poland	432	376	430	433	376	374
Portugal	88	6				
Romania	66	61	158		227	239
Slovak Rep.	108	107	107	102	108	108
Slovenia	33	23			44	44
Spain	620	620	620	620	590	582
Sweden	784	748			857	370
United Kingdom	84	82				70
EU	4514	4210	3166	2896	4973	4749
Andorra		3	3	3	3	3
Belarus	403	398	339	320	330	328
Croatia	33	32				
Montenegro						49
Norway	460	463	476	481	487	491
Russian Fed.					336	279
Serbia	62	74	53	35	97	88
Switzerland	20	19	18	23	6	11
Turkey						415
Total Europe	5492	5199	4055	3758	6232	6413

3.3.2.2 Assessment parameters

The assessment of damage to trees based on the ICP Forests methodology includes three steps: symptom description, determination of causes, and quantification of the symptoms. Several symptoms of damage can be described for each tree. The symptom description should focus on important factors which may influence crown condition.

Symptoms

Symptom description aims at describing visible damage causes for single trees. The description indicates affected parts of the assessed trees and type of symptoms observed. Symptom description should focus on important factors that may influence the crown condition.

Three main categories are distinguished for indicating the affected part of each tree: (a) leaves/needles, (b) branches, shoots, & buds, and (c) stem & collar. For each affected tree area, further specification is required (Tab. 3-15).

Table 3-15: Affected parts of a tree

Affected part	**Specification of affected part**	**Location in crown**
Leaves/needles	Current needle year	Upper crown
	Older needles	Lower crown
	Needles of all ages	Patches
	Broadleaves (incl. evergreen spec.)	Total crown
Branches, shoots & buds	Current year shoots	Upper crown
	Twigs (diameter < 2 cm)	Lower crown
	Branches diameter 2 – < 10 cm	Patches
	Branches diameter ≥ 10 cm	Total crown
	Varying size	
	Top leader shoot	
	Buds	
Stem & collar	Crown stem: main trunk or bole within the crown	
	Bole: trunk between the collar and the crown	
	Roots (exposed) and collar (≤ 25 cm height)	
	Whole trunk	
Dead tree	*see below*	
No symptoms on any part of tree	*see below*	
No assessment	*see below*	

Symptoms are grouped into broad categories like wounds, deformations, necrosis etc. This allows a detailed description of the occurring symptoms.

Extent

The damage extent is classified in eight classes (Tab. 3-16). In trees where multiple damages occurred (and thus multiple extent classes), only the highest value was evaluated. In total, 49.1% of all assessed trees have been assigned a damage extent class of 1.

Table 3-16: Damage extent classes

Class
0 %
1 – 10 %
11 – 20 %
21- 40 %
41 – 60 %
61 – 80 %
81 – 99 %
100 %

Causal agents

For each symptom description a causal agent must be determined. The determination of the causal agent is crucial for the study of the cause-effect mechanism. Causal agents are grouped into nine categories (Tab. 3-17). In each category a more detailed discription is possible through a hierarchical coding system. In 2010, agent groups were identified for 59 520 trees (Tab. 3-18).

Table 3-17: Main categories of causal agents

Agent group
Game and grazing
Insects
Fungi
Abiotic agents
Direct action of men
Fire
Atmospheric pollutants
Other factors
(Investigated but) unidentified

Table 3-18: Number of sample trees with agent group. In this overview trees with more than one agent group are only counted once.

Country	Number of sample trees					
	2005	2006	2007	2008	2009	2010
Austria	607	747				982
Belgium	239	450	408	455	451	193
Bulgaria	1283	1231	1155	469	2563	2522
Cyprus	255	248	234	321	341	310
Czech Rep.	59		144	110	134	170
Denmark					86	94
Estonia	1013	1007	732	830	897	2068
Finland	4261	4274	3278	2959	2310	2137
France	5385	6101	6259	5951	6107	6607
Germany	2146	2216	2471	2000	10088	2115
Greece	1023				2071	1983
Hungary	957	928			1225	1231
Ireland	198	143		211	283	171
Italy	5346	5274	5232	5148	5468	6541
Latvia	507	456	403	398	604	536
Lithuania	139	146	140	159	235	326
Luxembourg	70	41	6	20		
Netherlands	111				75	86
Poland	3734	4215	4869	5102	4165	4179
Portugal	1693	97				
Romania	585	565			1623	1890
Slovak Rep.	690	4229	3894	3907	4312	4211
Slovenia	312	185			765	799
Spain	9452	9150	8925	8168	8781	7620
Sweden	7653	3829			506	543
United Kingdom	1806	1619				1243
EU	49524	47151	38150	36208	53090	48557
Andorra		7	7	8	8	8
Belarus	1827	1628	1770	1393	1271	1276
Croatia	257	256				
Montenegro						626
Norway	792	973	1053	975	779	817
Russian Fed.					3723	3475
Serbia	856	1167	503	188	838	941
Switzerland	100	71	76	74	79	105
Turkey						3715
Total Europe	53356	51253	41559	38846	59788	59520

3.3.3 Results

3.3.3.1 Affected part in 2010

In 2010, a total of 96 197 trees were included in the damage cause assessment. A share of 21.7% of the assessed trees showed symptoms on their leaves (only broadleaves), 13.1% of the trees had symptoms on the bole, and 11.8% symptoms on twigs. 35.8% of the trees showed no symptoms at all (Fig. 3-35).

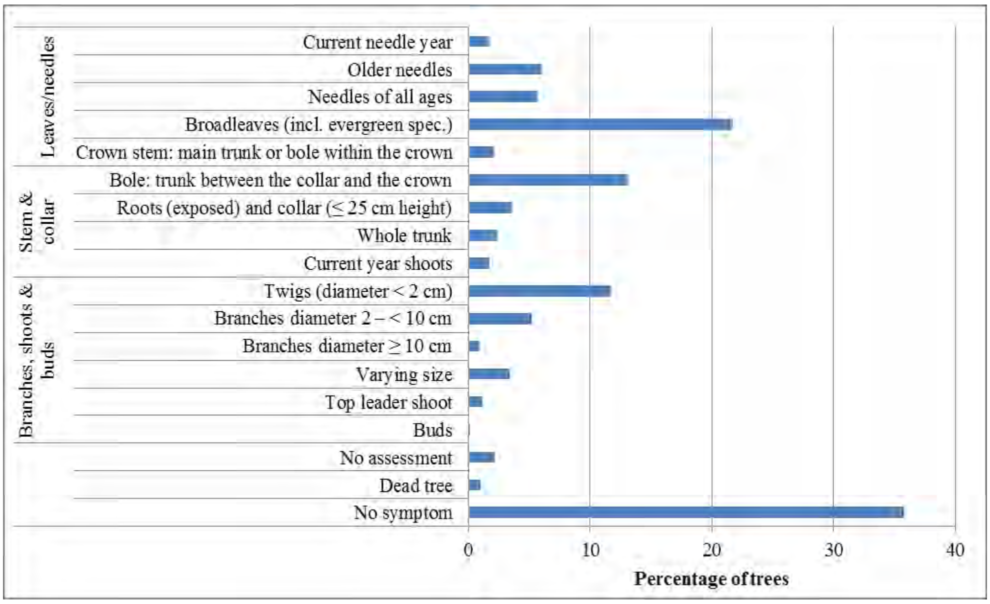

Figure 3-35: Frequency of affected part

3.3.3.2 Extent in 2010

About one quarter of all trees for which damage was recorded had an extent class of 2 and 16.1% had an extent class of 3. Higher classes rarely occurred (Fig. 3-36).

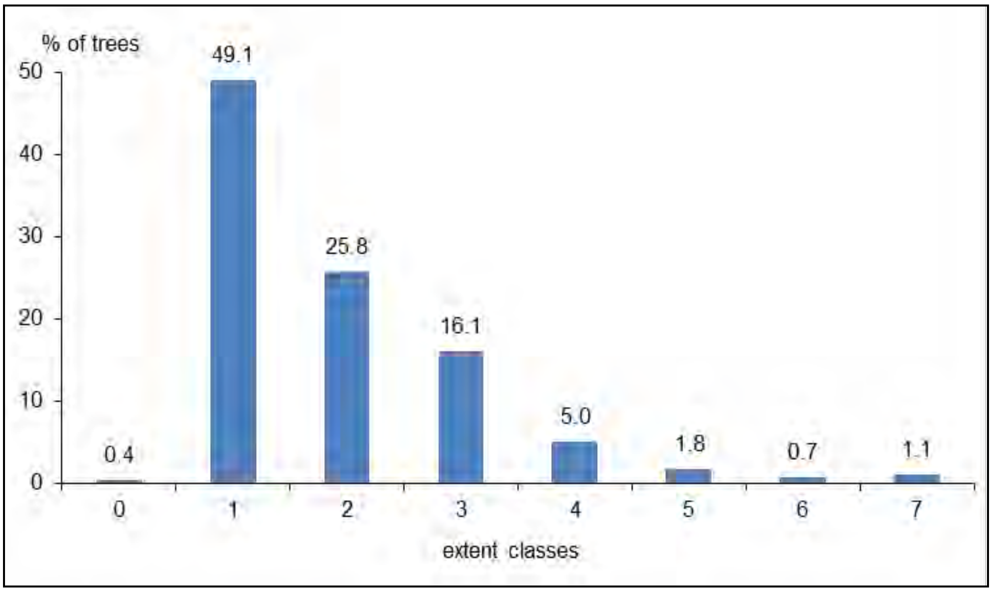

Figure 3-36: Share of trees with recorded damage extent class 2010

3.3.3.3 Agent groups in 2010

The distribution of the agent groups in 2010 shows that over 20 000 trees displayed symptoms caused by insects (Fig. 3-37) corresponding to 27% of the records (Tab. 3-19). Roughly half of the insect-caused symptoms were attributed to defoliators and to the other half to borers and other insects. Significantly fewer trees, namely just over 11 000, displayed damage caused by fungi, corresponding to 15% of the trees. In about 10 000 trees, an abiotic symptom (i.e. drought, frost) was found. Altogether, ca. 20 000 trees showed no signs of damage. Multiple agent groups were recorded for a number of trees.

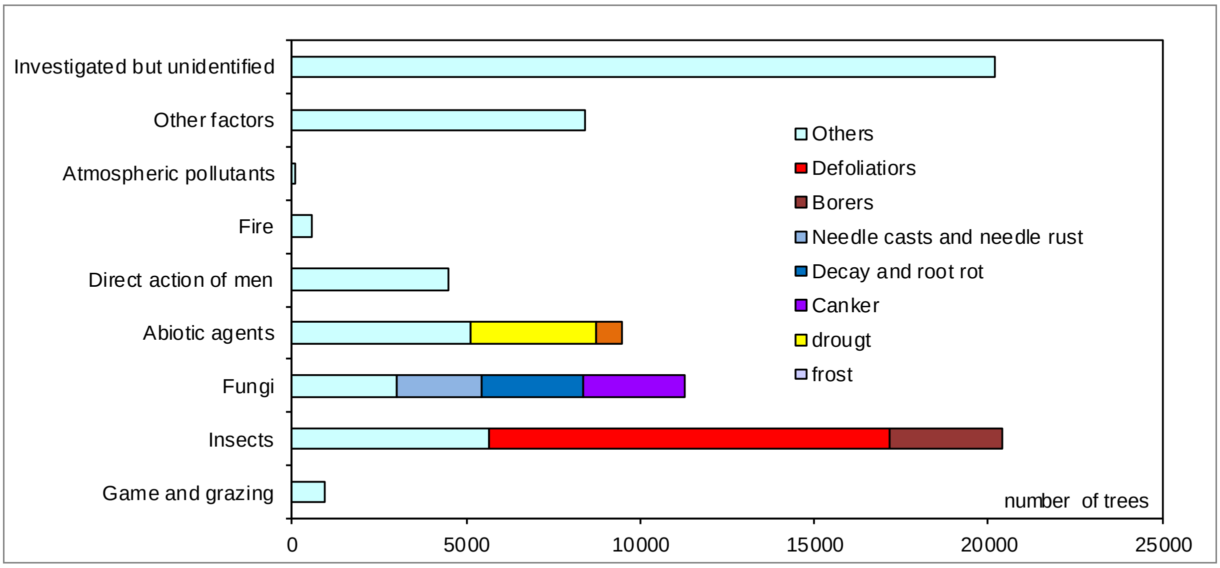

Figure 3-37: Frequency of agent groups

Table 3-19: Share of damages by agent group and country for the year 2010

share of damages by agent group and country for the year 2010	Game and grazing	Insects	Fungi	Abiotic agents	Direct action of men	Fire	Atmospheric pollutants	Other factors	Investigated but unidentified
Austria	9	4	10	29	21	0	0	19	8
Belgium	1	15	19	5	10	0	0	0	50
Bulgaria	0	46	29	3	5	0	0	0	16
Cyprus	0	81	0	12	0	0	0	7	0
Czech Rep.	31	0	1	36	6	0	0	10	15
Denmark	5	72	2	9	3	0	0	1	7
Estonia	1	6	37	5	6	0	0	1	43
Finland	1	21	20	14	8	0	0	18	18
France	0	12	6	7	0	0	0	2	73
Germany	4	47	10	4	5	0	0	5	25
Greece	2	26	6	26	4	0	0	31	6
Hungary	1	36	26	13	14	2	0	8	1
Ireland	0	1	27	43	27	0	0	2	0
Italy	1	33	7	5	0	0	0	6	48
Latvia	22	3	16	12	34	0	4	4	4
Lithuania	6	6	19	26	15	0	0	4	25
Netherlands	0	7	9	75	0	0	0	1	8
Poland	1	20	11	8	12	0	1	24	24
Romania	3	46	9	26	7	0	0	8	2
Slovak Rep.	1	29	23	11	11	0	0	17	8
Slovenia	0	30	14	8	8	0	0	5	34
Spain	0	30	14	28	5	3	0	12	7
Sweden	5	1	8	14	19	1	0	1	52
United Kingdom	0	40	10	12	2	0	0	15	21
EU	**1**	**27**	**14**	**13**	**6**	**1**	**0**	**10**	**28**
Andorra	0	13	63	13	0	0	0	0	13
Belarus	1	13	36	7	22	1	1	13	7
Montenegro	0	28	8	5	9	3	0	0	48
Norway	2	30	29	14	1	0	0	3	22
Russian Fed.	0	13	28	13	5	3	0	15	23
Serbia	0	67	24	3	2	1	0	4	1
Switzerland	0	45	0	18	8	0	0	30	0
Turkey	0	34	4	11	1	0	0	22	27
Total Europe	**1**	**27**	**15**	**12**	**6**	**1**	**0**	**11**	**27**

Agent Group "Game and grazing"

In 2010, only minor damage from "game and grazing" was observed on the assessed trees throughout Europe. Just 1.2% of all recorded damages were caused by this agent group. It has however to be taken into account that only adult trees in KRAFT classes 1-3 are regularly assessed for damage types and browsing in the herb and shrub layer is not recorded in this assessement. 80.4% of all affected plots show a share of damaged trees of 25% or lower (Fig. 3-38).

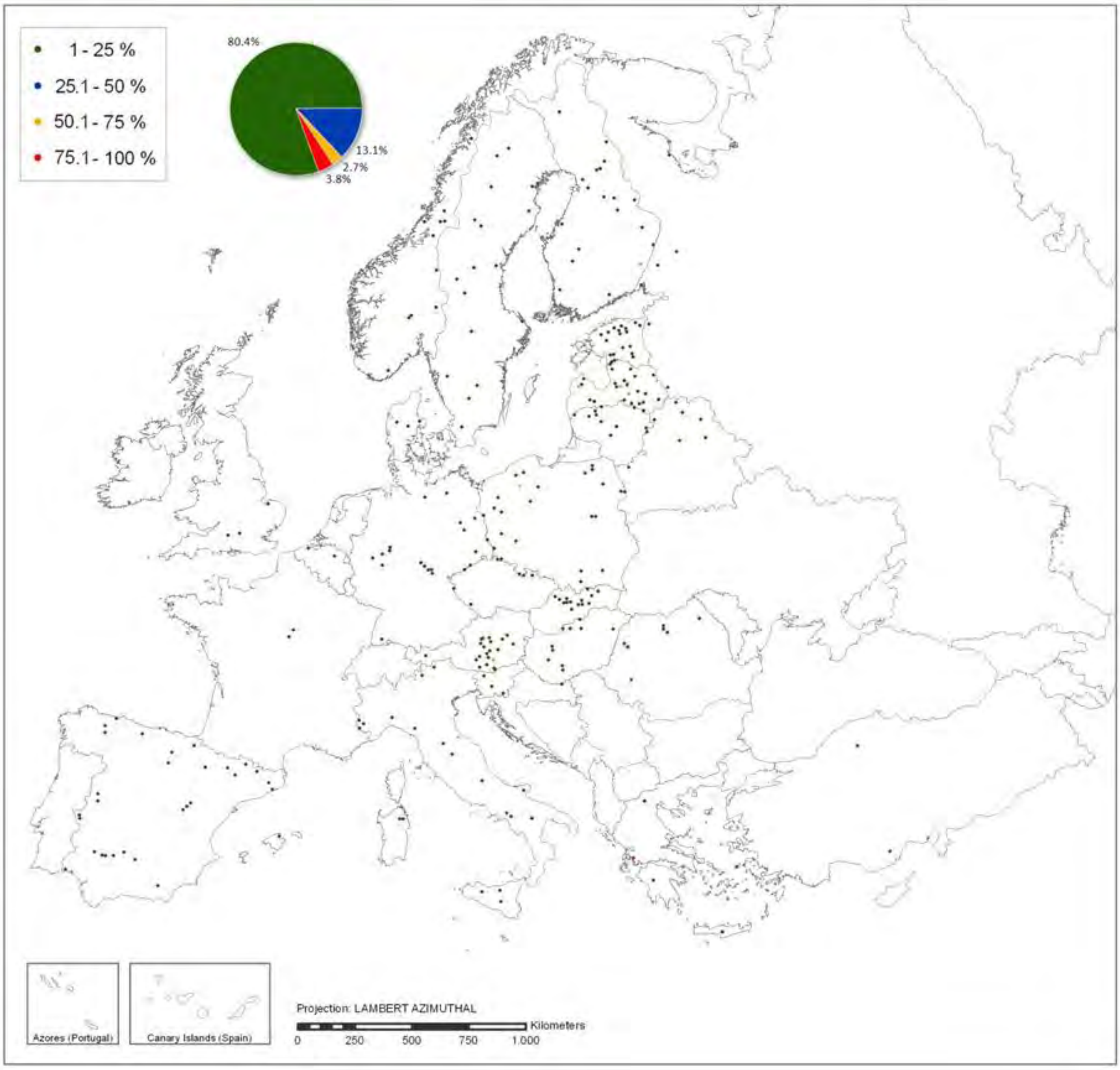

Figure 3-38: Shares of trees per plot with recorded agent group "game and grazing", 2010

Agent Group "Insects"

"Insects" were the most frequently detected agent group (26.9% of all damages) in 2010. They were observed in different intensities throughout Europe. On around half of all affected plots, more than 25% of the trees were damaged by insects. Plots with over 75% of the trees affected account for nearly one fifth of all plots. They are clustered e.g. at the eastern edge of the Pyrenean Mountains, Italy, Cyprus, and in the east of Slovak Republic (Fig. 3-39).

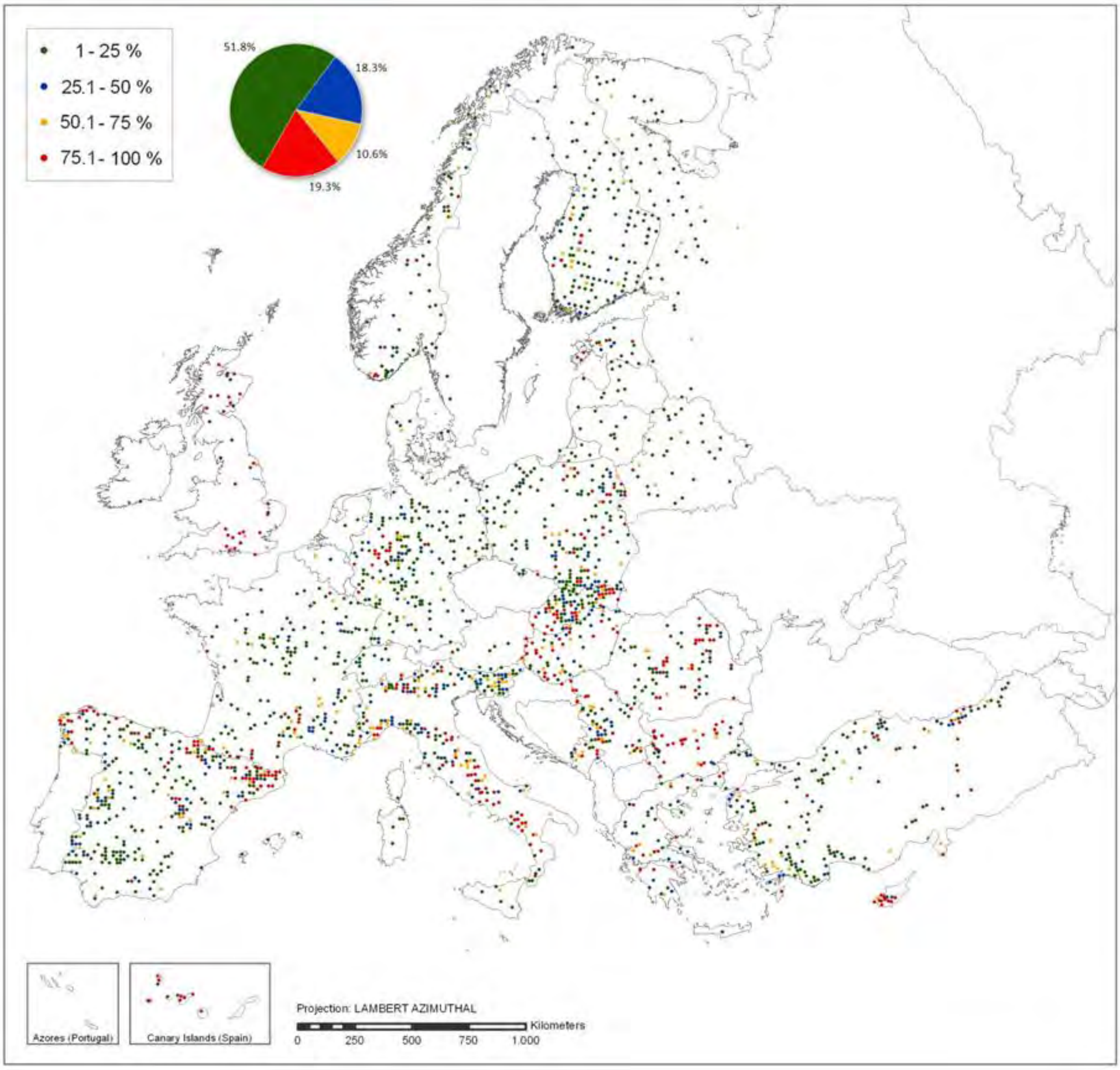

Figure 3-39: Shares of trees per plot with recorded agent group "insects", 2010

Agent Group “Fungi”

A total of 14.9% of all damages were included in the agent group “fungi”. Most affected plots (68.5%) showed only a small share of damaged trees. On 7.3% of all affected plots, between 50 and 75% of the trees showed damage caused by fungi, and on 7.6% of all plots more than 75% of the trees were damaged. A particularly high share of plots damged by fungi was found in Estonia, in the north of Slovac Republic and western Bulgaria (Fig. 3-40).

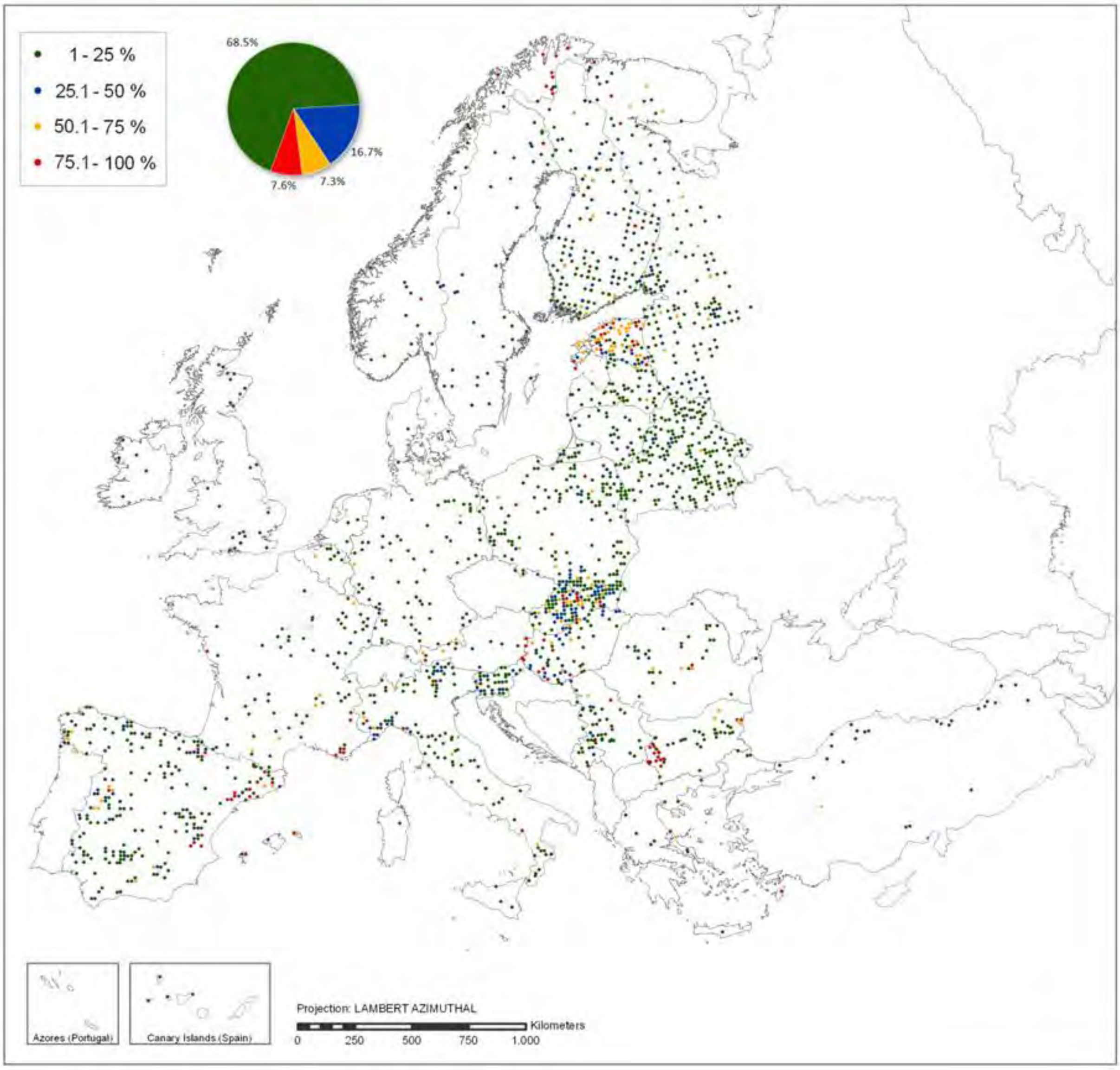

Figure 3-40: Shares of trees per plot with recorded agent group “fungi”, 2010

Agent Group "Abiotic agents"

In 2010, the share of trees with damage caused by "abiotic agents" was 12.5%. The most frequent causes were drought, frost/snow, and wind. 72.9% of all affected plots showed a small share of damaged trees. Plots with a higher share of damaged trees were found mainly in Mediterranean areas of Europe. In particular, these plots occured at the eastern edge of the Pyrenean Mountains and in southern France (Fig. 3-41).

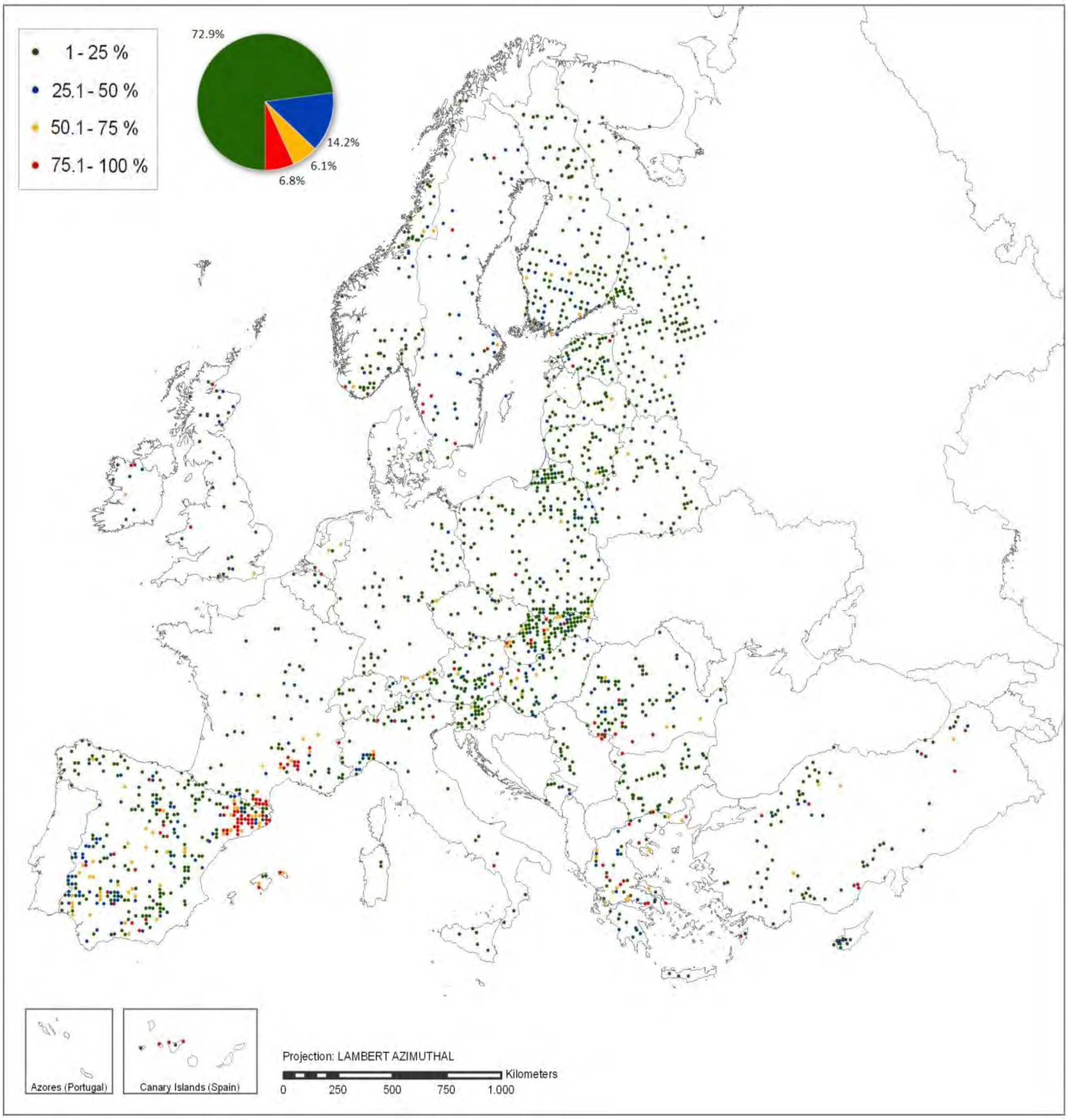

Figure 3-41: Shares of trees per plot with recorded agent group "abiotic agents", 2010

Agent Group "Direct action of men"

The agent group "direct action of men" was recorded on 5.9% of all damaged trees in 2010. The agent group includes mechanical damage e.g. through harvesting operations or road construction. Over 80% of all affected plots displayed only a small number of damaged trees. (Fig. 3-42).

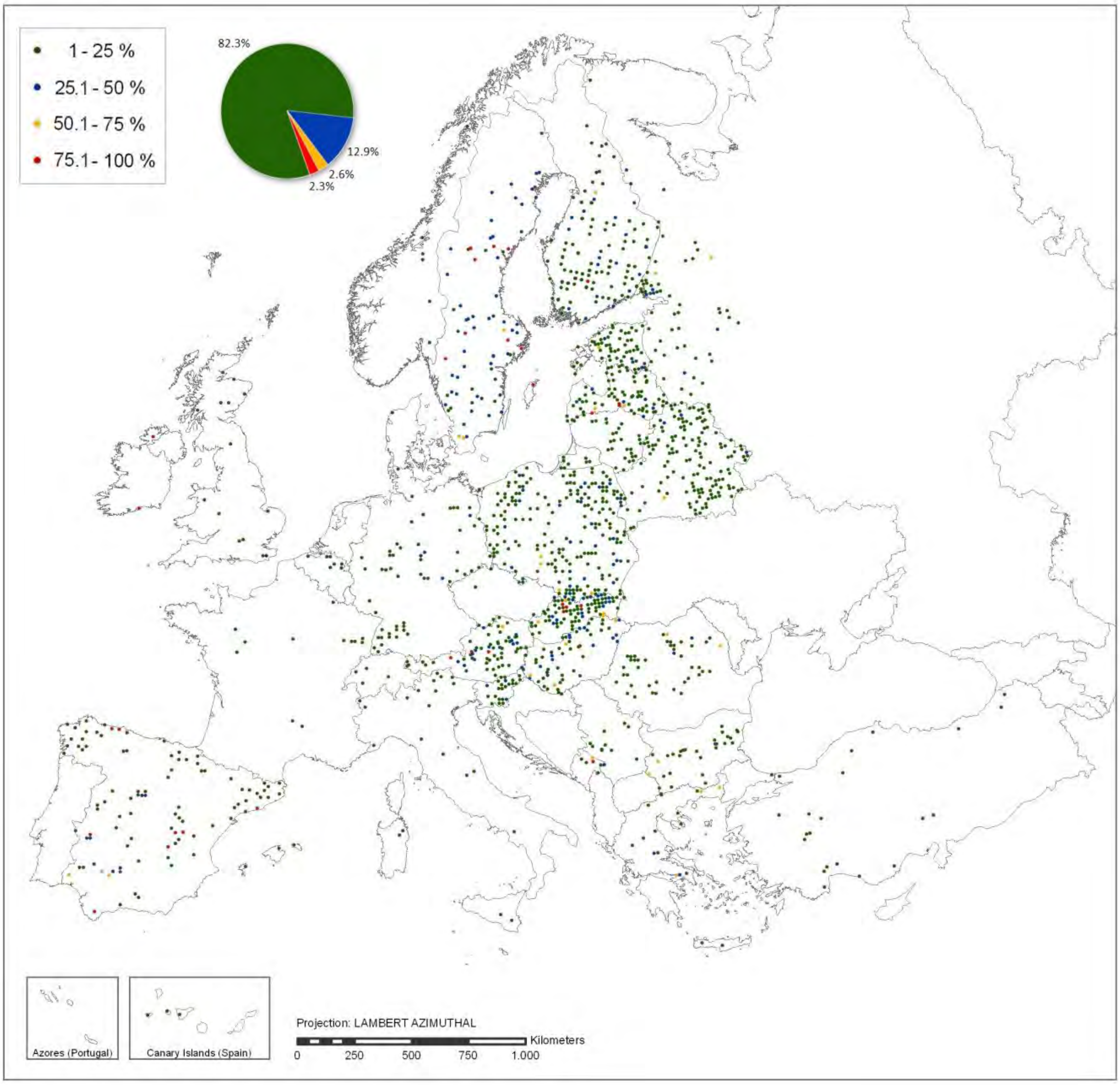

Figure 3-42: Shares of trees per plot with recorded agent group "direct action of man", 2010

Agent Group “Fire”

A share of 0.7% of all damages in 2010 was attributed to the agent group “fire”. Damage caused by fire occured relatively infrequently, but often involved several trees on one plot. On over one third of the affected plots, roughly 25% of the trees were damaged (Fig. 3-43). The data provide a good basis for assessing the importance of fire induced damages in relation to other agents. For time near monitoring of forest fire occurrence the terrestrial survey and the related data processing is not appropriate. Such surveys are possible based on satellite imagery yielding spatially higher resoluted information.

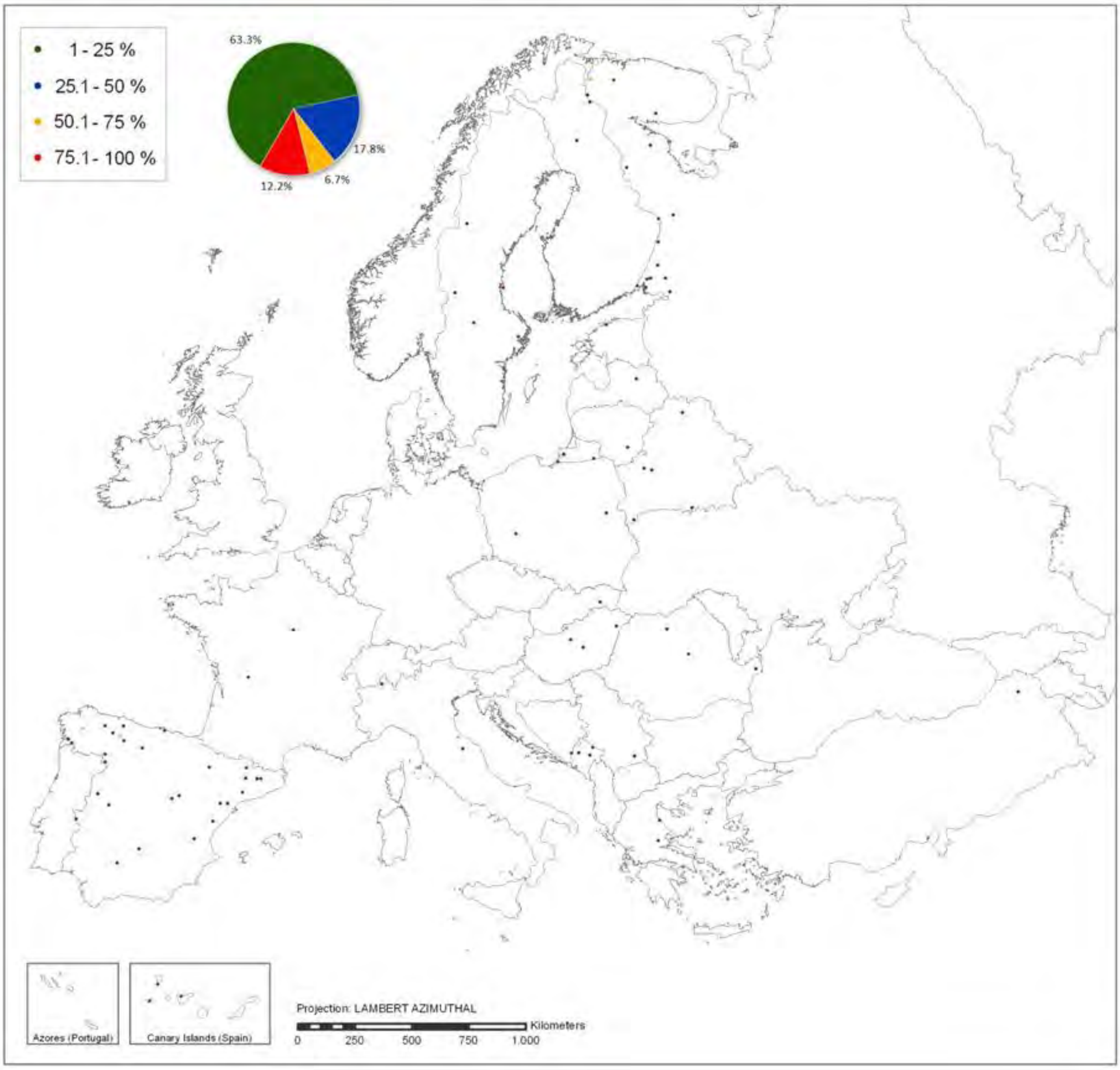

Figure 3-43: Shares of trees per plot with recorded agent group “fire”, 2010

3.4 Conclusions

The 2010 large scale health and vitality survey was based on over 7 500 plots and 145 000 trees in 33 participating countries, including 26 EU member states. It was thus the most comprehensive survey that has ever been carried out on the Level I network. The increase is due to the co-financing through the FutMon project under the EU LIFE+ regulation which lead to the participation of Austria, Greece, The Netherlands, Romania and United Kingdom. These countries had not assessed forest health in the year before the start of the project. As concerns non-EU countries, Montenegro for the first time assessed forest condition in 2010 and Turkey as well as the Russian Federation have only very recently started the survey.

In 2010, the evaluation of defoliation was extended to 7 species (-groups) in order to take into account the extended geographical scope of the surveys. It also included the first comprehensive, even though descriptive, presentation of results from damage cause assessments. These assessments had been started in 2005. The continuously updated manual (ICP Forests 2010) provided the methodological basis and is an important cornerstone for the implementation of harmonized assessments. Whereas for the health and vitality assessments of the trees the manual gives explicit prescriptions, plot and tree selection allow for national approaches, requiring, however, that plots and trees selected must provide the basis for country representative results (Chapt. 1). The differing national approaches are reflected in the different numbers of trees selected per Level I plot (Fig. 3-1).

Defoliation results show slightly higher mean defoliation for broadleaves as compared to the conifers assessed. Taking into account the wide coverage of the assessments, these overall means need to be analysed species and region wise. Deciduous temperate oaks had the highest mean defoliation, followed by the south European tree species groups. *Picea abies* and *Pinus sylvestris* showed lowest mean defoliation. There are spatial clusters of plots with above and below average defoliated trees. The Mediterranean coast in southern France and northern Spain is a hot spot with specifically high defoliation in several species groups. Most of the spatial trends are, however, species specific. High defoliation of Mediterranean lowland pines was observed in southwestern Turkey and a cluster of plots with above average defoliation of *Picea abies* occured in Slovak Republic. *Pinus sylvestris* showed comparatively low defoliation on plots in northern Europe, in the Baltic States and Belarus.

Over the last five years temporal trends show some recuperation for evergreen oaks and a continuously increasing defoliation of *Pinus sylvestris*. For the other species/-goups there is no pronounced trend in the most recent years. In general, the extreme heat and drought in summer 2003 is reflected in defoliation of the tree species occurring in temperate Europe, with the exception of *Pinus sylvestris*. The sharp increase of defoliation for four species /-groups at the beginning of the study and the continued fluctuation at comparatively high defoliation levels since then show that the development of tree health and vitality in terms of tree crown defoliation still requires further attention. Through the increasing number of trees in the survey regional developments are more and more levelled off in European mean values. This points to the increasing importance of national and regional studies.

Defoliation reflects a variety of natural and human induced environmental influences. Weather and site conditions as well as tree age influence tree health. The newly introduced damage cause assessment is thus of importance to show the extent of such factors. Insects and fungi are the most widespread agents that were assessed on the trees within the survey. The occurrence of these factors shows clear regional trends like plots with high insect occurrence in north-eastern Spain, Italy or Hungary or high occurrence of trees with fungal infestations in Estonia. The occurrence of insects and fungi is of high relevance for forest health and vitality as well as for forest management (Requardt et al 2009). Forest damage is one of the four indicators under the criteria of the Forest Europe Ministerial Conference on the Protection of Forests in Europe. The ICP Forests and FutMon data base offers the only transnational, harmonized and plotbased information system for such information in Europe. The descriptive evaluations need to be continued and integrated evaluations with other data sets on weather and site conditions are needed as insects and fungi themselves reflect changes in environmental conditions.

The continuation of the time series and the further implementation of related quality assurance measures like field intercomparison courses and quality checks in the data base (Chapt. 2) are of importance to ensure an early warning system for tree health and vitality in the future and to provide the basis for further integrated statistical evaluations which need to be supported by research projects.

3.5 References

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3.6 Annexes

Annex I: Broadleaves and conifers

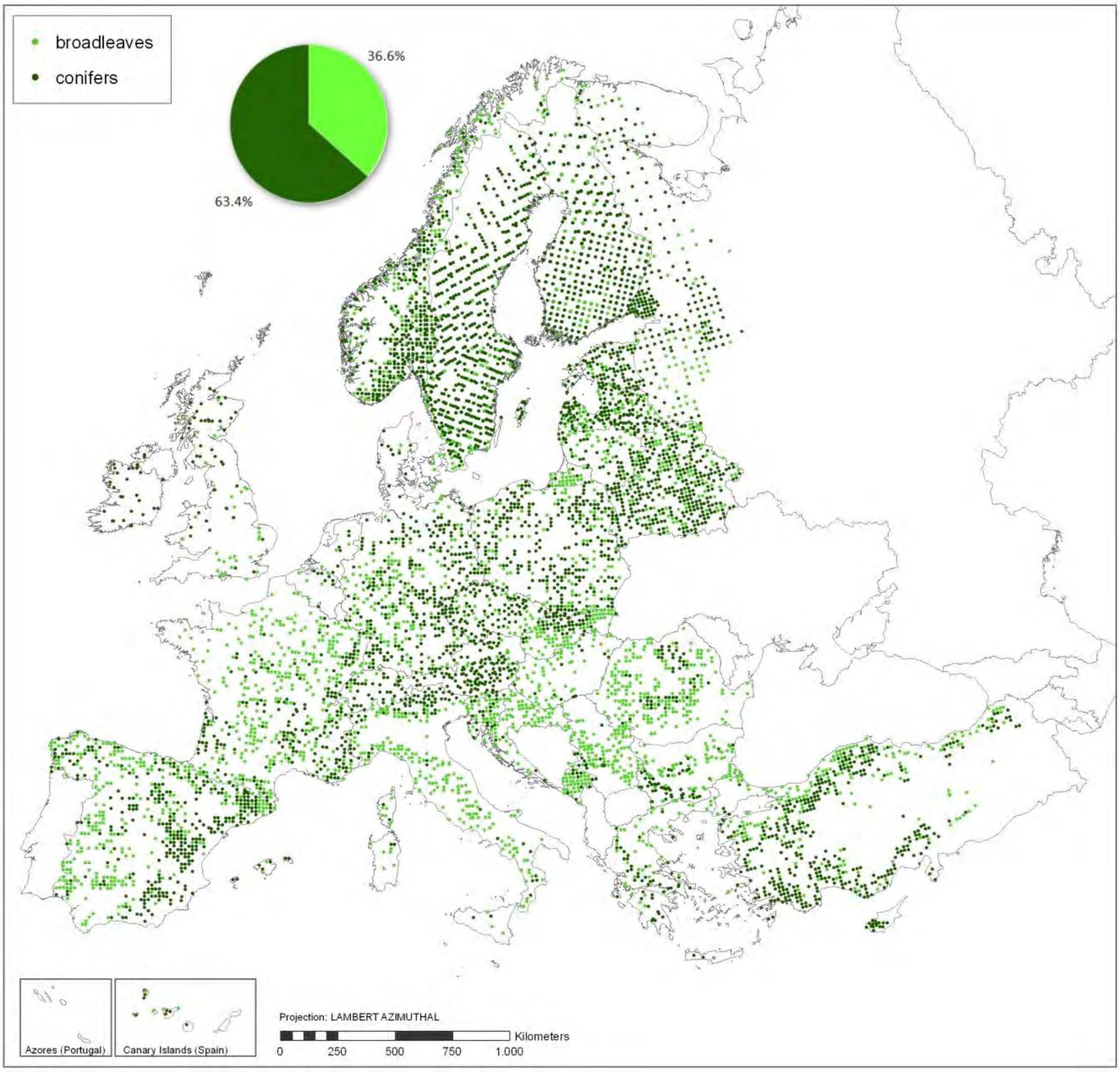

Figure 3-47: Shares of broadleaves and conifers assessed on Level I plots in 2010

Annex II: Number of tree species per plot (Forest Europe classification) (2010)

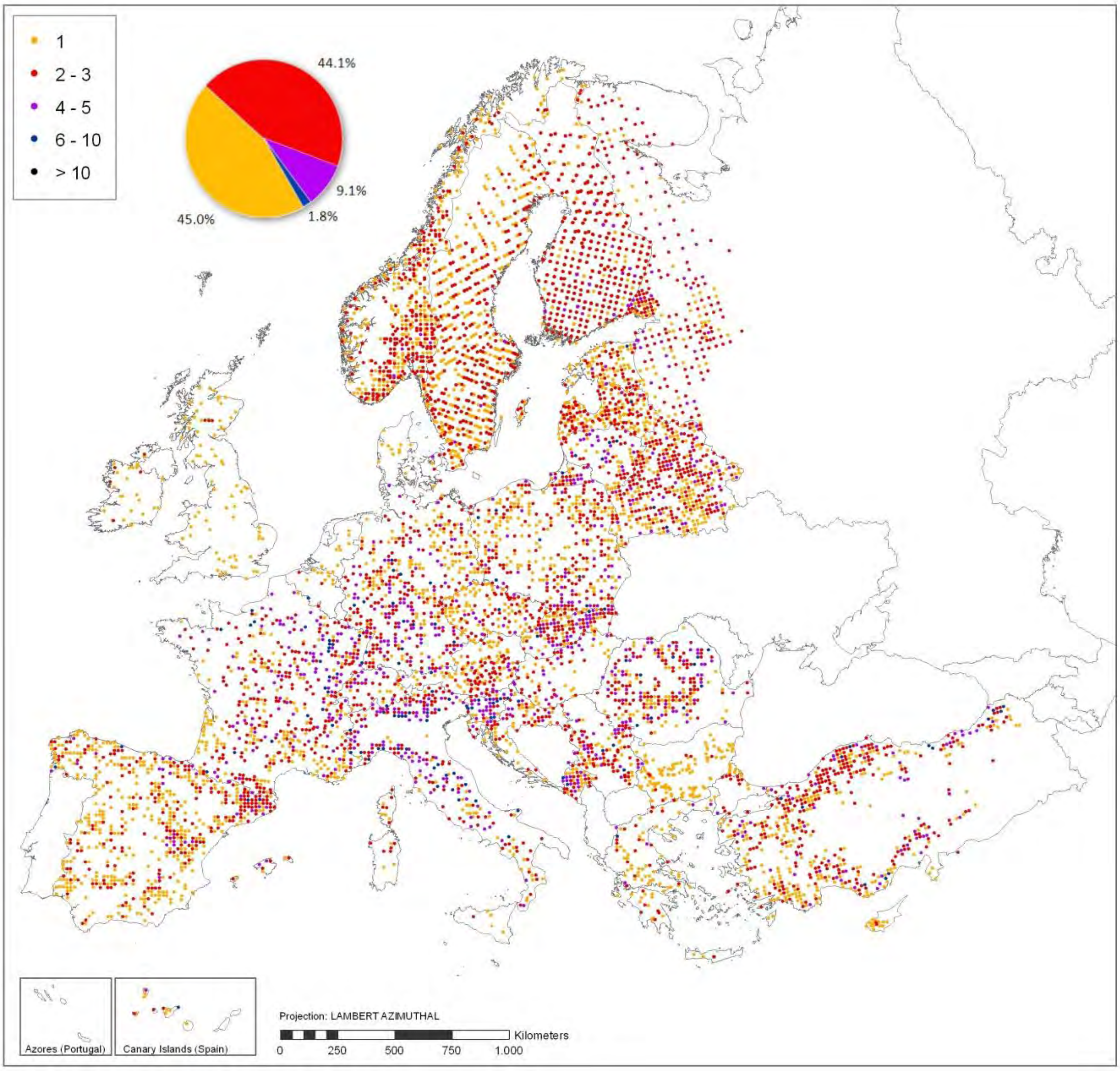

Figure 3-48: Number of tree species assessed on Level I plots in 2010

Annex III: Percentage of trees damaged (2010)

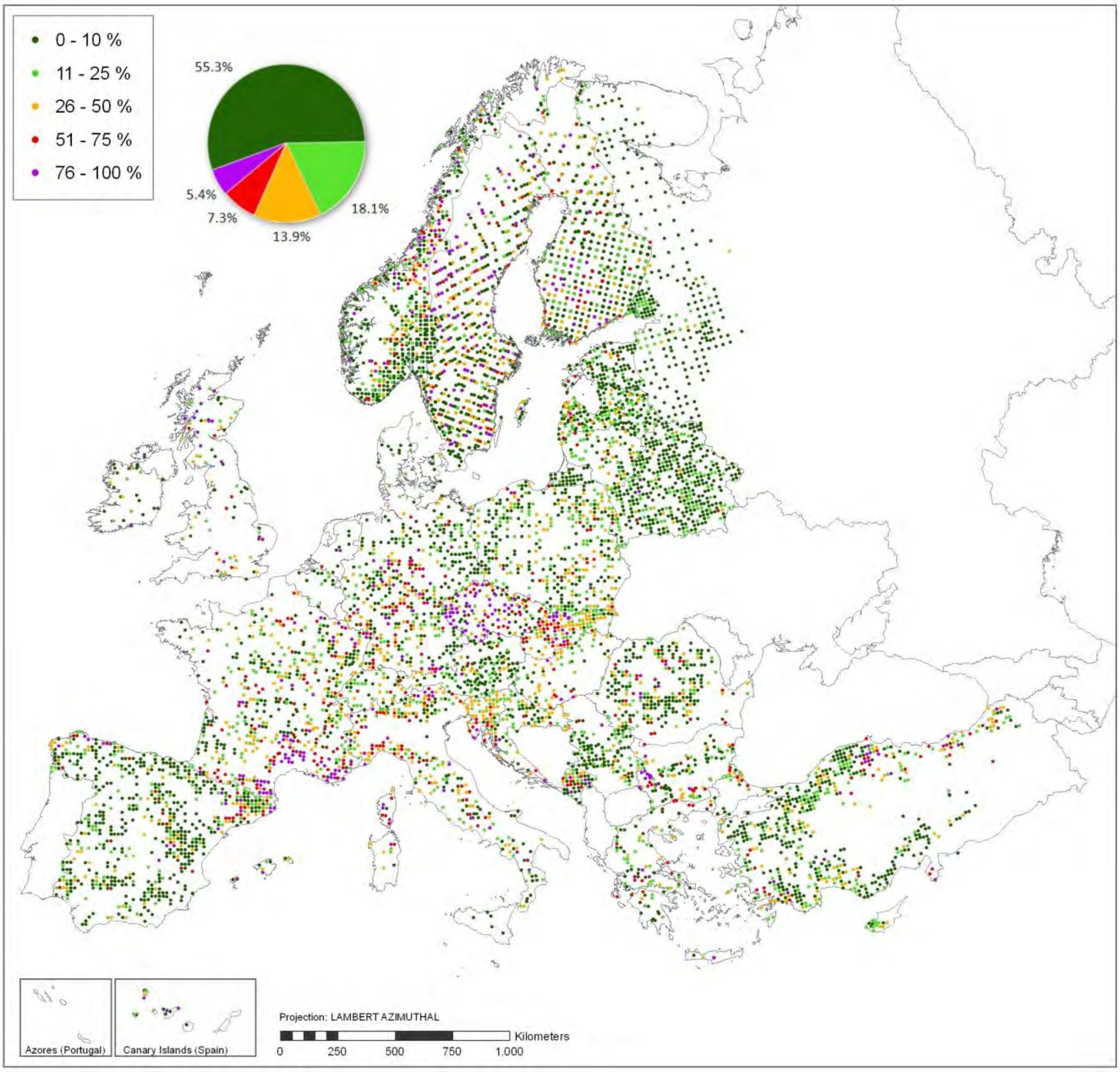

Figure 3-49: Percentage of trees assessed as damaged (defoliartion >25%) on Level I plots in 2010

Annex IV: Mean plot defoliation of all species (2010)

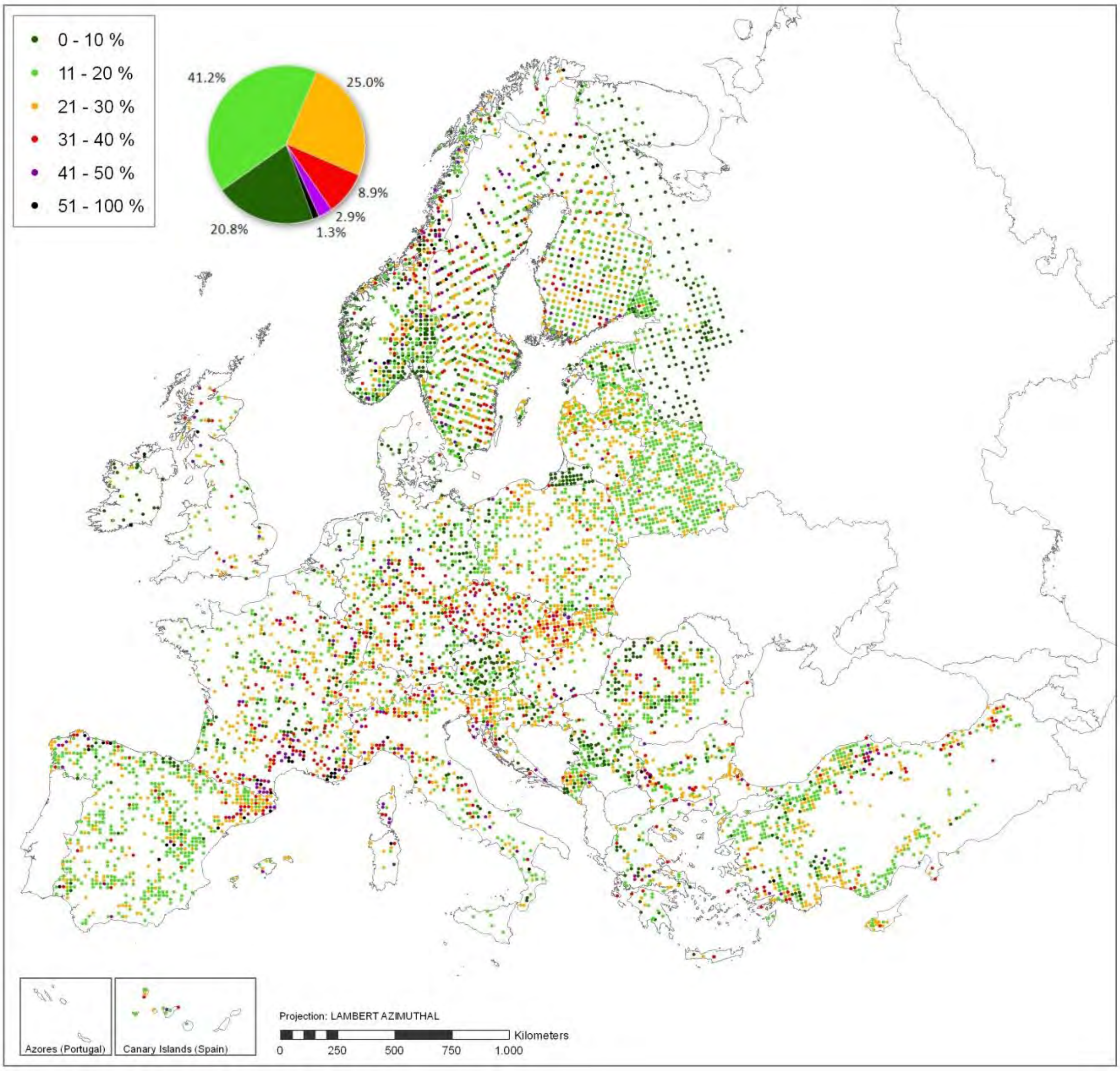

Figure 3-50: Mean defoliation of all trees assessed per Level I plot in 2010

Annex V: Changes in mean plot defoliation (2009 - 2010)

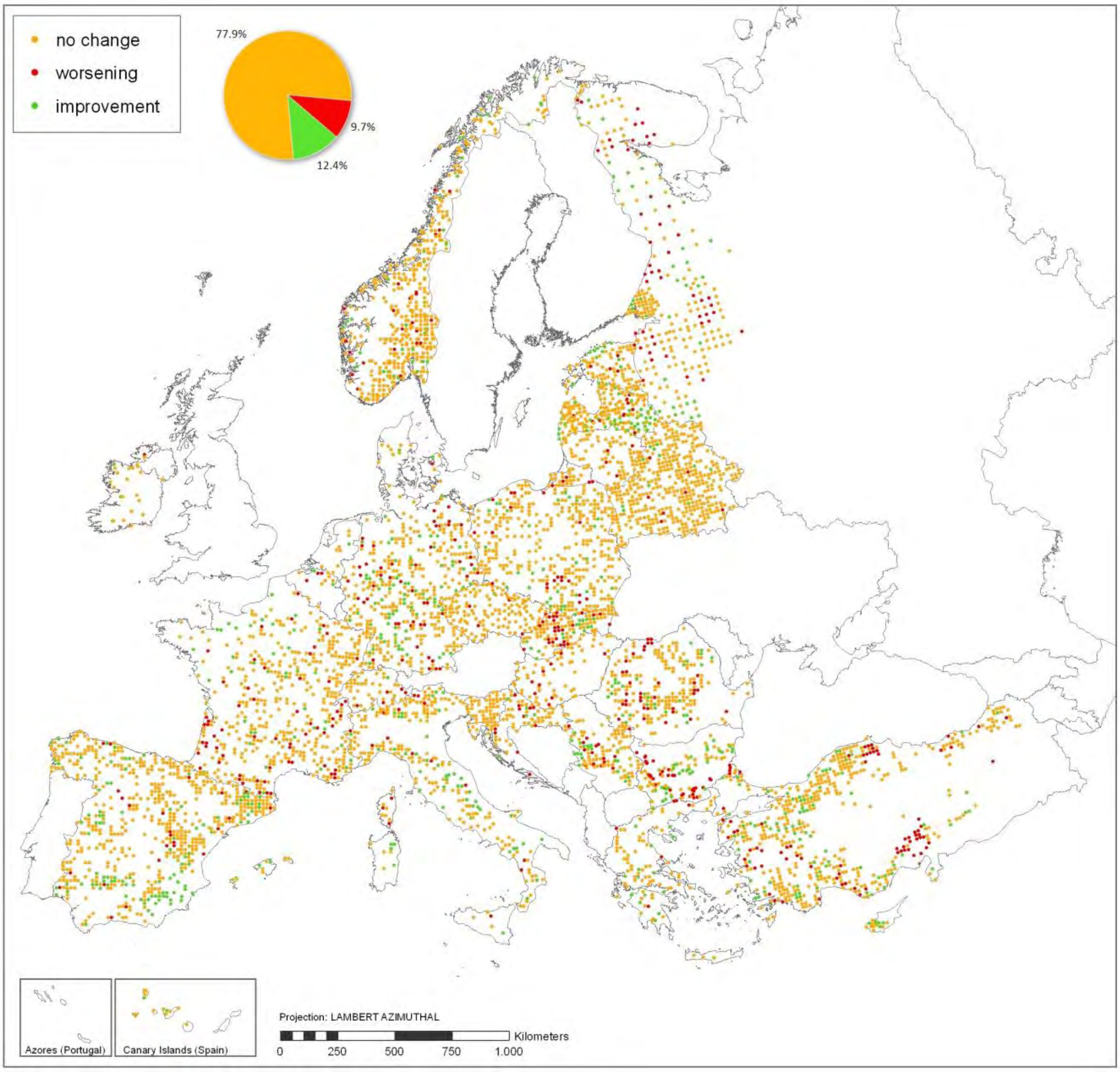

Figure 3-51: Changes in mean defoliation of all trees assessed per Level I plot from 2009 to 2010

Part III

ELEMENT FLUXES

4. Exceedance of critical limits of nitrogen concentration in soil solution

Susanne Iost[1], Pasi Rautio[2], Antti-Jussi Lindroos[3], Richard Fischer[1], Martin Lorenz[1]

4.1 Abstract

Exceedances of critical limits for total nitrogen concentrations in soil solution were calculated based on samples from 171 Level II plots from the early 1990s to 2006. Mean concentrations were compared to critical limits that were available from literature. Results show that N concentrations in soil solution regularly exceed two widely used critical limits on the majority of ICP Forests intensive monitoring plots in Europe. On 93% of the plots critical limits for nutrient imbalances in the organic layer were exceeded in more than 50% of the measurements. On 67% of the plots critical limits for elevated N leaching in the organic layer were exceeded in more than 50% of the measurements. For the mineral topsoil and subsoil, the critical limits for elevated N leaching were exceeded on 38% and 37% of the plots, respectively, in more than 50% of the measurements. The respective share of plots where limits for reduced fine root biomass or enhanced sensitivity to frost and fungi were exceeded in organic layers were 32% and 16%. Exceedances in the mineral soil layers were lower. Data from 140 plots were available for the calculation of time trends of at least five years per plot. In most of the plots there was no temporal trend in the critical limit exceedance for nitrogen. In cases where trends could be documented they were usually decreasing. Nutrient imbalances and N saturation and leaching to deeper soil layers are expected consequences of these findings in large parts of Europe.

4.2 Introduction

Soil solution chemistry is an important indicator to monitor air pollution effects on forest ecosystems, as well as possible effects of air pollution abatement policies. Soil solution represents a medium for many chemical reactions in the soil like nutrient uptake by roots. In polluted soils, the same interface also enables the uptake of elements with harmful effects. Accordingly, the composition of soil solution has been one of the central indicators since the establishment of intensive monitoring plots of ICP Forests in the early 1990s.

Most important effects of acidifying deposition (i.e. sulphur, but also nitrogen) in soil solution (and as such on the solid soil phase) are a depletion of nutrient cations and the mobilisation of potentially toxic elements. This may change the buffer range and result in an unbalanced tree nutrition and nutrient deficiencies. These soil and soil solution mediated processes affect vegetation in terms of reduced growth resulting from impaired nutrient uptake, enhanced growth due to eutrophication, fine root dieback and general stress reactions of the vegetation like excessive flowering (Fischer et al., 2010; Koch and Matzner, 1993; Løkke et al., 1996).

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

Model-based approaches for calculating critical loads aim at linking the deposition of air pollutants with its chemical or biological effects to the ecosystem. As the biological effects often are of complex nature, chemical criteria are mostly used to simplify the modelling. This calls for appropriate (soil) chemical criteria with proven (empirical) relationships to biological effects. For these chemical criteria values have to be defined that mark the threshold below which harmful effects on the specified biological indicator are not expected (UNECE, 2007). Exceedances of these critical limits do not necessarily result in instant dieback of trees or ecosystems but do illustrate an enhanced risk for trees to be more susceptible to additional stressors. Exceedances may result in a loss of assimilation area, growth reductions and nutrient imbalances (Augustin et al., 2005). The critical loads are a function of the chosen chemical threshold values (critical limits) applied within the model (Hall et al., 2010).

The 2010 ICP Forests Technical Report (Fischer et al. 2010) presented critical limit exceedances for pH and for the base cation to aluminium ratio in the soil solution of Level II plots and evaluated these against well documented critical limits. In this year's report, nitrogen concentrations in soil solution are presented in relation to different, widely used critical limits criteria that are used for the calculation of critical loads (UNECE, 2007).

The objectives of this study were to i) examine whether soil solution data from Level II sites show any exceedances with respect to different of critical limits criteria that are currently used in critical load calculations, and if so ii) find out about spatio-temporal trends in soil solution chemistry in relation to presented critical limits in Europe.

4.3 Data

For the years 1990 to 2006, soil solution chemistry data were available from 301 different plots in 26 countries. In 2006, soil solution data were collected at 226 plots in 21 countries. The number of samplers per plot varied, the maximum being 7 lysimeters per plot in the organic layer, 26 in the mineral topsoil and 12 in the mineral subsoil. The length of the measured temporal trend varied from plot to plot because samplers were installed in different years and a number of plots had to be abandoned for different practical reasons during the observation period. Earliest measurements started in 1990 but generally the monitoring was initiated between 1994 and 1997. The study includes data until the year 2006.

Field sampling and chemical analysis were carried out by the National Focal Centres of ICP Forests following harmonised methods developed by the ICP Forests Expert Panel on Soil and Soil Solution (Derome et al., 2002). On most plots, sampling took place at weekly to monthly intervals using non-destructive methods. 72% of the plots were equipped with suction cup lysimeters and 28% with zero tension lysimeters. In total, data were derived from more than 2000 samplers. After intensive data quality checks, data were submitted to the data centre of ICP Forests for central data storage and validation. Data were submitted either separately for each lysimeter or as plotwise means for each single soil layer.

In order to enable comparisons between different soil types, results were aggregated into three classes:

- organic layer (7% of the samplers)
- mineral topsoil 0 – 40 cm soil depth (51% of the samplers)
- mineral subsoil below 40 cm soil depth (42% of the samplers).

4.4 Methods

Analysis of critical limit exceedances of nitrogen was carried out for plots for which both nitrate and ammonium concentrations were available. Critical limits were applied based on published literature (Tab. 4-1)

Table 4-1: Specific critical limits for nitrogen concentration in soil solution in different forest types (UNECE, 2007)

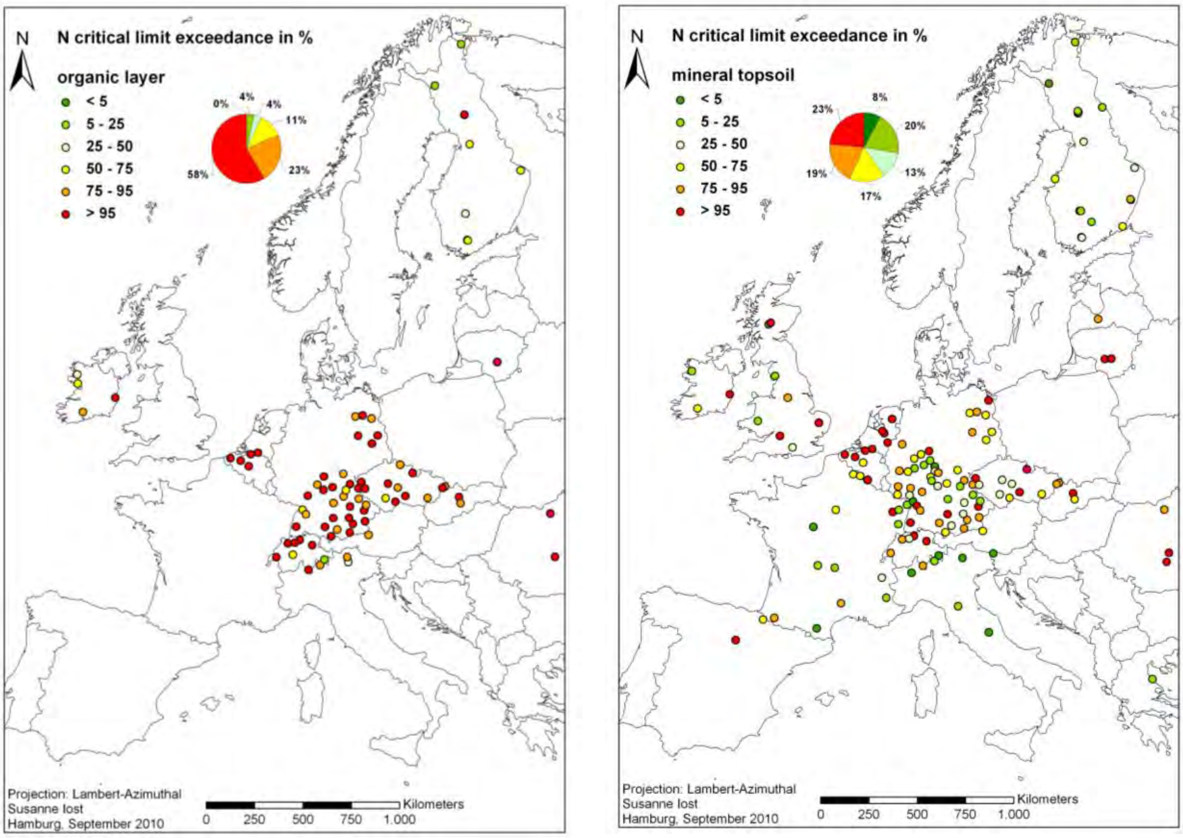
Effect	Chemical Criterion	Receptor
Nutrient imbalances	> 0.2 mg N / l soil solution > 0.4 mg N /l soil solution	Coniferous forests Deciduous forests
Elevated N leaching / N saturation	> 1 mg N / l soil solution	All forest types
Reduced fine root biomass /root lenght	> 3 mg N / l soil solution	All forest types
Enhanced sensitivity to frost and fungal diseases	> 5 mg N / l soil solution	All forest types

Critical limit exceedances are presented in relative frequencies per plot in order to be able to compare different geographical areas with different soils and tree species. Relative frequencies of critical limit exceedances were computed for each sampler (lysimeter) as the ratio of measurements that exceeded critical limits in all measurements over all available years. Using these samplerwise frequencies, a mean frequency for organic layer, mineral topsoil and mineral subsoil was computed for each plot. Plotwise frequencies for critical limit exceedances were classified into six groups.

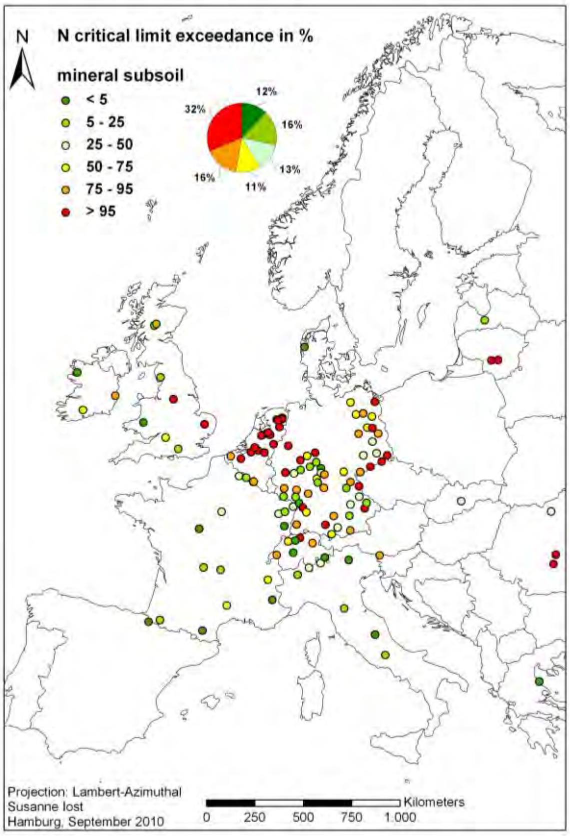
For the evaluation of temporal trends samplerwise exceedance frequencies were aggregated to annual plot means for organic layer, mineral top- and subsoil layers. Pearson correlation coefficients of annual plot means with number of years from the beginning of the measurements were calculated. Time trends were only calculated for plots that had at least five years of continuous measurements. Temporal tends were regarded as significant for $r \geq 0.7$ and $p < 0.05$.

4.5 Results

After data quality checks measurements from 1491 samplers on 173 plots in 17 countries were available for the analysis of nitrogen concentrations. On 93% of the plots CLim for nutrient imbalances in the organic layer were exceeded in more than 50% of the measurements (Fig. 4-1). For both, the mineral topsoil and mineral subsoil, such exceedances occurred on 59% of the plots. On 67% of the plots CLim for elevated N leaching in the organic layer were exceeded in more than 50% of the measurements. For the mineral topsoil and mineral subsoil such exceedances occurred on 38% and 37% of the plots respectively (Fig. 4-2). The share of plots where CLimE for reduced fine root biomass (Fig. 4-3) or enhanced sensitivity to frost and fungi (Fig. 4-4) occurred in more than 50% of all measurements, was 32% and 16% for organic layers, 16% and 8% for mineral topsoils and 18% and 15% for mineral subsoils.

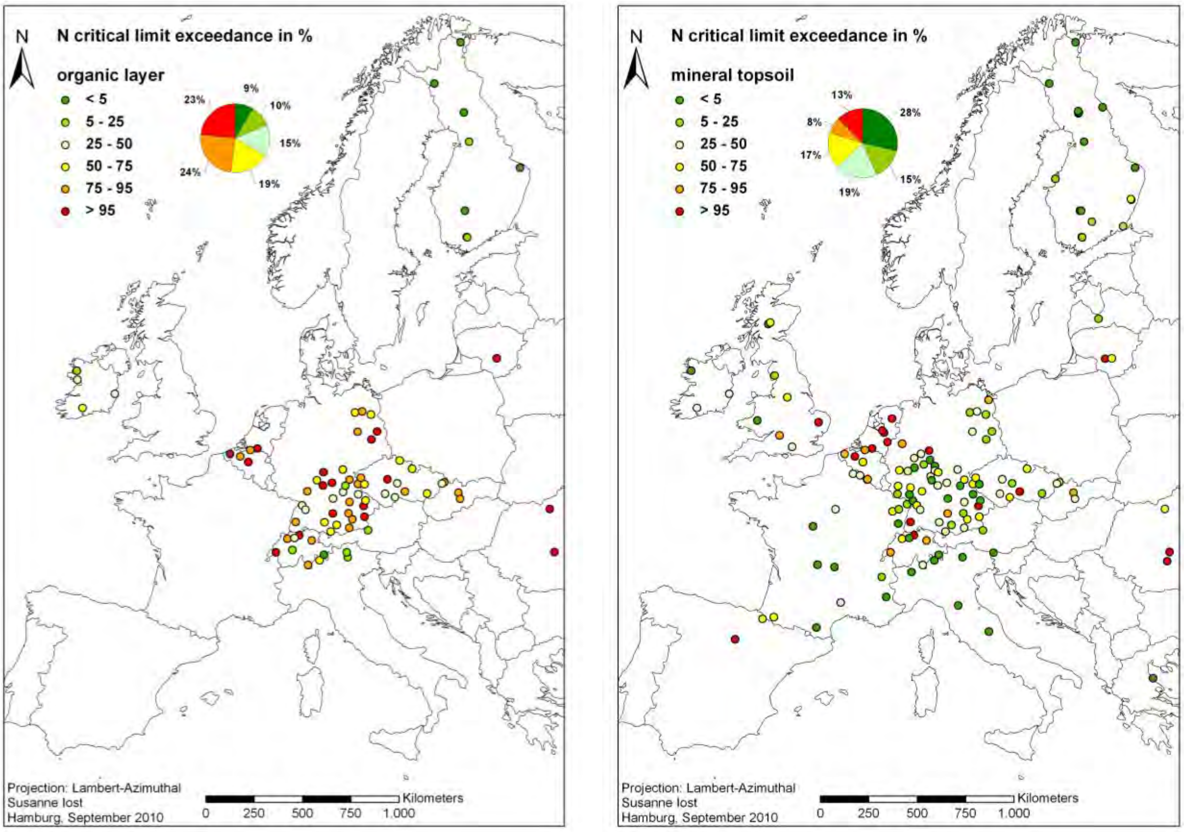


organic layers **mineral topsoils**

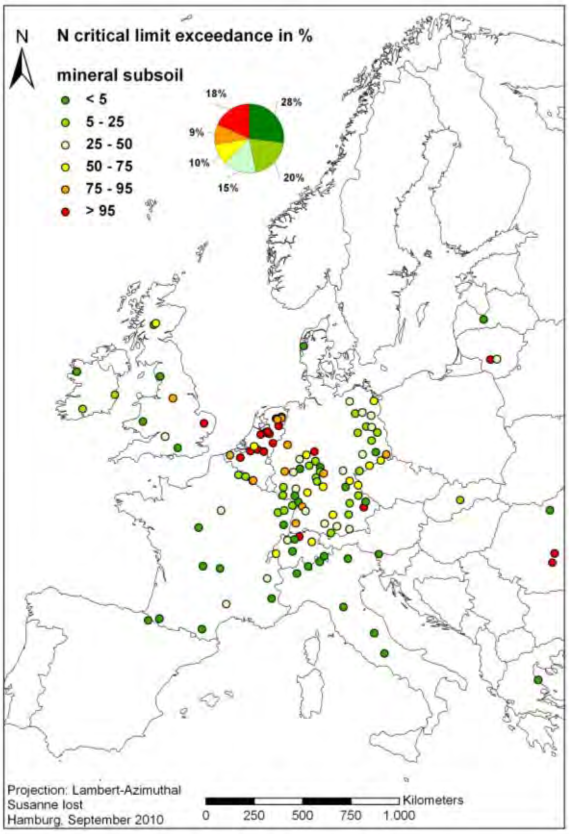


mineral subsoils

Figure 4-1: Frequency of N critical limit exceedances (CLimE) for nutrient imbalances in organic layers, mineral topsoils and mineral subsoils. Only plots with measurements in at least four consecutive years prior to 2006. Critical limits are >0.2 mgN/l for coniferous and >0.4 mgN/l for broadleaved forests. The colour of the plots display the proportion, e.g. <5% or ≥95%, of the measurements that have exceeded the CLimE (mean value per plot). The pie charts display the proportion of the plots that belong to the six categories

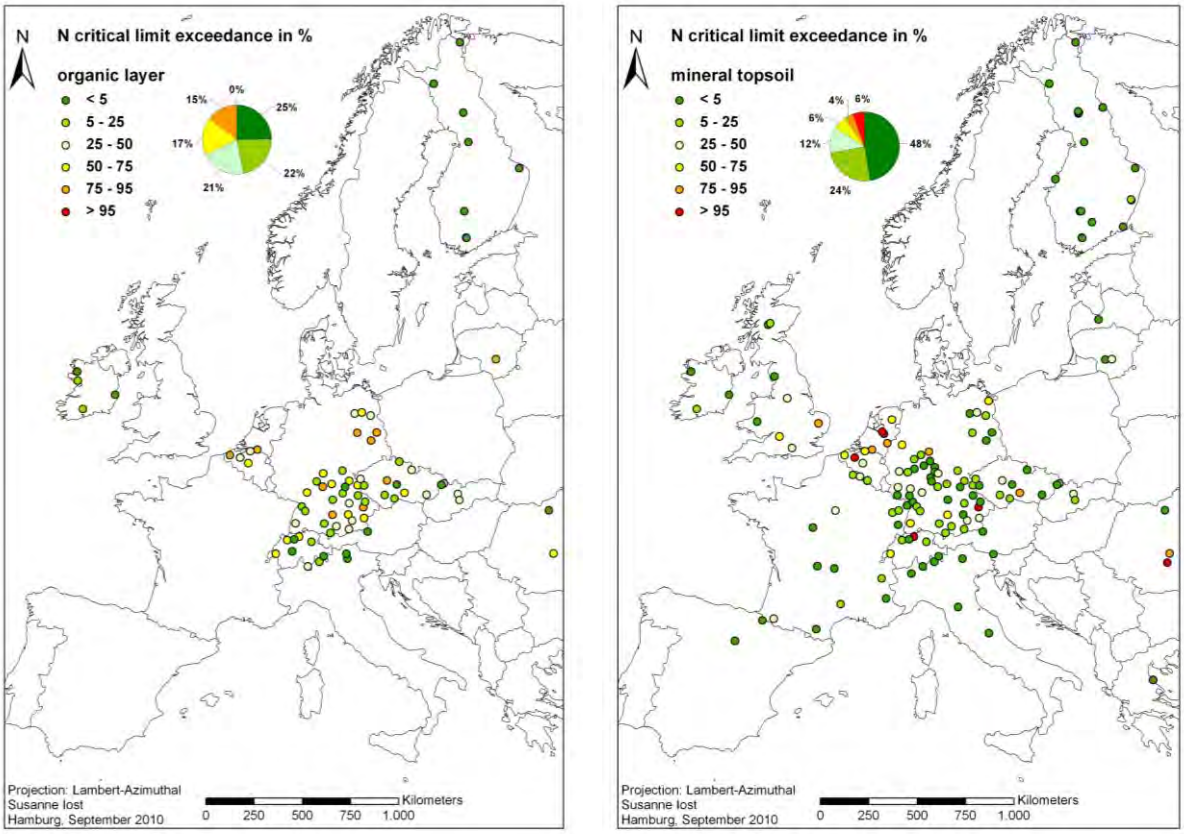


organic layers **mineral topsoils**

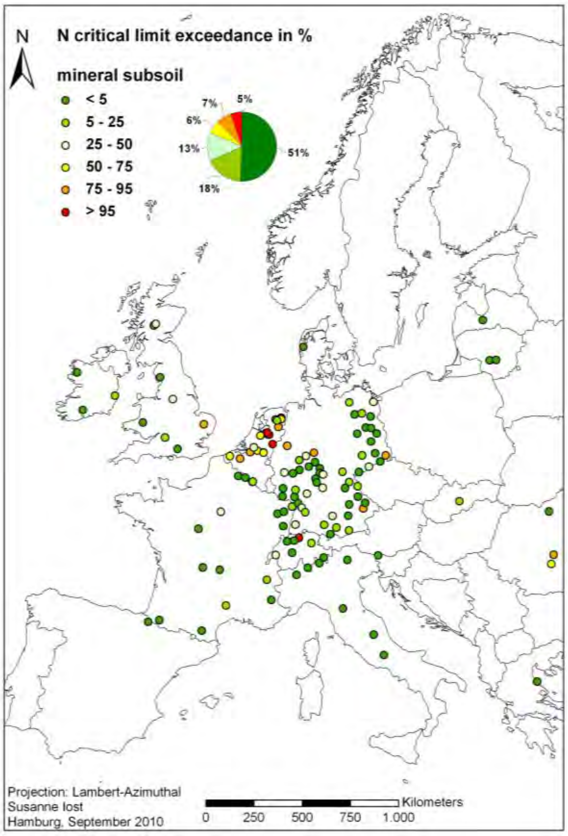


mineral subsoils

Figure 4-2: Frequency of N critical limit exceedances (CLimE) for N saturation / leaching in organic layers, mineral topsoils and mineral subsoils; Only plots with measurements in at least four consecutive years prior to 2006. The critical limit applied is >1 mgN/l; further details see Figure 4-1.

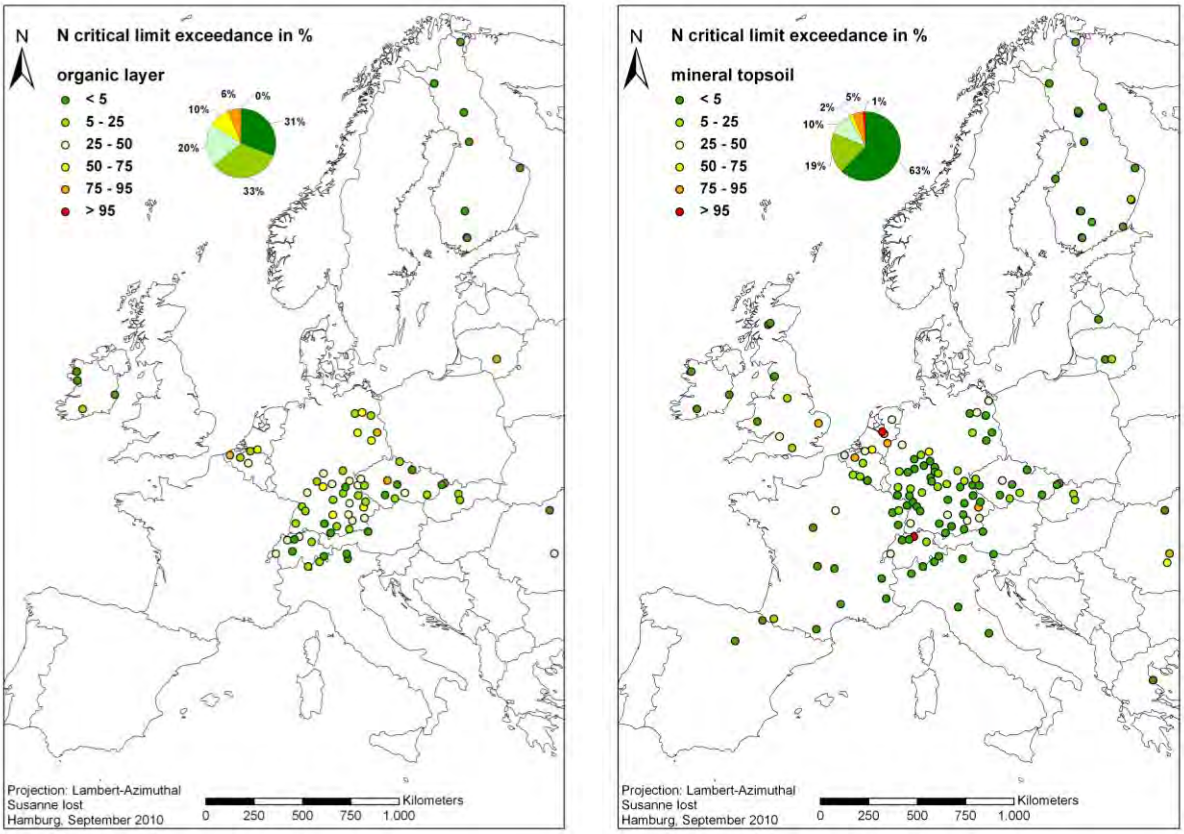


organic layers **mineral topsoils**

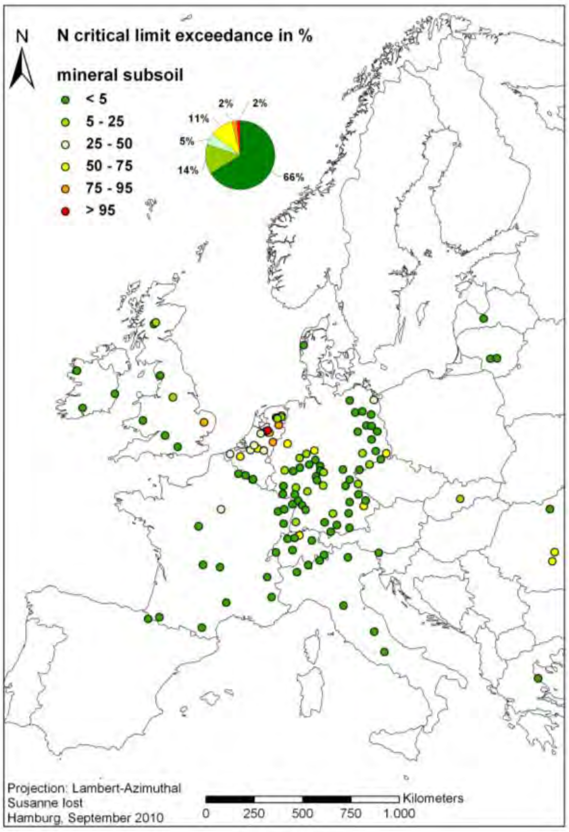


mineral subsoils

Figure 4-3: Frequency of N critical limit exceedances (CLimE) for reduced fine root growth in organic layers, mineral topsoils and mineral subsoils; Only plots with measurements in at least four consecutive years prior to 2006. The critical limit applied is > 3 mgN/l; further details see Figure 4-1.



organic layers **mineral topsoils**



mineral subsoils

Figure 4-4: Frequency of N critical limit exceedances (CLimE) for enhanced sensitivity for frost and fungi in organic layers, mineral topsoils and mineral subsoils; The critical limit applied is > 5 mgN/l; further details see Figure 4-1.

Data from 140 plots were available for the calculation of time trends. In most of the plots there was no temporal trend in the CLimE for nitrogen. In cases where trends could be documented they were usually decreasing (Table 4-2).

Table 4-2: Temporal trends of Critical Limit Exceedances (CLimE) in different soil layers. The values indicate number of plots where strong ($r \geq 0.7$; $p < 0.05$) correlations between mean annual frequency of CLimE and time (years since the start of measurements) were detected. In case no trend was detected, in addition to the number of plots, also the number of plots where CLimE was never exceeded and where it was exceeded in every measurement is reported in brackets (X / X) (modified from Iost et al., 2011).

Layer	CLimE	Trend			Total no of of plots
		no trend	increase	decrease	
Organic	N > 0.2 / 0.4 mg l^{-1}	22 (0 / 5)	3	9	34
	N > 1 mg l^{-1}	12 (4 / 2)	6	16	
	N > 3 mg l^{-1}	19 (8 / 0)	2	13	
	N > 5 mg l^{-1}	20 (8 / 0)	5	9	
Mineral topsoil	N > 0.2 / 0.4 mg l^{-1}	33 (2 / 5)	6	26	65
	N > 1 mg l^{-1}	36 (5 / 1)	8	21	
	N > 3 mg l^{-1}	49 (21 / 0)	7	9	
	N > 5 mg l^{-1}	46 (29 / 0)	6	13	
Mineral subsoil	N > 0.2 / 0.4 mg l^{-1}	18 (3 / 6)	4	19	41
	N > 1 mg l^{-1}	24 (8 / 1)	3	14	
	N > 3 mg l^{-1}	23 (15 / 0)	6	12	
	N > 5 mg l^{-1}	28 (20 / 0)	5	8	

4.6 Discussion and conclusions

The present results show that the critical limits for nitrogen were constantly exceeded in major parts of Europe. On almost all the plots where data for the organic layer were available, the critical limit for nutrient imbalances in soil was exceeded in more than half of the measurements. And further, the exceedance of critical limits for nutrient imbalances was not restricted to organic layer, but was also seen in mineral soil layers. Even in the subsoil, nearly 60% of the plots exceeded this limit. However, if the critical limit for enhanced sensitivity to frost and fungi is regarded, only on a small proportion of the plots critical limits were exceeded. Elevated N concentrations in soil and soil solution can originate from deposition originating from anthropogenic sources (e.g. combustion of fossil fuels, fertilizers) or they are natural (Gundersen et al. 1998). It has been shown that N deposition has direct effects on N concentrations in soil solution (Mustajärvi et al. 2008). However, in this study the highest N concentrations were found in areas with the highest site fertility (C/N ratio). In the present study areas of high concentrations in soil solution often coincide with the areas that received high N deposition, for example during 2002-2004 (Lorenz et al. 2007).

The fact that on most of the plots no significant temporal change was seen, and that on the few plots where a trend was found this trend was decreasing, is in line with the deposition data reported by Fischer et al. (2010). They showed that in most parts of Europe there was no change in nitrate and ammonium deposition (bulk and throughfall) between 1998-2007. When a change was detected – as observed on less than one fifth of the intensive monitoring plots situated mainly in central-Europe - the change generally indicated a decreasing trend.

Results of VSD+ model applications (Chapt. 6) suggest that until 2050 eutrophic conditions, i.e. C:N ratios between 10 and 17, will dominate on the intensive monitoring plots studied. These results are not conflicting with the findings here. The critical loads for nitrogen are exceeded and the surplus of nitrogen will partly be stored in the soil. Also, Graf Pannatier et al. (2011) found no trend of inorganic N in the soil solution in most depths of Swiss long-term monitoring plots and concluded that soil solution reacts little to changes in atmospheric deposition. The absence of clearly decreasing trends in concentrations of inorganic nitrogen in soil solution and critical limit exceedances allows assuming continued critical limit exceedances at least with respect to nutrient imbalances possibly leading to further destabilisation of forest ecosystems. The continued exceedance of critical limits and related leaching of nitrogen implies a potential risk for future ground water quality.

In this study only inorganic forms or nitrogen (nitrate and ammonium) were used to calculate exceedances. In studies where a more specific fractioning of nitrogen forms in soil solution has been conducted it has been found that organic N is a considerable part of total N percolating through the soil (Mustajärvi et al. 2008). This is seen especially in the areas with relatively low N deposition. Because only inorganic forms of N were reported here, the present results might give a too optimistic picture on the status of critical nitrogen limit exceedances. Furthermore, N can accumulate especially in the organic layer from where it can, after certain threshold is reached or when site is prepared (e.g. soil scarification) after cutting, leach in accelerated rate to deeper soil layers.

The interpretation of the critical limit exceedances has in addition to take into account that the limits published in the UNECE manual were originally used to calculate the acceptable leaching of N below the root zone, thus their application to organic layers and mineral topsoils might yield a too negative picture for critical limit exceedances as in the rooting zone nitrogen uptake and nitrification occurs. The UNECE manual states that the low N critical limits may lead to critical loads that are lower than empirical data on vegetation changes.

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5. Exceedance of critical loads for acidity and nitrogen and scenarios for the future development of soil solution chemistry

Hans-Dieter Nagel[1], Thomas Scheuschner[1], Angela Schlutow[1], Oliver Granke[2], Nicholas Clarke[3], Richard Fischer[2]

5.1 Abstract

Based on intensive forest monitoring data critical loads for acidification and eutrophication as well as their exceedances were modelled for 106 Level II plots using the simple mass balance approach. Dynamic modelling applying the VSD+ model was carried out for 77 plots using different deposition scenarios. Results show widespread soil acidification in the year 1980 with nearly 60% of the plots affected by critical load exceedances. A continued positive future development until 2020 is clearly visible leading to full protection at least under the most ambitious deposition scenario. Critical loads for nutrient nitrogen were exceeded on 60% of the plots in 1980 and continue to be so in 2020 on between 10 and 30% of the plots depending on the scenario. Dynamic modelling shows that soil solution pH can recover to pre-industrial values but that over all the 77 plots the C:N ratio shows a continuous decrease until 2050. A comparison with measured solid soil pH from large scale plots confirms recovery for acidified soils until 2008 but shows increased acidification on soils with pH above 4.0 and points to the fact that full recovery from acidification will take decades. Decreasing C:N and continued exceedance of critical loads for nutrient nitrogen point to soil eutrophication as a major and continued area of concern.

5.2 Introduction

Threshold values for the effects of air pollutants on ecosystems have attained much attention in the derivation of environmental policy targets. Critical loads are such threshold values. They provide criteria to determine tolerable inputs of anthropogenic pollutants to ecosystems taking into account the specific sensitivity of the ecosystem compartments. Critical loads provide a sustainable reference point against which pollution levels can be compared (ICP Modelling & Mapping 2010).

Critical loads as presented in this study represent a time independent steady-state approach. But will a decrease of deposition and reduced critical load exceedances over time result in forest ecosystem recovery? And if so, what are the time scales required? In order to take into account changes over time, dynamic models have been developed to assess temporal trends of air pollution effects. Dynamic models are necessary to estimate time delays of recovery in regions where critical loads are no longer exceeded and to calculate possible time delays of damage occurring in regions where critical loads continue to be exceeded. Existing studies based on mapping of critical loads of acidity and eutrophication and environmental monitoring supported by dynamic modeling show that recovery from pollutant stress will often be very slow and may sometimes even take decades or hundreds of years (Nagel and Gregor 2001).

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5.3 Data

The modelling of site specific critical loads and the dynamic modelling requires data sets on major compartments of forest ecosystems. Such data were taken from the ICP Forests and FutMon data base as well as from the BioSoil+ data base (Table 5-1).

Table 5-1: Data availability for critical load computation and dynamic modelling

Type of data	Source of data	Number of plots
Soil survey	BioSoil+	114
Soil solution measurements	ICP Forests	298
Vegetation survey	ICP Forests	935
Litterfall	ICP Forests	211
Deposition measurements	ICP Forests	423
Modelled deposition	EMEP / CCE	whole Europe

Data preparation took as well into account vegetation data as a basis for subsequent modelling of vegetation species composition with the BERN model (Chapt. 10). The data processing chain (Fig. 5-1) shows a continuous decrease in plot numbers when additional surveys were subsequently added in order to filter the data base for plots with complete data sets. A follow up project is currently tackling data gaps and the repetition with a larger number of plots is foreseen in the near future.

After screening and exploiting the ICP Forests and FutMon data base, 106 Level II plots in 17 countries were available for modelling of critical loads and exceedances by a simple mass balance approach (SMB). As minimum input for SMB a comprehensive set of mostly mandatory data in the above mentioned surveys according the ICP Forests monitoring manual (ICP Forests 2010) is required. From the soil data all layers per plot were aggregated as VSD+ is a single soil layer model. Thus the soil thickness in the evlaution depends on the measurement depths of each single plot. For dynamic modelling (VSD+) 77 plots with sufficed input parameters were selected (Figure 5-2). 20 Level II plots were used to combine dynamic modelling results with the biodiversity model BERN (Chapt. 10).

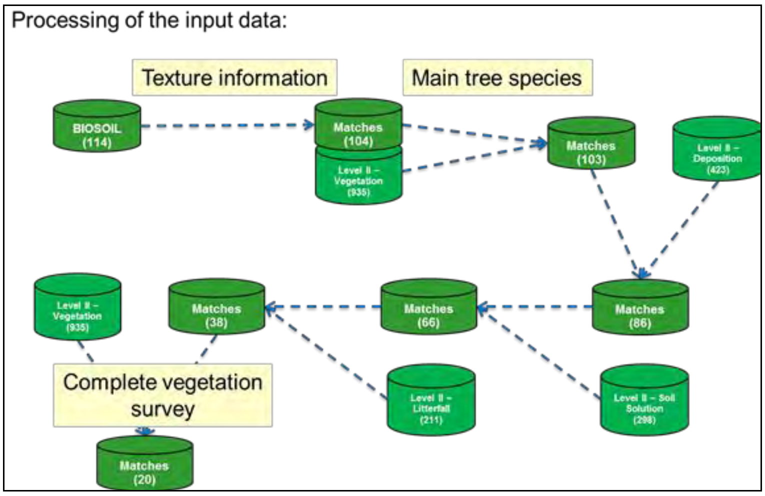

Figure 5-1: Flowchart of data processing chain

The outcome of this modelling relies on the models itself, but also on the accuracy, time consistency and continuity of the input data. Improvements in the database and the continuation of the measurements are essential for improving the output of advanced modelling.

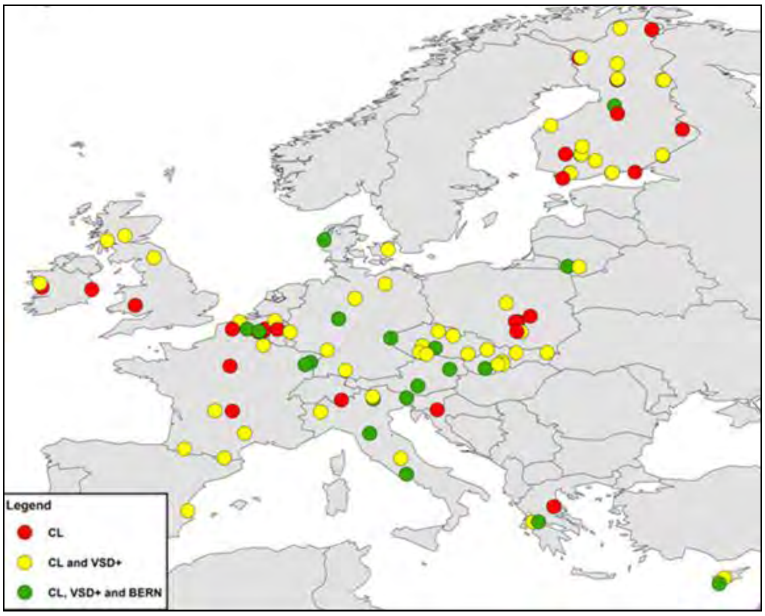

Figure 5-2: Selected Level II plots for critical load calculation (CL), dynamic modelling (VSD+) and vegetation assessments (BERN)

5.4 Methods

By definition critical loads are quantitative estimates of an exposure to a deposition of one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge (ICP Modelling & Mapping 2010). They are derived by combinations of chemical and biological indicators. While they reflect the state of present knowledge, they are subject to revision as science further develops. The application of the critical loads concept is suitable to describe the limit to which a receptor system may be exposed to pollution without detectable damage on the long term, or the threshold below which present loads have to be reduced for recovery.

According to the general definition of critical loads as ecologically based environmental objectives for airborne pollutants, the upper limit of a tolerable input must be calculated, which will not cause any long term adverse effect to structure and function of the ecosystems. The magnitude of the critical load value should only be depending on the characteristics of the regarded ecosystems. Changes in the forest ecosystems which are due to pollutant deposition can be identified using parameters of the chemical composition of the soil solution. Significant damage can be expected to occur, when certain chemical parameters in the soil solution exceed sit specific critical loads. This will lead to destabilization of soil processes or to direct damage to the vegetation.

The critical loads methodology is comprehensively described in the "Mapping Manual" of the ICP Modelling & Mapping, a revised version is presently elaborated (ICP Modelling & Mapping 2010).

Critical loads for acidification and eutrophication were derived following the Mapping Manual and applying the steady-state Simple Mass Balance (SMB) equations. Thresholds for inputs of acidity by sulphur, $CL_{max}(S)$, and nitrogen, $CL_{max}(N)$, were calculated as well as the input of nutrient nitrogen, $CL_{nut}(N)$, which is assumed to not cause any long term adverse effect to the ecosystems. Taking into account the essential nutrient supply of nitrogen, $CL_{min}(N)$, a Critical Load Function (CLF) outlines the environmentally safe area. The CLF is a three-node line graph representing the acidity critical loads, and a four-node graph taking into account the effects of eutrophication as well. The intercepts of the CLF on the sulphur and nitrogen axes define the sulphur and nitrogen critical load values (Figure 5-3).

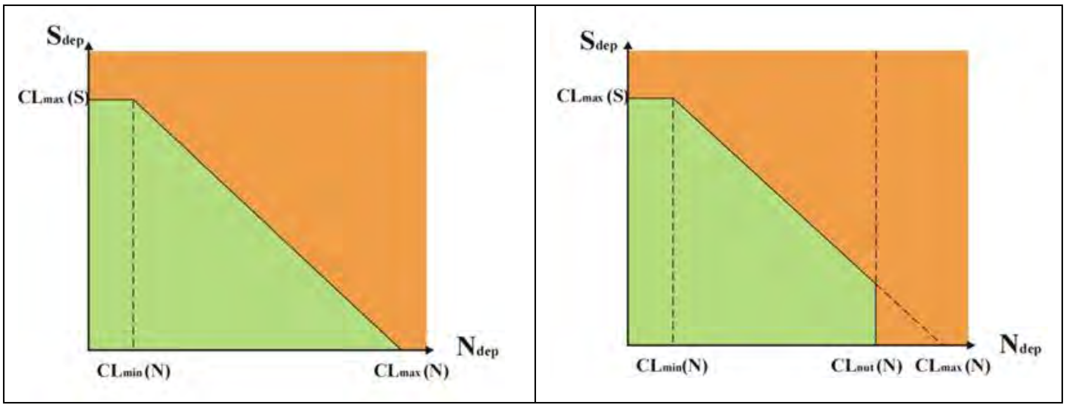

Figure 5-3: Critical load function for acidification (left) and effects of acidification and eutrophication (right)

The amount of deposition above the critical load is called the exceedance. Critical deposition load exceedances were calculated for 106 Level II plots by a comparison of critical loads with present throughfall deposition. For this, measured throughfall deposition (Fischer et al. 2010) was plotted in relation to the critical load function. In the same graph also deposition scenarios provided by the Coordination Centre for Effects of the ICP Modelling & Mapping program were used to plot deposition trends of nitrogen and sulphur (Figure 5-4). The exceedance of sulphur and nitrogen was calculated for the measured ICP Forests throughfall deposition, modelled EMEP[1] deposition (1980) and the scenarios NATIONAL[2], PRIMES[3] and MFR[4]. Critical deposition loads were compared to modelled deposition for the years 1980 (EMEP), 2000 (NATIONAL) and 2020. For the year 2020 deposition values were derived as PRIMES, NATIONAL and as MFR scenarios.

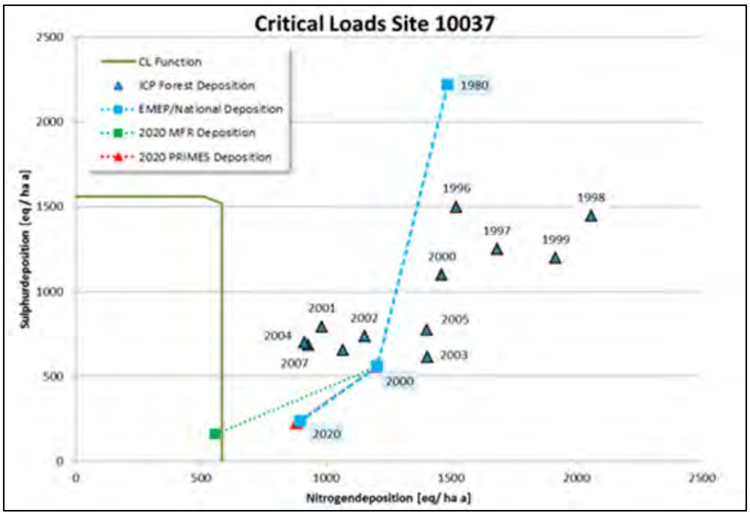

Figure 5-4: Measured (ICP Forests troughfall) and modelled deposition in relation to the critical load function as an example at Level II site 10037 (France**)**

The critical load concept aims at two objectives: protection against acidification driven by sulphur and nitrogen deposition and protection against eutrophication driven by nitrogen deposition. Therefore the actual deposition can be divided into an ecologically “accepted” part and a part of exceedance (Fig. 5-5).

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[1] Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP), see www.emep.int

[2] NATIONAL 2000 and 2020: modelled deposition values assuming the implementation of all presently decided emission-related legislation in all countries of the EU-27

[3] PRIMES determines the development of the EU energy system under current trends and policies until 2030 (see http://ec.europa.eu/energy/observatory/trends_2030/doc/trends_to_2030_update_2009.pdf)

[4] MFR (Maximum Feasible Reduction) scenario made available by the LRTAP Convention EMEP Centre for Integrated Assessment Modelling (CIAM) at the International Institute for Applied Systems Analysis (IIASA)

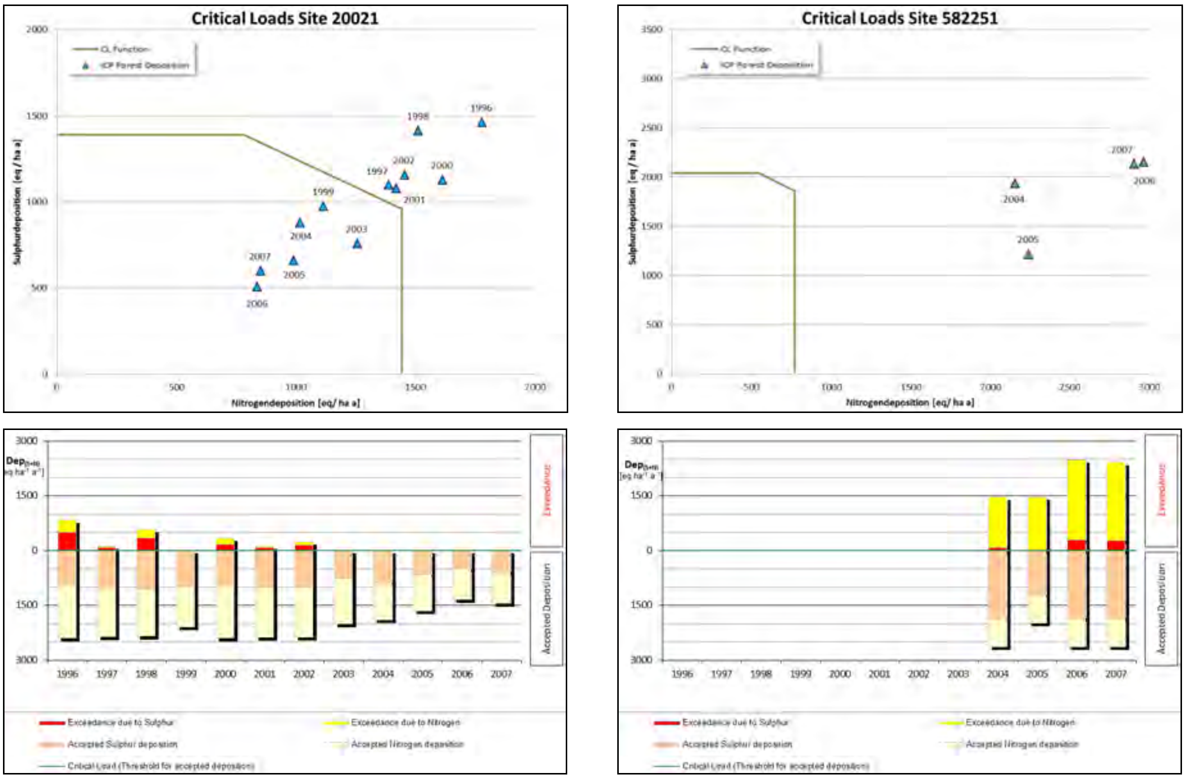
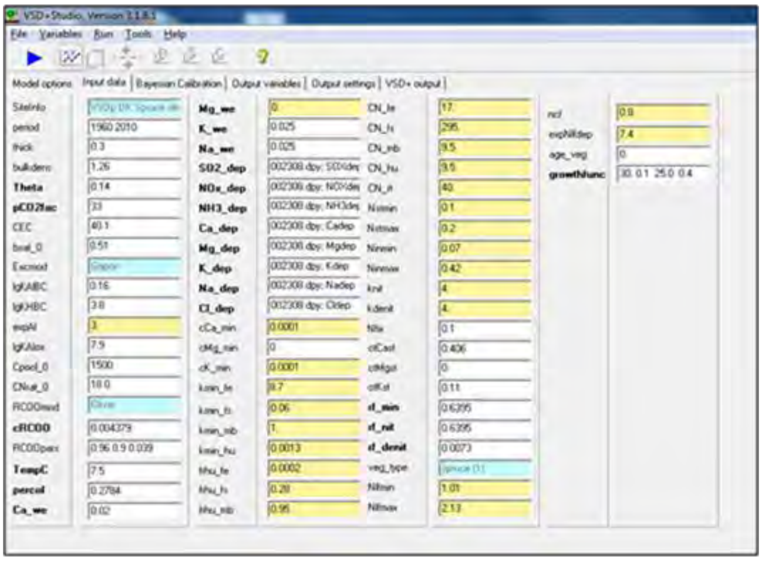


Figure 5-5: Critical and deposition loads of sulphur and nitrogen in different years, inside the critical load function (green line) significant harmful effects of acidification or eutrophication do not occur according to present knowledge (top graphs) and ecological "accepted" deposition and exceedances for sulphur (red) and nitrogen (yellow) at two example plots: 20021 in Belgium (left) and plot 582251 Czech Republic (right) based on measured depositions (bottom graphs)

Critical loads data on which these exceedance calculations are based, are derived from the steady-state mass balance method, used to define long-term critical loads for systems at steady-state. Therefore, exceedance is an indication of the potential for harmful effects to systems at steady-state. This implies that current exceedance does not necessarily equate with damage. In addition, the non-exceedance of critical loads does not necessarily mean that previously damaged ecosystems have already recovered, and chemical recovery will not necessarily be accompanied by biological recovery. Both chemical and biological recovery can take decades, particularly for the most sensitive ecosystems.

Therefore under the Convention on Long-range Transboundary Air Pollution (CLRTAP), the VSD+ model was developed as an extension of the Very Simple Dynamic (VSD) model by including organic C and N dynamics. VSD+ is the simplest extension of the steady-state SMB model into a dynamic soil model by including cation exchange (Gaines-Thomas or Gapon) and time-dependent N immobilization. It was specifically designed for use in support of the review of effects-based Protocols under the CLRTAP (Bonten et al. 2011).



SiteInfo	VSDp DK Spruce	**Mg_we**	0	CN_fe	17.	rcf	0.8
period	1960 2010	**K_we**	0.025	CN_fh	295	expNitdep	7.4
thick	0.3	**Na_we**	0.025	CN_mb	9.5	age_veg	0
bulkdens	1.26	**SO2_dep**	002308 dpy: SO2dep	CN_hu	9.5	**growthfunc**	30. 0.1 25.0 0.4
Theta	0.14	**NOx_dep**	002308 dpy: NOXdep	CN_rt	40		
pCO2fac	33	**NH3_dep**	002308 dpy: NH3dep	Nutmin	0.1		
CEC	40.1	**Ca_dep**	002308 dpy: Cadep	Nutmax	0.2		
bsat_0	0.51	**Mg_dep**	002308 dpy: Mgdep	Ninmin	0.07		
Exchmod	Gapon	**K_dep**	002308 dpy: Kdep	Ninmax	0.42		
lgKABC	0.16	**Na_dep**	002308 dpy: Nadep	knit	4		
lgKHBC	3.8	**Cl_dep**	002308 dpy: Cldep	kdenit	4.		
expAl	3	cCa_min	0.0001	fde	0.1		
lgKAlox	7.9	cMg_min	0	ctCacf	0.406		
Cpool_0	1500	cK_min	0.0001	ctMgcf	0		
CNrat_0	18.0	kmin_fe	0.7	ctKcf	0.11		
RCOOmod	Oliver	kmin_fh	0.06	**rf_min**	0.6395		
cRCOO	0.004379	kmin_mb	1.	**rf_nit**	0.6395		
RCOOpars	0.96 0.9 0.039	kmin_hu	0.0013	**rf_denit**	0.0073		
TempC	7.5	fhu_fe	0.0002	veg_type	spruce (1)		
percol	0.2784	fhu_fh	0.28	Nfmin	1.01		
Ca_we	0.02	fhu_mb	0.95	Nfmax	2.13		

Figure 5-6: Input data for the VSD+ model

The VSD+ model is documented in the VSD+ manual published and distributed by CCE (2011). The VSD+ model is based on chemical, physical and biological processes. The user-interface (Figure 5-6) highlights additional site information (light blue), parameters with default values (yellow) and parameters that can be changed by the user (white). A number of parameters are single values; others are a set of parameters or a time series (parameters in bold letters in Figure 5-6). 23 parameters can be calibrated with an internal Bayesian Calibration if measured values are available. These parameters are exchange constants, specifying parameters and parameters describing starting conditions.

5.5 Results of critical loads and their exceedances

The comparison of present critical loads for acidity with modelled past sulphur and acidifying nitrogen deposition in 1980 shows exceedances on all plots in central Europe. The threat of acidification was widespread in the year 1980 and demonstrates potential for severe effects of air pollution in the centre of Europe in the past. Nearly 60% of the plots showed exceedances of the critical loads. The situation improved considerably until 2000 when more than 80% of the plots had no exceedances. A continued positive future projection is clearly visible under all three future scenarios with the MFR scenario as the best among them. A comparison of measured throughfall deposition with critical loads for acidity reveals results comparable to the modelled inputs for the year 2000, even though that the number of observation plots and the year of observation are not fully comparable (Figure 5-7).

In 1980, critical loads for nutrient nitrogen were exceeded on almost 60% of the plots, a percentage comparable to the share of the plots with exceedances for critical acidity loads. The high exceedance of the critical loads implies a high risk of eutrophication for the forest ecosystems. Especially plots in the centre of Europe, in the United Kingdom, in southern France and in Spain were affected. Even though the exceedances were mostly lower in 2000, the share of plots with exceedances hardly decreased over two decades. The NATIONAL and the PRIMES scenarios show similar results for the year 2020, i.e. a further decrease of the unprotected sites to approx. 30% of the plots. Maximum technically feasible reductions (MFR) would improve the situation, but still would not protect all sites from risks through eutrophication (Figure 5-8). On most plots there is hardly any difference in the NATIONAL and the PRIMES scenario for the year 2020. Specifically plots with high exceedances would, however, benefit from the advanced deposition reduction in the MFR scenario (Fig. 5-9).

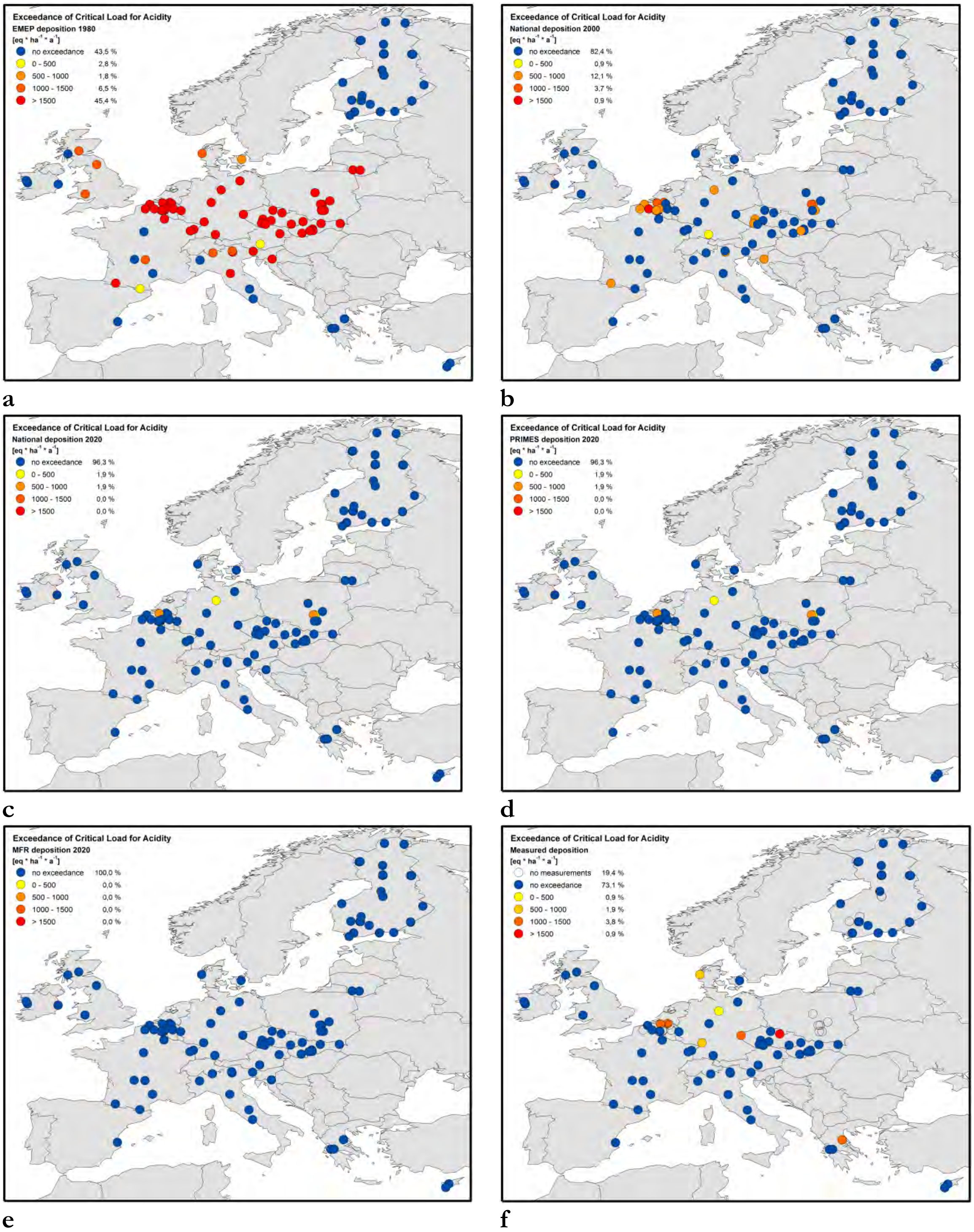
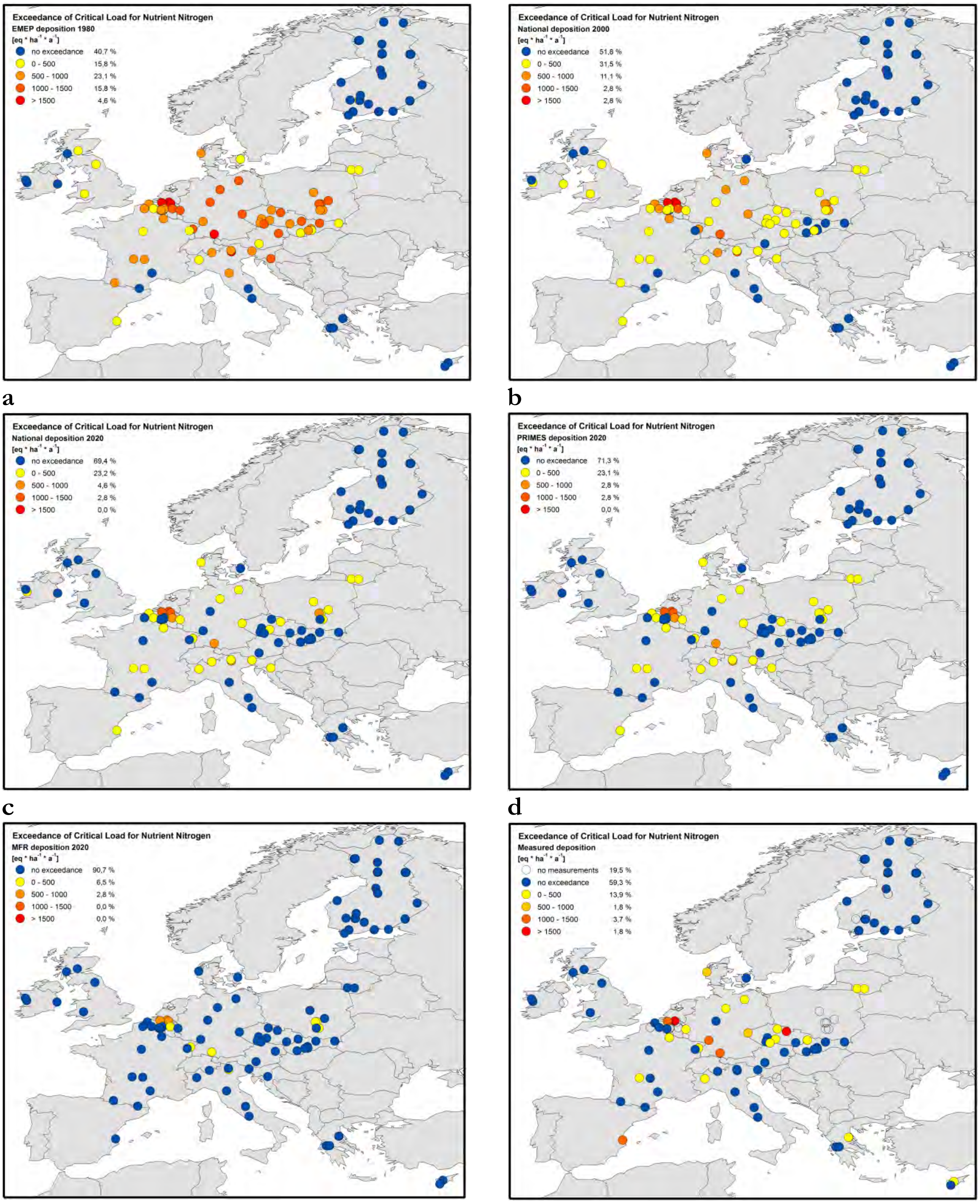


Figure 5-7: Exceedances of critical loads for acidity in the years 1980(a), 2000(b), and 2020 national projection (c), modelled by PRIMES (d), MFR scenario (e), and exceedance of critical loads by the last known measurements of Level II data (f)



a **b** **c** **d** **e** **f**

Figure 5-8: Exceedance of critical loads for nutrient nitrogen in the years 1980(a), 2000(b), 2020 national projection (c), modelled by PRIMES (d), MFR scenario (e) and the last known measurement of Level II data (f)

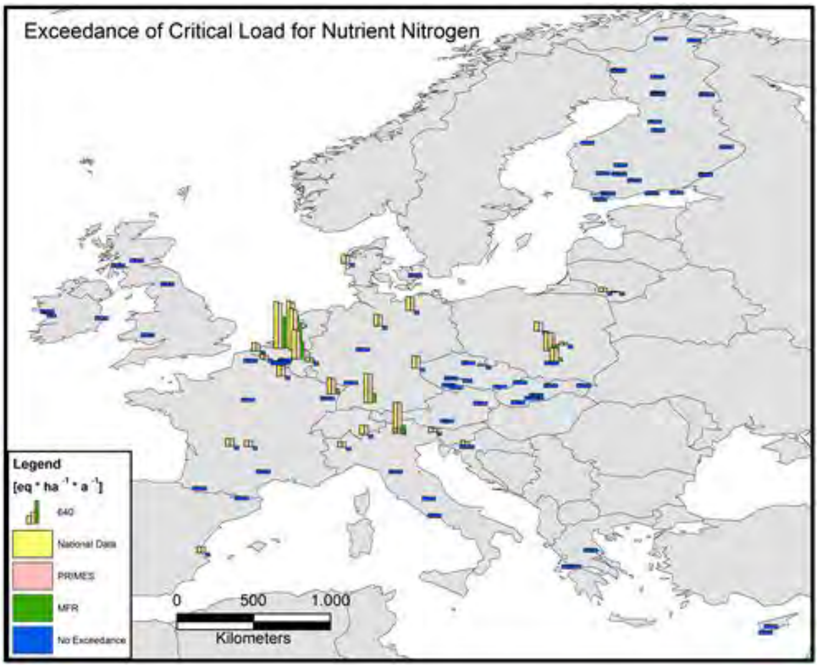


Figure 5-9: Exceedances of critical loads for nutrient nitrogen following different deposition scenarios, 2020

5.6 Results of dynamic modelling with VSD+

Single plot wise results from the VSD+ model show time trends for major geochemical parameters like pH value, carbon pool, acid neutralization capacity (ANC), C:N ratio and base saturation (EBc) based on the underlying deposition scenarios (Figure 5-10). Deposition development of site 40301 is typical for many central European sites with sulphur and NO_x showing a peak between 1970 and 1980 and a decreasing trend starting 1990. Base cation deposition peaked slightly in 1980 and remains rather unchanged from the year 2000 onwards. The model output shows the response of soil solution to deposition. Measurements of the C:N ratio and base saturation were used for model calibration so that the figures include the measured values as well.

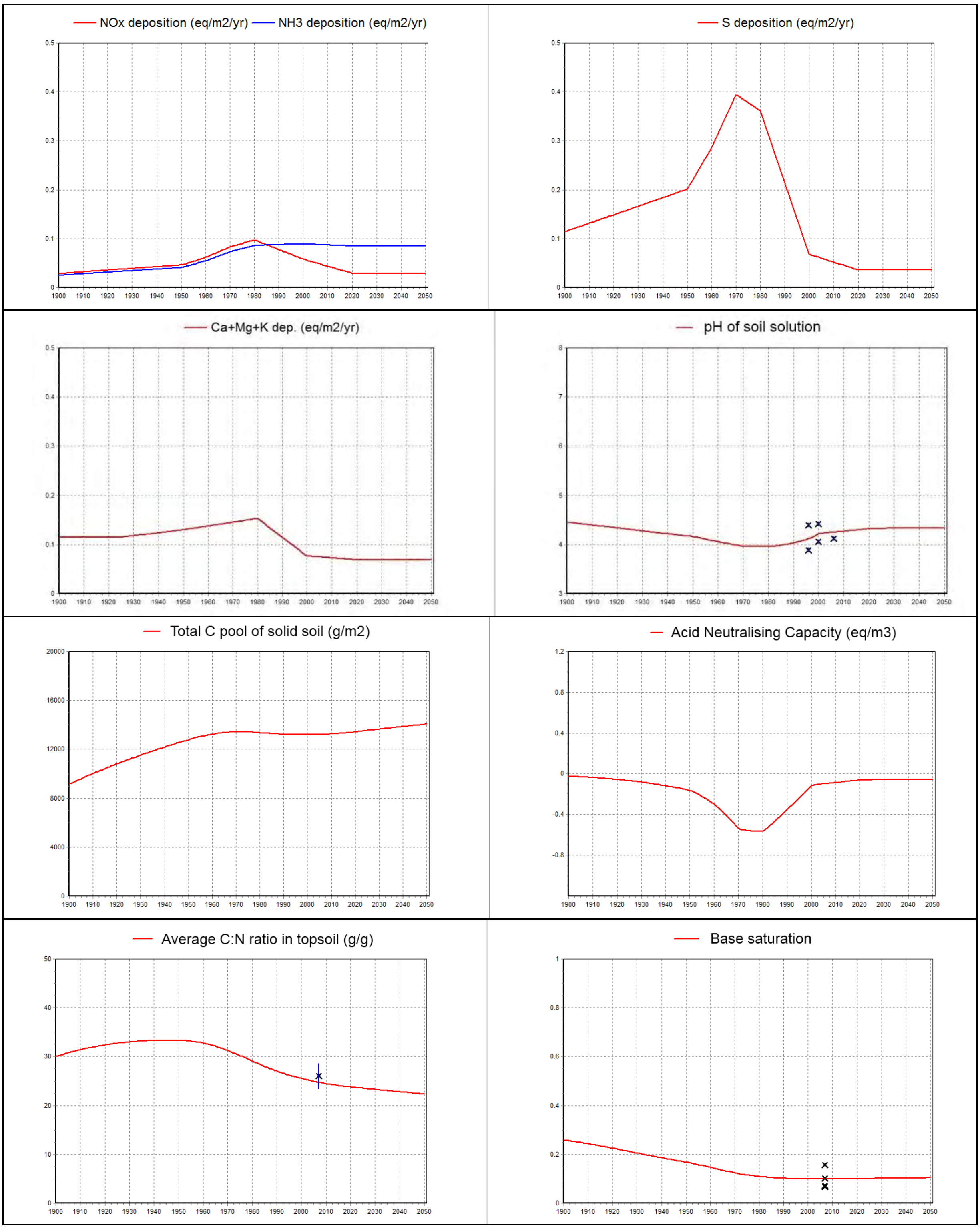
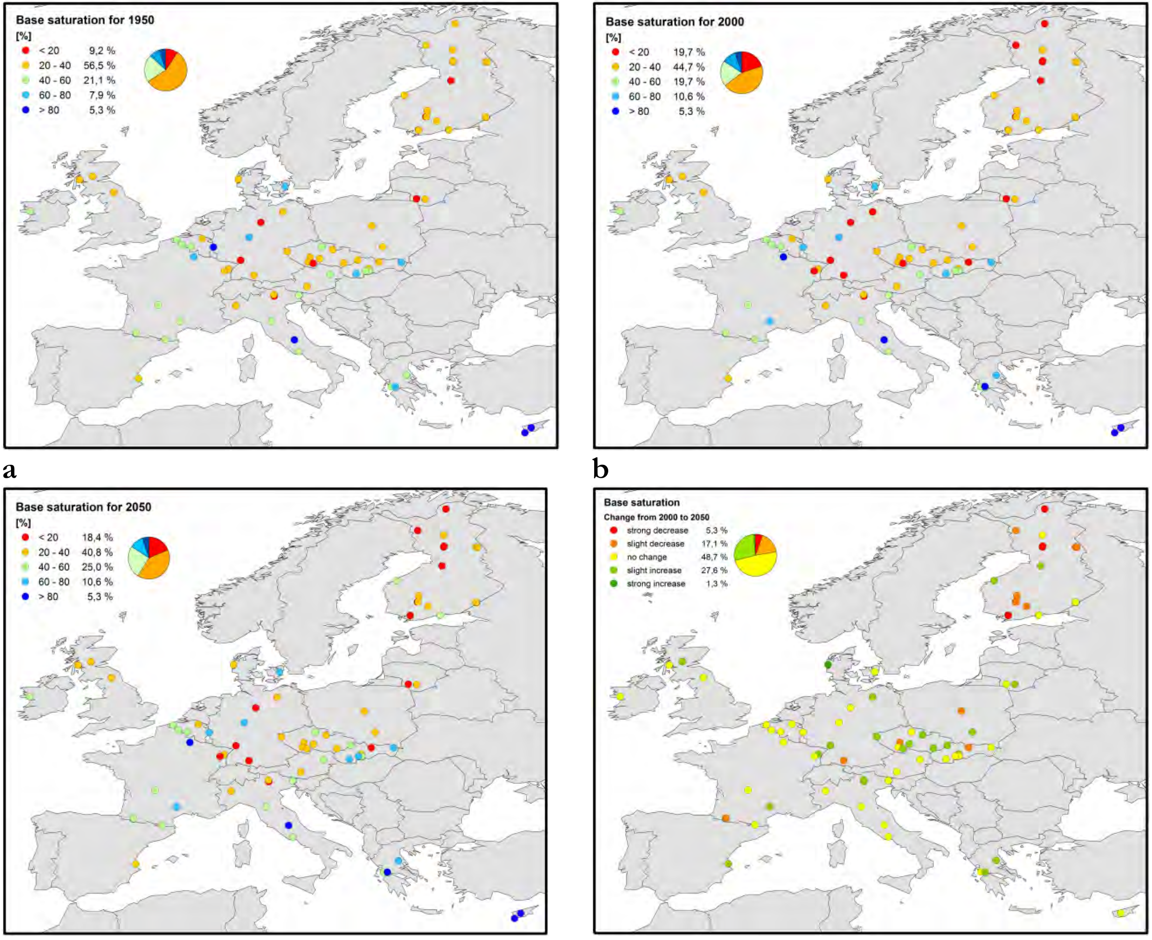


Figure 5-10: Dynamic change of geochemical parameters, modelled with VSD+ (red/blue lines) and measured / observed values (blue dots); example for Level II site 40301, Germany. Base saturation, ANC and pH refer to soil solution

5.6.1 Base saturation

The spatial trend for base saturation in soil solution of different plots is heterogeneous with a tendency of low base saturation for central and eastern/north-eastern Europe in all years. Model results suggest that most plots had a base saturation between 20 and 40% in the year 1950. The share of plots in this class decreases until the year 2000. In contrast, the share of plots in the <20% class doubles between 1980 and 2000. Across all plots, there is less change between the years 2000 and 2050. On more than 90% of the plots no or only slight changes are observed between these two years (Figure 5-11). The analysis of longer time series based on the model outputs confirms this observation. Most changes occurred between the years 1960 and 2000 (Fig. 5-12).



a **b**

c **d**

Figure 5-11: Base saturation of soil solution for the years 1950(a), 2000(b), 2050(c) and changes between 2000 and 2050(d) derived by the VSD+ model

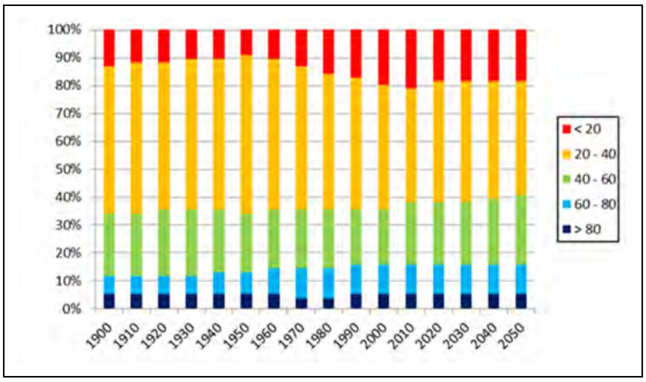
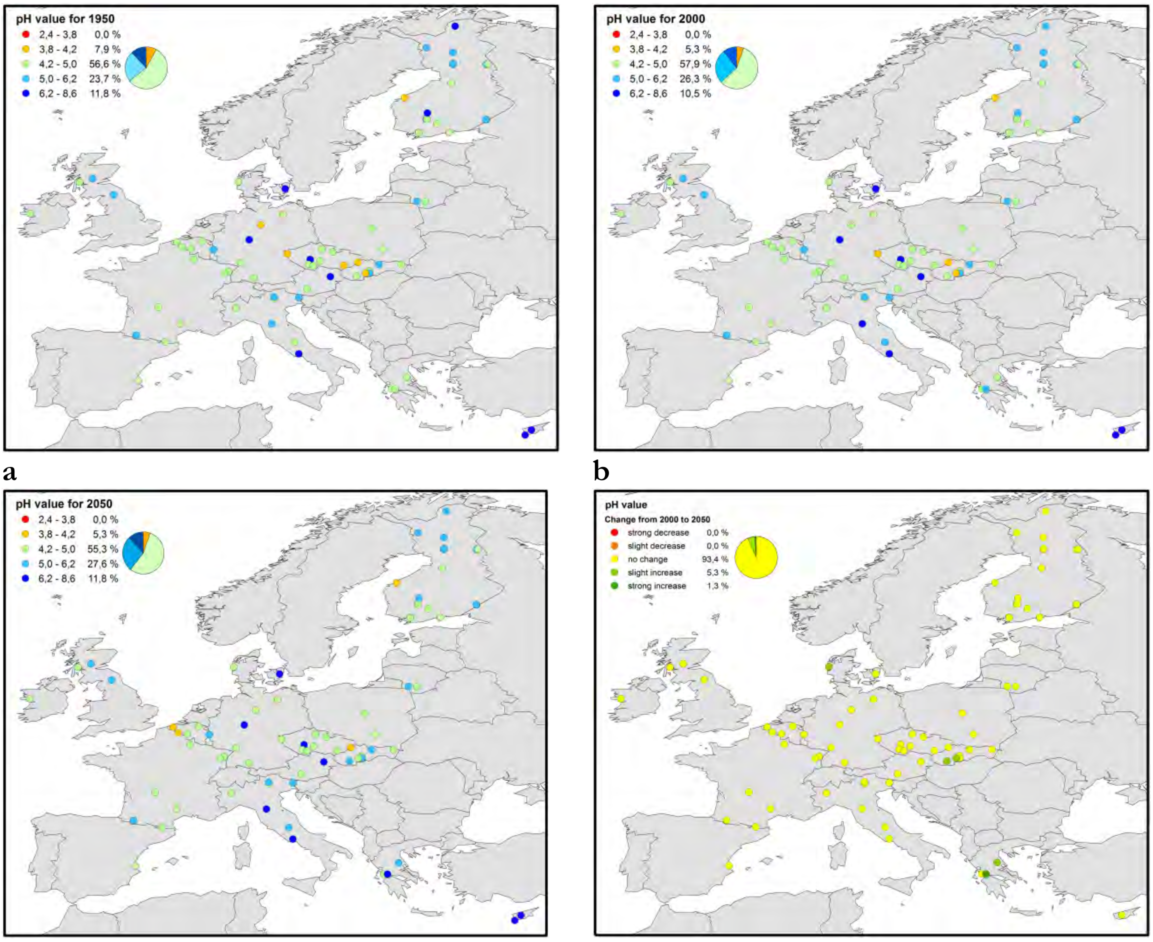


Figure 5-12: Overall trend for base saturation classes in soil solution modelled by VSD+ for 77 plots

5.6.2 pH value

pH values were grouped into ranges according to Ulrich (1981): 2,4 – 3,8 Iron buffer range, 3,8 – 4,2 Aluminium buffer range, 4,2 – 5,0 Exchanger buffer range, 5,0 – 6,2 Silicate buffer range, 6,2 – 8,6 Carbonate buffer range. In all years depicted, the exchange buffer range dominates. There is hardly any spatial trend visible (Figure 5-13). Between the years 2000 and 2050 there is no significant change visible on 93% of the plots. Major changes occurred between 1950 and 2000. These changes include an increase in the share of plots with extremely low pH values in the years 1970 and 1980 and a recovery from 1990 onwards (Fig. 5-14).



a b

c d

Figure 5-13: pH values in soil solution for the years 1950(a), 2000(b), 2050(c) and changes from 2000 to 2050(d) derived by the VSD+ model

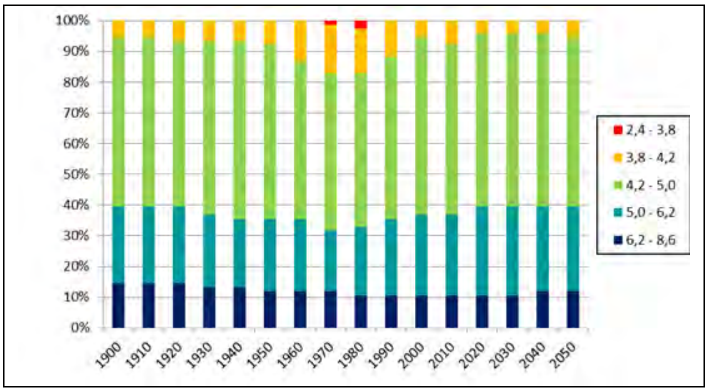
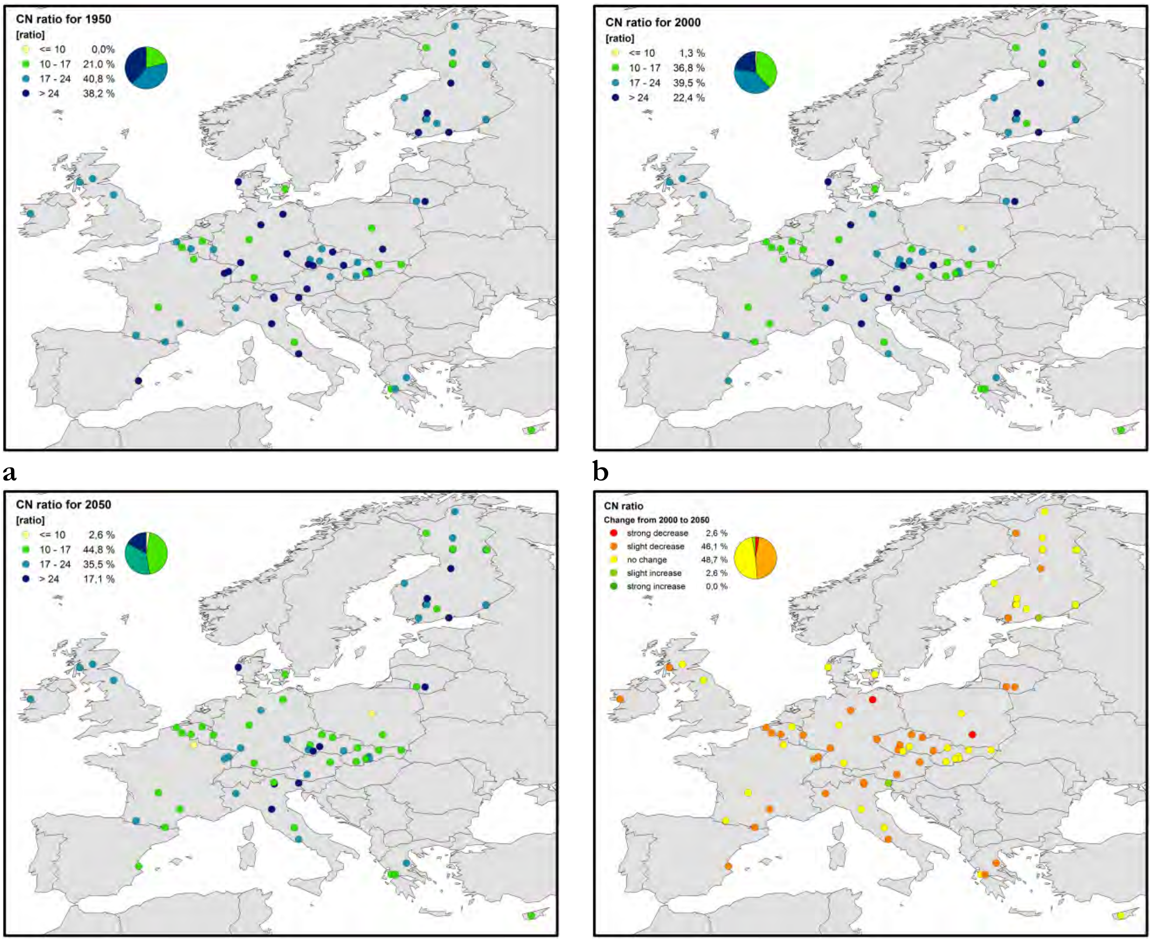


Figure 5-14: Overall trend for pH value in soil solution modelled by VSD+ for 77 plots and classified by buffering classes (Ulrich 1981)

5.6.3 C:N ratio

The C:N ratio was classidied into different levels of nutrient availabilities. C:N ratios below 10 mark hypertrophic conditions, C:N ratios between 10 and 17 are regarded as eutrophic, between 17 - 24 they are mesotrophic, whereas above 24 they indicate nutrient poor (oligotrophic) conditions. In the year 1950, 80% of the plots were characterized by mesotrophic or oligotrophic conditions. Until the year 2000, the share of eutrophic plots increased and is assumed to further increae until the year 2050 when eutrophic conditions will dominate according to the model results. For 2050, even hypertrophic conditions are predicted for a small share of plots (Figure 5-15). The summary trend for all plots also suggests a continuous eutrophication from 1960 until the year 2050 (Figure 5-16).



a b

c d

Figure 5-15: CN ratio in soil solution for the years 1950(a), 2000(b), 2050(c) and changes from 2000 to 2050(d) derived by the VSD+ model

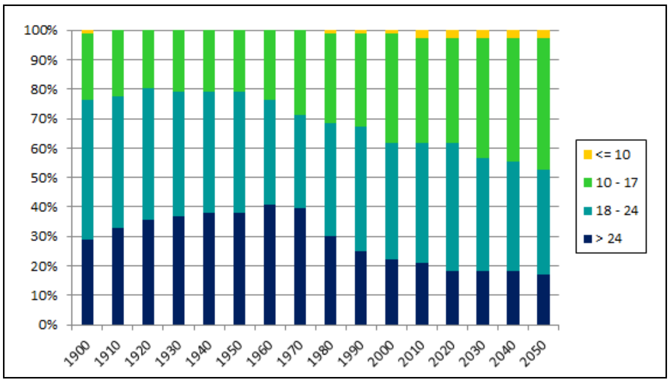


Figure 5-16: Overall trend for C:N ratio in soil solution modelled by VSD+ for 77 plots and classified by nutrient levels

5.7 Discussion and conclusions

The widespread and clear reduction of sulphur deposition starting in the 1970s shows the success of the clean air policies under the UNECE and the EU. For nitrogen inputs, however, the monitoring data (Chapt. 4) and model values reveal only minor changes. By relating past, present and future deposition scenarios to present stand and soil condition, critical load exceedances offer an important tool to assess deposition effects and their potential for damage to forest ecosystems. Results suggest that for acidifying inputs the situation will considerably improve: in 2020, over 90% of the forested sites will be protected from acidifying inputs. But even assuming full implementation of national legislation, approximately 30% of the sites will still receive eutrophying nitrogen inputs above the critical loads according to the models.

The critical loads were compared to measured and modelled thorughfall deposition. Throughfall deposition does not reflect total deposition but rather total deposition plus net canopy exchange. This might result in an underestimation of the exceedances, so that the results present a rather conservative estimation.

The VSD+ model allows for the assessment of soil chemical changes over time taking into account the reaction and development of the system. A summarizing, Europe-wide interpretation for nearly 80 forest sites - each with specific conditions and soil reactions - is hardly possible. Thus, only basic and general trends can be discussed. An integrated interpretation of base saturation, pH and C:N ratio in soil solution shows:

- a decreasing C:N ratio is the dominant trend after about 1970. Such a decrease occurs on half of the plots;
- astonishingly, pH shows a full recovery to preindustrial conditions after the 1980s;
- for base saturation there is no change or increase in central Europe, and a decrease mainly on the Finnish plots.

Base saturation and pH

A widespread effect of increasing deposition of inorganic nitrogen and non-marine sulphate since the beginning of the last century was base cation leaching from mineral top soil layers. This process is reflected in the model results from plots in most regions of Europe and also in a generally decreasing base saturation in the soils until the present time. It will probably take many decades to build up the base saturation to pre-industrial levels. Nutrient imbalances result from lower availability of base cations and increasing availability of nutrient nitrogen in the soil solution. Such imbalances can have direct effects on forest ecosystems including increased susceptibility to pathogens and pests (Bobbink et al. 2010). Indicators such as branch length and shoot multiplication rate, which include effects accumulated over several years, are suitable to illustrate stress by nutrient imbalances on tree vitality (Rosengren et al. 2002). Until about 1980, soil pH decreased, showing a similar trend to base saturation. However, unlike base saturation, pH appears to have recovered surprisingly quickly after 1980.

Changes in C:N ratio

Results suggest an increasing C:N ratio on many plots (Fig. 5-16), especially in the first half of the 20th century. This might be due to a build-up of soil organic carbon without at the same time building up the soil nitrogen content. Some microbial communities appear to be sensitive to reductions in pH. In addition, nutrient imbalances are linked to decreasing mineralization rates, specifically through negative effects on soil organisms and decomposers that depend on balanced nutrient composition. Thus, as soils become more acidified, there may have been a change in the composition of the microbial community, ultimately leading to decreased decomposition. With reduced mineralization rates an increasing accumulation of organic carbon is observed, especially in the humus layer. Simultaneously to the increasing carbon concentrations, the VSD+ model shows loss of nitrogen. This might be due to plant uptake and the leaching of nitrate in ecosystems are already nitrogen-saturated. Both processes provide an explanation for the increasing C:N ratios until the 1960/70s as calculated in the VSD+ model. Since the mid-80s, a significant decrease of C:N ratios was modelled, suggesting increased nitrogen saturation as a result of continued high, although decreasing, inorganic nitrogen deposition. At the same time, increased pH may have led to recovery of the decomposer community. The ongoing decrease of the C:N ratio is an indicator for a continuous eutrophication of the forest stands. This result is closely linked to the modelled exceedance of critical loads for nutrient nitrogen. A confirmation of such trends with measured time trends in soil solution is hardly possible due to the short time series available. Iost et al. (2011) evaluated trends in critical limit exceedances for nitrogen concentrations on 140 Level II plots with at least 6 years of continuous measurements and could not find trends on most of these plots (Chapt. 5).

Previous soil acidification is still a burden to forest soils. Soil solution pH shows an astonishingly quick recovery. But a comparison with measured data shows that critical limits for soil acidification are still exceeded on around half of the ICP Forests samplers (Fischer et al. 2010). Measurement periods available are not long enough to confirm the modelled recovery. In contrast to soil solution, the recovery of soil solid phase takes decades. The comparison of soil solid phase pH on over 2000 Level I plots between a first survey end of the 1980s / early 1990s and a second survey in the years 2004 to 2008 even showed further decrease of the pH on plots with pH above 4.0 and significant recovery only on the strongly acidified soils with pH below 4.0.

The intensive forest monitoring plots provide the basis for the risk assessment and for evaluating potential recovery of forest ecosystems under reduced atmospheric deposition. Critical loads of acidity and nutrient nitrogen as well as assessments of their exceedances contribute to the scientific basis for UNECE and EU air pollution prevention policy. Together with results of dynamic modelling they support optimized control strategies in the ongoing review of the Gothenburg Protocol. The long-term intensive monitoring data of ICP Forests also enable the derivation of trends in soil condition. This information is used to validate recovery effects predicted by dynamic models. The effects on forest vitality and biodiversity reveal a considerable delay after changes of soil conditions which also occur with some delay after the impact of atmospheric pollution. Influences of climate change might become more important in the future. This all requires adaptation of forest management and nature conservation practices, continued observation of forest, monitoring and modelling.

5.8 References

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Part IV

CARBON AND CLIMATE CHANGE

6. Analysis of forest growth data on intensive monitoring plots

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6.1 Abstract

Based on existing long term and intensive forest monitoring data, forest growth has been evaluated for 822 plots in 30 European countries. Data include information on breast height diameter of all trees, heights of selected trees and plot area. For nearly 600 plots remeasurements were available within different measurement intervals. In addition to the data quality checks routinely applied in the context of data submission to the central data base, accuracy of the data and the calculations were checked by independent remeasurements on selected plots and by applying national form functions to a test data set provided to national experts. Results show stocking wood volumes between 300m³/ha and 600m³/ha for most plots with higher volumes for plots in the Alps and lower volumes in the northern and southern regions. Basal area and stem volume increments show similar spatial patterns. Low increments are located in the south and north whereas the plots in Spain show very low increments. Moderate increments are observed on the plots of central and eastern Europe and high increments are found in the western region. The results provides a unique overview on forest growth based on standardized measurements. They are a valuable basis for future validation, refinement or creation of forest growth models, for the determination of growth responses to site and environmental conditions and their changes and for the estimation of harvestable wood and potential stocking biomass in European forests under different management scenarios.

6.2 Introduction

The growth of trees is a key ecological parameter of forests and thus of high importance as an indicator of forest condition. Increment is defined as the growth of trees (shoots in coppice forests) and stands within a defined period and can be expressed as increment of diameter, basal area, height and/or volume. On Level II plots of the ICP Forests programme, growth assessments are carried out on fixed plots, thus the calculation of area related estimates is possible. These parameters can be linked to external as well as internal factors serving as a proxy parameter for the reaction of trees and stands to management, as well as changes in site and environmental conditions. The advantages compared to other proxies lie in their direct economical and ecological importance of growth parameters.

An evaluation done already in 2003 focusing on carbon pools (de Vries et al., 2003) presented first results of growth assessments on intensive monitoring plots. After the last remeasurement of 2009/2010 an evaluation based on all information available up to 2011 and based on intensified data quality checks now allowed improved and updated evaluations. Revised data of stocking biomass and main increment information are now available for further use within the programme.

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6.3 Data and methods

6.3.1 Data completeness and spatial/temporal extent

Evaluations are based on a database export created in March 2011. It contained data from 822 plots in 30 countries. Some plots have been established in 1991 already and are still observed, covering a time period of up to 18 years (Fig. 6-1). On the other hand, more than 250 more recently established plots have still not been remeasured which does not permit their use for a growth examination. The total area of all observed plots amounts to around 250 ha. In addition to the total period covered by the observations at specific plots the remeasurement interval is as well of importance. On the evaluated plots, most intervals are in a range of up to 6 years (Fig. 6-2), which is a suitable basis for calculating and interpreting increments. If remeasurement intervals are long, short term growth deviations caused by environmental changes (e.g. temperature, precipitation) are hidden. Also, if the remeasurement interval is too long the bias of underestimating the increment increases as the growth of ingrowth trees dying between the observations is not recorded. In such cases growth of trees which have been removed between two observations is as well not included. This bias is increasing with increasing measurement interval length.

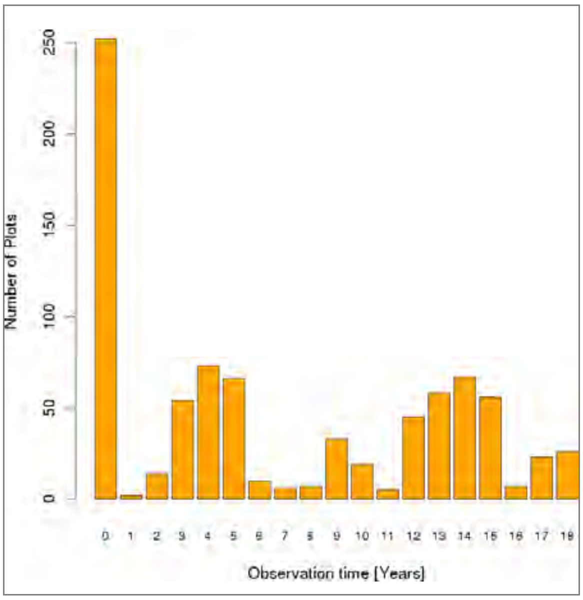


Figure 6-1: Plot observation time

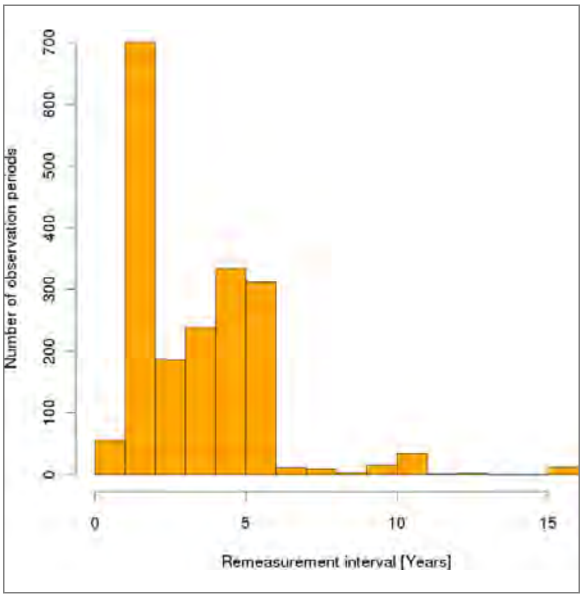


Figure 6-2: Observed remeasurement interval

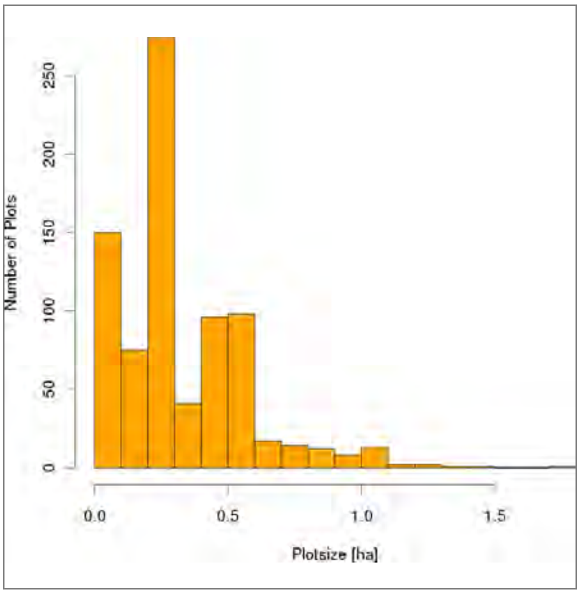


Figure 6-3: Plot size distribution.

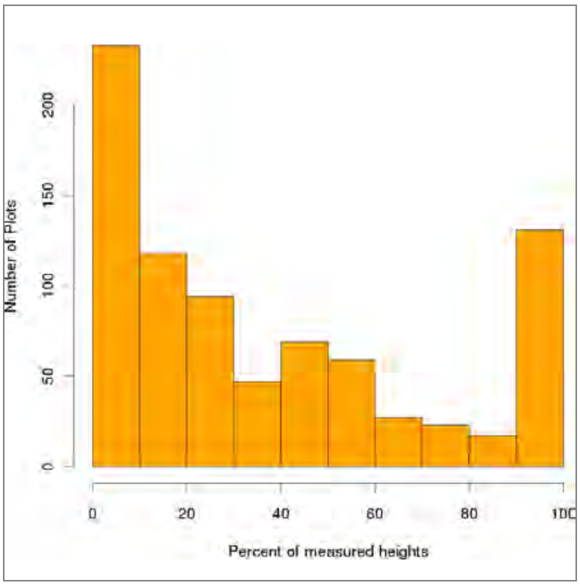


Figure 6-4: Percent of measured tree heights.

Most of the plots have a size of or around 0.25 hectares (Fig. 6-3). Plot size also has an influence on the growth analysis: small plots have larger deviations and biases than larger plots as imprecise measurements have a larger effect when only few trees are measured. On the other hand, the variation of site condition is increasing with plot size as well as the error in plot size determination.

Complete height measurements for nearly all trees with dbh information were carried out on over 100 plots (Fig. 6-4). On the other hand, for nearly 250 plots only up the 10% of the trees with dbh measurements were also measured for height. The necessary height estimations are a source of bias in the calculated volume and volume increment estimates. Here the missing heights are estimated by (1) interpolating between two height observations using observation date, (2) creating height curves using measured diameter with local regressions for individual plots, species and year, (3) applying height curves per plot and species, (4) per plot, (5) per species and (6) for all trees.

Height curves show considerable differences between different plots (Fig. 6-5). Ideally these functions should be derived for each species, plot and observation year separately. But this is only possible if there are enough height observations. Also it can be observed that there is much variation in measured heights around such a height curve. As the influence of height on the tree volume is not linear, estimated heights from height curves may result in a bias in volume calculation.

All spatial data is shown in aggregated raster cells of 1°x2/3° size which prevents the overlap of neighbouring plots in the maps. Many plots have been observed repeatedly. Therefore the data have been spatially and temporally aggregated. Most of the grids contain less than 4 plots (Fig. 6-6).

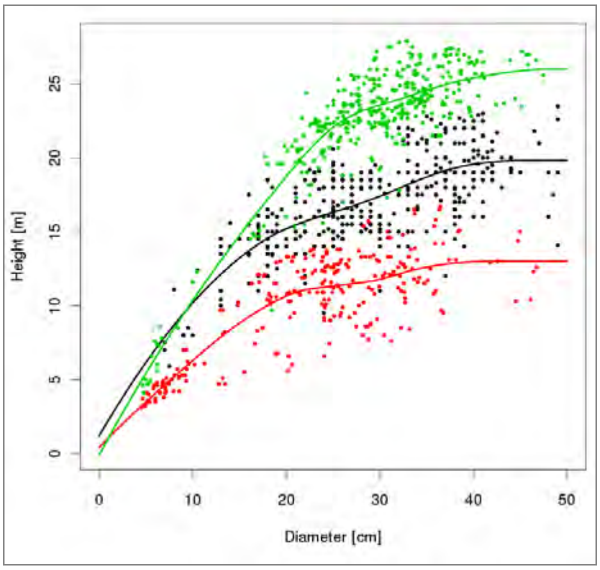


Figure 6-5: Height curves of *Pinus sylvestris* on three example Level II plots

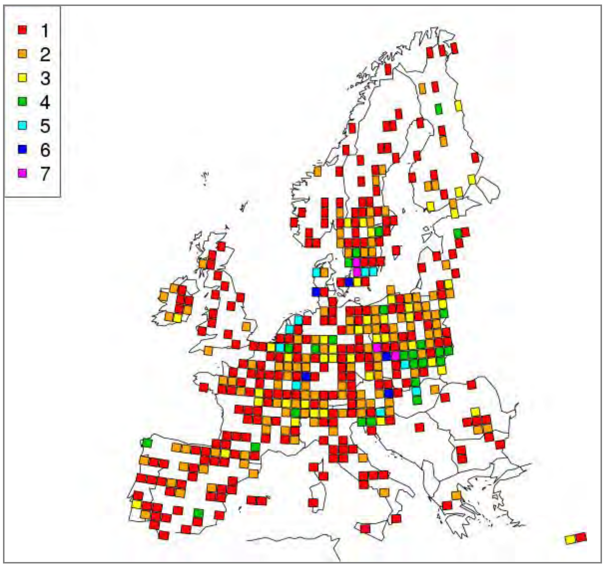
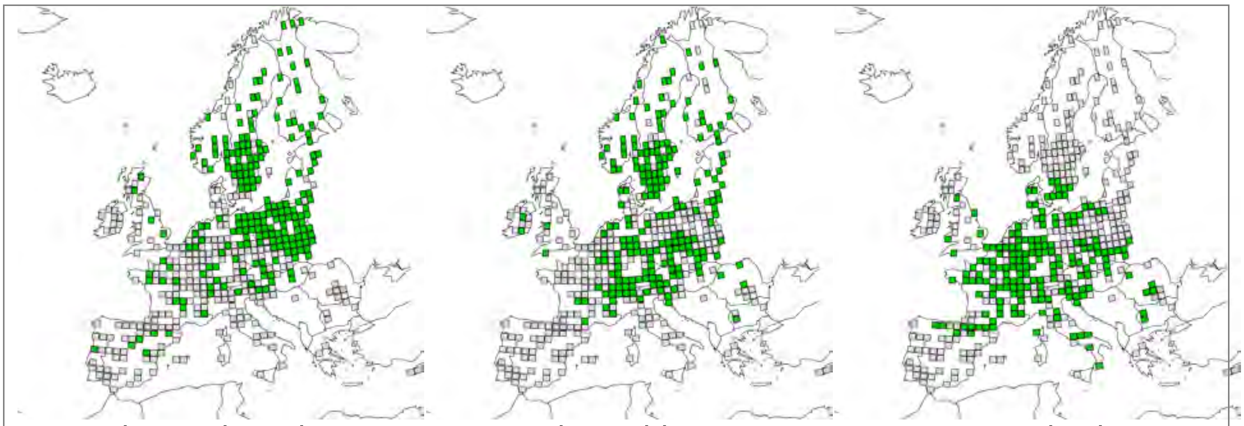


Figure 6-6: Number of plots per grid

Tree species compositon on the plots differs (Fig. 6-7). *Pinus sylvestris* can be found in the whole region. *Picea abies* is not present in the south, *Fagus sylvatica* is in central European regions, *Quercus robur, Abies alba* and *Carpinus betulus* also occur mainly in Central Europe, while *Quercus petraea* shows a more southern distribution. *Quercus ilex* is observed in the south west and *Quercus cerris* in the south east.

In the context of the growth calculation implausible data were routinely reported back to the countries which in a number of cases initiated a resubmission of the raw data. Most of these updates are already included in the presented results. Nevertheless the data correction process is still ongoing which will lead to a still increased data quality as basis for coming applications.



Pinus sylvestris *Picea abies* *Fagus sylvatica*

Quercus robur *Quercus petrea* *Carpinus betulus*

Abies alba *Quercus ilex* *Quercus cerris*

Figure 6-7: Observed species on the plots. Green cells indicate the occurrence of at least one tree on the plots represented by the respective cell.

6.3.2 Measurement accuracy

The ICP Forests Manual (ICP Forests, 2010) requires for the two most important measured variables an accuracy of 90% of the values to be within +/- 1% of the mean (true) diameter, to be within +/- 2% of the mean tree height measurement for conifers and to be within 5% of the mean tree height for broadleaves. Independent remeasurements from seven sites in Austria and Switzerland were used to analyze if the desired accuracy was reached. The remeasurements show that the limits are reached for diameter, but not always for height assessments, especially in broadleaved stands (Fig. 6-8).

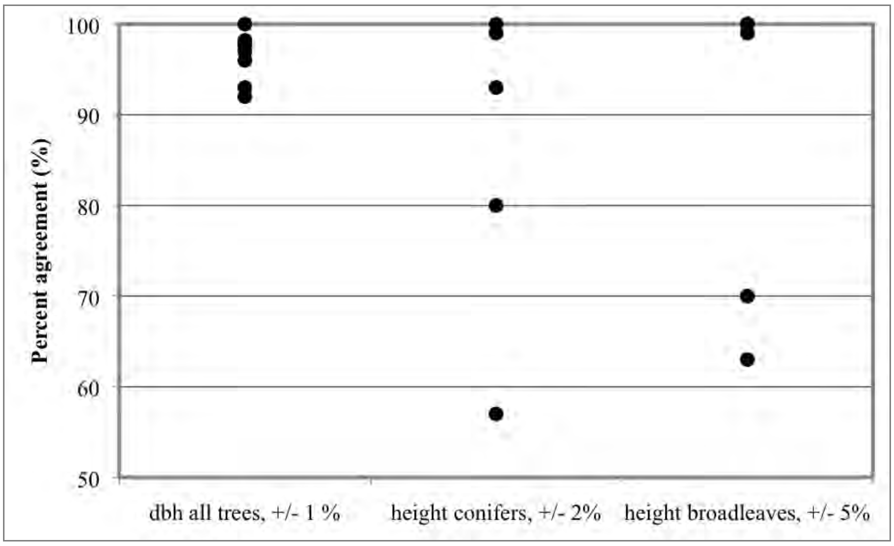


Figure 6-8: Agreement reached between two independent observers for dbh and height growth.

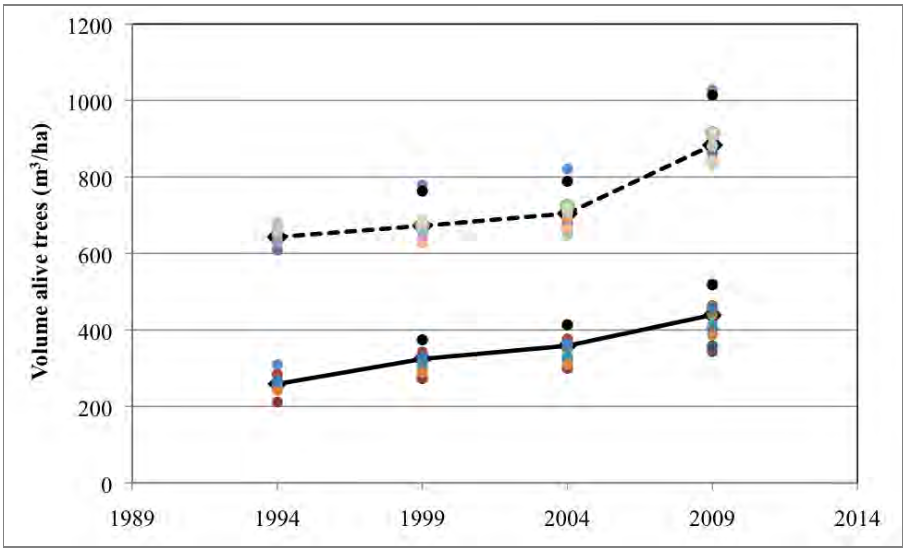


Figure 6-9: Calculated standing volume for two stands in the ring test. Lines represent the median value. Dots show different participating countries.

6.3.3 Differences caused by different calculation methods

In addition to the measurement errors in the field, forest stand parameters (stand density, stocking volume and its increment) are prone to typing errors (e.g. wrong digits used or digits switched, misnumbered trees, switched species) and calculation differences. Calculation differences occur when different form functions are used and missing tree heights are substituted with regression estimates. To test how these calculations differ, a test data set for two sites with 4 subsequent inventories was compiled using two existing plots from Austria. Measurement errors, missing tree heights, mortality and removal codes and switched tree numbers were added to the data set. The last survey was modelled and thus not prone to measurement errors. The data set were sent around to the participating countries and the experts were asked to provide the key forest stand and increment parameters for each inventory as required for in ICP Forests. Experts were asked to use there own form functions to calculate tree volume and in addition to use the Austrian form functions. Thirteen countries participated in the ring test. Most countries used only their own form functions. It was tested how many estimates were within +/- 10 % of the median value. As expected for basal area per ha agreement was very high. All values were within +/- 10% and more than 90% of all values were within +/- 1% of the median value. For standing volume on average 80% of the calculated volume was within +/- 10 % of the median volume (Fig. 6-9). Usually the ordering of the volume estimate stayed the same for the subsequent inventories. This indicates that the main reason for the different orderings were the form functions applied. Volume increment is much smaller than volume stocks and therefore has a higher relative variability. Here, only 40% of the increment values were within +/- 10% of the median values. Similarly, the mean coefficient of variation was 12 and 21% for the standing volume estimates and 28 and 29% for the volume increment.

6.3.4 Methods used for calculations

The basal area increment for the Level II plots was calculated with:

$$\text{Basal area increment/ha/Year} = \frac{\frac{\text{ba}_{\text{t1}}}{\text{area}_{\text{t1}}} - \frac{\text{ba}_{\text{t0}}}{\text{area}_{\text{t0}}} + \frac{\text{ba removals}_{\text{t0 to t1}}}{\text{area}_{\text{t0}}}}{\text{t1} - \text{t0}}$$

where *ba* is the basal area, *area* the plot size, *t0* observation time of the first and *t1* of the second observation. Removals are all trees which have no dbh in the following survey or have a code describing their removal and mortality. This calculation depends on an identification of removals. They can either explicitly be given e.g. by removal codes or can be identified with a unique tree number. So changes of tree numbers need to be avoided or reported. Another way to identify the removals is to remeasure a plot before and after a removal and assume that there was no increment in between these two observations. As trees are not growing constantly over the year the dates of observation are related to the vegetation period. The time between two surveys was calculated using their observation date and assuming that there is a linear increment between day 120 and day 240 of the year. This rough estimation may be improved in future by additional information on the percentage of annual growth already accomplished until the observation date. Normally this percentage should be either 0% or 100% because the plots should have been observed outside the growing period.

If the plot was shifted or its size has been changed between two surveys the removed/died trees can not be detected by a missing dbh. Here only the removal codes, which are available in the newer surveys, can be used. Still, plots which have a change of the observed area (change of size and/or location) should not be used to calculate increments as a difference in basal area or wood volume will be interpreted as an increment. Changes of plot size can be detected, but changes in the location need to be reported.

Typically the wood volume is either related to total stem volume or to merchantable volume (above a certain diameter threshold). If the stocking aboveground biomass is of interest the fraction of branches and leaves/needles is needed. Usually the volume or biomass can not be observed directly. They are calculated using functions which typically use diameter(s) and height(s) of the tree. These functions might be different in different regions and there are numerous different types and functions in use through Europe. To test if an existing form factor function can be used in whole Europe, or a new one which includes e.g. latitude and longitude needs to be created, measured volume data of trees from Europe are needed. For this analysis the functions from Pollanschütz (1974) have been used to calculate stem wood and those from Kennel (1973) to calculate merchantable wood. The form factor of trees with a broken or forked crown were not calculated separately.

6.4 Results

6.4.1 Development on plot level

Measured diameters at breast height (dbh) range from 1cm to 120cm, with an average of 23cm. Heights range from 1m to 45m and show an average of 18m. Observed stem numbers are between 8 and 5000 trees per hectare, basal area ranges between 0.2 and 105m²/ha and stocking stem volume between 1.5 and 1200m³/ha. The average basal area increment is approximately 1m²/ha/year and the average stem volume increment is 5.6m³/ha/year.

Graphs of height and diameter development can give an overview on growth dynamics of the single trees in the stand (Fig. 6-10). Measurement errors can easily be detected like the tree which has a DBH slightly above 30 cm in 1995 and 2005 and 20 cm only in 2000. The lines of this tree are crossed by a tree whose height is decreasing from ~30m to ~25m. This decrease might be a data error but could as well be due to a broken crown. The lines for large trees (dbh >50 cm) show a strong trend from lower left to upper right and their lines are long, indicating that those trees have a large diameter and height increment. The smaller the trees are (down to dbh=20 cm) the more the lines shift from right leaning long lines to vertical lines with moderate length. Those trees in the dbh range from 20cm to 30cm show moderate height growth and very small diameter growth in the years 1995 to 2000. Those trees are understorey trees competing for light in the crown canopy and therefore showing a relative high height growth. It seems that for many of these trees the attempt to reach the crown canopy will not be successful as their height increment from 2000 to 2005 is very low. The third group in this forest are trees smaller than dbh=20cm. Most of them are fir. Fir is very shade tolerant and these trees show some height and diameter increment. They might be located in a gap between larger trees and are not so strongly suppressed. Trees which end with a red or green point have been removed, died or their dbh and height was not measured in the last two periods. Trees starting with green or blue colour are either ingrowth or their dbh and height was not measured in the first two periods.

Comparing the growth of single plots allows for additional plausibility checks (Fig. 6-11). Plot 1 has a basal area of around 20 m²/ha in 1994 and a basal area increment below 0.1 m²/ha/year between 1994 and 2004. The right leaning line indicates a increasing increment and basal area. In the following period this trend is continuing but in the last period the increment is stagnating. Plot 2 is starting from a similar position like plot 1 but its basal area decreases to 5 m²/ha in the next assessment. This leads also to a declining increment. In the following two periods basal area and basal area increment are increasing again. Plot 3 shows a similar pattern like plot 2 but basal area and basal area increment are on a higher level. Plot 4 starts with a basal area around 35 m² which is increasing over time up to 45 m². Its basal area increment is fluctuating on a very low level. Plots 5 and 6 show constant basal areas and a strong variation in the basal area increment between the measurements. This variation might be caused by environmental factors but could as well be due to measurement errors that might show a strong effect in short growing period lengths of only one year.

The basal area increments of all plots and remeasurement intervals cover a wide range but most observations show an increment of basal area between 0 and 2 m²/ha/year (Fig. 6-12). Stem volume increment mostly ranges between and 0 and 20 m³/ha/year (Fig. 6-13). Outliers are caused e.g. by short observations intervals, small areas or errors in the data.

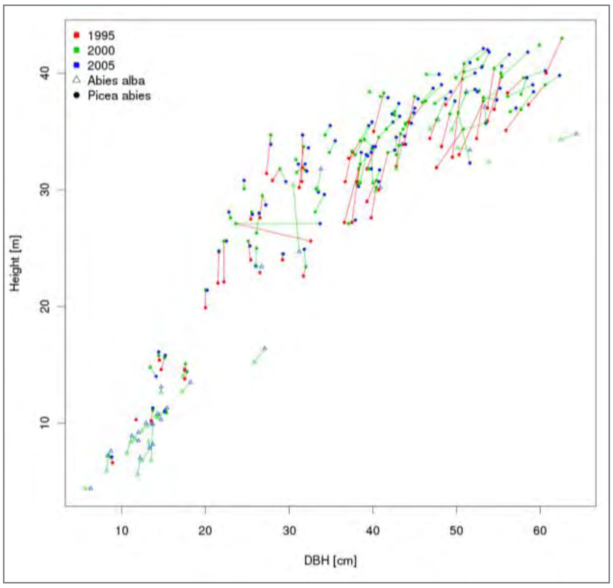


Figure 6-10: Height and DBH development of single trees on an example plot in the years 1995, 2000, and 2005. Connected dots represent single trees.

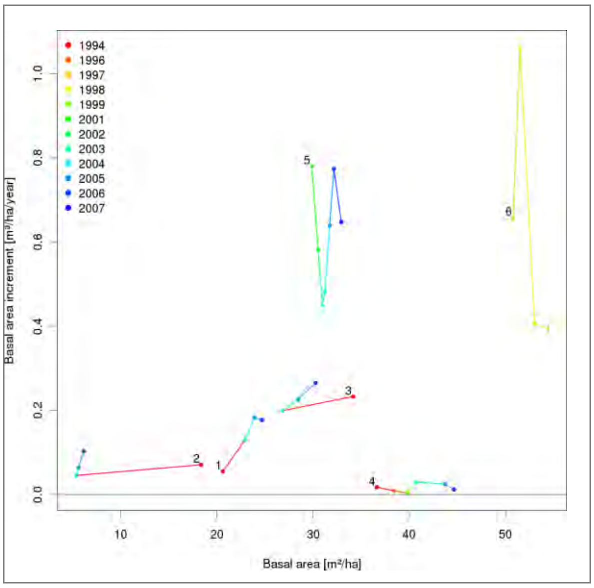


Figure 6-11: Development of example plots. Connected dots represent single plots.

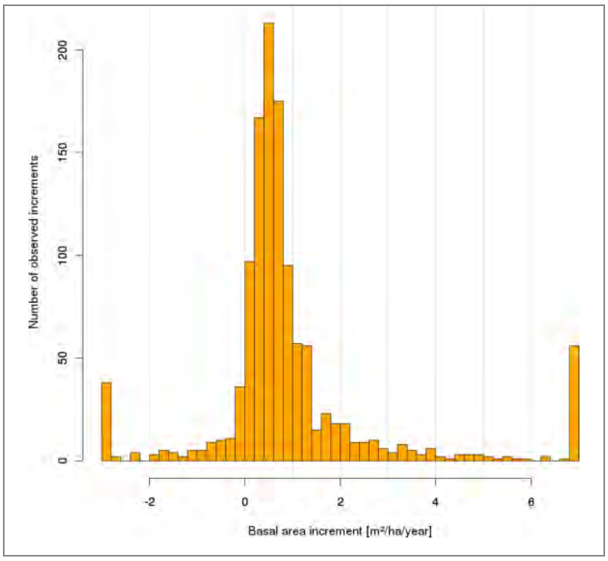


Figure 6-12: Basal area increment for all plots and remeasurement intervals

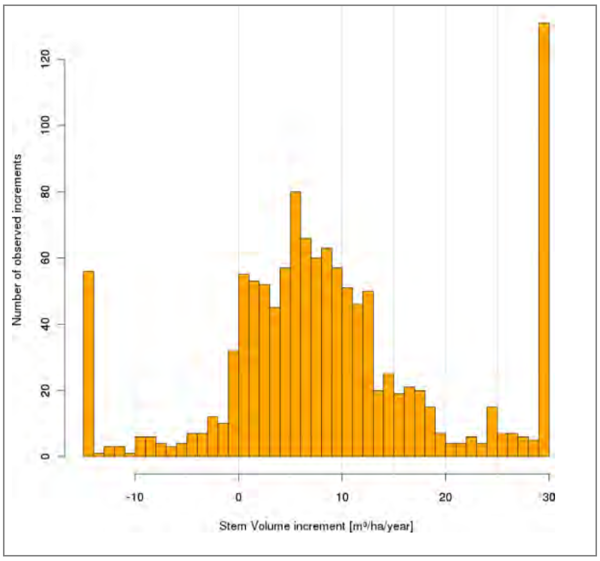


Figure 6-13: Stem volume increment for all plots and remeasurement intervals

6.4.2 Spatial stocking volume and increment on all observed plots

The spatial distribution of the stocking stem volume shows higher volumes for plots in the Alps and lower volumes in the northern and southern regions (Fig. 6-14). Many plots have a volume between 300m³/ha and 600m³/ha. As there are many plots and many time periods which provide data, this information has been reduced in spatial and temporal dimension.

Diameter deviation on the plots can be used as an indicator of the homogeneity (low deviation) or heterogeneity (high deviation) of the trees on a plot. Plots in central Europe show more deviation than the others, indicating larger diameter- and a higher stand structural-diversity (Fig. 6-15).

Basal area and stem volume increments show similar spatial patterns (Fig. 6-16). Low increments are located in the south and north whereas the plots in Spain show very low increments. Moderate increments are observed on the plots in central and eastern Europe and high increments are found in the western region.

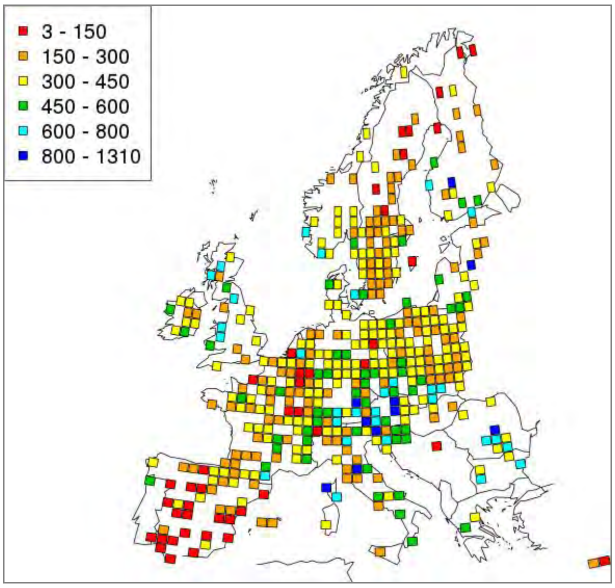


Figure 6-14: Stocking stem volume [m³/ha]. Plot data averaged to means per grid cell.

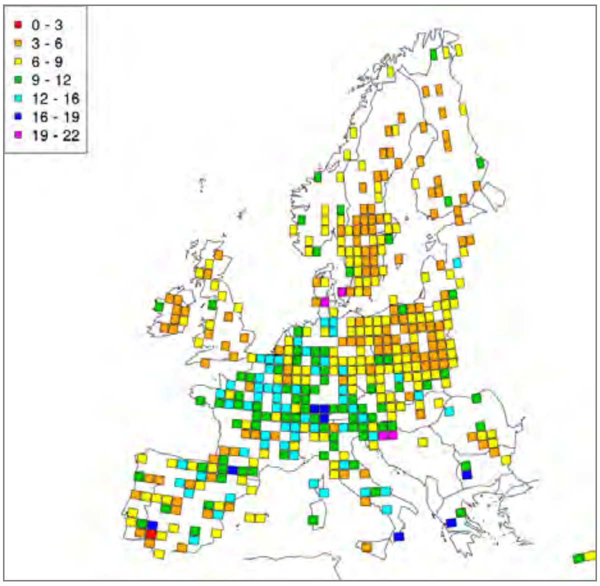


Figure 6-15: Average dbh-deviation [cm]. Plot data averaged to means per grid cell.

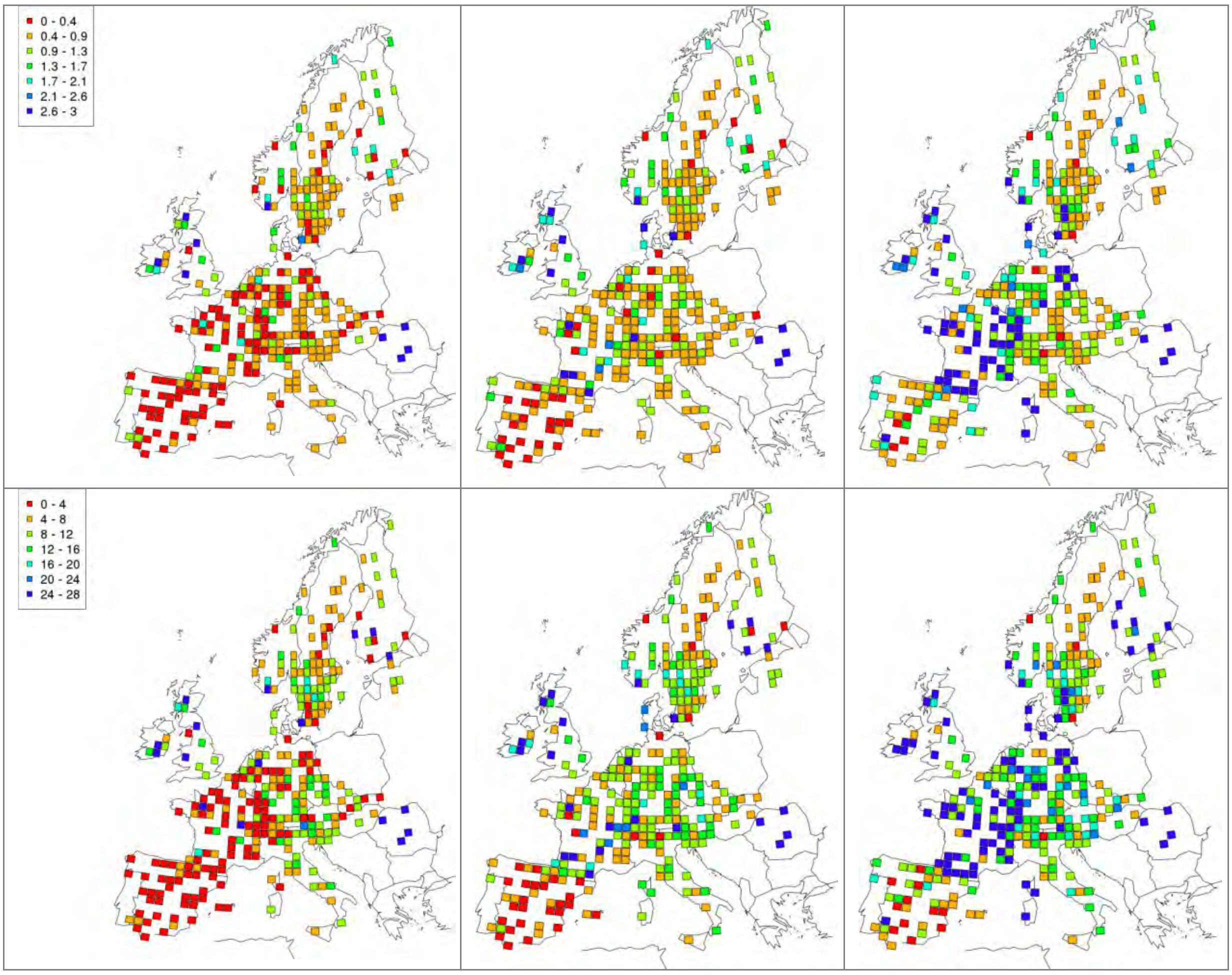


Figure 6-16: Basal area (top in m2/ha/a) and stem volume (bottom, in m3/ha/a) increment
Left: lower 10%; Middle: median; Right: higher 90% of the observations.

6.5 Discussion and conclusions

The collected data provides a unique source of forest growth information for Europe. The various growth parameters can be linked to external as well as internal factors serving as a proxy parameter for the reaction of trees and stands to management, changes in site and environmental conditions. Furthermore they can be used e.g. for:

- Validation, refinement or creation of forest growth models.
- Observation of the geographical extension and growth response of specific species in relation to site and environmental conditions and their changes (soil, climate, deposition, pest and diseases).
- Estimation of harvestable wood and potential stocking biomass in European forests for different management (species selection, thinning, harvest) and environment scenarios.

The highly aggregated results provide a first and general overview on forest growth in Europe. More specific investigations for single tree species will be essential to exploit the full benefit of the data set.

The current dataset includes more than 250 Plots which have not been remeasured up to now. For those plots no increment can yet be calculated. The longer the observations time of a plot the higher the value of such data if the remeasurement interval is in the range of 5 years. To estimate volume increments at least the tree height is essential. There are many ways to estimate tree heights using the measured diameter but none of them is as good as a measured height. Hasenauer and Monserud (1997) have reported that usage of estimated (smoothed) tree heights will lead to biased predictions. The tree volume is typically calculated using form factor functions based on diameter(s) and height. Currently there exists no pan europaen form factor function for different tree species. Such functions would allow consistent volume estimates for Europe. In addition e.g. terestrial laser scanners could be used to observe the taper form of the trees (Klemmt and Tauber 2008).

In general the tree measurements are fairly precise. Diameter measurements are commonly more reproducible - compared to the observed size - than height assessments. The diameter is usually measured with a calliper or a circumference tape which will diverge if the stem has no circular shape. The basal area is calculated using the measured diameters. These calculations are usualy done by assuming a circular stem diameter. Unbiased diameter observation will lead to a biased basal area calculation if the diameter has random measurment errors. The measurment error should be considerd in the basal area calculation. Volume estimates including basal area, tree height and estimated form factors are necessarely prone to lower accuracy. Changes (increment) in basal area or stocking volume are influenced by two error components resulting from two measurements and are therefore less reliable than parameters describing actual condition like stocking volume. The magnitude of change variables is also normaly smaller and measurement errors have a larger impact. Although volume estimates are more (economical) important, the separate analyses of basal area (e.g. stand density) and tree height (e.g. site index) and their changes are ecologically more relevant and more precise.

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Part V

BIODIVERSITY

7. Epiphytic lichen diversity in relation to atmospheric deposition

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7.1. Introduction

Lichens have been considered to be among the most sensitive groups of organisms at the ecosystem level for several types of pollutants (Nimis et al., 2002). They have been recently used for revising the critical levels for NH_3 in sensitive ecosystems (e.g. Geiser et al., 2010) and they have also been used for defining critical loads (e.g. for forest habitats) under the Air Quality Directive and UNECE/CLRTAP. Besides their use for evaluating effects in sensitive ecosystems, they can be used in other ecosystems as early-warning indicators since they are most likely the first species group to react. In the present chapter, methodological aspects for assessing epiphytic lichen diversity and possible relations between this diversity and nitrogen deposition are studied in 83 Level II plots from Czech Republic, Denmark, Finland, France, Italy, Germany, Netherlands, Slovak Republic, Spain, Switzerland. In particular, the question of the minimum number of trees that should be used in lichen diversity surveys at a large scale in different types of forest is tackled, and the possible relations of lichen functional groups with different levels of nitrogen deposition are explored.

7.2 Methods

7.2.1. Data

The evaluations are mainly based on the existing ForestBIOTA database. The dataset includes information on the occurrence and frequency of epiphytic lichen species at 83 Level II plots of the EU and ICP Forests networks located in 10 countries, which had been monitored within the ForestBIOTA project (www.forestbiota.org). The data were collected in the years 2004-2006 according to the ForestBIOTA sampling protocol (Stofer et al. 2003), which largely follows the basic principles described in Asta et al. (2002). Information on the ecology of lichen species follows ITALIC – The information system on Italian Lichens (Nimis & Martellos 2008) and Wirth (1995).

The data on the throughfall deposition of atmospheric pollutants (mainly nitrogen compounds) have been collected by different institutions collaborating within the ICP Forests and the LIFE+ FutMon project ("Further Development and Implementation of an EU-level Forest Monitoring System" - www.futmon.org) and other previous European and national projects.

The statistical analyses applied within each evaluation step are described in the following paragraphs.

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7.2.2. Lichen diversity

The minimum number of trees that have to be sampled in order to obtain reliable estimates of lichen diversity in terms of species number and species composition was evaluated using a Jackknife approach. Rarefaction curves were calculated to determine the increase in the number of species sampled when the number of studied trees per plot increased (i.e., subsamples of 1 to *n*-1 trees, species present in all the studied trees per plot = *n* trees).
The Jaccard distance was calculated to check the similarity of the species composition of the tree subsamples with regard to the overall species composition of the plot. Calculations were performed using the software packages PC-ORD (McCune and Mefford, 1999) and Statistica 8.0 (StatSoft inc., 2007).

7.2.2.1 Jacknife estimations

Palmer (1990, 1991, 1995) compared several ways of estimating species richness of an area subsampled with smaller sample units. In these comparisons two jackknife estimators were included which were nonparametric resampling procedures. The approach is based on the assumption that the number of observed species in a subsample will typically be smaller than the true number of species. These jackknife estimators produce more accurate and less biased estimates, at least when subsampling a restricted area. The first-order jackknife estimator was used (Heltshe and Forrester 1983; Palmer 1990), which is defined as:

$$\text{Jacknife} = S + r1(n-1)/n$$

where S = the observed number of species, r1 = the number of species occurring in one sample unit (tree in this case), and n = the number of sample units (trees).

7.2.2.2 Jaccard distance measures

Within Jaccard distance measures, the average distance is calculated for each possible size of subsamples (i.e. from 1 tree vs. all sampled trees in the plot to “n-1 trees” vs. all sampled trees in the plot). If the average distance between a subsample and the whole sample is small, then one can conclude that the subsample is nearly as effective for characterizing the community as it is the whole sample. Like the species area curve, this is most informative for determining whether the community has been oversampled, compared to the expected subsample size. Among the several indices of similarity, the Jaccard distance measure was used, which is defined as:

$$1-2W/(A+B-W)$$

where W is the sum of shared abundances and A and B are the sums of abundances in individual sample units (trees).

7.2.3 Nitrogen deposition and lichen functional groups

The possible effects of nitrogen deposition on lichens, based on functional groups, were studied in a subset of 70 plots for which nitrogen deposition data were available. For the correlation with lichen data, mean deposition values (years 1996-2007) were used. The methodology for the calculation of mean deposition follows Fischer et al. (2010). The functional group “Oligotrophic lichens” was selected based on species ecology in Italy and Germany (Nimis & Martellos, 2008; Wirth 2005). Each lichen taxon was classified as oligotrophic, mesotrophic or nitrophitic (Annex). When the expert evaluations of nitrogen tolerance were in disagreement, the more conservative one was selected (e.g., Species X, which is “mesotrophyc” according to Wirth’s and “nitrophytic” according to Nimis’ index, was considered as “nitrophytic”).

Oligotrophic species are associated to weak or even absent levels of eutrophication, mainly caused by nitrogen compounds and/or alkaline dust. Since the fall in SO_2 concentrations, there has been an increase in lichen diversity especially in areas of former lichen “deserts”, but this did not follow expected patterns. Former oligotrophic species did not return, instead an increase in species associated with high nitrogen was observed. This shift towards nitrogen tolerant species was observed in several countries in Europe, characterized by the intensification of livestock and other agriculture practices.

7.3 Results: method development

An evaluation of the adequate number of trees to be sampled for obtaining reliable estimations of lichen diversity was carried out, in order to provide suggestions for increasing the cost-effectiveness of future sampling efforts and the overall quality of the results.

7.3.1 Representativeness of sampled trees

Within the ForestBIOTA project, the assessment of a minimum number of 12 trees per plot was prescribed. On average of all 83 plots nearly 14 species were determined on 12 trees (Fig. 7-1, left). An increase in the number of trees resulted in a negligible increase in species number. The peak of 16 species found on average on 15 trees is probably associated to a shift to other epiphytic lichen communities mainly observed in conifer forests by sampling more than 14 trees. When considering the total number of species, relevant differences have been observed between forest groups (Fig. 7-1, right). As a general outcome, the higher the number of trees per plot, the higher the overall number of recorded species, but, given the same number of trees, plots with broadleaved evergreen forests showed more species than plots with broadleaved deciduous tree species and conifers.

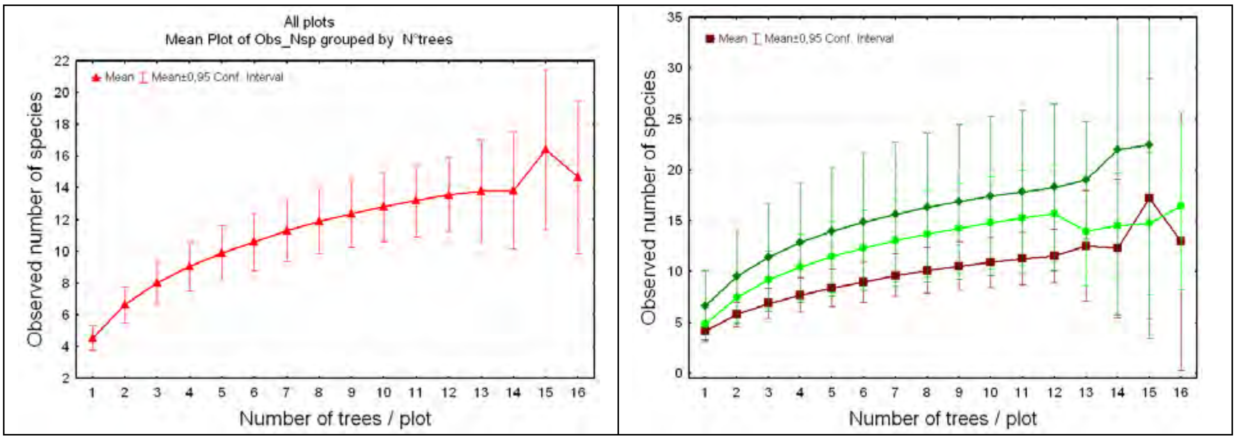

Figure 7-1: Rarefaction curves plotting the cumulated number of observed species vs. the number of sampled trees in the plot; left: all 83 plots; right: disaggregated analysis per forest type (light green: deciduous broadleaves forests; dark green: evergreen broadleaves; brown: conifers).

On the average, the Jacknife estimation suggests that by sampling 12 trees/plot 77% of the total number of species is found. This percentage did not increase significantly by adding more trees (Fig. 7-2, left). Some small differences have been observed between forest groups (Fig. 7-2, right) when considering the total number of observed species (conifers > broadleaves deciduous > broadleaves evergreen), but for 12 trees these differences were not statistically significant.

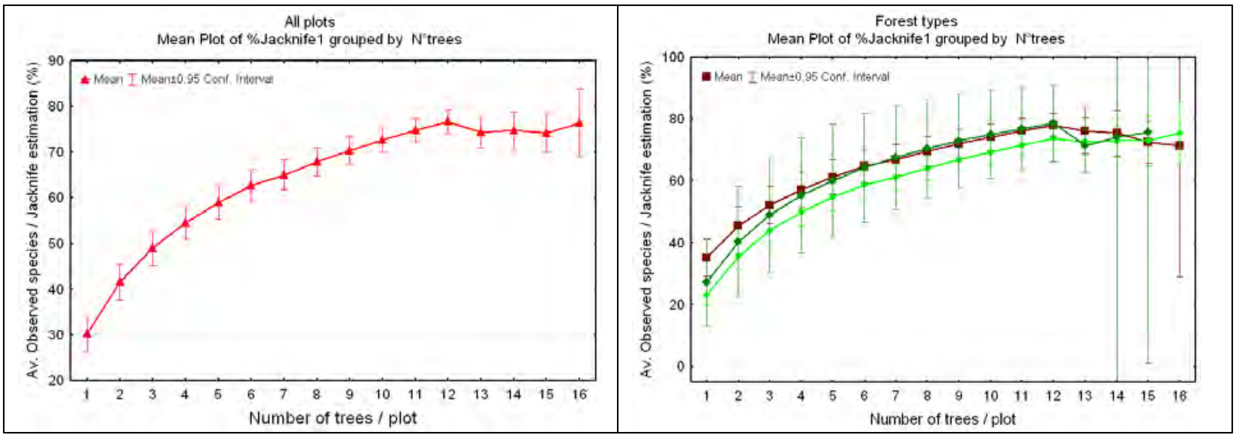

Figure 7-2: Trend of the observed/estimated species ratio, in relation with the number of the number of sampled trees in the plot; left: all 83 plots; right: disaggregated analysis per forest type (light green: deciduous broadleaves forests; dark green: evergreen broadleaves; brown: conifers).

Some minor differences also occur from country to country. With 12 trees, the percentage of lichen species found in the surveys was always > 70% of the total in all countries, with a minimum of 71% (Czech Republic) and a maximum of 89% (Spain).

With an increasing number of trees per plot, the Jaccard curve was continuously decreasing to 11 trees/plot (Fig. 7-3, left). As in many plots more than 12 trees were sampled, the results showed the improvement that can be expected with more than 12 sampled trees. On average, a reduced distance measure between subsample vs. total sample was not observed if there were less than 18 trees in the plot. This shows that, once 12 trees have been sampled, at least 18 trees have to be sampled in order to at least slightly increase the representativeness in species composition of the subsample.

Stratification of the data per forest type (Fig. 7-3, right), shows that, given the same number of trees, on plots with coniferous woodlands the lichen species composition on the trees was more similar than in broadleaves woodland. Nevertheless, for 11-12 sample trees these differences among forest groups were quite small.

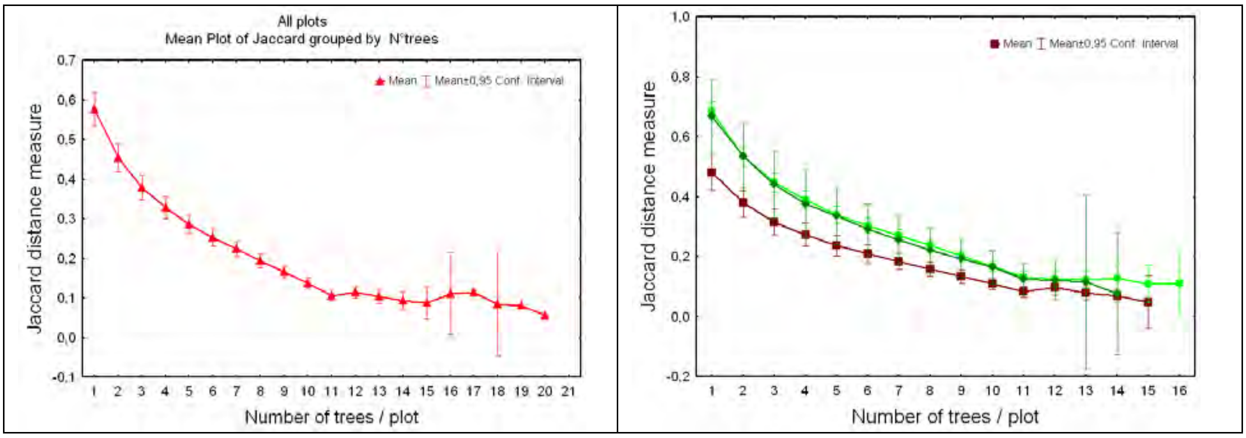

Figure 7-3: Jaccard distance measure in relation to the number of sampled trees per plot; left: All 83 plots; right: disaggregated analysis per forest type (light green: deciduous broadleaves forests; dark green: evergreen broadleaves; brown: conifers).

7.4 Results: effects of nitrogen deposition

A total of 292 epiphytic lichen species was determined on 1 155 trees of the ForestBIOTA plots. The total epiphytic lichen species richness on the observed plots was related to the average yearly total throughfall deposition, and significantly decreased for nitrogen deposition > 10 kg ha^{-1} yr^{-1} (Fig. 7-4).

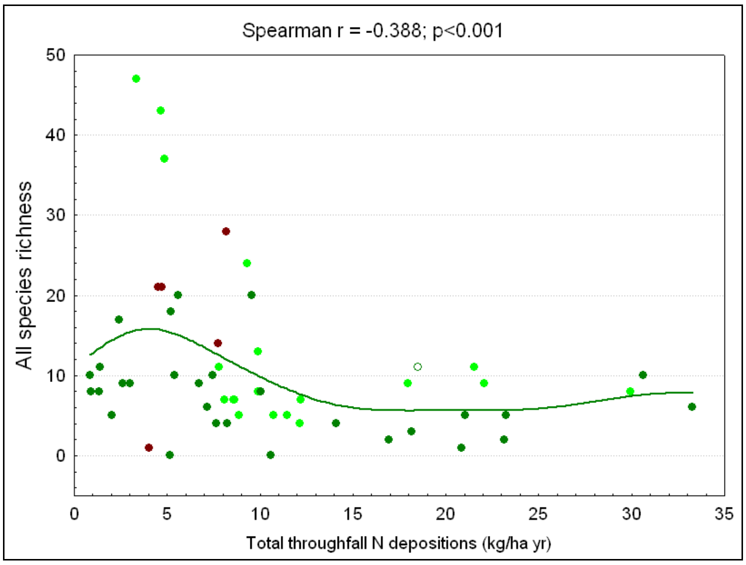

Figure 7-4: Biplot of the richness of all species as a function of the total throughfall nitrogen deposition at plot level. The fitting line is a distance weighted least square function with stiffness = 0.25. Plots (dots) are categorized according to the forest type: dark green: conifers; light green: deciduous broadleaves forests; brown: evergreen broadleaves forests; white: mixed forests.

7.4.1 Relation between nitrogen deposition and % oligotrophic macrolichen species

142 species corresponding to a share of 49% from all determined species were classified as oligotrophic. When focussing more specifically on aggregated descriptors of lichen communities (e.g. functional groups), closer links between lichen species composition and deposition could be determined. In particular, aggregated descriptors showed relations between nitrogen compounds (ammonium and nitrate) and the epiphytic lichen vegetation at plot level. A value of 40% of all lichens species on a plot being oligotrophs has been considered a critical threshold for nitrogen deposition (Geiser et al., 2010). When evaluating the percentage of oligotrophic macrolichens on the evaluated plots, a throughfall nitrogen deposition of ≈ 3.8 kg ha^{-1} yr^{-1} was related to the threshold of 40% oligotrophs (Fig. 7-5). The effects of NH_4^+ and NO_3^- on the percentage of oligotrophs seem to be quite similar (Figs. 7-6, 7-7).

As expected, the effects of nitrogen compounds were closely related to the amount of throughfall precipitation (Fig. 7-8). Although the correlation was always statistically significant, in drier plots a nitrogen deposition of > 9 kg ha^{-1} yr^{-1} led to a complete disappearance of oligotrophic species, whereas, given the same amount of nitrogen deposition, a modelled percentage of 20% oligotrophic species is still expected in plots with higher annual precipitation.

Moreover, significant differences between coniferous and broadleaved forests were observed. The effects of nitrogen deposition are by far less evident in the coniferous than in the latter forest types. The underlying ecological phenomena has still to be explored in more detail. A separate analysis of the results for different forest types might be appropriate. It might be hypothesized that a relevant synergistic interaction between nitrogen and light may more strongly limit the colonization by oligotrophs in deciduous broadleaved forests as compared to evergreen conifers. Forthcoming applications of this approach should consider differentiated interpretations, taking into account the amount of dry vs. wet deposition and the forest type.

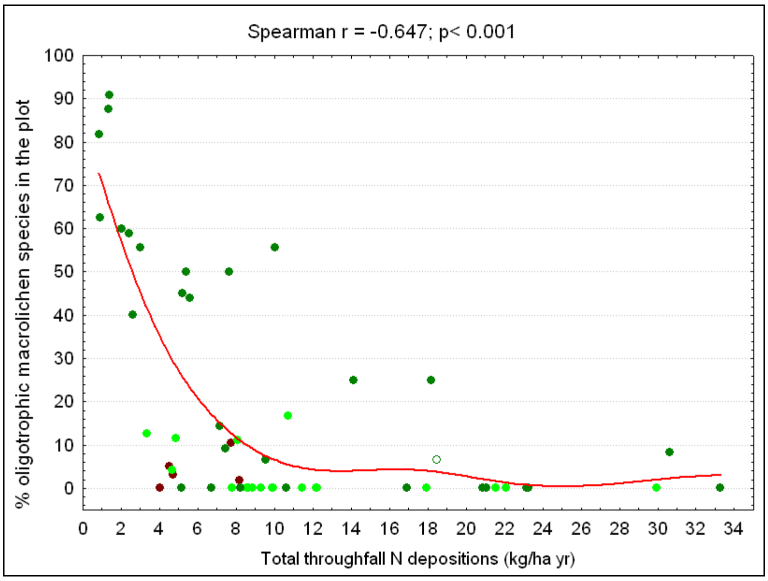

Figure 7-5: Biplot of the % oligotrophic macrolichens as a function of the total throughfall nitrogen deposition at plot level. The fitting line is a distance weighted least square function with stiffness = 0.25.

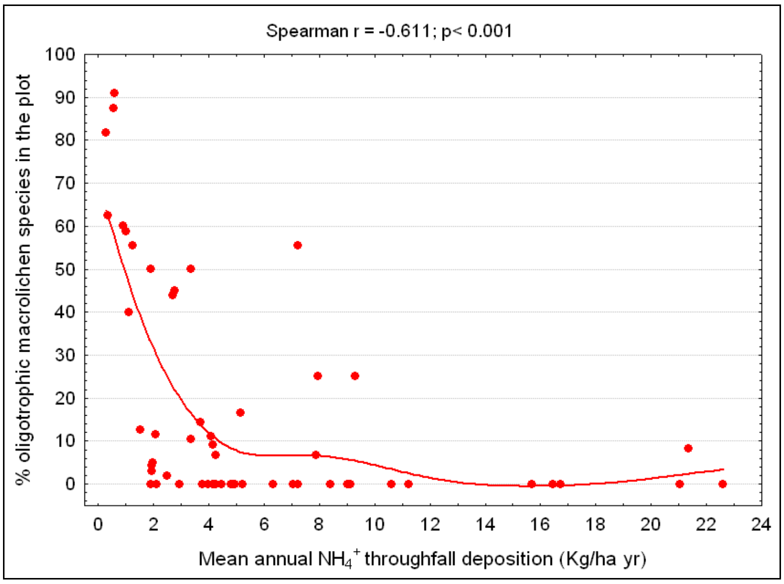

Figure 7-6: Biplot of the % oligotrophic macrolichens as a function of the mean annual NH_4^+ deposition at plot level. The fitting line is a distance weighted least square function with stiffness = 0.25.

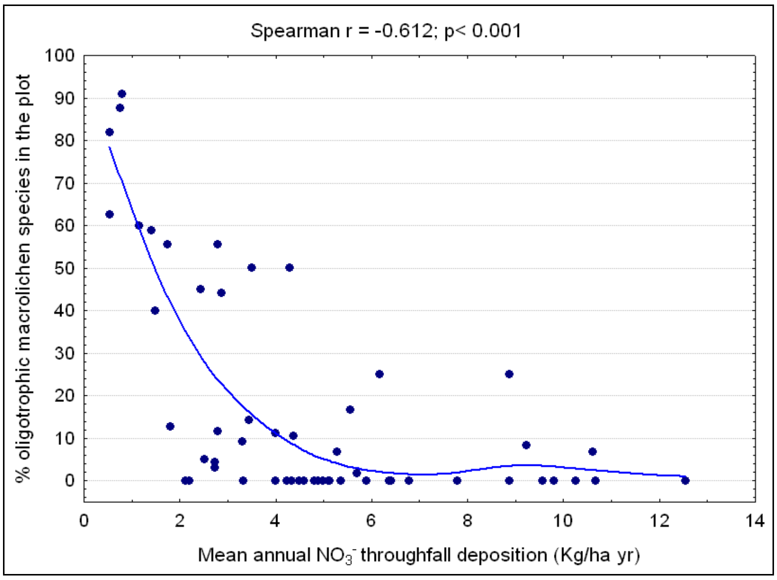

Figure 7-7: Biplot of the % oligotrophic macrolichens as a function of the mean annual NO_3^- deposition at plot level. The fitting line is a distance weighted least square function with stiffness = 0.25.

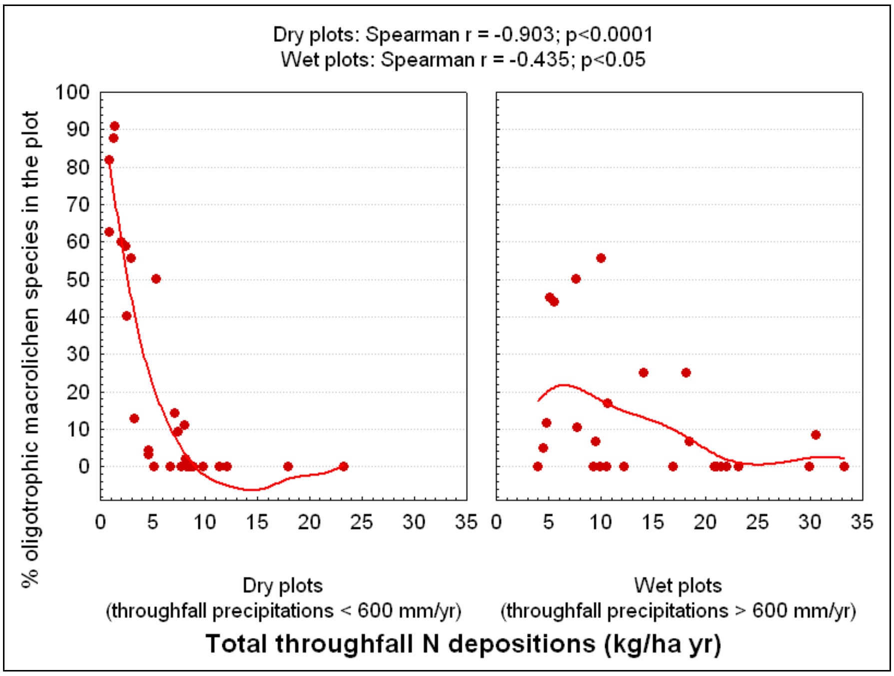

Figure 7-8: Percentage of oligotrophic macrolichens as a function of the total throughfall nitrogen deposition at plot level, I relation with the amount of precipitations. Left: dry plots; right: wet plots. The fitting line is a distance weighted least square function with stiffness = 0.25.

7.4.2 Mapping of the percentage of oligotrophic lichens

As far as the spatial pattern is concerned (Fig. 7-9), the higher values of % oligotrophs have been observed in Finland and in some Oromediterranean plots of Italy and Spain, whereas most of the plots in Central Europe (esp. Germany) were characterized by very low percentages of oligotrophic lichen species. Plots in Central Europe and the Netherlands are affected by relatively high nitrogen deposition values (Lorenz & Granke, 2009). Interestingly, in some plots of Italian Eastern Alps (IT8, IT17, IT27) and Spain (ES22, ES30) a mean annual N deposition over the critical value did not correspond to a decrease of oligotrophs under the 40% threshold.

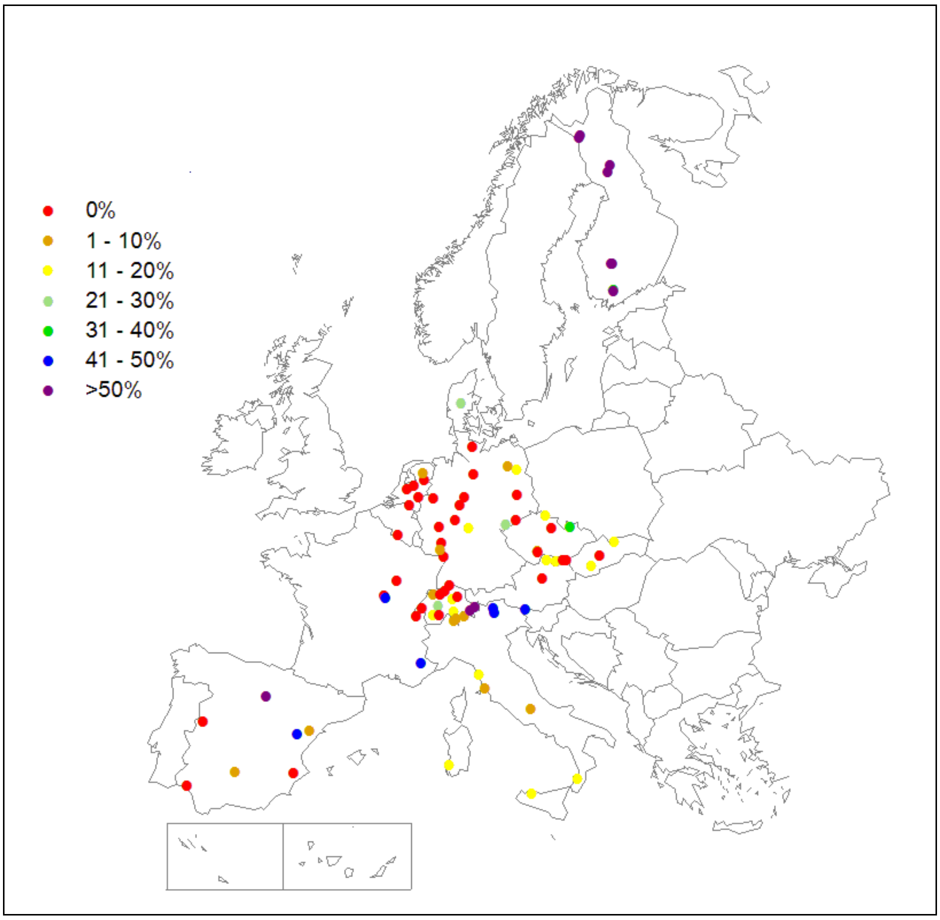

Figure 7-9: Percentage of oligotrophic macrolichens on the total number of species on selected ICP Forests Level II plots.

7.5 Discussion and conclusions

Based on the statistical analysis of the ForestBIOTA dataset, a number of conclusions for large-scale lichen biodiversity studies can be drawn as a basis for future lichen assessments on forest monitoring plots.

- Jacknife and Jaccard analyses showed that a sample of 12 trees per plot is enough for ensuring a sufficient sampling effort/species catching ratio in the considered forest types in Europe. On average, such a sample allowed to catch 77% of the total number of species estimated by Jacknife. This percentage did not increase significantly by adding more trees. Results of Jaccad analysis also suggest that with 12 trees the lichen species composition is also well characterized. Moreover the results were quite stable both considering conifer and broadleaved forests and no relevant differences have been observed between countries.

For the determination of critical thresholds of nitrogen deposition and for the further use of epiphytic lichens as bioindicators the following conclusions are relevant:

- The occurrence of oligotrophyc lichen species provided information on the actual impact of reduced nitrogen compounds (mainly ammonia). This functional group has been recently used to revise of the critical levels of NH_3 and of the nitrogen critical loads for forest habitats (Geiser et al., 2010). Based on the relative share of oligotrophic macrolichen species at plot level, it was shown that approx. 80% of the ForestBIOTA Level II plots are affected by an unsustainable throughfall nitrogen deposition, that can be suspected to cause a significant change of the expected composition of epiphytic lichen vegetation, together with a significant decrease in total lichen diversity, as well. About 58% of the plots, mainly located in Germany and other central European countries, showed a very low occurrence or even a complete lack of oligotrophic lichen species. Possible interactions between the effects of nitrogen on lichens and those caused by other pollutants and/or climatic factors have been mainly explored at local scale (e.g. Giordani 2006, 2007) and should be taken into account in forthcoming applications of this approach at European scale.

- Lichen functional groups for eutrophication and/or, more specifically, nitrogen tolerance have been extensively used to assess the critical level and critical load of nitrogen compounds in several forest ecosystems all over the world (Geiser et al., 2010, Fenn et al., 2008, Geiser and Neitlich, 2007, Pinho et al., 2008a, Pinho et al., 2008b, Pinho et al., 2009). According to Geiser et al. (2010), the percentage of oligotrophic macrolichen species within the plot was used as indicator of alteration caused by the deposition of nitrogen compounds. Following these authors the critical threshold indicating a significant response of lichen species composition to nitrogen has been set when more than 40% of all lichens species were oligotrophs. Geiser et al. (2010) found, for wet deposition, a critical load ranging from 0.7 to 4.4 kg ha^{-1} yr^{-1}, depending on the amount of precipitation in conifer forests of the Pacific North West of USA. The results for European ForestBiota Level II plots are in accordance with these findings. A percentage of 40% oligotrophs seemed to be related to throughfall nitrogen deposition of approx. 3.8 kg ha^{-1} yr^{-1}. The effects of NH_4^+ and NO_3^- deposition on the percentage of oligotrophs are supposed to be similar. Nevertheless, a contribution of other influencing factors (e.g. other pollutants or climate) can not yet be excluded and more studies are still needed at European level for a better understanding of the underlying cause-effect relationships.
- Based on these findings, the use of lichens as bioindicators is recommended for inclusion in the monitoring activities both on Level I and Level II plots, in order to quantify effects of nitrogen atmospheric deposition on sensitive forest ecosystems components even on plots without direct measurements of nitrogen deposition.

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7.7 Annex

Eco-functional traits for the lichen species observed during the ForestBIOTA test phase.

Eutrophycation indices: oligo = oligotrophic; meso = mesotrophic; nitro = nitrophytic.
Growth form. Microlichens: Lepr = leprose; Cr = crustose; cr.pl = crustose placodiomorph; sq = squamulose; Macrolichens: Fol.n = foliose with narrow lobes (*Physcia*-type); Fol.b = foliose with broad lobes (*Parmelia*-type); Frut = fruticose; Fut.f = fruticose filamentous.
Photobiont: Ch = chlorococcoid green algae; Tr = trentepohlioid algae; Cy.h = cyanobacteria, filamentous (e.g. *Nostoc*, *Scytonema*).
Reproductive strategy: S = mainly sexual; A.s = mainly asexual by soredia; A.i = mainly asexual by isidia; A.f = mainly asexual, by thallus fragmentation.

ID ForestBIOTA	Taxon (ForestBIOTA nomenclature)	Nimis' eutrophycation index (Nimis & Martellos 2008)	Wirth's eutrophycation index (Wirth 2005)	Growth form	Photobiont	Reproductive stategy
10	*Acrocordia cavata*	oligo		Cr	Tr	S
12	*Acrocordia gemmata*	oligo	meso	Cr	Tr	S
30	*Amandinea punctata*	nitro	meso	Cr	Ch	S
47	*Anaptychia ciliaris*	meso	meso	Frut	Ch	S
66	*Anisomeridium polypori*	oligo		Cr	Tr	S
102	*Arthonia cinnabarina*	oligo	oligo	Cr	Tr	S
109	*Arthonia didyma*	meso		Cr	Tr	S
140	*Arthonia leucopellaea*	oligo	oligo	Cr	Tr	S
144	*Arthonia mediella*	oligo		Cr	Tr	S
163	*Arthonia punctiformis*	oligo		Cr	Tr	S
164	*Arthonia radiata*	meso	oligo	Cr	Tr	S
168	*Arthonia spadicea*	oligo	oligo	Cr	Tr	S
170	*Arthonia stellaris*	oligo		Cr	Tr	S
178	*Arthonia vinosa*	oligo	oligo	Cr	Tr	S
183	*Arthonia sp.*	oligo		Cr	Tr	S
211	*Arthopyrenia persoonii*	oligo		Cr	Tr	S
227	*Arthopyrenia sp.*	oligo		Cr	Tr	S
236	*Arthothelium ruanum*	oligo	oligo	Cr	Tr	S
396	*Bacidia chloroticula*	oligo		Cr	Ch	S
402	*Bacidia fraxinea*	oligo		Cr	Ch	S
417	*Bacidia naegelii*	meso		Cr	Ch	S
419	*Bacidia neosquamulosa*	oligo		Cr	Ch	S
426	*Bacidia rosella*	meso		Cr	Ch	S
427	*Bacidia rubella*	meso	meso	Cr	Ch	S
437	*Bacidia subincompta*	oligo	oligo	Cr	Ch	S
447	*Bacidia sp.*	oligo		Cr	Ch	S
451	*Bacidina sp.*	oligo		Cr	Ch	S
453	*Bactrospora dryina*	oligo	oligo	Cr	Tr	S
536	*Bryoria capillaris*	oligo	oligo	Frut.f	Ch	A.s
539	*Bryoria furcellata*	oligo		Frut.f	Ch	A.s
540	*Bryoria fuscescens*	oligo	oligo	Frut.f	Ch	A.s
543	*Bryoria implexa*	oligo		Frut.f	Ch	A.s
559	*Bryoria sp.*	oligo		Frut.f	Ch	
568	*Buellia arborea*	oligo		Cr	Ch	S
581	*Buellia disciformis*	oligo	oligo	Cr	Ch	S
600	*Buellia griseovirens*	oligo	oligo	Cr	Ch	A.s
634	*Buellia schaereri*	oligo		Cr	Ch	S
675	*Calicium abietinum*	oligo		Cr	Ch	S

682	*Calicium glaucellum*	oligo	oligo	Cr	Ch	S
685	*Calicium montanum*	oligo		Cr	Ch	S
692	*Calicium trabinellum*	oligo	oligo	Cr	Ch	S
693	*Calicium viride*	oligo	oligo	Cr	Ch	S
694	*Calicium sp.*	oligo		Cr	Ch	S
730	*Caloplaca cerina*	nitro	meso	Cr	Ch	S
734	*Caloplaca cerinella*	nitro		Cr	Ch	S
743	*Caloplaca citrina*	nitro	nitro	Cr	Ch	S
766	*Caloplaca ferruginea*	meso		Cr	Ch	S
769	*Caloplaca flavorubescens*	meso		Cr	Ch	S
782	*Caloplaca herbidella*	nitro	oligo	Cr	Ch	A.i
808	*Caloplaca lobulata*	meso		Cr.pl	Ch	S
836	*Caloplaca pyracea*	nitro		Cr	Ch	S
891	*Candelaria concolor*	nitro	meso	Fol. n	Ch	A.s
906	*Candelariella reflexa*	nitro	meso	Cr	Ch	A.s
914	*Candelariella xanthostigma*	meso	meso	Cr	Ch	S
915	*Candelariella sp.*	nitro		Cr	Ch	
975	*Catillaria nigroclavata*	meso		Cr	Ch	S
979	*Catillaria pulverea*	oligo		Cr	Tr	A.s
1006	*Cetraria chlorophylla*	oligo	oligo	Fol.b	Ch	A.s
1019	*Cetraria laureri*	oligo		Fol.b	Ch	A.s
1026	*Cetraria sepincola*	oligo	oligo	Frut	Ch	S
1032	*Cetrelia olivetorum*	oligo		Fol.b	Ch	A.s
1037	*Chaenotheca chrysocephala*	oligo	oligo	Cr	Ch	S
1039	*Chaenotheca ferruginea*	oligo	oligo	Cr	Ch	S
1045	*Chaenotheca phaeocephala*	oligo	oligo	Cr	Ch	S
1049	*Chaenotheca trichialis*	oligo	oligo	Cr	Ch	S
1051	*Chaenotheca sp.*	oligo				
1064	*Chrysothrix candelaris*	oligo	oligo	Lepr	Ch	A.s
1085	*Cladonia caespiticia*	oligo	oligo	Frut/sq	Ch	
1094	*Cladonia chlorophylla s.l.*	oligo		Frut/sq	Ch	
1100	*Cladonia coniocraea*	meso	oligo	Frut/sq	Ch	A.s
1104	*Cladonia cornuta*	oligo		Frut/sq	Ch	
1117	*Cladonia digitata*	oligo	oligo	Frut/sq	Ch	A.s
1120	*Cladonia fimbriata*	meso	oligo	Frut/sq	Ch	A.s
1137	*Cladonia macilenta*	oligo	oligo	Frut/sq	Ch	S
1153	*Cladonia parasitica*	oligo	oligo	Frut/sq	Ch	S
1158	*Cladonia polydactyla*	oligo	oligo	Frut/sq	Ch	
1172	*Cladonia squamosa*	oligo	oligo	Frut/sq	Ch	
1196	*Cladonia sp.*	oligo		Frut/sq	Ch	
1256	*Collema furfuraceum*	meso		Fol.b	Cy.h	A.i
1278	*Collema subnigrescens*	meso		Fol.b	Cy.h	S
1390	*Dimerella pineti*	oligo	oligo	Cr	Tr	S
1394	*Diploicia canescens*	nitro	nitro	Cr.pl	Ch	A.s
1475	*Evernia divaricata*	oligo	oligo	Frut	Ch	A.f
1479	*Evernia prunastri*	meso	oligo	Frut	Ch	A.s
1497	*Fellhanera viridisorediata*	oligo		Cr	Ch	A.s
1523	*Fuscidea arboricola*	oligo		Cr	Ch	S
1531	*Fuscidea cyathoides s.l.*	oligo		Cr	Ch	S
1545	*Fuscidea pusilla*	oligo		Cr	Ch	S
1568	*Graphis scripta*	oligo	oligo	Cr	Tr	S
1572	*Gyalecta flotowii*	oligo		Cr	Tr	S
1584	*Gyalecta truncigena*	oligo		Cr	Tr	S
1602	*Gyalideopsis*	oligo		Cr	Ch	A.i

	anastomosans					
1614	*Haematomma ochroleucum*	oligo	oligo	Cr	Ch	A.s
1657	*Heterodermia obscurata*	meso		Fol.n	Ch	A.s
1673	*Hyperphyscia adglutinata*	nitro	meso	Fol.n	Ch	A.s
1677	*Hypocenomyce caradocensis*	oligo	oligo	Sq	Ch	S
1680	*Hypocenomyce friesii*	oligo		Sq	Ch	
1682	*Hypocenomyce praestabilis*	oligo		Sq	Ch	A.s
1683	*Hypocenomyce scalaris*	oligo	oligo	Sq	Ch	A.s
1684	*Hypocenomyce sorophora*	oligo		Sq	Ch	A.s
1685	*Hypocenomyce stoechadiana*	meso		Sq	Ch	S
1690	*Hypogymnia bitteri*	oligo		Fol.n	Ch	A.s
1691	*Hypogymnia farinacea*	oligo	oligo	Fol.n	Ch	A.s
1696	*Hypogymnia physodes*	oligo	oligo	Fol.n	Ch	A.s
1698	*Hypogymnia tubulosa*	oligo	oligo	Fol.n	Ch	A.s
1701	*Hypogymnia sp.*	oligo		Fol.n	Ch	
1707	*Hypotrachyna sp.*	oligo		Fol.b	Ch	
1711	*Imshaugia aleurites*	oligo	oligo	Fol.n	Ch	A.i
1740	*Koerberia biformis*	oligo		Fol.n	Cy.h	S
1770	*Lecanactis abietina*	oligo	oligo	Cr	Tr	S
1784	*Lecanactis patellarioides*	oligo		Cr	Tr	S
1847	*Lecanora albella*	oligo	oligo	Cr	Ch	S
1850	*Lecanora allophana*	meso	meso	Cr	Ch	A.s
1850	*Lecanora allophana*	meso	meso	Cr	Ch	S
1854	*Lecanora argentata*	oligo	oligo	Cr	Ch	S
1864	*Lecanora cadubriae*	oligo		Cr	Ch	S
1868	*Lecanora carpinea*	meso	oligo	Cr	Ch	S
1874	*Lecanora cf. phaeostigma*	oligo		Cr	Ch	
1875	*Lecanora chlarotera*	nitro	meso	Cr	Ch	S
1882	*Lecanora circumborealis*	oligo		Cr	Ch	S
1890	*Lecanora conizaeoides*	meso	meso	Cr	Ch	S
1911	*Lecanora expallens*	oligo	meso	Cr	Ch	A.s
1932	*Lecanora hagenii*	nitro	nitro	Cr	Ch	S
1936	*Lecanora horiza aggr.*	meso		Cr	Ch	S
1944	*Lecanora intumescens*	oligo	oligo	Cr	Ch	S
1988	*Lecanora phaeostigma*	oligo		Cr	Ch	
2002	*Lecanora pulicaris*	oligo	oligo	Cr	Ch	S
2021	*Lecanora saligna*	oligo	meso	Cr	Ch	S
2045	*Lecanora strobilina*	oligo		Cr	Ch	S
2050	*Lecanora subcarpinea*	oligo		Cr	Ch	S
2052	*Lecanora subintricata*	oligo		Cr	Ch	S
2057	*Lecanora subrugosa*	oligo		Cr	Ch	S
2065	*Lecanora symmicta aggr.*	oligo		Cr	Ch	S
2066	*Lecanora symmicta var. aitema*	oligo		Cr	Ch	S
2077	*Lecanora umbrina*	nitro		Cr	Ch	S

2082	*Lecanora varia*	oligo	oligo	Cr	Ch	S
2089	*Lecanora sp.*	oligo		Cr	Ch	S
2100	*Lecidea amaurospoda*	meso		Cr	Ch	S
2180	*Lecidea hypopta*	oligo		Cr	Ch	S
2231	*Lecidea nylanderi*	oligo		Cr	Ch	A.s
2328	*Lecidea sp.*	oligo		Cr	Ch	S
2346	*Lecidella elaeochroma*	nitro	meso	Cr	Ch	S
2346	*Lecidella elaeochroma*	meso	meso	Cr	Ch	A.s
2351	*Lecidella flavosorediata*	nitro		Cr	Ch	A.s
2362	*Lecidella sp.1*	nitro		Cr	Ch	S
2363	*Lecidella sp.2*	nitro		Cr	Ch	S
2364	*Lecidella sp.3*	nitro		Cr	Ch	S
2405	*Lepraria elobata*	oligo		Lepr	Ch	A.s
2408	*Lepraria incana*	oligo	oligo	Lepr	Ch	A.s
2409	*Lepraria jackii*	oligo		Lepr	Ch	A.s
2411	*Lepraria lobificans*	oligo	oligo	Lepr	Ch	A.s
2416	*Lepraria rigidula*	meso		Lepr	Ch	A.s
2417	*Lepraria sp.1*	oligo		Lepr	Ch	A.s
2420	*Lepraria sp.*	oligo		Lepr	Ch	A.s
2465	*Leptogium lichenoides*	meso	nitro	Sq	Cy.h	S
2489	*Leptogium sp.*	oligo		Fol.b	Cy.h	
2507	*Letharia vulpina*	oligo	oligo	Frut	Ch	A.s
2551	*Lobaria pulmonaria*	oligo	meso	Fol.b	Ch	A.s
2567	*Loxospora elatina*	oligo	oligo	Cr	Ch	A.s
2578	*Megalaria sp.*	oligo		Cr		
2619	*Melaspilea sp.*	oligo		Cr		
2622	*Menegazzia terebrata*	oligo	oligo	Fol.b	Ch	A.s
2635	*Micarea cinerea*	oligo		Cr	Ch	S
2652	*Micarea lignaria*	oligo	oligo	Cr	Ch	S
2658	*Micarea melaena*	oligo	oligo	Cr	Ch	S
2666	*Micarea nitschkeana*	oligo		Cr	Ch	S
2671	*Micarea peliocarpa*	oligo	oligo	Cr	Ch	S
2672	*Micarea prasina*	oligo	oligo	Cr	Ch	S
2689	*Micarea sp.*	oligo		Cr	Ch	S
2732	*Mycoblastus affinis*	oligo		Cr	Ch	S
2735	*Mycoblastus fucatus*	oligo		Cr	Ch	A.s
2736	*Mycoblastus sanguinarius*	oligo	oligo	Cr	Ch	S
2740	*Mycomicrothelia sp.*	oligo		Cr		S
2767	*Nephroma laevigatum*	oligo	meso	Fol.b	Cy.h	S
2775	*Normandina pulchella*	meso	meso	Sq	Ch	A.s
2782	*Ochrolechia alboflavescens*	oligo	oligo	Cr	Ch	A.s
2783	*Ochrolechia androgyna*	oligo	oligo	Cr	Ch	A.s
2784	*Ochrolechia arborea*	meso	meso	Cr	Ch	A.s
2796	*Ochrolechia microstictoides*	oligo	oligo	Cr	Ch	A.s
2798	*Ochrolechia pallescens*	oligo	oligo	Cr	Ch	S
2806	*Ochrolechia tartarea*	oligo		Cr	Ch	S
2808	*Ochrolechia turneri*	meso	meso	Cr	Ch	A.s
2823	*Opegrapha atra*	oligo	oligo	Cr	Tr	S
2830	*Opegrapha celtidicola*	oligo		Cr	Tr	S
2862	*Opegrapha rufescens*	oligo	oligo	Cr	Tr	S
2874	*Opegrapha varia*	oligo	oligo	Cr	Tr	S
2879	*Opegrapha viridis*	oligo	oligo	Cr	Tr	S

2880	***Opegrapha vulgata***	**oligo**		**Cr**	**Tr**	**S**
2883	***Opegrapha sp.***	**oligo**		**Cr**	**Tr**	**S**
2905	***Pannaria conoplea***	**oligo**	**meso**	**Fol.n**	**Cy.h**	**S**
2913	***Pannaria mediterranea***	**oligo**		**Sq**	**Cy.h**	**A.s**
2923	***Parmelia acetabulum***	**meso**	**meso**	**Fol.b**	**Ch**	**S**
2929	***Parmelia caperata***	**meso**	**oligo**	**Fol.b**	**Ch**	**A.s**
2938	***Parmelia elegantula***	**meso**	**oligo**	**Fol.b**	**Ch**	**A.i**
2941	***Parmelia exasperatula***	**meso**	**meso**	**Fol.b**	**Ch**	**A.i**
2944	***Parmelia glabra***	**meso**	**meso**	**Fol.b**	**Ch**	**S**
2947	***Parmelia glabratula ssp. fuliginosa***	**meso**		**Fol.b**	**Ch**	**A.i**
2955	***Parmelia laciniatula***	**meso**	**meso**	**Fol.b**	**Ch**	**A.i**
2956	***Parmelia laevigata***	**oligo**		**Fol.b**	**Ch**	**A.s**
2966	***Parmelia pastillifera***	**meso**	**meso**	**Fol.b**	**Ch**	**A.i**
2978	***Parmelia reticulata***	**oligo**		**Fol.b**	**Ch**	**A.s**
2982	***Parmelia saxatilis***	**meso**	**oligo**	**Fol.b**	**Ch**	**A.i**
2994	***Parmelia subaurifera***	**meso**		**Fol.b**	**Ch**	**A.s**
2995	***Parmelia submontana***	**oligo**	**oligo**	**Fol.b**	**Ch**	**A.i**
2996	***Parmelia subrudecta***	**meso**		**Fol.b**	**Ch**	**A.s**
2998	***Parmelia sulcata***	**meso**	**meso**	**Fol.b**	**Ch**	**A.s**
3000	***Parmelia tiliacea***	**meso**	**meso**	**Fol.b**	**Ch**	**A.i**
3003	***Parmelia sp.***	**meso**		**Fol.b**	**Ch**	
3010	***Parmeliopsis ambigua***	**oligo**	**oligo**	**Fol.n**	**Ch**	**A.s**
3011	***Parmeliopsis hyperopta***	**oligo**	**oligo**	**Fol.n**	**Ch**	**A.s**
3017	***Parmotrema chinense***	**oligo**	**oligo**	**Fol.b**	**Ch**	**A.s**
3019	***Parmotrema stuppeum***	**oligo**		**Fol.b**	**Ch**	**A.s**
3021	***Parmotrema sp.***	**oligo**		**Fol.b**	**Ch**	
3050	***Peltigera praetextata***	**oligo**	**meso**	**Fol.b**	**Cy.h**	**A.i**
3069	***Pertusaria albescens***	**meso**	**meso**	**Cr**	**Ch**	**A.s**
3071	***Pertusaria albescens var. corallina***	**meso**		**Cr**	**Ch**	**A.s**
3074	***Pertusaria amara***	**meso**	**oligo**	**Cr**	**Ch**	**A.s**
3086	***Pertusaria coccodes***	**meso**	**oligo**	**Cr**	**Ch**	**A.i**
3092	***Pertusaria coronata***	**oligo**	**oligo**	**Cr**	**Ch**	**A.i**
3103	***Pertusaria flavida***	**oligo**	**oligo**	**Cr**	**Ch**	**A.s**
3110	***Pertusaria hemisphaerica***	**oligo**	**oligo**	**Cr**	**Ch**	**A.s**
3112	***Pertusaria hymenea***	**oligo**	**oligo**	**Cr**	**Ch**	**S**
3122	***Pertusaria leioplaca***	**oligo**	**oligo**	**Cr**	**Ch**	**S**
3137	***Pertusaria pertusa***	**oligo**	**oligo**	**Cr**	**Ch**	**S**
3145	***Pertusaria pustulata***	**oligo**		**Cr**	**Ch**	**S**
3162	***Pertusaria sp.***	**meso**		**Cr**	**Ch**	
3179	***Phaeophyscia endophoenicea***	**meso**	**meso**	**Fol.n**	**Ch**	**A.s**
3180	***Phaeophyscia hirsuta***	**nitro**		**Fol.n**	**Ch**	**A.s**
3185	***Phaeophyscia orbicularis***	**nitro**	**nitro**	**Fol.n**	**Ch**	**A.s**
3194	***Phlyctis agelaea***	**oligo**	**oligo**	**Cr**	**Ch**	**S**
3195	***Phlyctis argena***	**oligo**	**oligo**	**Cr**	**Ch**	**A.s**
3203	***Physcia adscendens***	**nitro**	**nitro**	**Fol.n**	**Ch**	**A.s**
3204	***Physcia aipolia***	**nitro**	**meso**	**Fol.n**	**Ch**	**S**
3226	***Physcia semipinnata***	**meso**		**Fol.n**	**Ch**	**S**
3231	***Physcia tenella***	**nitro**		**Fol.n**	**Ch**	**A.s**
3239	***Physcia sp.***	**meso**		**Fol.n**	**Ch**	
3241	***Physconia distorta***	**nitro**	**nitro**	**Fol.n**	**Ch**	**S**
3242	***Physconia enteroxantha***	**nitro**	**meso**	**Fol.n**	**Ch**	**A.s**
3248	***Physconia perisidiosa***	**meso**	**meso**	**Fol.n**	**Ch**	**A.s**

3251	*Physconia venusta*	oligo		Fol.n	Ch	S
3291	*Placynthiella dasaea*	oligo		Cr		
3293	*Placynthiella icmalea*	oligo	oligo	Cr		
3317	*Platismatia glauca*	oligo	oligo	Fol.b	Ch	A.i
3442	*Porina aenea*	oligo	oligo	Cr	Tr	S
3463	*Porina leptalea*	oligo		Cr	Tr	S
3480	*Porina sp.*	oligo		Cr	Tr	S
3525	*Protoparmelia hypotremella*	oligo		Cr	Tr	S
3546	*Pseudevernia furfuracea*	oligo	oligo	Fol.b	Ch	A.i
3546	*Pseudevernia furfuracea*	oligo	oligo	Fol.b	Ch	A.i
3664	*Pyrenula nitida*	oligo	oligo	Cr	Tr	S
3665	*Pyrenula nitidella*	oligo	oligo	Cr	Tr	S
3673	*Pyrrhospora quernea*	meso		Cr	Ch	A.s
3691	*Ramalina arabum*	oligo		Frut	Ch	
3709	*Ramalina farinacea*	oligo	oligo	Frut	Ch	A.s
3715	*Ramalina fastigiata*	meso	meso	Frut	Ch	S
3717	*Ramalina fraxinea*	meso	meso	Frut	Ch	S
3726	*Ramalina obtusata*	oligo		Frut	Ch	A.s
3924	*Rinodina exigua*	meso	nitro	Cr	Ch	S
3980	*Rinodina pyrina*	meso	meso	Cr	Ch	S
4006	*Rinodina sp.*	nitro		Cr	Ch	
4022	*Ropalospora viridis*	oligo	oligo	Cr	Ch	A.s
4061	*Schismatomma decolorans*	meso		Cr	Tr	A.s
4066	*Schismatomma pericleum*	oligo	oligo	Cr	Tr	S
4079	*Scoliciosporum chlorococcum*	meso	meso	Cr	Ch	S
4085	*Scoliciosporum sarothamni*	oligo		Cr	Ch	A.s
4087	*Scoliciosporum umbrinum*	meso	meso	Cr	Ch	S
4088	*Scoliciosporum sp.*	meso		Cr	Ch	S
4242	*Sticta limbata*	oligo		Fol.b	Cy.h	A.s
4258	*Strigula affinis*	meso		Cr	Tr	S
4267	*Strigula stigmatella*	oligo		Cr	Tr	S
4271	*Strigula sp.*	oligo		Cr	Tr	S
4282	*Teloschistes chrysophthalmus*	meso		Frut	Ch	S
4290	*Tephromela atra*	oligo	meso	Cr	Ch	S
4432	*Thelopsis sp.*	oligo				
4435	*Thelotrema lepadinum*	oligo	oligo	Cr	Tr	S
4512	*Trapelia corticola*	oligo		Cr	Ch	A.s
4520	*Trapeliopsis flexuosa*	oligo		Cr	Ch	S
4523	*Trapeliopsis granulosa*	oligo	oligo	Cr	Ch	S
4599	*Usnea ceratina*	oligo		Frut.f	Ch	A.f
4605	*Usnea filipendula*	oligo	oligo	Frut.f	Ch	A.s
4615	*Usnea hirta*	oligo	oligo	Frut.f	Ch	A.s
4639	*Usnea sp.*	oligo		Frut.f	Ch	
4884	*Vulpicida pinastri*	oligo	oligo	Fol.b	Ch	A.s
4899	*Xanthoria parietina*	nitro	nitro	Fol.b	Ch	S
4913	*Zamenhofia coralloidea*	oligo		Cr	Tr	S
7116	*Bacidia adastra*	oligo		Cr	Ch	
7118	*Lecanora strobilina aggr.*	oligo		Cr	Ch	S
7119	*Caloplaca ferruginea aggr.*	meso		Cr	Ch	S
7120	*cf. Lecidea nylanderi*	meso		Cr	Ch	
4918	*indet. species*	N/A	N/A	N/A	N/A	N/A

8. Development of vegetation under different deposition scenarios

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8.1 Abstract

In a pilot evaluation, the plant biodiversity model BERN was applied to 20 Level II sites. Based on the BERN data base, possibility degrees for the existence of recent plant communities were calculated based on present geo-ecological site conditions. The adaptability of presently existing vegetation to future site conditions was calculated assuming a deposition scenario with full implementation of current national emission legislation in all countries of the EU. Results suggest that at present vegetation is fully adapted to present site conditions on 10 out of the 20 plots. On 13 plots the "regeneration ability" is assumed to remain unchanged under the deposition scenario applied, on four plots it is assumed to decrease until 2050 and on three plots there are indications for an increased "regeneration ability". For eight plots, changes in main tree species are recommended. Changes in main tree species are mainly recommended for sites where already today's tree species are not optimally adapted to site conditions. The main challenges for future application of the model are the inclusion of a larger number of plots and the application of climate change scenarios in addition to the deposition scenario.

8.2 Introduction

Understorey vegetation constitutes a major component of forest ecosystems. It is linked to and dependant from nutrient cycles and interacts directly with other biotic and abiotic components. Changes in vegetation structure may serve as indicator for recent alterations of site parameters. In this sense the vegetation plant communities provide essential and useful information to indicate and validate such changes. On the other hand, it is of interest to quantify effects of environmental changes on plant species composition. In forests, trees are dominating vegetation elements and tree species composition is directly influenced by forest management. Therefore tree species composition is in the specific focus of this study.

8.3 Data

Based on the data processed for the VSD+ modeling (Chapt. 6) as well as on additional ground vegetation and tree data, 20 Level II plots were selected for a combination of VSD+ results with the biodiversity model BERN (Bioindication for Ecosystem Regeneration towards Natural conditions) (Schlutow and Huebener 2004). The selection of plots for this pilot study was determined by data availability for single plots, while at the same time a broad spatial coverage across Europe was envisaged. A follow up project is foreseen to provide resources for the application of the model to additional plots.

8.4 Methods

The BERN model has been designed to integrate ecological cause-effect relationships into environmental assessment studies and for deriving critical load values. More than 38 000

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empirical vegetation data sets and data from related soil surveys form the basis of the BERN model. Nearly all biological components in a natural or semi-natural ecosystem are adapted to a long-term evolutionary status of relations between essential nutrients, such as nitrogen (N), phosphorus (P), carbon (C), and base cations (Na, Ca, Mg, K), as well as water supply, solar radiation and temperature conditions.

In order to model physiological reactions of plant communities the BERN model in a first step takes into account the plant species level. The relationship between site and plant composition has been called "blurred relationship" Glavac (1996). To mathematically depict the blurred condition determining the relations between site properties and plants all possible combinations between the observed vegetation and soil conditions have to be quantified. Fuzzy-logic (Zadeh 1978) is a mathematical instrument for characterizing these blurred relationships.

The BERN model in the first step only describes the fundamental niches of the plant species based on vegetation surveys. This fundamental niche - also called "possibility field" - is defined by a range of parameters in which each plant species can exist. This range of occurrence possibilities is determined by the physiological and genetic properties of the plant species and is rather unchangeable (Dierschke 1994).

In the second step, the realistic niche of the whole plant community is modelled using fuzzy logic methods. The combination of the fundamental niches of the plant species results in typical realistic niches for plant communities at a specific site type. These are defined by possibility functions for plant existence based on the combination of site factors which influence the vegetation vitality and which are classified to site types. All site parameter ranges have to lie within the physiological niche widths of a specific plant community. The problem of unknown competition is solved by using knowledge on existing plant species combinations. The realistic niche is thus a result of the plant sociological properties and is determined by the competitive power and reproductive fitness of the species in connection with all other existing species at the site (Schlutow and Huebener 2004). The distribution function of possibilities (DFP) for a plant community is determined by all constantly occurring plant species in a plant community. The n-dimensional DFP reaches a maximum at the point where most constant species building up the community have their highest possibility values. The regeneration ability of a plant community is assumed to be in an optimum when the DFP reaches its maximum.

Currently fundamental niches of 1602 plant species are defined by fuzzy thresholds for site variables (base saturation, C:N ratio, soil moisture, length of vegetation period, climate water balance, temperature and solar radiation) in the BERN database.

Realistic niches of 547 plant communities are integrated by combining the fundamental niches of the consistent plant species using the fuzzy logic minimum operator. Based on historical data from pre-industrial vegetation surveys, combinations of variables from sites assumed to be undisturbed together with their related plant communities are classified to reference site types.

The BERN model relies on its background database to assess possibility degrees for the existence of recent plant communities, which are then grouped into classes of different regeneration abilities at given plots in relation to a given site condition. The possibility class "no regeneration abilities" indicates non-natural disharmonious conditions for a plant community without chances for its self-regeneration. The possibility class "low regeneration abilities" indicates that a certain plant community can exist, but clearly faces degradation. The possibility class "full regeneration ability" is equal to the ecological niche where a plant community can reach its highest functionality. In this case the plant community can develop well and is fully capable of providing ecosystem services. With decreasing site suitability the competition capacity for the respective plant community also decreases, leading to reduced resistance against environmental influences like windfall, snow damage, frost, damaging insects and pests.

The BERN scenarios for predicted possibility degrees of the recent main tree species were driven by the modelled C:N ratio and base saturation in the years 2000 and 2050 as output of the VSD+ model (Chapt. 6). Changes in C:N ratio and base saturation are based on a deposition scenario assuming full implementation of current national legislation in the EU (NATIONAL scenario, see Chapt. 6). The current application of the BERN model assumes constant climate. Additional runs of the model additionally taking into account climate change scenarios are ongoing.

The knowledge on the optimum natural plant community offers information on main tree species with the potentially highest vitality. Therefore, in a next step, the main tree species of the “natural” or optimum plant communities for a specific site was compared to the main tree species of the presently occurring species composition as indicated by the recent vegetation surveys. This approach is based on the assumption that there is mostly a clear link between the vitality and regeneration potential of the main tree species and the possibility degrees for existence of recent plant communities to which the trees belong. The comparison of recent tree species with the dominating tree species of the optimum plant communities results in recommendations for future main tree species for specific plots.

8.5 Results

The evaluated plots show a wide variety of plant species communities and related presently occurring main tree species (Tab. 8-1). From the 20 sites analyzed with the model, 10 were classified with “full regeneration abilities” of the presently occurring plant species composition, indicating that species composition was rated as adapted to the presently occurring geo-chemical site conditions. On five sites regeneration ability was rated as low and on the remaining five sites there was “no regeneration ability” indicating that vegetation is not adapted to present site conditions (Fig. 8-1).

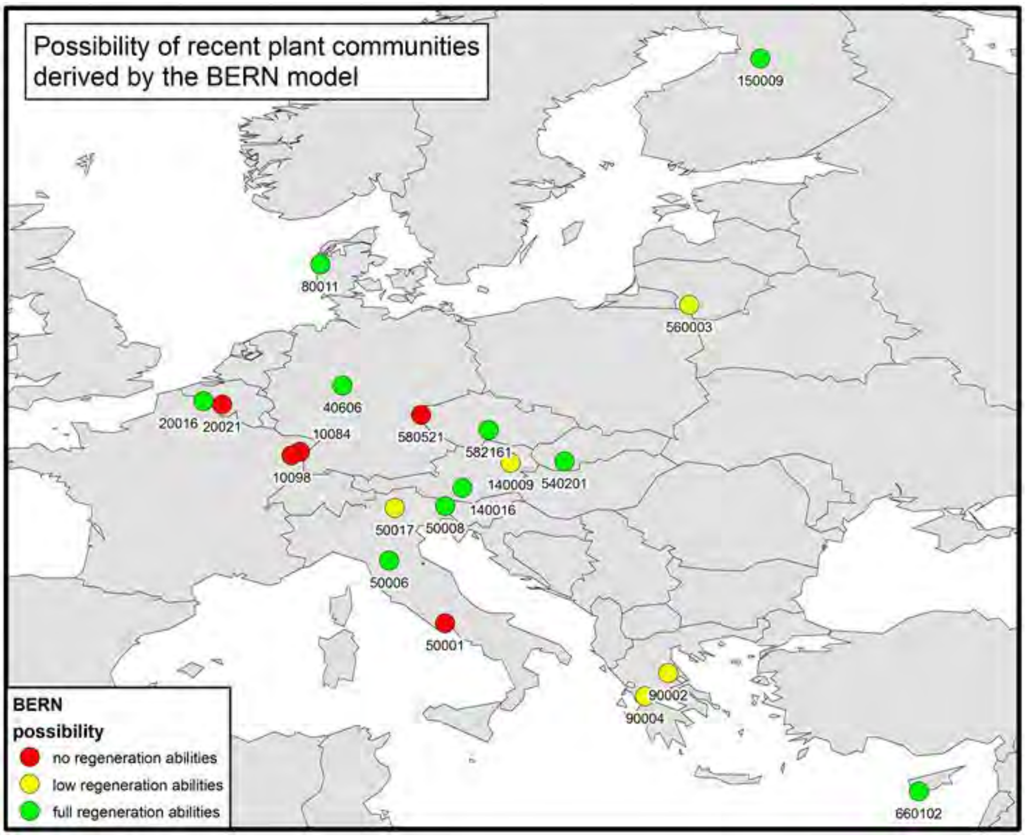

Figure 8-1: Evaluation of the regeneration abilities for recent plant communities derived by the BERN model and plotnumbers.

Table 8-1: Recent plant communities and tree species for the Level II plots
* tree species in **bold** indicate the present main tree species on the plot, tree species in *italic* letters are present at the site but not in the tree layer, tree species without special format are not present at the site, but would fit into the recent plant community

Level II plot	Recent plant community 2000	Typical tree species composition of the recent community*	Plant community with optimum in 2050	Main tree species with optimal vitality in 2050
10084	Molinio-(Betulo-) Quercetum	*Betula pendula* **Pinus sylvestris** *Quercus petraea* Quercus robur	Deschampsio flexuosae-Fagetum sylvatici (Dryopteris-Subass.)	Betula pendula Quercus petraeae Fagus sylvatica
10098	Vaccinio-Abietetum	Betula pendula **Abies alba** *Pinus sylvestris* Picea abies	Dryopteri-Cultoquercetum	Betula pendula Pinus sylvestris Quercus robur
20016	Endymio-Carpinetum	*Acer pseudoplatanus* *Fagus sylvatica* **Quercus robur** *Fraxinus excelsior*	Fraxino excelsi-Fagetum sylvatici	*No changes of main trees required*
20021	Endymio-Fagetum betuli	*Acer pseudoplatanus* **Fagus sylvatica** Quercus robur *Fraxinus excelsior*	Fraxino excelsi-Fagetum sylvatici	*No changes required*

40606	Fraxino excelsi-Fagetum sylvatici	**Fagus sylvatica** *Acer pseudoplatanus* *Ulmus glabra* *Fraxinus excelsior*	Fraxino excelsi-Fagetum sylvatici	Fraxinus excelsior
50001	Calamintho grandiflorae-Fagetum sylvatici	**Fagus sylvatica** *Acer platanoides* *Acer pseudoplatanus* Abies alba	Calamintho grandiflorae-Fagetum sylvatici	*No changes required*
50006	Daphno laureolae-Fagetum sylvatici	**Fagus sylvatica** Acer campestre Acer platanoides Fraxinus excelsior Tilia platyphyllos	Daphno laureolae-Fagetum sylvatici	*No changes required*
50008	Helleboro nigri-Abieti-Fagetum sylvatici	*Fagus sylvatica* *Abies alba* **Picea abies**	Deschampsio flexuosae-Fagetum sylvatici	Fagus sylvatica
50017	Vaccinio myrtilli-Piceetum	**Picea abies** Betula pendula	Vaccinio myrtilli-Piceetum	*No changes required*
80011	Vaccinio-Abietetum	Betula pendula Abies alba Pinus sylvestris **Picea abies**	Vaccinio-Abietetum	*No changes required*
90002	Quercetum frainetto-brachyphyllae	**Quercus frainetto** *Castanea sativa*	Quercetum frainetto-cerris macedonicum	Quercus petraea dalechampii
90004	Abietetum cephalonicae	*Abies cephalonica* **Abies borisii-regis**	Abietetum cephalonicae	*No changes required*
140009	Fraxino excelsi-Fagetum sylvatici	**Fagus sylvatica** *Acer pseudoplatanus* Ulmus glabra *Fraxinus excelsior*	Fraxino excelsi-Fagetum sylvatici	Fraxinus excelsior
140016	Calamagrostio villosae-Piceetum	**Picea abies**	Fago-Piceetum	*No changes of main trees required*
150009	Empetro nigri-Pinetum sylvestris	Quercus robur **Pinus sylvestris**	Empetro nigri-Pinetum sylvestris	*No changes required*
540201	Quercetum dalechampii-cerris	**Quercus cerris** Quercus petraea dalechampii	Quercetum dalechampii-cerris	Quercus petraea dalechampii
560003	Dicrano-Quercetum roboris	Betula pendula **Pinus sylvestris** *Quercus robur*	Dicrano-Quercetum roboris	Quercus robur
580521	Vaccinio myrtilli-Piceetum	**Picea abies** Betula pendula	Vaccinio myrtilli-Piceetum	*No changes required*
582161	Vaccinio myrtilli-Piceetum	**Picea abies** Betula pendula	Vaccinio myrtilli-Piceetum	*No changes required*
660102	Staehelino-Pinetum pallasianea	**Pinus nigra pallasiana** Quercus pubescens Fraxinus ornus Fagus moesiaca *Juniperus oxycedrus*	Staehelino-Pinetum pallasianea	*No changes required*

On 10 plots the presently occurring main tree species was assessed to have full regeneration abilities according to the model. On three plots the current main tree species was assessed with “no regeneration ability” whereas on seven plots the model assumes “low regeneration ability”. When relating the presently occurring main tree species to geo-chemical site conditions that are predicted under the deposition scenario “NATIONAL” for the year 2050 an increased regeneration ability was indicated on three plots, whereas a reduced regeneration ability of the present main tree species was indicated for four plots (Fig. 8-2). The condition doesn’t change on 13 plots but 4 of them are still classified as having “no” or only “low regeneration abilities”. On 9 out of 20 plots the main tree species maintain “full regeneration abilities”.

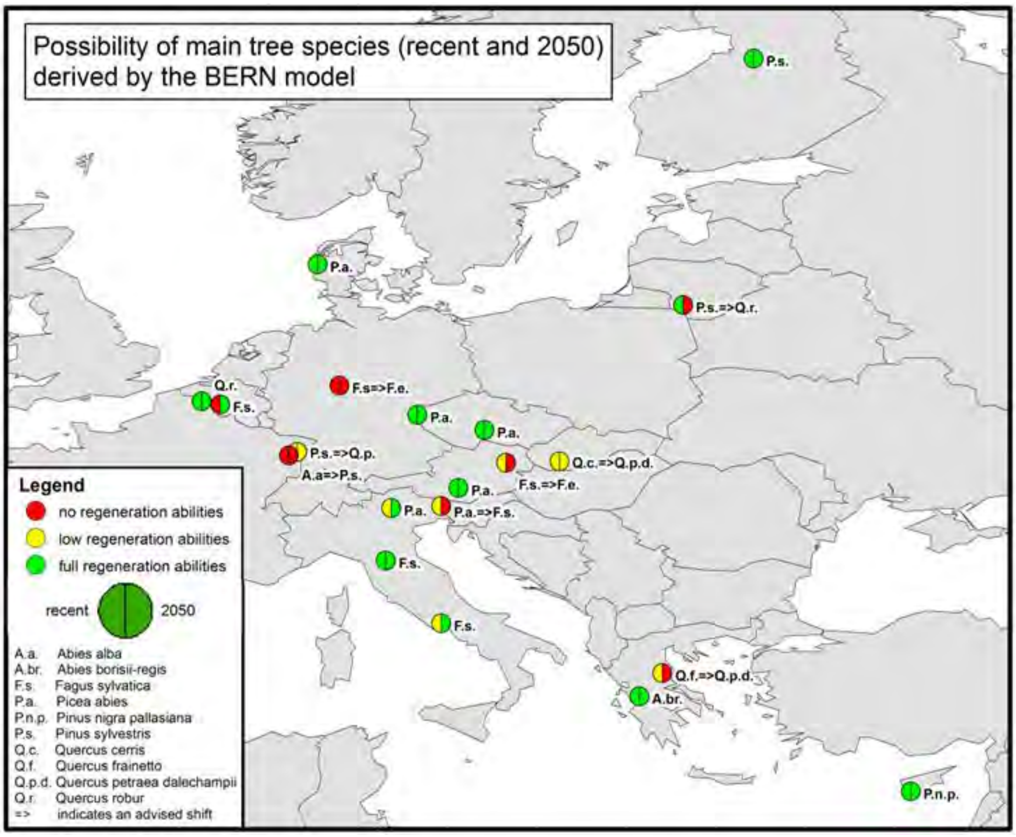

Figure 8-2: Current possibility of the recent main tree species and their predicted possibility in 2050, additional proposals for optional main tree species in the future (2050).

The four plots with decreasing suitability and the four plots with constantly low site potential for the existing vegetation were analyzed regarding recommendations for new main tree species (Table 8-1). For three of these plots a change from a coniferous main species to a broadleaved species is recommended, on five plots a change from a broadleaved species to another broadleaved species is recommended (Fig. 8-2). The potentially best fitting main tree species was already found in the vegetation survey in understorey layers on several sites even if it was not identical with the recent main tree species. In these cases the presence of the potentially best fitting tree species in spontaneous plant composition is an indicator for a potentially good vitality of these species in the future.

8.6 Discussion and conclusions

In the context of the BERN model a so called natural plant species composition or combination of (forest) plant species is a result of evolutionary processes and is assumed to be the best fitting balance of ecological competition according to a certain site factor configuration. Also it represents the most efficient plant composition in terms of resource consumption. Such natural plant communities feature an ecological sustainability with a maximized potential of self-regeneration. It is suggested that such a natural plant community with its adapted vegetation structure can best guarantee a sustainable balance between coexistence and competition of the individual species. The site specific adaptation improves the capability of a natural plant community to react to site factor changes, calamities or other stress events. Adapted communities are more flexible and dynamic in their reactions to environmental changes and thus less vulnerable than less adapted stands of trees. Therefore, one aim of sustainable forest management should be the close-to-nature management and the improvement of the naturalness of the forests in the sense of creating site adapted stands.

The 20 selected plots of the pilot study show different degrees of adaptation of the tree species and associated plant communities. On 8 plots present site conditions do not match requirements of the presently occurring main tree species, or the present tree species will be less adapted in future. With decreasing site suitability there is a risk for higher latent mortality and the need for sanitary felling. In addition to reduced economic benefits the stability of the stands may be at risk.

Deposition leads to changes in soil properties (Chapt. 6). These changes can improve or worsen the site conditions for presently stocking tree species. On half of the plots the anticipated deposition scenario does, however, not significantly change site conditions with respect to presently growing tree species.

In order to support the occurrence of adapted tree species, changes in main tree species are recommended for eight plots. It has to be noted that on only one of these plots (pine plot in Lithuania) today’s tree species is adapted but will have reduced regeneration ability in 2050 due to expected deposition. On the other seven of these plots already today’s tree species are not adapted to existing site conditions. Even though the number of plots available for this pilot study is low and not representative, this might be an indication for questionable tree species selection in the past or for changes in site conditions that already took place during the life time of the existing stand e.g. by atmospheric deposition, climate change or past silvicultural treatment.

The BERN model offers a tool for the estimation of deposition effects and for operational forest management recommendations. In future studies plot numbers need to be increased and the influence of climate change will needs to included in the modelled scenarios.

8.7 References

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Part VI

NATIONAL SURVEYS

9. National crown condition surveys and contacts

Richard Fischer[1] and Georg Becher[1]

Reports on the results of the national crown condition surveys at Level I of the year 2010 were received from 33 countries. For these countries, the present chapter presents summaries. Besides that, numerical data on crown condition in 2010 were received. These results are tabulated and presented as graphs.

It has to be noted, however, that in contrast to the transnational survey (Chapt. 3) it is not possible to directly compare the national survey results of individual countries. The sample sizes and survey designs in national surveys may differ substantially and therefore conflict with comparisons. In a number of cases the plots for the transnational survey are identical with the national survey, in other cases the national survey is carried out on condensed nets. Gaps in the Annexes, both tabulated and plotted, may indicate that data for certain years are missing. Gaps also may occur if large differences in the samples were given e.g. due to changes in the grid, or the participation of a new country.

9.1 National Survey Reports

9.1.1 Andorra

The assessment of crown condition in Andorra in 2010 was conducted on the only 3 plots of the transnational grid and included 72 trees, 42 *Pinus sylvestris* and 30 *Pinus uncinata*.

Results obtained in 2010 for both species show a majority of trees classified in defoliation and discolouration classes 0 and 1, as noticed in 2009. These results continue to show the improving tendency in forest condition after the worst results for the Andorran assessments reported in 2007. Related to defoliation, there was a slight decrease in not defoliated and slightly defoliated trees and an increase in the moderate defoliation class rate which passed from 5.5% in 2009 to 13.9% in 2010. Only 1.4% of the trees were rated as severely damaged.

Results for discolouration showed a different distribution. There was a decrease in the not discolouration class which passed from 67.1% in 2009 to 41.7% in 2010, mainly caused by an increase in slight and moderate discolouration classes. Severe discolouration was registered on only 1.4% of the trees.

In 2010, the assessment of damage causes showed, as in previous surveys, that the main causal agent was the fungus *Cronartium flaccidum* which affected 6.9% of the sample trees and which occurred on all plots. During this year, one tree was affected by the insects *Ips acuminatus* and *Phaenops cyanea*.

9.1.2 Austria

The 2010 crown condition survey was carried out on 135 plots of the transnational 16 x 16 km grid net. The assessment covered 3 087 trees, 90.4% coniferous trees and 9.6% broadleaved trees. The main coniferous tree species was *Picea abies* comprising 70.9% of all sample trees, the main broadleaved species was *Fagus sylvatica* comprising 6.9% of all sample trees.

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The mean defoliation of all tree species was estimated to 10.6%. The mean defoliation for coniferous trees was 10.7% and for broadleaves 10.6% in 2010. 14.2% of the assessed trees were classified as damaged (defoliation classes 2-4). The respective figures were 14.5% for conifers and 10.5% for broadleaved trees. 54.9% of all sample trees were classified as not defoliated (class 0) and 0.5% were found standing dead, this means having died since the last assessment in 2006.

No evaluation of the development of crown condition over the last years is possible, as the assessment of crown condition on the Level I grid net has been discontinued since 2006.

The assessment of biotic and abiotic damage types revealed that about 30% of all sample trees showed some kind of damage symptoms. The most frequent symptoms were different kinds of wounds on the stem/collar found on about 15% of the sample trees. The main causal agent responsible for this damage symptom is direct action of man.

9.1.3 Belarus

The forest condition survey in 2010 was conducted on 411 Level I plots of the transnational grid. The condition of 9 778 trees was assessed. 71.8% of all trees were conifers. *Pinus sylvestris* and *Picea abies* accounted for 61.9% of all sample trees. 28.2% were deciduous trees (*Betula* spp., *Populus tremula*, *Alnus* spp., etc.).

In comparison to 2009, the share of trees without defoliation increased by 1.7 percentage points and was 29.5%, the share of trees in defoliation classes 2-4 decreased by 1.0 percentage points and was 7.4%. Mean defoliation of all species decreased by 0.5 percentage points and was 17.2%.

As in previous years, *Alnus glutinosa* had the lowest defoliation (13.9%), and *Fraxinus excelsior* and *Quercus robur* showed the highest mean defoliation, 43.1% and 19.3%, respectively. These species had the highest share of trees in defoliation classes 2-4 (52.3% and 10.4%), and the smallest share of trees without defoliation (11.4% and 20.9%, respectively).

In comparison to 2009, *Fraxinus excelsior* revealed a clear increase in the share of dead trees and in mean defoliation. A continuous deterioration of crown condition of *Fraxinus excelsior* has been observed during the last years. In contrast, for *Quercus robur*, since 2006 an obvious improvement has been observed.

Damage signs by various factors were observed on 14.1% of the sample trees. Damage was most frequently recorded for *Fraxinus excelsior* (55.5% of all trees), *Populus tremula* (34.3%) and *Quercus robur* (29.9%), and more rarely for *Pinus sylvestris* (9.9%). The most frequent damage types were fungi (4.8%), direct action of man (3.3%), and insects (1.7%). The highest share of trees with signs of damage by fungi was recorded for *Fraxinus excelsior* (40.0%, *Armillaria* sp.), *Populus tremula* (23.8%, mainly *Phellinus tremulae*) and *Quercus robur* (10.8%, mainly *Phellinus robustus*). 5.0% *Betula pendula* and 4.6% *Picea abies* were damaged mechanically. Insect infestation was most frequently recorded for *Alnus glutinosa* (21.7%) and *Quercus robur* (6.2%).

Over the last three years significant wind damage has occurred in Belarus forests. On 28 July and on 8 August 2010 storms caused 2.5 million m^3 storm felled timber mainly in the central part of the republic. This volume corresponds to more than 15% of the annually harvested wood.

9.1.4 Belgium

Belgium/Flanders

In the northern part of Belgium large scale assessments were carried out on 72 plots on a 4 x 4 km grid, with a total of 1 733 trees. The main tree species in the survey were *Quercus* *robur*, *Pinus sylvestris*, *Fagus sylvatica*, *Quercus rubra*, *Pinus nigra* subsp. *laricio* and *Populus* spp.

16.1% of the trees were rated damaged and the mean defoliation in the plots was 20.4%. 16.4% of the trees were considered as healthy. Dead trees were found on 4 plots (0.3% mortality rate). The share of damaged trees was 9.7% in conifers and 19.1% in broadleaves, with a mean defoliation of 18.4% and 21.3%, respectively. Defoliation was higher than the mean in *Quercus robur*, *Populus* spp., *Pinus nigra* and 'other broadleaves'.

Crown condition deteriorated compared to the year before. The share of damaged trees increased by 1.2 percentage points and the mean defoliation by 0.6 percentage points. There was only a slight change for conifers, with a small increase in defoliation in *Pinus sylvestris* and a decrease in *Pinus nigra.* With 20.8% of the trees in defoliation classes 2-4, *Pinus nigra* revealed higher defoliation compared to *Pinus sylvestris*, with 6.7% of the sample trees in the same classes. The main changes were detected in broadleaved species. With 22.4% moderately to severely damaged trees, *Populus* spp. showed an improvement of the crown condition. Compared to 2008 and 2009, defoliation caused by rust infection (*Melampsora* spp.) started later. Both oak species showed a significant increase in defoliation. *Quercus robur* was the most affected oak species, with 23.2% of the trees in defoliation classes 2-4. Serious insect damage was recorded in several *Quercus robur* plots. In *Quercus rubra*, 11.0% of the sample trees showed moderate to severe defoliation. There was no significant increase in defoliation of *Fagus sylvatica* and the group of 'other broadleaves'. 9.2% *Fagus sylvatica* and 22.5% the 'other broadleaves' showed more than 25% defoliation. In the category 'other species', serious damage by *Phytophthora alni* occurred on *Alnus glutinosa*. *Chalara fraxinea* infection was observed in two *Fraxinus excelsior* stands outside the Level I grid.

Within the framework of the FutMon C1-NFI action, the plot design of the Flemish forest inventory was introduced and the volume of coarse woody debris was compared using regional and reference definitions. The downed deadwood volume in the Level I plots ranged from 0 to 68m³, with a mean volume of 8 m³.

A storm on 14 July 2010 caused damage in a few plots. 0.8% of the sample trees were removed because of thinning or mechanical damage.

Belgium-Wallonia

The survey in 2010 concerned 1 017 trees on 47 plots, on the regional 8 x 8 km systematic grid, a subdivision of the 16 x 16 km transnational European grid. The percentage of trees with a defoliation >=25% shows different long term trends for conifers and broad-leaved trees: The conifers, which were two time more defoliated in the beginning of the nineties, show this year a rate of 29.3%, which is much higher than last year with 15.5% of the trees. The broad-leaved trees showed an increase from 10% in 1990 to about 20% in 2005. This damage increase was mainly due to the degradation of beech (*Scolytidae* in 2000-2002, drought in 2003 followed by fruiting in 2004) and of *Quercus robur* (drought in 2003).

Concerning the mean defoliation observed for the four main species, after an improvement since 2006 for *Fagus sylvatica* and *Quercus robur*, mean defoliation increased to about 22% for *Fagus sylvatica* and to 26.7% for *Quercus robur* in 2010. *Quercus petraea* as well was in a bad condition in 2010 with 16.7%, and also *Picea abies* showed a distinct increase in mean defoliation, with 19.6%.

Damage causes, which were identified for only about 10% of the trees, were mainly defoliators for beech and oak, abiotic causes (storm) and big herbivors (*Cervus elaphus*) for spruce, and sometimes human induced damages (forest operation). Sunburn for *Fagus sylvatica* bark was sometimes mentioned. In 2010, June and July were two months with low rain; in July, sunshine duration and temperatures were very high (about 4°C higher than the average), with dry conditions, which may explain the increase in defoliation.

9.1.5 Bulgaria

A revision and restructuring of the existing 22 years old forest monitoring network was carried out in the period 2009-2010. When building the new network the following items were taken into consideration:

1. The sampling plots of the new network should include existing ICP Forests sampling plots as many as possible.
2. The sampling plots should include the most typical biotopes of the Bulgarian forests.
3. Part of the sampling plots should be located in protected zones of the Bulgarian ecological network and should characterize priority habitats, subject to protection.
4. The sampling plots should be representative for the tree species of the country.
5. Plots disturbed or destroyed by various reasons like felling or wind throws should be replaced.

In 2010, large-scale monitoring of forests in Bulgaria was carried out on 159 sample plots. 69 sampling plots were located in coniferous stands and 90 plots in deciduous forest types. 62% of the sampling plots were previous ICP Forests plots. The monitoring activities were carried out in conformity with the requirements of ICP Forests Manual.

The assessment included 2 396 coniferous trees and 3 173 deciduous trees. The results regarding the indicator "defoliation" for *Pinus nigra* showed that up to 59 years of age 11.6% of the assessed trees were in defoliation class 0, and 49.9% were in defoliation class 1. The overall condition remained unchanged compared to 2009. *Pinus sylvestris* also retained its condition up to 59 years of age, and in older age a small decrease in the healthy and slightly defoliated trees was observed. *Picea abies* was the species that showed lowest defoliation with a slight increase in the trees in defoliation classes 0 and 1. For *Pinus nigra* there was some increase in defoliation classes 1 and 2. Most of the damage for conifers was caused by *Lophoderminium pinastri*.

Among the deciduous tree species, *Fagus sylvatica* showed the lowest defoliation, followed by *Quercus petraea*. The condition of *Quercus cerris* was also very good. A tendency towards deterioration was not determined. The results for the observed deciduous trees showed that in general most trees were healthy or slightly defoliated. The results for *Fagus sylvatica* showed that up to 59 years of age, 55.1% of the observed trees were in defoliation class 0. For older trees the share of healthy and slightly defoliated trees slightly decreased. In comparison with 2009, a small decrease in the healthy and slightly defoliated trees was determined for *Quercus frainetto* and *Quercus petraea.*

Damage on *Fagus sylvatica* was due to *Rhynchaenus fagi, Ectoedemia libwerdella,* and *Nectria* spp., and damage on *Quercus* spp. was mainly caused by *Tortix viridana*. Most frequent abiotic agents for both, coniferous and deciduous species, were drought, snow, and ice.

9.1.6 Cyprus

The annual assessment of crown condition was conducted on 15 Level I plots, during the period September - October 2010. The assessment covered the main forest ecosystems of Cyprus and a total of 360 trees of *Pinus brutia, Pinus nigra* and *Cedrus brevifolia* were assessed. Defoliation, discoloration and damaging agents were recorded.

A comparison of the results of the conducted survey with those of the previous year (2009) shows significant improvement among the four categories on all species. From the total number of trees assessed (360 trees), 12.2% were not defoliated, 68.6% were slightly defoliated, 17.8% were moderately defoliated, and 1.4% were severely defoliated.

Compared to the previous year, the 2010 results show an increase in the first two classes, by 9.2 percentage points in class 0 (not defoliated) and 7.9 percentage points in class

1 (slightly defoliated). A decrease by 16.5 percentage points was observed in class 2 (moderately defoliated). In class 3 (severely defoliated) no changes were observed, and no dead trees were recorded (class 4). The observed improvement of crown in 2010 is mainly due to the sufficient rainfall in 2008-2009 compared to the rainless period 2007-2008.

In *Pinus brutia*, 12.7% of the sample trees showed no defoliation, 67.3% were slightly defoliated, 18.3% were moderately defoliated and 1.7% were severely defoliated. In *Pinus nigra*, 8.3% of the sample trees showed no defoliation, 72.2% of the sample trees showed slight defoliation while the remaining 19.5% were moderately defoliated. In *Cedrus brevifolia*, 12.5% of the sample trees showed no defoliation, 79.2% of them were slightly defoliated, 8.3% were moderately defoliated. No dead trees were observed. In contrast to the assessment of the year 2009, no discoloration was assessed at any of the trees.

From the total number of sample trees surveyed, 70.6% showed signs of insect attack and 8.6% showed signs of "*other agents*" (lichens, dead branches and rat attacks). 6.9% showed signs of both factors (insect attack and other agent). The major abiotic factors causing defoliation in Cyprus during the year 2010 were climatic factors in combination with the edaphic conditions. As a result of these factors, half of the trees were attacked by *Leucaspis* spp., which contributed to the defoliation during the year 2010 as a secondary factor. *Leucaspis* spp. was one of the two important insects causing damage; the other one was *Thaumetopoea wilkinsoni*. No damage was attributed to any of the known air pollutants.

9.1.7 Czech Republic

In 2010, there was a very slight decrease in the total defoliation of conifers in the older age category (stands 60 years old and older) when compared with the preceding year. Defoliation in the classes 0 and 1 slightly increased and decreased in classes 2 and 3. The change was mostly due to the development in *Picea abies* and partly *Abies alba.* Defoliation of *Picea abies* in class 2 dropped from 68.7% in 2009 to 64.0% in 2010 with a related increase in defoliation in classes 0 and 1. *Abies alba* defoliation decreased in class 1 from 38.2% to 34.3% and increased in class 0 from 2.9% to 5.7%. No important changes occurred in the development of total defoliation in the younger age category of conifers (stands up to 59 years of age).

Younger conifers (up to the age of 59 years) showed lower defoliation in the long-term period compared to stands of younger broadleaves. For the older stands (stands 60 years old and older) this comparison was reverse, the older conifers were of markedly higher defoliation than the stands of older broadleaves.

Development of total defoliation of broadleaves in the older age category slightly decreased, based on an increasing defoliation in classes 0 and 1 and a fall in classes 2 and 3. This insignificant change was caused by two main deciduous species *Fagus sylvatica* and *Quercus* spp.. Defoliation of *Fagus sylvatica* in class 2 fell from 12.5% to 8.2% and at the same time defoliation in class 0 increased from 19.8% to 24.2%. Defoliation of *Quercus* spp. increased in class 1 from 26.3% to 30.3% and at the same time defoliation in classes 2 and 3 dropped. A slight worsening occurred in the younger broadleaves (stands up to 59 years of age). Defoliation in class 2 increased from 14.6% in 2009 to 20.0% in 2010 with a related decrease in class 0. This change was mainly due to the group of other broadleaves where defoliation in class 2 increased from 8.1% to 29.2% and decreased in class 0 from 31.1% to 11.5%.

At the beginning of the vegetation period, during May, some forest stands, mainly in north-eastern Bohemia, were mechanically damaged by strong wind and hailstorm. Compared with long term mean temperatures, the average monthly temperatures in the vegetation period were mostly above average. In July with the deviation of mean temperature was +3.1 °C. In contrast, below-average temperatures were measured in September and October 2010.

Average monthly precipitation was mostly above average. The only exceptions were June with 88% and October with only 31% of the long-term means.

Over the last ten years, no important change has been recorded for the main pollutants (particulate matters, SO_2, NO_x, CO, VOC, NH_3). Total emissions of most of these substances, despite a certain fluctuation, have been slightly dropping since many years. Emissions of particulate matters and NH_3 were constant.

9.1.8 Denmark

The Danish forest condition monitoring in 2010 was carried out in the National Forest Inventory (NFI) and on the remaining Level I and II plots. Monitoring showed that most tree species had a satisfactory health status. Exceptions were *Fraxinus excelsior* where the problem with extensive dieback of shoots had continued. Average defoliation was 40% for all monitored ash trees and 31% of the trees had more than 50% defoliation. However, this result was mainly due to one long-term ash monitoring plot where all the trees were dying, but even discounting this plot average defoliation was 25%. The situation for ash in Denmark has thus not improved since 2009.

Picea sitchensis still had higher than normal mean defoliation (13%), and *Pinus sylvestris* also showed some signs of stress (14% mean defoliation). *Picea abies* and other conifers had low defoliation, and the health situation for *Picea abies* in Denmark was very satisfactory. With 8% mean defoliation *Fagus sylvatica* stays at a low level of leaf loss, and no health problems had been noted for this important species for some years. *Quercus robur* and *petraea* had a slightly increased defoliation, but even with 15% mean defoliation the health condition of oak can be considered satisfactory.

Based on both NFI plots and Level I and II plots, the results of the crown condition survey in 2010 showed that 73% of all coniferous trees and 65% of all deciduous trees were undamaged. 19% of all conifers and 24% of all deciduous trees showed warning signs of damage. The mean defoliation of all conifers was 8% in 2010, and the share of damaged trees was 7%, which was the same as in 2009. Mean defoliation of all broadleaves was 13%, and 11% were damaged, also similar to last year's result.

9.1.9 Estonia

Forest condition in Estonia has been systematically monitored since 1988. In 2010, altogether 2 348 trees were examined on 97 permanent Level I sample plots. Assessment covered 582 *Picea abies*, 1 489 *Pinus sylvestris*, 209 *Betula pendula* and 28 *Betula pubescens*, 13 *Populus tremula*, 16 *Alnus glutinosa*, 6 *Alnus incana* and 4 *Fraxinus excelisior*, also 1 *Quercus robur*.

The total share of not defoliated trees was 52.8%. The percentage of trees in classes 2 to 4 (moderately defoliated to dead) was 8.2%. In Estonia the most defoliated tree species has traditionally been Scots pine (*Pinus sylvestris*). The percentage of pine trees in defoliation classes 2-4 was 9.4% in 2010. Essential improvement in crown condition of Scots pine was observed in the period 1991–2000. Subsequently a certain decline was registered up to 2003 and since 2004 defoliation has remained on the same level. In 2008-2009, 37% of Scots pines were not defoliated, but in 2010 a new improvement occurred and already 45.3% of pines were not defoliated (defoliation class 0). The increase in defoliation of *Picea abies* started in 1996, stopped in 2003 and remained on the same level up to 2005. In 2006, some worsening in crown condition occurred. In 2007-2010 the share of *Picea abies*, which were not defoliated, remained almost at the same level. In 2010, 63.7% of *Picea abies* were not defoliated. The condition of deciduous tree species was estimated to be better than that of the conifers. In 2010, 68.4% of *Betula pendula* were not defoliated.

Numerous factors determine the condition of forests. Climatic factors, disease and insect damage as well as other natural factors have an impact on tree vitality. In 2010, 5.5% of the trees assessed showed some kind of insect damage and 36% identificable damage symptoms of diseases. Needle cast and shoot blight were the most significant reasons for biotic damage on trees.

9.1.10 Finland

In Finland the integration of the ICP Level I and national forest inventory (NFI) networks was accomplished in 2009. The sampling design of the current NFI (NFI 11) is a systematic cluster sampling. The distance between clusters, the shape of a cluster, the number of field plots in a cluster and the distance between plots within a cluster vary in different parts of the country according to spatial variation of forests and density of the road network.

Principally, every fourth cluster is marked as a permanent cluster. Annually a new set of permanent plots, established during the 9th NFI in 1996-2003, is to be assessed. The same permanent plots will be assessed in five- year intervals. All dominant and co-dominant *Picea abies, Pinus sylvestris* and *Betula pendula* trees are assessed, and results from 6 pre-selected permanent plots from each cluster are reported to the ICP Forests and to the EU.

The results of the 2010 forest condition survey are reported from 932 permanent sample plots. Of the 7 876 trees assessed in 2010, 51.5% of the conifers and 56.8% of the broadleaves were not suffering from defoliation (leaf or needle loss 0-10%). The proportion of slightly defoliated conifers (11- 25%) was 37.9%, and that of moderately defoliated (over 26%) 10.6%. For broadleaves the corresponding proportions were 34.0% and 9.2%, respectively.

The average tree-specific degree of defoliation was 13.3% in *Pinus sylvestris*, 18.5% in *Picea abies*, and 14.2% in broadleaves (*Betula pendula* and *B. pubescens*). 70 trees (50 of which conifers), which were broken or felled by storms, are not included in the defoliation scores. Compared to the previous year, the mean defoliation had increased in both *Pinus sylvestris* (by 1.4 percentage points) and in broadleaves (by 3.1% percentage points). As the plots assessed during 2009 and 2010 are completely different samples, the results from 2009 and 2010 are not directly comparable.

Abiotic and biotic damage was also assessed in connection with the large-scale monitoring of forest condition. 31% of *Pinus sylvestris*, 24% of *Picea abies* and 30% of the broadleaves were reported to have visible/ symptoms attributed to abiotic or biotic damaging agents. Apart from physical contact, *Neodiprion sertifer* (5.5%*)* and *Gremmeniella abietina* (5.0%) were the most abundant identified damaging agents in *Pinus sylvestris*. *Neodiprion sertifer* was having a massive outbreak in the mid-western parts of the country, but the amount of damaged pines was about the same as in the previous year in the whole data. The most notable change in the incidence of biotic causes was the much lesser occurrence of *Chrysomyxa ledi* on *Picea abies* in the 2010 sample. In broadleaves, undetermined defoliating insects (4.5%) were the most common group of biotic/abiotic causes. However, the number of broken, fallen or tilted conifers was much higher than in the previous year's sample.

9.1.11 France

In 2010, the forest damage monitoring in the French part of the systematic European network comprised 10 584 trees on 532 plots. The increase in plot number is due to a correction in the network taking into account the increasing forest area in France since several years.

The climatic conditions of the year were not really favourable to the forest vegetation due to a hot and dry summer which particularly affected broadleaved stands.

Defoliation slightly increased for most of the broadleaved species. *Quercus pubescens* and evergreen oak, species which are frequent in the South East of France, still had the worst crown condition of all monitored species in 2010, and did not show any sign of improvement. Death of sampled trees stayed at a relatively low level. The number of discoloured trees was still low except for *Populus* spp., *Fagus sylvatica, Prunus avium* and *Pinus haleppensis*.

Damage was reported on about a quarter of the sampled trees, mainly on broad-leaved species. The most important causes of damage were mistletoe (*Viscum album*) on *Pinus sylvestris,* chestnut canker (*Cryphonectria parasitica*) and the oak buprestid (*Coroebus florentinus*) on *Quercus* spp. Abnormally small leaves were observed on different species, specially on *Quercus* spp. (mainly on evergreen oaks and Q. *pubescens*).

9.1.12 Germany

The national results of 2010 were calculated based on the crown condition data of 10 159 sample trees which were assessed on 415 sampling plots of the national 16 x 16 km grid. The assessment covered 38 different tree species. However, about 85% of all trees included in the samples belonged to the four main tree species: *Picea abies, Pinus sylvestris, Fagus sylvatica* and *Quercus* spp.(*Quercus robur* and *Quercus petraea* are assessed together). The remaining tree species were grouped as “other conifers” and “other broadleaves”.

Forest condition has slightly improved in comparison to 2009. The improvement is mainly due to the significant recovery of *Fagus sylvatica*. Defoliation of *Picea abies* and *Pinus sylvestris* remained nearly unchanged on the national average; this is, however, the result of contrasting trends at the regional scale. *Quercus* spp. still shows severe defoliation. The recovery that seemed to start in 2009 did not continue in 2010; on the contrary: the percentage of trees showing more than 25% defoliation as well as mean defoliation increased in 2010.

Over all tree species, 23% of the forest area was assessed as damaged, i. e. showed more than 25% of defoliation (damage classes 2 to 4). This is a decrease by 2 percentage points as compared to 2009. 39% of the forest area was in the warning stage and 38% of the area was assessed as undamaged (2009: 36%). Mean crown defoliation continued to decrease from 19.7% to 19.1%.

The main tree species show the following development:

- *Picea abies*: the area percentage of damaged trees was 26%, the same as in 2009, while the percentage of trees in damage class 0 has increased. Mean crown defoliation decreased from 19.4% in 2009 to 18.7%.
- *Pinus sylvestris*: the area percentage of damaged trees was 13% and remained unchanged. Mean crown defoliation slightly increased from 15.8% to 16.0%.
- *Fagus sylvatica* showed a significant recovery of crown condition. The area percentage of damaged trees decreased by 17 percentage points from 50% in 2009 to 33% in 2010. Mean crown defoliation decreased from 27.0% to 23.3%.
- *Quercus petraea and Q. robur* showed increasing defoliation compared to the previous year. The area percentage of damaged trees amounted to 51% (2009: 48%). Mean crown defoliation was 29.6%, the highest score ever since the beginning of the surveys in 1984 (2009: 26.5%). According to the reports from the *laender*, damage caused by defoliators has intensified and was further aggravated by mildew infections of the secondary shoots.

9.1.13 Greece

In the 2010 survey, a total of 90 plots was assessed in the high forests (89 in 2009). 8 plots were assessed in maquis vegetation types. The installed plots are representative for the Greek forest ecosystems. No other forest health observation network exists in Greece.

In total, 2 135 forest trees in the high forests and 176 trees in the 8 maquis plots were assessed, on average corresponding to roughly 24 trees per plot. From the forest trees, 1 150 were conifers and 985 trees were deciduous broadleaves (mainly *Quercus* spp.). The survey was carried out from the beginning of July to the end of October 2010. During the assessments, 12 trees dead since previous assessments were replaced (3 conifers and 9 broadleaves), 13 new dead trees were found (1 conifer and 12 broadleaves).

Compared to 2009, a slight deterioration of tree crown condition is obvious but generally forest trees in Greece are in a good condition. The period 2008-2010 was characterized by low precipitation with frequent summer droughts and extreme temperatures.

44.5% of all sample trees in the high forest were not defoliated, 31.7% were slightly defoliated, 20.2% were moderately, 3.0% were severely defoliated and 0.6% were dead. In the maquis 39.8% were not defoliated, 38.6% were slightly defoliated, 18.8% were moderately, 2.3% were severely defoliated and 0.5% of the trees were dead. A comparison of defoliation results between 2009 and 2010 shows that the share of trees in the classes 0, 1 and 3 increased by 0.5 percentage points. The share of trees in class 2 decreased by 0.9 percentage points and the share of dead trees decreased by 0.1 percentage points.

42.3% of all conifers (1 150 trees), showed no defoliation, 34.0% were slightly, 21.4% were moderately and 2.2% and 0.1% were severely defoliated and dead, respectively. A comparison of defoliation results between 2009 and 2010 shows an increase by 4.4 percentage points in the share of not defoliated trees with a corresponding decrease in all the other classes. Conifers clearly appear in better condition as compared to 2009.

In broadleaves (985 trees), 47.1% showed no defoliation, 29.0% were slightly, 18.8% were moderately and 3.9% and 1.2% were severely defoliated and dead, respectively. Compared to 2009, a decrease by 1.9 percentage points in the slightly defoliated class was observed with a corresponding increase in all the other classes. This points to a slight worsening of tree crown condition.

Main damaging factor for *Abies* spp. was the insect *Choristoneura murinana*. In a number of plots also *Viscum album* was registered. *Pinus* spp. was affected by the insects *Thaumetopoea pityocampa* and *Marchalina hellenica.* In the various species of deciduous *Quercus* spp. *Lymantria dispar*, as well as *Tortrix viridana, Archips xylesteana,* and *Altica quercetorum* were registered. Necroses were caused by abiotic (frost, drought) or biotic (insects) factors. In *Fagus* species *Rhynchaenus fagi* was registered. *Platanus orientalis* was affected by the fungus *Nectria dittisima. Castanea sativa* suffered from the fungus *Cryphonectria parasitica.* In *Acer* spp. infestation by the fungus *Uncinula aceris* played a certain role. In maquis plots there were signs of intense grazing (ovines) during the regeneration period and damage from the insect *Lymantria dispar*.

9.1.14 Hungary

In 2010, the forest condition survey was based on the 16 x 16 km grid including 1 848 sample trees on 77 permanent plots in Hungary. The assessment was carried out during the period of July – August. 88.7% of all assessed trees were broadleaves, 11.3% were conifers.

The share of trees without visible damage decreased from 54.8% to 49.3%. The mean defoliation of all species was 22.0%, which is worse than in 2009 but still means a slight damage. Based on the defoliation of all trees, 49.3% showed no defoliation, 28.9% were slightly defoliated, 14.7% were moderately defoliated, and 4.4% were severely defoliated. 2.7% of all trees assessed were dead.

The percentage of all tree species in defoliation classes 2-4 was in 2010 higher than in 2009 (21.8% and 18.4%, respectively). The ICP Forests defoliation class 4 was divided into two classes. Whereas in class 4 trees were included that died in the current year, trees were included in class 5 which died in previous years. 2.7% of the trees were dead, but only one tenth of these trees died this year (0.5% and 2.5%, respectively). In the classes 2-4 the most damaged species was *Pinus nigra,* with 55.7% of the trees in these defoliation classes, followed by *Pinus sylvestris* (28.8%) and *Robinia pseudoaccacia* (14.0%). *Fagus sylvatica* had the lowest defoliation (9.7%) in classes 2-4.

Discolouration rarely occurred in Hungarian forests, 94.8% of the trees showed no discolouration.

In 2010, the dominant weather factor was rainfall. From March to August the monthly rainfall exceeded the average of many years. In middle Hungary the average rainfall exceeded twice or even three times the average rate for several months. The daily average temperatures, with few exceptions, in June and July were nearly 5 degrees warmer than average for many years. Due to the high precipitation no drought did occur. The humid and warm weather favoured the formation of fungus damage.

Two thirds of visible damage, 65% were caused by biotic pests (37% by insects, 26% by fungi and 2% by game). Abiotic accounted for 13% of the damage assessed while 12% were caused by direct human impact. Fire was responsible for 1%, 8% of the damages were caused by other factors and 1% was defined as unknown.

Following the classification defined in the ICP manual on crown condition assessment, it can be ascertained that damage caused by insects was still the main damage factor, 57.4% of the trees were damaged in total. Defoliators were responsible for damage on 80.1% of other conifers, 76.9% of other oaks and 62.6% of *Quercus robur* trees. Mean defoliation of the assessed trees caused by insects was 8.0%. The stem and branch damage assessed on coniferous trees was mainly caused by pine shoot moth (*Rhyacionia buoliana*). On *Pinus sylvestris* 60.2% of the stems and 37.7% of the branches were damaged by this species. Fungal damage on leaves was assessed on 11.7%, on branch and on stem together on 27.2% of all assessed trees. The mean damage attributed to fungi was 19.1%.

Abiotic damage was recorded on 19.4% of the sample trees. Among abiotic damages 35% were caused by drought and 29.2% by frost.

Based on the surveys it can be concluded that the health of Hungarian forests is in a good state, the extent of damage is low, negative trends have not been observed in recent years.

9.1.15 Ireland

The annual assessment of crown condition was conducted on the Level I plots in Ireland between August 15th and November 24th 2010. Overall mean percent defoliation and discolouration recorded for 2010 was 6.7% and 5.4% respectively. These results indicate that overall mean percent defoliation and mean percent discolouration levels have improved since the 2009 survey by 2.9 percentage points and 2.0 percentage points respectively. Defoliation and discolouration levels recorded in 2010 were significantly below the respective long term 22 year averages of 14.0% and 7.6%.

In terms of species, defoliation decreased in the order of *Picea abies* (13.8%)> Pinus *contorta* (13.6%)> *Picea sitchensis* (4.5%), while the trend in discolouration was in the order of *Pinus contorta* (12.8%)> *Picea abies* (2.5%)> *Picea sitchensis* (2.4%).

Twelve of the plots assessed in the 2010 survey are newly established plots which are fully integrated with the National Forest Inventory. Since the 2009 assessment two plots from the long established Level I plot network were felled as part of normal forest management planned operations.

As observed through long-term trend analysis, exposure continued to be the greatest single cause of damage to the sample trees in 2010. Other damage types (aphid, shoot die-back, top dying and nutritional problems) accounted for damage in a smaller percentage of trees. No instances of damage attributable to atmospheric deposition were recorded in the 2010 survey.

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9.1.16 Italy

The 2010 Level I survey on crown condition was carried out on 8 338 selected trees on 253 plots belonging to the 16 x 16 km EU network. The number of sample plots was reduced by 4 plots compared to 2009 because the plots did not meet the requirements (threshold diameters, dominance, etc.). The number of trees has increased considerably as a result of integrating the second adjustment inventory model.

Defoliation data were reported in different classes: for all species, 72.0% were in defoliation classes 1 to 4, of which 29.8% were in defoliation classes 2 to 4. Regarding the groups of conifers and broadleaves, it was noted that conifers with 31.8% in defoliation class 0 (not defoliated) were in a better condition than broadleaves with 21.3% not defoliated trees. 29.1% conifers and 30.1% broadleaves were assessed in defoliation classes 2-4. Among the young conifers (<60 years), the rates in defoliation classes 2-4 were for *Pinus sylvestris* 37.4%, followed by *Pinus nigra* (24.0%), *Larix decidua* (19.9%), and *Picea abies* (15.2%), whereas the best condition was observed for *Pinus halepensis* with 0.0%. Among the old conifers (>60 years), the highest percentage of trees in defoliation classes 2-4 was assessed for *Pinus nigra* (75.5%), followed by *Picea abies* (41.7%), *Pinus cembra* (24.1%), and *Larix decidua* (24.0%), while *Abies alba* had the lowest rate of defoliation among the conifers (22.5%). Among the young broadleaves (<60 years), 56.3% *Castanea sativa* and 46.3% *Quercus pubescens* were in defoliation classes 2 to 4, while the rates for other young broadleaves were distinctly lower: 15.4% *Quercus cerris*, 21.7% *Fagus sylvatica*, and 25.1% *Ostrya carpinifolia*. Among the old broadleaves (>60 years), 56.2% *Castanea sativa*, 42.6% *Quercus pubescens* were in defoliation classes 2-4, while very low defoliation levels were assessed for *Fagus sylvatica* (15.6%), *Quercus ilex* (14.0%), and *Ostrya carpinifolia* (13.7%)

93.1% of conifers and 95.8% of broadleaves did not show discolouration, only in young *Pinus sylvestris* stands 7.6% of the trees were in classes 2 to 4. For uneven aged coniferous stands, *Picea abies* showed 10.0% of the trees in discolouration classes 2 to 4.

Starting from 2005, a new methodology for a more detailed assessment of damage factors (biotic and abiotic) was introduced. The main results are as follows: Most of the observed symptoms were attributed to insects (25.5%), subdivided into defoliators (19,1%), wood borers (1.9%) aphids (0.9%), needle miners (0.8%), among fungi (5.9%) the most significant damages were attributable to “dieback and canker fungi” (3.4%). Among abiotic agents, “hail” (1.6%) was the most significant one.

9.1.17 Latvia

The forest condition survey 2010 in Latvia was carried out in parallel on two plot sets – on the old Level I plots on the 8 x 8 km grid, in total 325, including 92 plots on the transnational 16 x 16 km grid, and on recently established NFI plots, in total 115. Whilst the comparison of both data sets and the integration between ICP Level I and NFI is ongoing, the national report of 2010 is still based on the old Level I plot data.

In total, on 325 Level I plots 7 606 trees were assessed, of which 72% were conifers and 28% broadleaves. Of all tree species, 15.0% were not defoliated, 71.6% were slightly defoliated and 13.4% moderately defoliated to dead. Compared to 2009 no considerable changes were observed in the distribution in these classes. The proportion of trees in defoliation classes 2-4 remained to be about 5% higher for conifers than for broadleaves.

Mean defoliation of *Pinus sylvestris* was 21.8% (21.5% in 2009). Insignificant fluctuations of the mean defoliation, not exceeding 0.3 percentage points, were observed for *Pinus sylvestris* during the recent years. The share of moderately damaged to dead trees constituted 15.4% (15.1% in 2009). Mean defoliation of *Picea abies* was 20.4% - that is only 0.1 percent point higher than in 2009. Changes in the distribution of trees in defoliation classes are insignificant for *Picea abies* as well. The mean defoliation level of *Betula* spp. was 18.3% in 2010, staying practically at the same level as in previous years (18.5% in 2009). The share of trees in defoliation classes 2-4 decreased to 9%. The worst crown condition of all assessed tree species remained for *Fraxinus excelsior* with mean defoliation of 26.8% and 36.0% in defoliation classes 2 to 4 – however, based on data of a comparatively low number of trees in the survey.

Visible damage symptoms were observed to a lesser extent than in previous years, namely on 11.3% of the assessed trees (16.1% in 2009). No serious and extensive attacks of biotic agents were recorded in 2010. The outbreaks of spruce bark beetle (*Ips typographus*) and European pine sawfly (*Neodiprion sertifer*) observed in previous years have gradually decreased. Most frequently recorded damage was caused by direct action of man (19.3% of all cases), followed by fungi (16.1%) and abiotic factors (mostly wind, winter frost) (13.9%). The proportion of insect damage has decreased considerably compared to the previous years. The greatest share of trees with damage symptoms was recorded for *Populus* spp..

Alarming dieback of *Picea abies* stands was observed in several regions of Latvia in 2010, the causes of which are currently examined. In August 2010 windstorm damaged large forest areas in eastern Latvia, increasing the risk of new local attacks of bark beetles.

9.1.18 Lithuania

The national forest inventory and the regional forest health monitoring grids (4 x 4 km) in Lithuania are combined since 2008. The transnational grid of Level I (16 x 16 km) plots was kept unchanged and the monitoring activities were continued. In 2010 the forest condition survey was carried out on 1 065 sample plots from which 75 plots were on the transnational Level I grid and 990 plots on the national forest inventory grid. In total, 6 349 sample trees representing 19 tree species were assessed. The main tree species assessed were *Pinus sylvestris*, *Picea abies*, *Betula pendula*, *Betula pubescens*, *Populus tremula*, *Alnus glutinosa*, *Alnus incana*, *Fraxinus excelsior*, and *Quercus robur*.

The mean defoliation of all tree species slightly increased up to 22.6% (21.3% in 2009). 14.7% of all sample trees were not defoliated (class 0), 64.0% were slightly defoliated and 21.3% were assessed as moderately defoliated, severely defoliated and dead (defoliation classes 2-4). Mean defoliation of conifers was 22.0% (20.8% in 2009) and for broadleaves 23.4% (22.1% in 2009).

Mean defoliation of *Pinus sylvestris* was 21.5% (20.8% in 2009). Starting from 1998, mean defoliation of *Pinus sylvestris* has not exceeded 22.0%. The number of trees in defoliation classes 2-4 increased to 16.0% (14.9% in 2009). Mean defoliation of *Picea abies* increased to 22.9% (20.6% in 2009) and the share of trees in defoliation classes 2-4 increased to 25.8% (20.9% in 2009).

Populus tremula had the lowest mean defoliation and the lowest share of trees in defoliation classes 2-4. Mean defoliation of *Populus tremula* was 19.3% (17.8% in 2009) and the proportion of trees in defoliation classes 2-4 was 14.5% (9.3% in 2009). Mean defoliation of *Alnus glutinosa* decreased to 23.4% (25.1% in 2009) and the share of trees in defoliation classes 2-4 to 25.0% (27.9% in 2009). In 2009 – 2010 the condition of *Alnus glutinosa* was the worst in the whole observation period (1989 – 2010). Mean defoliation of *Alnus incana* increased up to 25.1% (23.2% in 2008). The share of trees in defoliation classes 2-4 distinctly increased up to 28.3% (19.6% in 2009). Mean defoliation of *Betula* spp. increased to 21.5% (19.8% in 2009) and the share of trees in defoliation classes 2-4 increased up to 19.6% (13.8% in 2009).

The condition of *Fraxinus excelsior* remained the worst between all observed tree species. This tree species had the highest defoliation since 2000. In 2007 – 2008 mean defoliation of *Fraxinus excelsior* has been gradually decreasing, but increased again in 2009 - 2010. The assessed mean defoliation was 41.2% (39.8% in 2009). The share of trees in defoliation classes 2-4 increased up to 55.6% (48.4% in 2009). Mean defoliation of *Quercus robur* was 3.2% percentage points higher than in 2009 (22.2%) and the number of trees in defoliation classes 2-4 increased up to 24.8% (16.8% in 2009).

21.1% of all sample trees had some kind of identifiable damage symptoms. The most frequent damage was caused by fungi (5.0%), abiotic agents (4.9%) and direct action of man (4.1%). The highest share of damage symptoms was assessed for *Fraxinus excelsior* (48.4%), *Alnus incana* (35.7%) and for *Populus tremula* (34.0%), the least for *Pinus sylvestris* (15.1%) and for *Alnus glutinosa* (16.8%).

In general, the mean defoliation of all tree species has slightly increased since 2007. However, mean defoliation of all tree species has varied inconsiderably from 1997 to 2010 and the condition of Lithuanian forests can be defined as relatively stable.

9.1.19 Republic of Moldova

In 2010, the forest condition survey was carried out on 622 plots on a 2 x 2 km grid. A total of 14 347 sample trees was assessed, 135 of them were conifers and 14 212 broadleaves.

The weather conditions of the reference year were favourable for the growth of arboreal and shrubby vegetation, which had a positive impact on stand conditions. Thus, for broadleaves, trees in defoliation classes 1-4 constituted 57.2% against 56.9% in the previous year. Trees without visible signs of damage constituted 42.8% against 43.1% in 2009.

In 2010 trees in discolouration classes 2-4 remained with 7.9% at the same level.

A decreasing number of trees in defoliation classes 2-4 was observed for *Robinia pseudoacacia* with 38.4% in comparison with 2009 (41.5%). In *Quercus robur* stands 27.3% of the trees were in these defoliation classes, and a distinct decrease could also be observed for *Fraxinus* with 20.4% in defoliation classes 2-4 (28.2% in 2009). The slight improvement of health condition of trees in 2010 reflects a stabilization of forest condition.

For conifers, a decrease in the percentage of trees in defoliation classes 2-4 was recorded, from 46.7% in 2009 to 33.3% in 2010. For *Pinus* spp. this index in 2009 was 54.6%, and in 2010 43.5%. For 2010 a decrease of trees in discolouration classes 2-4 was recorded: 4.6% in 2009 in comparison with 4.4% in 2010. All this indicates the stabilization of degradation processes of coniferous stands. Under favorable environmental conditions, it is likely that the degradation processes in the future will be stabilized at this level.

The number of trees with identified types of damage constituted 1 969 or 13.7%. The most common type of injury was damage caused by insects, which affected 73.1% of all trees with recorded damage.

9.1.20 The Netherlands

The 2010 crown condition survey was carried out on 11 Level I plots of the transnational 16 x 16 km grid net. Tree species on these plots are representative for the Dutch forest on sandy soils. The assessment covered 227 trees, 65.2% coniferous trees and 34.8% broadleaved trees. The main coniferous tree species was *Pinus sylvestris* comprising 83.1% of all sample trees, *Pseudotsuga menziesii* had a share of 11.0%. The broadleaved species was

Quercus robur comprising 34.8% of all sample trees. The mean defoliation of all tree species was estimated to 16.0%. The mean defoliation for coniferous trees was 12.1% (*Pinus sylvestris* 4.5% and *Pseudotsuga menziesii* 49.4%) and for broadleaves 23.4% in 2010. 40% of the trees assessed showed no defoliation.

29.5% of the assessed trees were classified as damaged. The respective figures were 2.6% for conifers and 26.9% for broadleaved trees. 0.4% of the assessed trees were found standing dead, this means having died since the last assessment in 2009. The main damage cause was drought.

Between 2006 and 2009 no tree assessments were performed on the Level I plots. Compared to 2006 and 2009 tree vitality of oak has slightly increased. Although during the spring of 2009 and 2010 oak was severely attacked by mainly *Operophthera brumata*. Tree vitality for *Pinus sylvestris* and *Pseudotsuga menziesii* have more or less stabilised in the same period.

9.1.21 Norway

The results for 2010 show a small decrease in crown defoliation for all tree species compared to the year before. The mean defoliation for *Picea abies* was 14.8%, for *Pinus sylvestris* it was 14.6%, and for *Betula* spp. 20.9%. After a peak with high defoliation for all 3 tree species in 2007, the last three years 2008-2010 represent a decrease in defoliation. During the last ten years *Betula* spp. had the lowest defoliation in 2001, while *Picea abies* and *Pinus sylvestris* had the same low defoliation in 2010 as in 2004.

Of all the coniferous trees, 50.1% were rated not defoliated in 2010, which is a small increase by about 1.4 percentage points compared to the year before. Only 40.8% of the *Pinus sylvestris* trees were rated as not defoliated, while 56.4% of all *Picea abies* trees were not defoliated, also an increase by 1.9 percentage points compared to the year before. For *Betula* spp. 28.4% of the trees were observed in the class not defoliated, also representing an increase by 2.1 percentage points compared to the year before. For *Betula* spp. and *Pinus sylvestris* especially the class ‘moderately defoliated’ decreased, to 26% and 11%, respectively in 2010. For other classes of defoliated trees, only small changes were observed.

In crown discolouration 9.3% discoloured trees were observed for *Picea abies*, the same as in 2009. For *Pinus sylvestris*, only 2.8% of the assessed trees were discoloured, also about the same as the year before. For *Betula* spp., the discolouration increased from 4.7% in 2009 to 7.7% in 2010. For *Betula* spp, the observed trees in the most serious classes ‘moderate discolouration’ and ‘severe discolouration’ was doubled: 3.0% and 1% respectively were observed in these classes in 2010.

The mean mortality rate for all species was 0.3% in 2010. The mortality rate was 0.4%, 0.3% and 0.3%, for *Picea abies*, *Pinus sylvestris* and *Betula* ssp., respectively. The mortality rate of *Betula* ssp. has been more normal over the last two years and has been clearly reduced from the high level of 1-1.8% which occurred in the tree year period 2006-2008 probably due to serious attacks of insects and fungi.

In general, the observed crown condition values result from interactions between climate, pests, pathogens and general stress. According to the Norwegian Meteorological Institute the summer (June, July and August) of 2010 was regarded as normal warm but with much more precipitation as normal. The mean temperature for the whole country was 0.4°C above normal, while the precipitation was 125% of the normal for these months which is the 4th wettest summer since 1900. There are of course large climatic variations between regions in Norway.

9.1.22 Poland

The 2010 survey was carried out on 1 957 plots. Forest condition was slightly worse than in the previous year. 21.0% of all sample trees were without any symptoms of defoliation, indicating a decrease by 3.1 percentage points compared to 2009. The proportion of defoliated trees (classes 2-4) increased by 3.0 percentage points to 20.7% in 2010. The share of trees defoliated more than 25% increased by 3.1 percentage points for conifers and by 2.9 percentage points for broadleaves.

18.8% of conifers were not suffering from defoliation. For 20.3% of the conifers, defoliation of more than 25% (classes 2-4) was observed. With regard to the three main coniferous species, *Picea abies* remained the species with the highest defoliation, indicating a slight worsening in younger stands and quite a great improvement in older stands. A share of 23.6% (22.6% in 2009) of *Picea abies* trees up to 59 years old and 24.4% (33.0% in 2009) of *Picea abies* trees 60 years old and older was in defoliation classes 2-4.

25.2% of the assessed broad-leaved trees were not defoliated. The proportion of trees with more than 25% defoliation (classes 2-4) amounted to 21.5%. As in the previous survey the highest defoliation amongst broad-leaved trees was observed in stands of *Quercus* spp and indicated a distinct worsening in younger stands. In 2010 a share of 29.3% (17.4% in 2009) of *Quercus* spp. trees up to 59 years old and 37.5% (37.1% in 2009) of *Quercus* spp. trees 60 years old and older was in defoliation classes 2-4.

9.1.23 Romania

In 2010, the assessment of crown condition on Level I plots in Romania was carried out on the 16 x 16 km transnational grid net, from 10th of July to 16th of September. The total number of sample trees was 5 736, which were assessed on 239 permanent plots. From the total number of trees, 1 082 were conifers and 4 654 broadleaves. Trees on 13 plots were harvested during the last year and several other plots were not accessible due to natural hazards.

For all species, 45.5% of the trees were rated as healthy, 36.8% as slightly defoliated, 16.6% as moderately defoliated, 0.9% as severely defoliated and 0.3% were dead. The percentage of damaged trees (defoliation classes 2-4) was 17.7%.

For conifers 16.1% of the trees were classified as damaged (classes 2-4). *Picea abies* was the least affected coniferous species with only 12.6% of the trees damaged (defoliation classes 2-4). For broadleaves 18.1% of the trees were assessed as damaged or dead (classes 2-4). From all broadleaved species, *Tillia* spp. had the lowest share of damaged trees (6.8%), followed by *Fagus sylvatica* with 13.7%. The most affected species was *Robinia pseudoaccacia* with a share of 27.3% damaged or dead trees (classes 2-4). For *Quercus* spp. a share of 25.2% trees was rated as damaged or dead. Compared to 2009, the overall share of damaged trees (classes 2-4) decreased by 1.2 percentage points. Forest health status was slightly influenced, mainly for conifers, by the relatively favourable weather conditions during the vegetation season.

Concerning the assessment of biotic and abiotic damage factors, most of the observed symptoms were attributed to insects (15.6%), and especially defoliators (14.8%), abiotic factors (8.7%), fungi (3.3%), and anthropogenic factors (2.5%).

In the framework of the FutMon project crown condition was assessed on plots of the National Forest Inventory as well on a 16 x 16 km grid, the share of the damaged trees differed by 1-3 percentage points compared to the results obtained in the Level I network. These findings are currently still analysed and interpreted statistically.

9.1.24 Russian Federation

In 2010, forest condition was assessed in 6 regions on the monitoring network of Russia. About 40% of the trees were considered ‘damaged’. Fire, men and insect pests were among the most frequent causes of direct damage of trees; they were observed on 6.5%, 7.8%, and 15.8% of the trees respectively. In the Murmansk region where the most severe sources of air pollution in Northern Europe are located, namely Cu-Ni smelters, no trees damaged by air pollution were noticed. The reason for that is an insufficient density of the network, the monitoring grid is 32 x 32 km. A denser network is in plan with a monitoring grid of 16 x 16 km and 8 x 8 km.

Compared to 2009, no significant increase in defoliation was found in 2010. The highest defoliation of *Pinus sylvestris* was observed in the Leningrad and Kaliningrad regions (11% and 12%), and relatively high defoliation of *Picea abies* in the Murmansk region (12%). As for the broad-leaved trees, *Alnus incana* showed highest defoliation in the Novgorod and Leningrad regions, and in Karelia (up to 16%), and *Fraxinus* spp. in the Kaliningrad region (12%).

Compared to 2009, the discolouration of trees was higher in the Kaliningrad region affecting 16%, 12%, 9%, and 9% for *Pinus sylvestris*, *Fraxinus* spp, *Quercus* spp. and *Betula* spp., respectively. Discolouration of *Picea abies* reached maximum values in the Murmansk region (12%). The level of discoloration of *Alnus incana* was highest in the Novgorod region (20%).

9.1.25 Serbia

A total of 2 786 trees was assessed on all sample plots, with 328 coniferous trees and a considerably higher number i.e. 2 458 broad-leaved trees. The coniferous tree species were: *Abies alba, Picea abies, Pinus nigra* and *Pinus silvestris,* and the most frequently occurring broadleaved tree species were: *Carpinus betulus, Fagus moesiaca, Quercus cerris, Quercus frainetto* and *Quercus petraea.*

For conifers, the share of trees with no defoliation was 70.1%, with slight defoliation 18.0%, with moderate defoliation 9.2% and with severe defoliation 2.7%. For broadleaves the percentages were as follows: no defoliation 66.8%, slight defoliation 22.5%, moderate defoliation 8.8%, severe defoliation 1.0% and dead trees 0.9%.

Discolouration was not detected on 89.3% of coniferous trees, slight discolouration on 9.8% and moderate on 0.9%. The degree of discolouration calculated for all broadleaved species was: no discolouration 95.5%, slight 2.8%, moderate 0.6%, severe discolouration 1.1% and dead 0.0%.

No visible damage types were observed on 85.1% of the conifers, 7.9% trees were with slight damage, 4.9% trees were moderately damaged and 2.1% trees were severely damaged. As for broadleaved tree species, the proportions were: no damage on 87.9% trees, 8.9% trees with slight damage, 1.6% moderately damaged trees, 0.8% trees with severe damage and 0.8% trees were dead.

Moderate and severe defoliation does not always imply a reduction of vitality caused by the effect of adverse agents (climate stress, insect pests, pathogenic fungi). Moderate and severe defoliation can as well be related to a temporary phase of natural variability of crown density.

9.1.26 Slovak Republic

The 2010 national crown condition survey was carried out on 108 Level I plots on the 16 x16 km grid net. The assessments covered 4 837 trees, 3 901 of which were being assessed as dominant or co-dominant trees. Of the 3 901 assessed trees, 38.6% were damaged (defoliation classes 2-4). The respective figures were 46.8% for conifers and 32.9% for broadleaves. Compared to 2009, the share of trees defoliated more than 25% increased by 6.5 percentage points. Mean defoliation for all tree species together was 26.0%, with 28.6% for conifers and 24.2% for broadleaves. Results show that crown condition in Slovak Republic is worse than on the European average. This is mainly due to the bad condition of coniferous species.

Compared to 2009 survey, worsening of mean defoliation was observed in all species except for *Robinia pseudoacacia* and *Abies alba*. Since 1987, the lowest damage was observed for *Fagus sylvatica* and *Carpinus betulus*, with an exception of fructification years. The most severely damaged species were *Abies alba*, *Picea abies* and *Robinia pseudacacia*.

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

As a part of the crown condition survey, damage types were assessed. 27.3% of all sample trees (4 837) had some kind of damage symptoms. The most frequent damage was caused by logging activities (14.0%) and fungi (11.0%) at tree stems. Additional damage causes were abiotic agents (6.4%), and insects (3.6%). Epiphytes had the most important influence on defoliation. 68% of trees damaged by epiphytes revealed defoliation above 25%.

9.1.27 Slovenia

In 2010, the Slovenian national forest health inventory was carried out on 44 systematically arranged sample plots on a 16 x 16 km grid net. The assessment encompassed 1 052 trees, 397 coniferous and 655 broadleaved trees. The sampling scheme and the assessment method were the same as in the previous years.

The mean defoliation of all tree species was estimated to 24.7%. In comparison to the results of 2009 when the mean defoliation was 26.1%, there was a change by 1.4 percentage points. In 2010, mean defoliation for coniferous trees was 24.1% and for broadleaves 24.5%.

The share of trees with more than 25% of unexplained defoliation (damaged trees) reached 31.8%. In comparison to the results of 2009, when the share of trees with more than 25% of unexplained defoliation was 35.4%, the value decreased by 4.1 percentage points. The change was specifically related to broadleaves where the share of damaged trees decreased from 33.3% in 2009 to 28.1% in 2010, while the share of damaged conifers decreased from 38.8% in 2009 to 37.8% in 2010.

As in the previous years conifers were still more damaged than broadleaves. While their mean defoliation and the share of damaged trees were assessed to 25.1% and 42.8% respectively (in 2009 26.4% and 39.1%), the values of the both indicators for broadleaves were assessed to 24.5% and 23.2% (in 2009 25.9% and 32.8%). The health condition of coniferous sample trees was worse than in 2009.

9.1.28 Spain

Results obtained in the 2010 inventory show a clear improvement in the general health condition of trees when compared to previous years. 85.4% of the surveyed trees were healthy (compared to 82.3% in the previous year). 12.2% of the trees were in defoliation classes 2 and 3, indicating defoliation levels higher than 25%. This is a clear improvement compared to 2009 when this percentage was 15.7%. The number of damaged trees decreased noticeably and the number of dead ones remained stable, with about a 2.3% of the trees surveyed. This general improvement was slightly lower for conifers, with 86.9% healthy trees (85.1% in the previous year), than for broadleaves (83.3% in 2010 and 79.3% in 2009).

The mortality of trees (2.0% dead trees of the total sample, the same percentage as in 2009) was due to strong water shortages which affected trees in previous years as well as to felling operations (frequent sanitary cuts).

Regarding the possible damaging agents, a general decrease is detected. This is especially remarkable in the case of damage due to drought, and in a lower degree to damage by insects. Damage caused by the pine processionary caterpillar (*Thaumetopoea pityiocampa*) and spring defoliators on broadleaves, decreased specifically. Records related to forest fires and to action of man increased slightly as did records of borers (*Cerambicidae* and *Buprestidae*), cochineal insects and some punctual attacks by insects which were, however, not very relevant on national scale.

The decline processes in *Pinus radiata* and *Pinus nigra* stands near the Cantabrian coasts continued as did the general presence of chestnut blight and chestnut ink disease in chestnut stands.

Mistletoe infestations have increased which is now a worrying trend and the decline process affecting *Populus* spp. stands near the Cantabrian coasts has again been confirmed. There are punctual decline processes in some juniper stands and a certain increase of damage related to the *Seca* syndrome.

The importance of atmospheric pollution for the evolution of forest condition is a factor which can not be quantified directly, as it is frequently disguised by other kind of processes which are more apparent. However, in combination with other agents it can contribute to the degradation processes of forests.

9.1.29 Sweden

The national results are based on the assessment of the main tree species *Picea abies* and *Pinus sylvestris* in the National Forest Inventory (NFI), and concern as previously only forest in thinning age or older. In total, 6 917 trees on 3 149 sample plots were assessed. The Swedish NFI is carried out on permanent as well as on temporary sample plots. The permanent sample plots, which are two thirds of the total sample, are remeasured every 5th year.

The proportion of trees with more than 25% defoliation was 25.5% for *Picea abies* (25.0% in 2009) and 10.5% for *Pinus sylvestris* (7.1% in 2009). Deterioration in both species compared to previous years was noticed in central Sweden. Increasing defoliation was also seen on *Pinus sylvestris* in southern Sweden.

An outbreak of the European spruce bark beetle (*Ips typographus*) has been noticed incentral Sweden. The outbreak in southern Sweden has declined, and the timber volume of *Picea abies* killed by the European bark beetle in 2010 in this region was estimated to 300 000 m3. In southeastern Sweden needle loss caused by the European pine sawfly (*Neodiprion sertifer*) has been observed on *Pinus sylvestris* .A new pest, Hungarian spruce scale (*Physokermes inopinatus*), caused damage on *Picea abies* in the southernmost Sweden. In northeastern Sweden the outbreak of chrysomyxa rust on *Picea abies* (*Chrysomyxa ledi*) was registered but less pronounced compared to 2009. In the same area resin top disease (*Cronartium flaccidum*) still is a problem in young *Pinus sylvestris* stands. Birch rust (*Melampsoridium betulinum*) had an outbreak in southern Sweden. The decline in Fraxinus excelsior has been continuing in southern Sweden. The decline is caused by a fungus (*Chalara fraxinea*). Although *Fraxinus excelsior* covers less than 1% of the total standing volume in Sweden, the trees are significant in the landscape of the agricultural areas.

9.1.30 Switzerland

In 2010 the Swiss national forest health inventory was carried out on 48 plots of the 16 x 16 km grid using the same sampling and assessment methods as in the previous years.

Crown condition in 2010 increased as compared to 2009. In 2010, 22.2% of the trees had more than 25% unexplained defoliation (i.e. subtracting the known causes such as insect damage, or frost damage; 2009: 18.3%) and 32.0% of the trees had more than 25% total defoliation (2009: 24.6%). There was no obvious explanation for the increase in transparency, in particular in deciduous tress.

The relatively high defoliation was somehow surprising as 2010 was characterized by extremely low fructification which followed a mast year. Low seed production was found for almost all tree species. For *Betula* spp. on Level I plots only 4% of all trees in 2010 had seeds, while in 2009 around 64% of all trees were recorded with seeds, for *Picea abies* in 2010 only 26% of all trees had fresh cones as compared to 63% in 2009.

On the other hand, low rates of insect defoliation or pathogens had been observed for most tree species in 2009. In 2010 the proportion of recorded insect increased, particularly for *Quercus* spp.. Annual mortality rates, however, remained very low (2 out of 1 000 trees died). For *Fraxinus excelsior*, so far no increased transparency or die-back could be detected neither on Level I nor on Level II plots. However, foliage discolouration and leaf fall in 2010 was extremely early in the areas where ash branch die-back occurred.

9.1.31 Turkey

In 2010, 13 009 trees were assessed for crown condition on 555 Level I plots. 28.4% of the assessed trees showed no defoliation (class 0). Mean defoliation rate was 19.2% for coniferous species and 22.1% for broadleaved species. There has been no significant change in tree vitality in comparison to results of 2009.

16.9% of the observed trees had defoliation scores greater than 25% (classes 2, 3 and 4). The proportions were 14.5% for coniferous species and 21.2% for broadleaved species. Among the most common coniferous species, defoliation of more than 25% was registered on 22.9% of the trees for *Pinus brutia*, 20.7% for *Juniperus excelsa*, 18.5% for *Pinus sylvestris*, 16.1% for *Pinus nigra* and 12.7% for *Abies nordmanniana*.

Among the most common broadleaved species, defoliation of more than 25% was registered on 29.5% of the trees for *Quercus pubescens*, 26.6% for *Quercus petraea*, 21.9% for *Quercus cerris*, 18.2% for *Fagus orientalis*, and 17.3% for *Quercus robur*. The most defoliated species were *Juglans regia* with 52.5% trees in defoliation classes 2-4 and *Ulmus glabra* with 46.3%.

There was no damage on 69% of all assessed trees. At the damaged trees, most of the observed symptoms were attributed to insects constituting a share of 31% of all damages, and abiotic factors with 10%. *Thaumetopoea pityocampa, Lymantria dispar, Tomicus destruens* were the major insects encountered. Damaging agents such as parasitism and competition constituted 20% of the registered damages.

The central and eastern Black Sea regions of Turkey were the regions with highest defoliation in 2010, as it was already the case in previous years. Furthermore, defoliation rates have increased in Southwestern regions in comparison to earlier years. 2010 results showed some recovery in terms of defoliation in Western Blacksea and Marmara regions in comparison to 2008. High levels of defoliation were observed in Kırklareli, İstanbul, Zonguldak, Amasya, Sinop, Artvin, İzmir ve Hatay provinces.

Crown condition, tree growth, deposition, ground vegetation, tree phenology, plant ozone injury and plant litterfall studies were conducted on 12 Level II plots. A laboratory which will be used for sample analysis in Forest Ecosystems Monitoring Program will soon be ready. As soon as the laboratory is ready for operation, other surveys requiring laboratory analysis will also be included in the future works.

9.1.32 United Kingdom

The scope of the Level I survey undertaken in the UK during 2010 encompassed the following species: *Fagus sylvatica*, *Quercus robur, Picea sitchensis, Picea abies* and *Pinus sylvestris*. A number of sites/trees were lost due to felling, windthrow and the loss of paint upon the trees over time and so a large number of replacements have been necessary making direct comparisons difficult to previous years. The National Forest Inventory (NFI) of Great Britain is locating 1-ha sample squares at all Level I and Level II sites to allow for comparison between data sets in future years where possible should these assessments continue.

Following a winter which was much colder than average, weather conditions in spring 2010 were slightly warmer than average but also drier than average. The amount of sunshine received during this time was also higher than average leading into a warmer and wetter summer than usual generally providing good growing conditions over most of the UK.

Mean defoliation rates from the 2010 assessments are Fagus sylvatica – 9.6%, Quercus robur – 44%, Picea sitchensis – 23%, Picea abies – 39% and Pinus sylvestris – 30%.

Insect damage was the greatest contributor to defoliation: 86% of recorded causes of attack in *Fagus sylvatica,* 70% of *Quercus robur*, 41% of *Picea sitchensis* and 30% of *Pinus sylvestris*. Fungal attacks were only recorded in high proportions in *Pinus sylvestris* (29%) and *Picea abies* (27%).

9.1.33 Ukraine

In 2010, 36 263 sample trees were assessed on 1 505 forest monitoring plots in 25 administrative regions of Ukraine. Mean defoliation of conifers was 10.5% and of broad-leaved trees 11.3%.

For the total sample only slight changes were observed compared to the previous year. In 2010, the percentage of healthy trees slightly increased (67.7% against 66.4%). At the same time, the share of slightly to moderately defoliated trees decreased from 33% to 32%.

For the sample of common sample trees (CSTs) (33 173 trees) inessential changes with tendency to improvement were observed. Mean defoliation slightly decreased in 2010 (10.9%), compared to 2009 (11.2%). Some improvement of tree condition was registered for CSTs of *Quercus robur, Fagus sylvatica,* and *Picea abies*. Changes are characterised by an increasing share of trees in defoliation class 0 (for *Picea abies* 4.1% and for *Fagus sylvarica* – 3.7%) and decreasing in all other classes. Acomparatively big amount of healthy trees was registered in *Pinus sylvestris* (72.9% in 0 class), and a relatively small amount of *Picea abies* (58.8% in 0 class). Among CSTs of *Pinus sylvestris* an increase in class 1 was observed with an insignificant decrease in all other classes. Some improvement of tree condition can be explained by a decreasing number of defoliating insects in 2010 compared to 2009.

9.1.34 United States of America

USDA Forest Service (USDA FS) continues its efforts into development of the Critical Loads (CL) approaches for the U.S. forests and other ecosystems. This is done in collaboration with other US agencies, such as the US EPA, National Park Service, US Geological Survey and the Bureau of Land Management as well as with various universities. Critical Loads is a scientifically accepted approach to link ecosystem effects to deposition loading, atmospheric concentrations and emissions of N and S pollutants. A successful implementation of this approach at the national scale requires a fully integrated monitoring and research approach — collocating deposition and ecosystem response data, processing and mapping the data, and documenting methods to develop CLs for a variety of purposes and scales. In order to accomplish this goal, scientists and managers conducting CL research in the U.S. have coordinated their activities through the NADP-CLAD (National Atmospheric

Deposition Program's Critical Loads for Atmospheric Deposition Science Subcommittee) with funding provided by US EPA, National Park Service, and the Forest Service. CLAD is currently spearheading an effort to consolidate the CL data and protocols developed under various agencies/universities into regional/national scale CL data layers or maps for aquatic and terrestrial acidification, and nutrient nitrogen excess. This effort which is named "FOCUS" has three goals: (1) Use the UNECE "call for CL data" to develop consistent regional/ national-scale critical loads & identify gaps and issues with consolidating data from multiple agencies and organizations; (2) identify geographic and ecosystem type gaps in CL development (including differences in methods, approaches, and assumptions); and 3) develop CL maps at scales the data permits preliminary use within the U.S. To fulfill these goals, a Project Manager has already been hired, and data processing has started with full participation of the USDA FS scientists and Air Quality Specialists. Phase II will entail a "data gap" analysis to identify overlap in monitoring efforts and infrastructure needs for monitoring and data collection and processing, including selected sites in the USDA FS Experimental Forest and Ranges.

An example of the experimental work related to forest health that addresses potential effects of ambient ozone and N deposition is a new study in the Lake Tahoe Basin in California & Nevada. This is a joint effort between the USDA FS Pacific Southwest Research Station, USDA FS managers representing Region 5 (California), the Desert Research Institute in Reno, Nevada, and several universities. In this study distribution of ozone, precursors of O_3 formation and gaseous pollutants that are important contributors to atmospheric nitrogen (N) deposition in the Lake Tahoe Basin are being characterized. In summer 2010, passive samplers were used for monitoring O_3, nitric oxide (NO), nitrogen dioxide (NO_2), ammonia (NH_3), nitric acid (HNO_3) and volatile organic compounds (VOCs) on a network of 32 sites inside and outside of the Basin. On a subset of 10 monitoring sites, real-time O_3 concentrations were measured with portable active UV absorption monitors to evaluate diurnal changes of the pollutant, calibrate passive O_3 samplers, and use that data for evaluation of the exceedances of O_3 air pollution standards in the Basin. At the same sites N deposition was measured with ion exchange resin (IER) collectors placed in forest clearings (bulk precipitation) and under tree canopies (throughfall). In these bulk and throughfall samples from the IER collectors the stable isotope composition (^{15}N and ^{18}O) of NO_3 and of NH_3 (^{15}N) will be measured from passive sampler extracts to evaluate the origin of N deposition in the Basin. Results of this study will help to evaluate the present and future potential of O_3 formation as well as the biological/ecological effects of N air pollutants and the resulting N deposition in the Lake Tahoe Basin. These results will also help to develop science-based management strategies aimed at improving air quality and ecological sustainability of the Basin.

9.2 Annex: National results

9.2.1 Forests and surveys in European countries (2010).

Participating countries	Total area (1000 ha)	Forest area (1000 ha)	Coniferous forest (1000 ha)	Broadleav. forest (1000 ha)	Area surveyed (1000 ha)	Grid size (km x km)	No. of sample plots	No. of sample trees
Albania	2875	1063	171	600	no survey in 2010			
Andorra	47	18	15	2	18	16 x 16	3	72
Austria	8385	3878	2683	798	3481	16 x 16	135	3087
Belarus	20760	7963	4764	3199	7963	16 x 16	410	9615
Belgium	3035	700	281	324	700	$4^2 / 8^2$	119	2750
Bulgaria	11100	4064	1289	2775	4064	$4^2/8^2/16^2$	159	5569
Croatia	5654	2061	321	1740	2061	16 x 16	84	2016
Cyprus	925	298	172	0	138	16x16	15	362
Czech Republic	7886	2647	2014	633	2647	$8^2/16^2$	132	5330
Denmark	4310	580	294	266	580	$7^2/16^2$	25	615
Estonia	4510	2209	1108	1101	2209	16 x 16	97	2348
Finland	30415	20150	17974	1897	19871	16^2 / 24x32	932	7876
France	54883	15840	4041	9884	13100	16 x 16	532	10584
Germany	35702	11076	6490	3857	10347	$16^2 / 4^2$	415	10159
Greece	12890	2034	954	1080	2034		90	2135
Hungary	9300	1913	216	1697	1913	16 x 16	77	1848
Ireland	7028	680	399	37	436	16 x 16	36	539
Italy	30128	8675	1735	6940		16 x 16	253	8338
Latvia	6459	3162	1452	1710	3162	8 x 8	325	7606
Liechtenstein	16	8	6	2	no survey in 2010			
Lithuania	6530	2160	1155	896		4x4/16x16	1065	6349
Luxembourg	259	89	30	54	no survey in 2010			
FYR of Macedonia					no survey in 2010			
Rep. of Moldova	3384	401	8	367	375	2 x 2	622	14347
The Netherlands	3482	360	140	136	360	16 x 16	11	227
Norway	32376	12000	6800	5200	12000	$3^2/9^2$	1651	9417
Poland	31268	9200	6955	2245	9200	16 x 16	1957	39154
Portugal	8893	3234	1081	2153	no survey in 2010			
Romania	23839	6233	1873	4360	6233	16 x 16	239	5736
Russian Fed.	1700075	809090	405809	195769	36173	32 x 32	288	8992
Serbia	8836	2360	179	2181	1868	16 x 16/4 x 4	130	2786
Slovak Republic	4901	1961	815	1069	1961	16 x 16	108	3901
Slovenia	2027	1099	410	688	1099	16 x 16	44	1052
Spain	50471	18173	6600	9626		16 x 16	620	14880
Sweden	41000	28300	19600	900	20600	varying	3149	6917
Switzerland	4129	1186	818	368	1186	16 x 16	48	1040
Turkey	77846	21189	12773	8416	8884	16 x 16	555	13009
Ukraine	60350	9400	2756	3285	6033	16 x 16	1505	36263
United Kingdom	20933	2665	1306	854		16 x 16	80	1912
TOTAL	2340295	1011868	514955	271591	180696	varying	15911	246831

9.2.2 Percent of trees of all species by defoliation classes and class aggregates (2010).

Participating countries	Area surveyed (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2010				
Andorra	18	72	58.3	26.4	13.9	1.4	15.3
Austria	3481	3087	54.9	30.9	11.9	2.3	14.2
Belarus	7963	9615	29.5	63.1	6.0	1.4	7.4
Belgium	700	2750	26.9	51.0	20.3	1.8	22.1
Bulgaria	4064	5569	29.6	46.6	21.9	1.9	23.8
Croatia		2016	35.1	37.0	22.9	5.0	27.9
Cyprus	138	362	12.2	68.6	17.8	1.4	19.2
Czech Republic	2647	5330	13.1	32.7	52.7	1.5	54.2
Denmark	580	615	70.6	20.2	4.6	4.7	9.3
Estonia	2209	2348	52.8	39.1	5.9	2.2	8.1
Finland	19871	7876	52.4	37.2	8.9	1.6	10.5
France	13100	10584	28.1	37.2	31.0	3.6	34.6
Germany	10347	10159	37.8	39.0	21.5	1.7	23.2
Greece	2034	2135	44.5	31.7	20.2	3.6	23.8
Hungary	1913	1848	49.3	28.9	14.7	7.1	21.8
Ireland	399	539	70.9	11.6	7.4	10.1	17.5
Italy		8338	28.0	42.2	25.8	4.0	29.8
Latvia	3162	7606	15.0	71.6	11.7	1.7	13.4
Liechtenstein			no survey in 2010				
Lithuania		6349	14.7	64.0	19.0	2.3	21.3
Luxembourg			no survey in 2010				
FYR of Macedonia			no survey in 2010				
Rep. of Moldova	375	14347	42.8	34.7	20.5	2.0	22.5
The Netherlands	360	227	56.4	22.0	18.9	2.2	21.6
Norway	12000	9417	44.8	36.3	15.7	3.2	18.9
Poland	9200	39154	21.0	58.3	19.6	1.1	20.7
Portugal			no survey in 2010				
Romania		5736	45.5	36.8	16.6	1.2	17.8
Russian Fed.	36173	8992	82.6	13.0	3.8	0.6	4.4
Serbia	1868	2786	67.2	22.0	8.8	2.0	10.8
Slovak Republic	1961	3901	9.5	51.9	37.2	1.4	38.6
Slovenia	1099	1052	18.3	50.0	27.7	4.1	31.8
Spain		14880	24.3	61.1	11.1	3.5	14.6
Sweden	20600	7052	56.3	26.6	14.5	2.6	17.1
Switzerland	1186	1040	25.3	52.5	12.8	9.4	22.2
Turkey	8884	13009	28.4	54.8	14.7	2.1	16.8
Ukraine	6033	36263	67.7	26.5	5.5	0.3	5.8
United Kingdom		1912	20.8	30.7	46.0	2.5	48.5

Andorra, Cyprus, Ireland, Sweden: Only conifers assessed.

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

9.2.3 Percent of conifers by defoliation classes and class aggregates (2010)

Participating countries	Coniferous forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2010				
Andorra	18	72	58.3	26.4	13.9	1.4	15.3
Austria	2683	2791	55.0	30.5	12.4	2.1	14.5
Belarus	4764	6937	26.7	65.6	6.4	1.3	7.7
Belgium	281	840	25.0	58.8	15.5	0.7	16.2
Bulgaria	1289	2936	23.2	45.7	27.9	3.2	31.1
Croatia	321	272	12.9	20.2	52.9	14.0	66.9
Cyprus	172	360	12.2	68.6	17.8	1.4	19.2
Czech Republic	2014	4194	12.1	27.8	58.3	1.8	60.1
Denmark	294	260	78.8	15.8	4.2	1.2	5.4
Estonia	1108	2071	50.5	40.5	6.5	2.5	9.0
Finland	17974	6543	51.5	37.9	9.2	1.4	10.6
France	4041	3680	42.8	29.8	25.1	2.3	27.4
Germany	6490	6150	42.4	38.4	18.0	1.2	19.2
Greece	954	1150	42.3	34.0	21.4	2.3	23.7
Hungary	216	254	35.8	29.1	21.3	13.8	35.1
Ireland	399	539	70.9	11.6	7.4	10.1	17.5
Italy	1735	2269	32.0	38.9	25.4	3.7	29.1
Latvia	1452	5478	9.8	75.2	13.3	1.7	15.0
Liechtenstein			no survey in 2010				
Lithuania	1155	3801	12.6	67.6	18.3	1.5	19.8
Luxembourg			no survey in 2010				
FYR of Macedonia			no survey in 2010				
Rep. of Moldova	8	135	27.4	39.3	33.3	0.0	33.3
The Netherlands	140	148	75.0	6.1	15.5	3.4	18.9
Norway	6800	7143	50.1	33.5	13.6	2.8	16.4
Poland	6955	25753	18.8	60.9	19.3	1.0	20.3
Portugal			no survey in 2010				
Romania	1873	1082	49.1	34.8	14.6	1.5	16.1
Russian Fed.	405809	5584	80.4	14.5	4.4	0.7	5.1
Serbia	179	328	70.1	18.0	9.2	2.8	12.0
Slovak Republic	815	1595	5.7	47.5	44.5	2.3	46.8
Slovenia	410	397	21.9	40.3	33.0	4.8	37.8
Spain	5910	7469	27.2	59.7	9.5	3.6	13.1
Sweden	19600	7052	56.3	26.6	14.5	2.6	17.1
Switzerland	818	725	22.0	57.1	13.2	7.7	20.9
Turkey	12773	8329	29.9	55.7	13.0	1.5	14.5
Ukraine	2756	15209	69.3	25.1	5.4	0.2	5.6
United Kingdom	1306	824	28.0	33.4	36.9	1.7	38.6

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

9.2.4 Percent of broadleaves by defoliation classes and class aggregates (2010).

Participating Countries	Broadleav. forest (1000 ha)	No. of sample trees	0 none	1 slight	2 moderate	3+4 severe and dead	2+3+4
Albania			no survey in 2010				
Andorra	2		only conifers assessed				
Austria	798	296	54.7	34.8	7.1	3.4	10.5
Belarus	3199	2678	36.7	56.4	5.1	1.8	6.9
Belgium	783	1910	27.7	47.7	22.3	2.3	24.6
Bulgaria	2775	3173	34.5	47.3	17.3	0.9	18.2
Croatia	1740	1744	38.5	39.6	18.2	3.7	21.9
Cyprus			only conifers assessed				
Czech Republic	633	1136	17.0	50.8	31.7	0.5	32.2
Denmark	266	355	64.5	23.4	4.8	7.3	12.1
Estonia	1101	277	70.1	27.4	1.8	0.7	2.5
Finland	1897	1333	56.8	34.0	7.5	1.7	9.2
France	9884	6864	20.2	41.1	34.3	4.4	38.7
Germany	3857	4009	30.4	40.1	27.3	2.1	29.4
Greece	1080	985	47.1	29.0	18.8	5.1	23.9
Hungary	1697	1594	51.5	28.8	13.7	6.0	19.7
Ireland	37		only conifers assessed				
Italy		6069	26.6	43.3	25.9	4.2	30.1
Latvia	1710	2128	28.3	62.3	7.3	2.1	9.4
Liechtenstein	2		no survey in 2010				
Lithuania	896	2548	17.7	58.6	20.1	3.6	23.7
Luxembourg	54		no survey in 2010				
FYR of Macedonia			no survey in 2010				
Rep. of Moldova	367	14212	42.9	34.7	20.4	2.0	22.4
			no survey in 2010				
The Netherlands	136	79	21.5	51.9	25.3	1.3	26.6
Norway	5200	2276	28.3	44.9	22.1	4.7	26.8
Poland	2245	13426	25.2	53.3	20.1	1.4	21.5
Portugal	2153		no survey in 2010				
Romania	4360	4654	44.8	37.2	17.0	1.0	18.0
Russian Fed.	195769	3408	86.1	10.7	2.9	0.3	3.2
Serbia	2181	2458	66.8	22.5	8.8	1.9	10.7
Slovak Republic	1069	2306	12.1	55.0	32.2	0.7	32.9
Slovenia	688	655	16.0	55.9	24.4	3.7	28.1
Spain	4056	7411	21.4	62.5	12.8	3.3	16.1
Sweden	900		only conifers assessed				
Switzerland	368	289	32.5	42.3	12.0	13.2	25.2
Turkey	8416	4680	25.6	53.2	17.8	3.4	21.2
Ukraine	3285	20364	64.7	28.9	6.0	0.4	6.4
United Kingdom	854	1088	15.3	28.6	52.9	3.2	56.1

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

9.2.5 Percent of damaged trees of all species (1999-2010)

Participating countries	All species Defoliation classes 2-4												change % points
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2009/ 2010
Albania	9.9	10.1	10.2	13.1		12.2		11.1					
Andorra						36.1		23.0	47.2	15.3	6.8	15.3	8.5
Austria	6.8	8.9	9.7	10.2	11.1	13.1	14.8	15.0				14.2	
Belarus	26.0	24.0	20.7	9.5	11.3	10.0	9.0	7.9	8.1	8.0	8.4	7.4	-1.0
Belgium	17.7	19.0	17.9	17.8	17.3	19.4	19.9	17.9	16.4	14.5	20.2	22.1	1.9
Bulgaria	44.2	46.3	33.8	37.1	33.7	39.7	35.0	37.4	29.7	31.9	21.1	23.8	2.7
Croatia	23.1	23.4	25.0	20.6	22.0	25.2	27.1	24.9	25.1	23.9	26.3	27.9	1.6
Cyprus			8.9	2.8	18.4	12.2	10.8	20.8	16.7	47.0	36.2	19.2	-17.0
Czech Rep.	50.4	51.7	52.1	53.4	54.4	57.3	57.1	56.2	57.1	56.7	56.8	54.2	-2.6
Denmark	13.2	11.0	7.4	8.7	10.2	11.8	9.4	7.6	6.1	9.1	5.5	9.3	3.8
Estonia	8.7	7.4	8.5	7.6	7.6	5.3	5.4	6.2	6.8	9.0	7.2	8.1	0.9
Finland	11.4	11.6	11.0	11.5	10.7	9.8	8.8	9.7	10.5	10.2	9.1	10.5	1.4
France	19.7	18.3	20.3	21.9	28.4	31.7	34.2	35.6	35.4	32.4	33.5	34.6	1.1
Germany	21.7	23.0	21.9	21.4	22.5	31.4	28.5	27.9	24.8	25.7	26.5	23.2	-3.3
Greece	16.6	18.2	21.7	20.9			16.3				24.3	23.8	-0.5
Hungary	18.2	20.8	21.2	21.2	22.5	21.5	21.0	19.2	20.7		18.4	21.8	3.4
Ireland	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	6.0	10.0	12.5	17.5	5.0
Italy	35.3	34.4	38.4	37.3	37.6	35.9	32.9	30.5	35.7	32.8	35.8	29.8	-6.0
Latvia	18.9	20.7	15.6	13.8	12.5	12.5	13.1	13.4	15.0	15.3	13.8	13.4	-0.4
Liechtenstein													
Lithuania	11.6	13.9	11.7	12.8	14.7	13.9	11.0	12.0	12.3	19.6	17.7	21.3	3.6
Luxembourg	19.2	23.4											
FYR of Macedonia													
Rep. of Moldova		29.1	36.9	42.5	42.4	34.0	26.5	27.6	32.5	33.6	25.2	22.5	-2.7
The Netherlands	12.9	21.8	19.9	21.7	18.0	27.5	30.2	19.5			18.2	21.6	3.4
Norway	28.6	24.3	27.2	25.5	22.9	20.7	21.6	23.3	26.2	22.7	21.0	18.9	-2.1
Poland	30.6	32.0	30.6	32.7	34.7	34.6	30.7	20.1	20.2	18.0	17.7	20.7	3.0
Portugal	11.1	10.3	10.1	9.6	13.0	16.6	24.3						
Romania	12.7	14.3	13.3	13.5	12.6	11.7	8.1	8.6	23.2		18.9	17.8	-1.1
Russian Fed.			9.8	10.9							6.2	4.4	-1.8
Serbia	11.2	8.4	14.0	3.9	22.8	14.3	16.4	11.3	15.4	11.5	10.3	10.8	0.5
Slovak Rep.	27.8	23.5	31.7	24.8	31.4	26.7	22.9	28.1	25.6	29.3	32.1	38.6	6.5
Slovenia	29.1	24.8	28.9	28.1	27.5	29.3	30.6	29.4	35.8	36.9	35.5	31.8	-3.7
Spain	12.9	13.8	13.0	16.4	16.6	15.0	21.3	21.5	17.6	15.6	17.7	14.6	-3.1
Sweden	13.2	13.7	17.5	16.8	19.2	16.5	18.4	19.4	17.9	17.3	15.1	17.1	2.0
Switzerland	19.0	29.4	18.2	18.6	14.9	29.1	28.1	22.6	22.4	19.0	18.3	22.2	3.9
Turkey									8.1	24.6	18.7	16.8	-1.9
Ukraine	56.2	60.7	39.6	27.7	27.0	29.9	8.7	6.6	7.1	8.2	6.8	5.8	-1.0
United Kingdom	21.4	21.6	21.1	27.3	24.7	26.5	24.8	25.9	26.0			48.5	

Andorra, Cyprus, Ireland, Sweden: Only conifers assessed. *Andorra:* observe the small sample size. *Austria*: From 2003 on. results are based on the 16x16 km transnational grid net and must not be compared with previous years. *Poland*: Change of grid net since 2006. *Russian Federation:* North-western and Central European parts only. *Ukraine*: Change of gridnet in 2005. *Hungary, Romania*: comparisons not possible due to changing survey designs. *Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.*

9.2.6 Percent of damaged conifers (1999-2010).

Paticipating countries	Conifers Defoliation classes 2-4												change % points
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2009/ 2010
Albania	12.1	12.3	12.4	15.5		14.0		13.6					
Andorra						36.1		23.0	47.2	15.3	6.8	15.3	8.5
Austria	6.4	9.1	9.6	10.1	11.2	13.1	15.1	14.5				14.5	
Belarus	28.9	26.1	23.4	9.7	9.5	8.9	8.4	7.5	8.1	8.1	8.3	7.7	-0.6
Belgium	15.5	19.5	17.5	19.7	18.6	15.6	16.8	15.8	13.9	13.2	13.6	16.2	2.6
Bulgaria	48.9	46.4	39.1	44.0	38.4	47.1	45.4	47.6	37.4	45.6	33.0	31.1	-1.9
Croatia	53.2	53.3	65.1	63.5	77.4	70.6	79.5	71.7	61.1	59.1	66.5	56.9	-9.6
Cyprus			8.9	2.8	18.4	12.2	10.8	20.8	16.7	46.9	36.2	19.2	-17.0
Czech Rep.	57.4	58.3	58.1	60.1	60.7	62.6	62.7	62.3	62.9	62.8	63.1	60.1	-3.0
Denmark	9.9	8.8	6.7	4.5	6.1	5.8	5.5	1.7	3.1	9.9	1.0	5.4	4.4
Estonia	9.1	7.5	8.8	7.9	7.7	5.3	5.6	6.0	6.7	9.3	7.5	9.0	1.5
Finland	11.9	12.0	11.4	11.9	11.1	10.1	9.2	9.6	10.4	10.1	9.9	10.6	0.7
France	14.1	12.0	14.0	15.2	18.9	18.6	20.8	23.6	24.1	25.1	26.8	27.4	0.6
Germany	19.2	19.6	20.0	19.8	20.1	26.3	24.9	22.7	20.2	24.1	20.3	19.2	-1.1
Greece	13.5	16.5	17.2	16.1			15.0				26.3	23.7	-2.6
Hungary	17.6	21.5	19.5	22.8	27.6	24.2	22.0	20.8	22.3		27.1	35.1	8.0
Ireland	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	6.2	10.0	12.5	17.5	5.0
Italy	23.1	19.2	19.1	20.5	20.4	21.7	22.8	19.5	22.7	24.0	31.6	29.1	-2.5
Latvia	20.6	20.1	15.8	14.3	12.2	11.9	13.2	15.2	16.2	16.7	14.8	15.0	0.2
Liechtenstein													
Lithuania	11.5	12.0	9.8	9.3	10.7	10.2	9.3	9.5	10.2	19.1	17.4	19.8	2.4
Luxembourg	8.7	7.0											
FYR. of Macedonia													
Rep. of Moldova					55.4	35.5	38.0	38.6	34.3			33.3	
The Netherlands	14.5	23.5	20.7	17.5	9.4	17.2	17.9	15.3			14.1	18.9	4.8
Norway	24.3	21.8	25.1	24.1	21.2	16.7	19.7	20.2	23.0	19.2	17.9	16.4	-1.5
Poland	30.6	32.1	30.3	32.5	33.2	33.4	29.6	21.1	20.9	17.5	17.2	20.3	3.1
Portugal	6.0	4.3	4.3	3.6	5.3	10.8	17.1						
Romania	9.1	9.8	9.6	9.9	9.8	7.6	4.7	5.2	21.8		21.7	16.1	-5.6
Russian Fed.			9.8	10.0							7.3	5.1	-2.2
Serbia	9.2	10.0	21.3	7.3	39.6	19.8	21.3	12.6	13.3	13.0	12.6	12.0	-0.6
Slovak Rep.	40.2	37.9	38.7	40.4	39.7	36.2	35.3	42.4	37.5	41.1	42.7	46.8	4.1
Slovenia	38.0	34.5	32.2	31.4	35.3	37.4	33.8	32.1	36.0	40.7	38.8	37.8	-1.0
Spain	9.8	12.0	11.6	15.6	14.1	14.0	19.4	18.7	15.8	12.9	14.9	13.1	-1.8
Sweden	13.6	13.5	18.4	17.7	20.4	16.0	19.6	20.1	17.9	17.3	15.1	17.1	2.0
Switzerland	18.3	33.0	19.1	19.9	13.3	27.4	28.2	22.5	20.7	18.7	18.8	20.9	2.1
Turkey									8.1	16.2	16.0	14.5	-1.5
Ukraine	50.0	47.3	16.8	14.6	15.4	11.4	8.1	6.9	7.1	7.1	6.3	5.6	-0.7
United Kingdom	20.1	20.2	20.6	25.1	25.8	23.2	22.2	23.3	16.1			38.6	

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

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

9.2.7 Percent of damaged broadleaves (1999-2010).

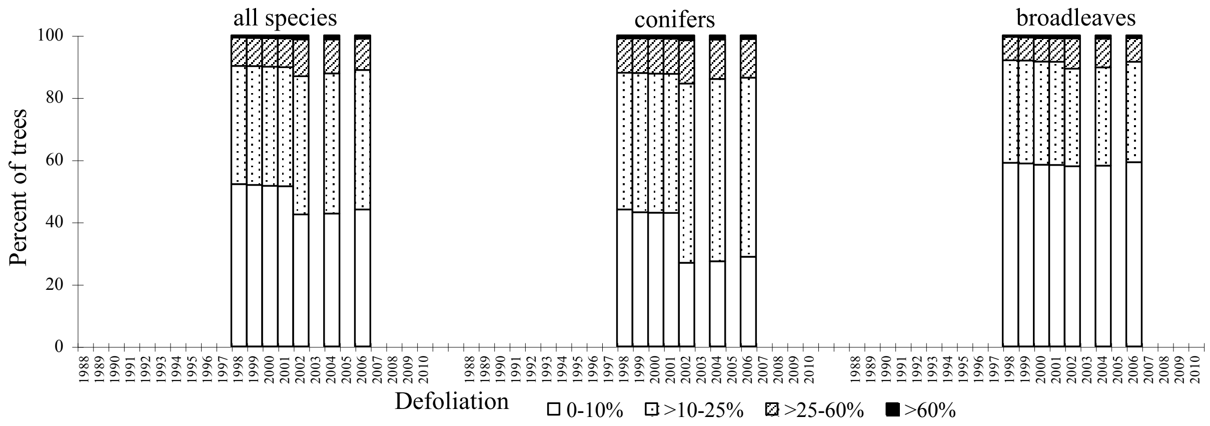
Paticipating countries	Broadleaves Defoliation classes 2-4												change % points
	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2009/ 2010
Albania	8.1	8.4	8.4	10.7		10.3		8.5					
Andorra							only conifers assessed						
Austria	9.4	7.6	10.4	11.3	10.2	13.6	12.9	20.1				10.5	
Belarus	17.0	16.9	13.3	9.0	15.8	12.9	10.6	8.9	8.2	7.6	8.7	6.9	-1.8
Belgium	19.1	18.8	18.3	17.0	16.6	21.3	21.4	18.8	17.5	15.3	23.4	24.6	1.2
Bulgaria	35.9	45.8	26.0	29.0	27.2	30.1	23.1	36.4	21.1	17.8	12.2	18.2	6.0
Croatia	16.8	18.3	18.7	14.4	14.3	17.2	19.2	18.2	20.0	19.1	20.7	21.9	1.2
Cyprus							only conifers assessed						
Czech Rep.	17.1	21.4	21.7	19.9	24.4	31.8	32.0	31.2	33.5	32.2	32.9	32.2	-0.7
Denmark	18.8	13.9	8.5	15.4	16.6	19.1	14.4	14.8	10.3	8.0	10.0	12.1	2.1
Estonia	1.1	9.5	2.1	2.7	6.7	5.3	3.4	8.6	7.6	3.4	3.5	2.5	-1.0
Finland	8.6	9.9	8.8	8.8	8.3	8.4	7.2	10.3	10.9	10.6	4.7	9.2	4.5
France	22.9	21.6	23.6	25.5	33.5	38.7	41.3	42.0	41.6	36.5	37.1	38.7	1.6
Germany	26.9	29.9	25.4	24.7	27.3	41.5	35.8	37.2	32.8	28.4	36.1	29.4	-6.7
Greece	20.2	20.2	26.6	26.5			17.9				5.2	23.9	18.7
Hungary	18.2	20.8	21.5	20.8	22.0	21.0	20.9	19.0	20.6		17.1	19.7	2.6
Ireland							only conifers assessed						
Italy	39.3	40.5	46.3	44.6	45.0	42.0	36.5	35.2	40.4	35.8	36.8	30.1	-6.7
Latvia	14.2	22.2	14.8	12.8	13.5	14.3	12.9	8.5	11.8	11.5	11.6	9.4	-2.2
Liechtenstein													
Lithuania	11.8	17.7	16.3	19.0	24.6	21.8	15.4	16.6	17.7	20.3	18.4	23.7	5.3
Luxembourg	25.8	33.5											
FYR. of Macedonia													
Rep. of Moldova	41.4	29.2	36.9	42.5	42.3	33.9	26.4	27.6	7.4	33.6	25.2	22.4	-2.8
The Netherlands	10.0	18.8	18.5	29.6	33.7	46.9	53.1	26.2			25.6	26.6	1.0
Norway	44.8	34.0	33.7	30.4	29.0	33.2	27.6	33.2	36.3	33.8	31.0	26.8	-4.2
Poland	31.1	32.0	31.4	33.1	39.6	38.7	34.1	18.0	18.9	19.1	18.5	21.5	3.0
Portugal	13.7	13.2	12.8	12.6	16.2	19.0	27.0						
Romania	14.0	15.8	14.7	14.8	13.3	13.0	9.3	9.9	23.5		18.3	18.0	-0.3
Russian Fed.				16.0							4.4	3.2	-1.2
Serbia	13.0	6.7	6.7	0.6	21.5	13.5	15.7	11.0	15.7	11.3	9.9	10.7	0.8
Slovak Rep.	19.3	13.9	26.9	14.5	25.6	19.9	13.6	17.0	16.6	20.8	24.5	32.9	8.4
Slovenia	23.2	18.4	26.7	25.9	22.6	24.2	28.5	27.6	35.7	34.6	33.3	28.1	-5.2
Spain	16.1	15.7	14.4	17.3	19.1	16.1	23.3	24.4	19.5	18.4	20.7	16.1	-4.6
Sweden	8.7	7.5	14.1	9.6	11.1	8.3	9.2	10.8		only conifers assessed			
Switzerland	20.4	22.1	16.3	16.0	18.1	32.8	27.9	22.6	26.1	19.6	17.4	25.2	7.8
Turkey										38.3	23.4	21.2	-2.2
Ukraine	59.7	69.6	53.3	36.7	35.3	43.2	9.2	6.2	7.1	9.1	7.2	6.4	-0.8
United Kingdom	23.2	23.8	21.9	30.3	23.2	30.6	28.2	29.2	35.3			56.1	

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

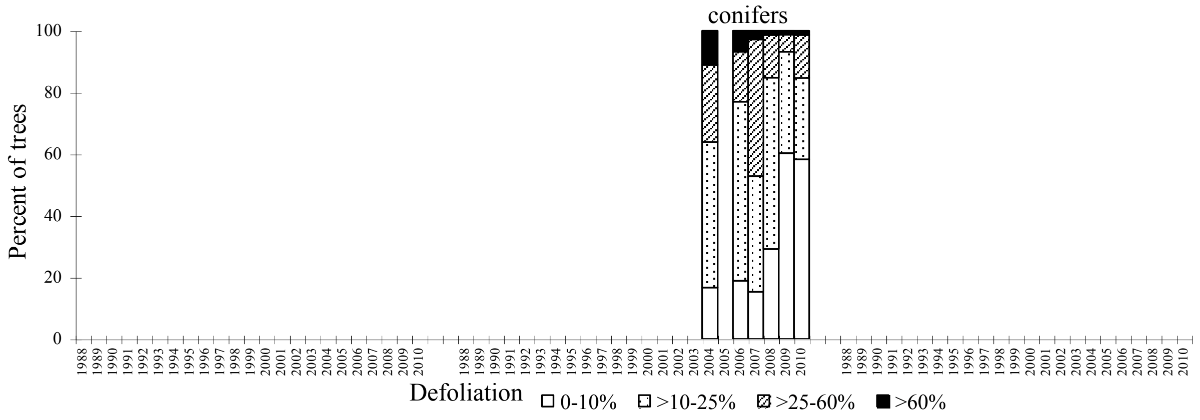
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used.

9.2.8 Changes in defoliation (1988-2010)

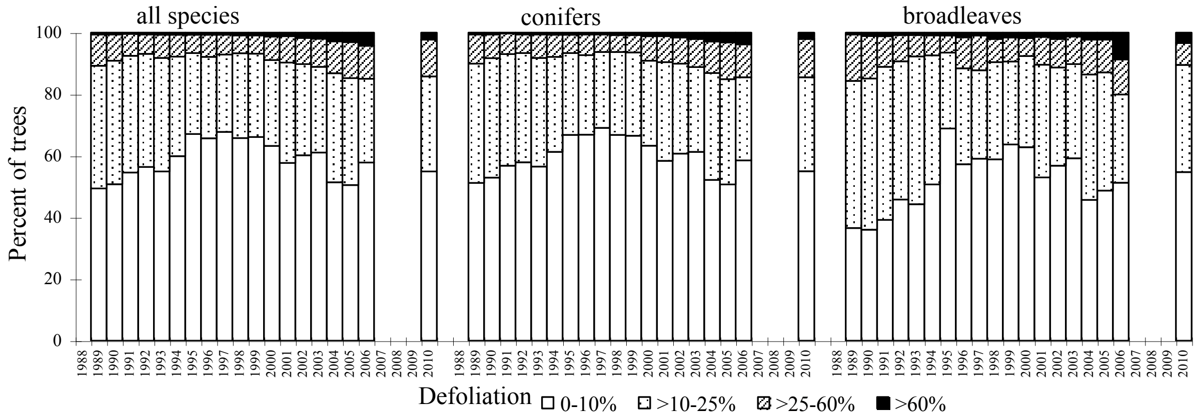
Albania



Andorra

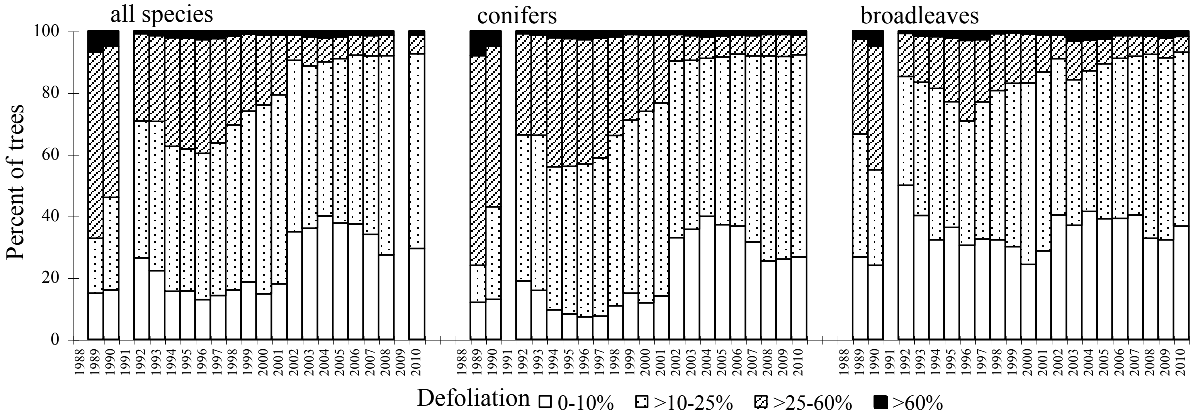


Austria *

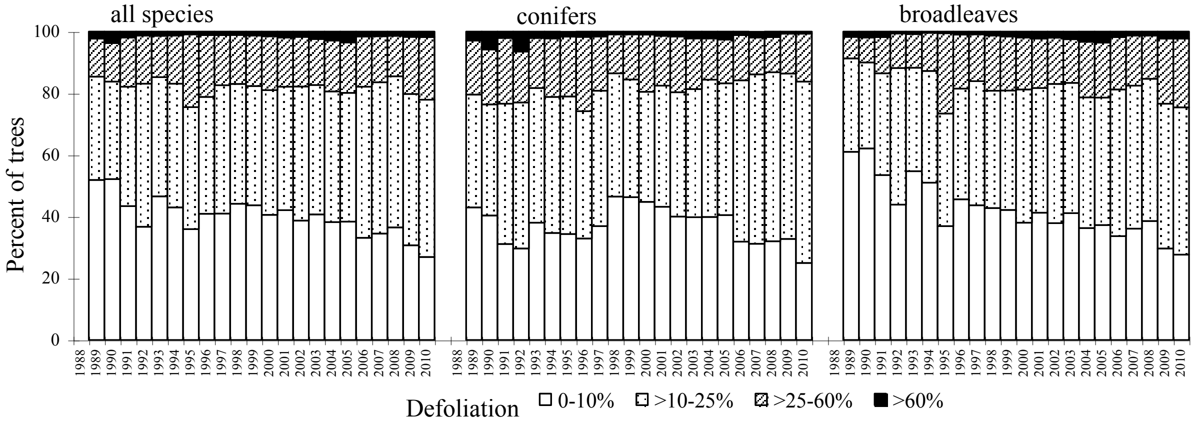


* from 2003 on, results are based on the 16 x 16 km transnational gridnet and must not be compared with previous years.

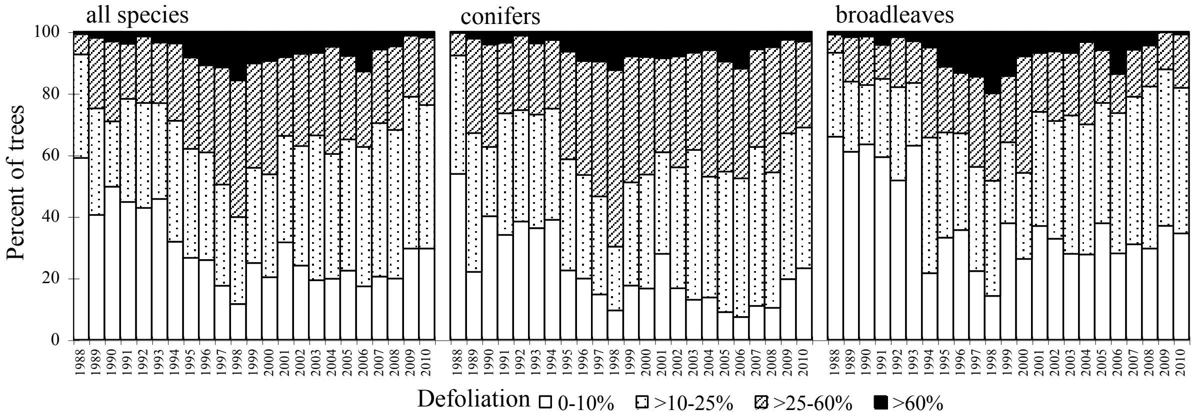
Belarus



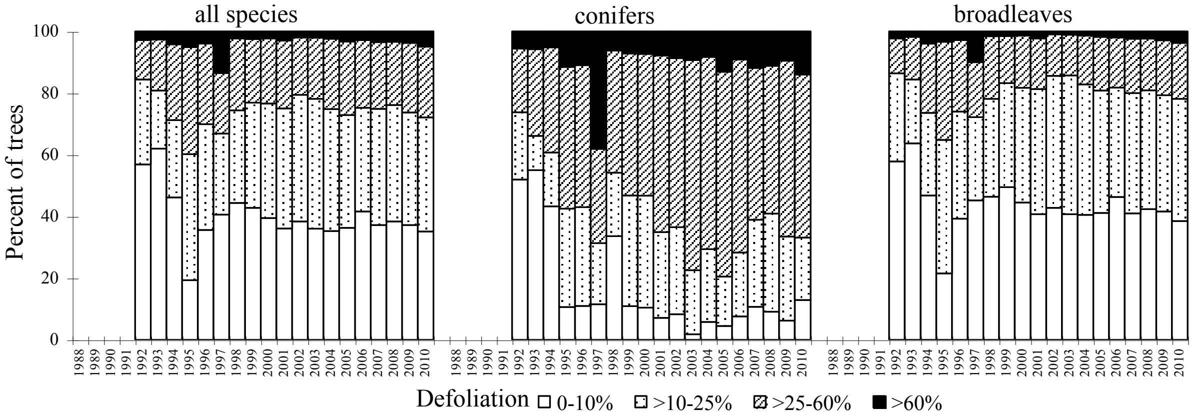
Belgium



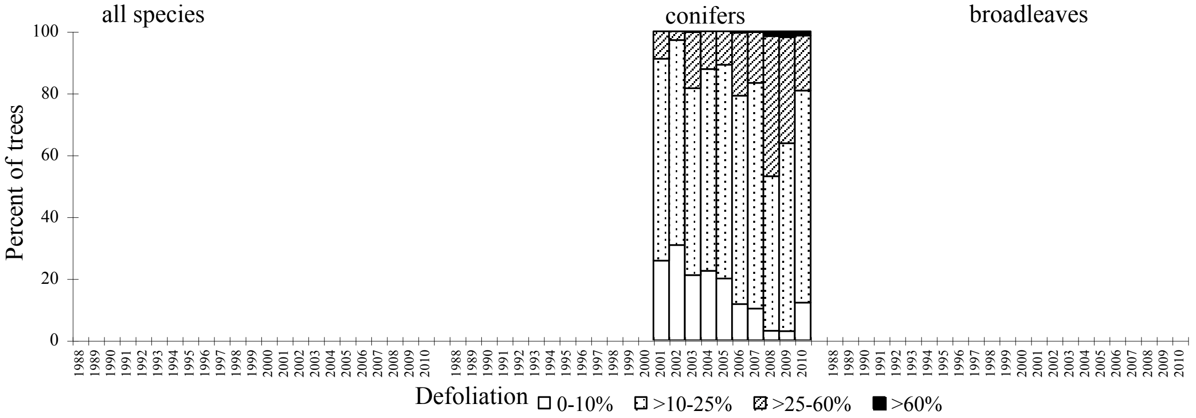
Bulgaria



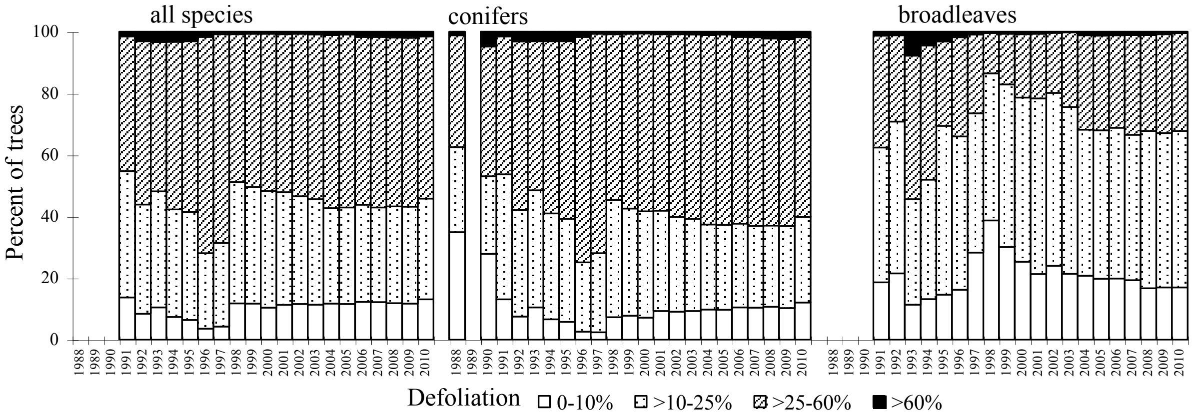
Croatia



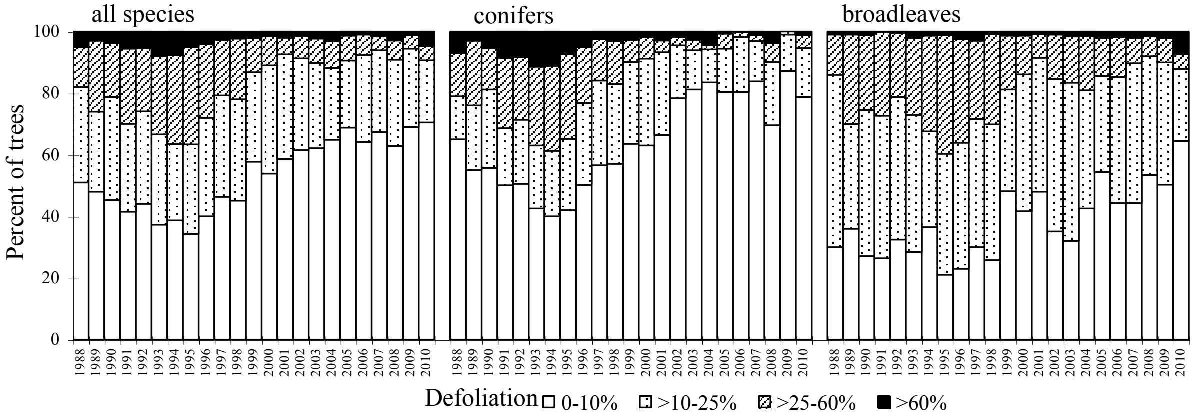
Cyprus



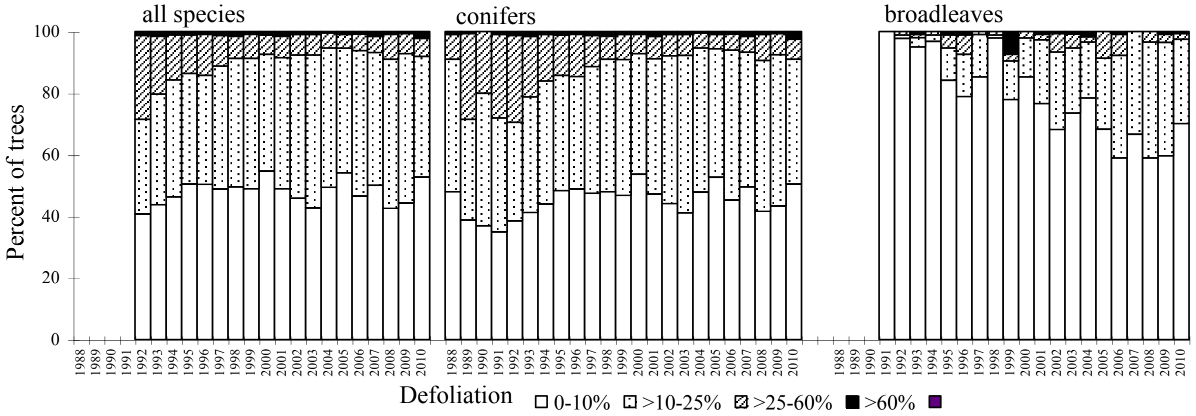
Czech Republic



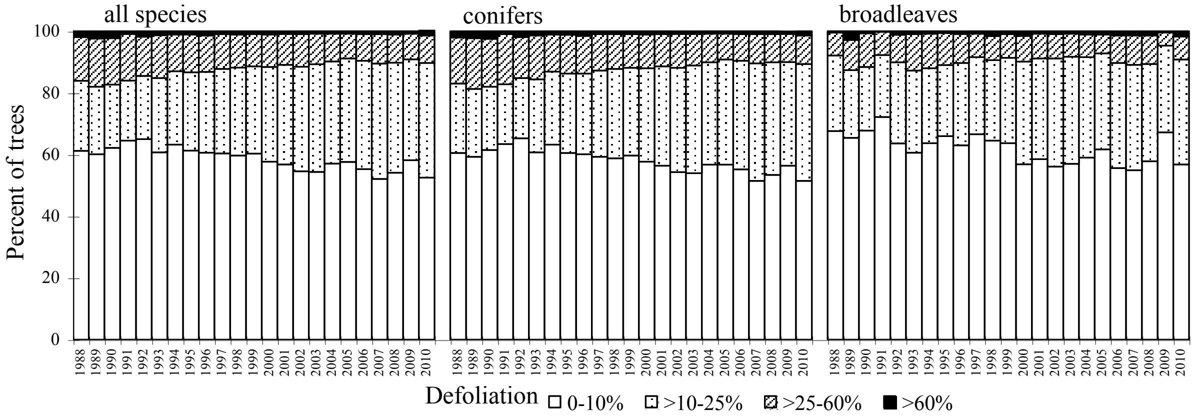
Denmark



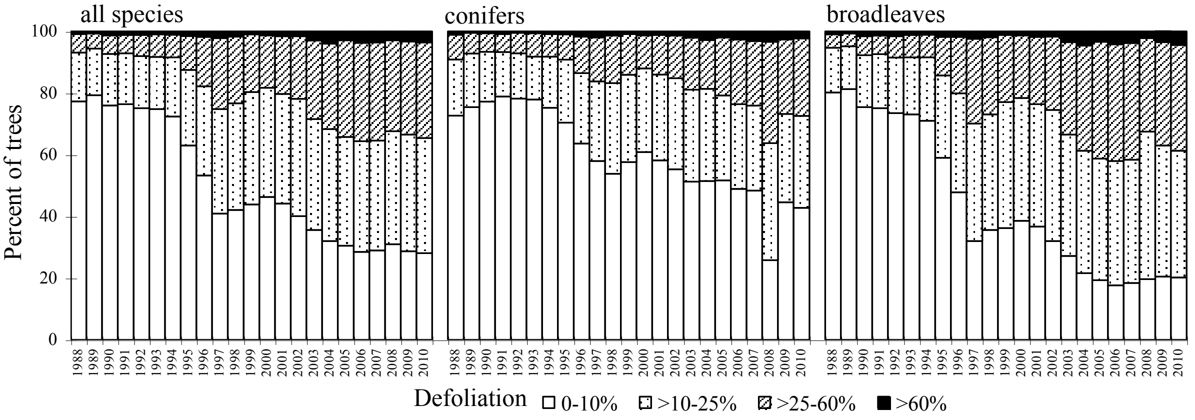
Estonia



Finland

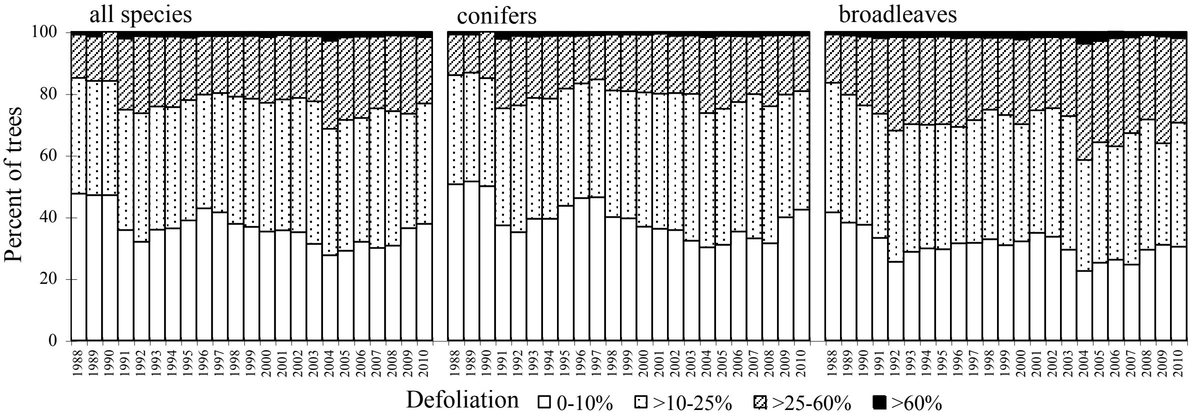


France *



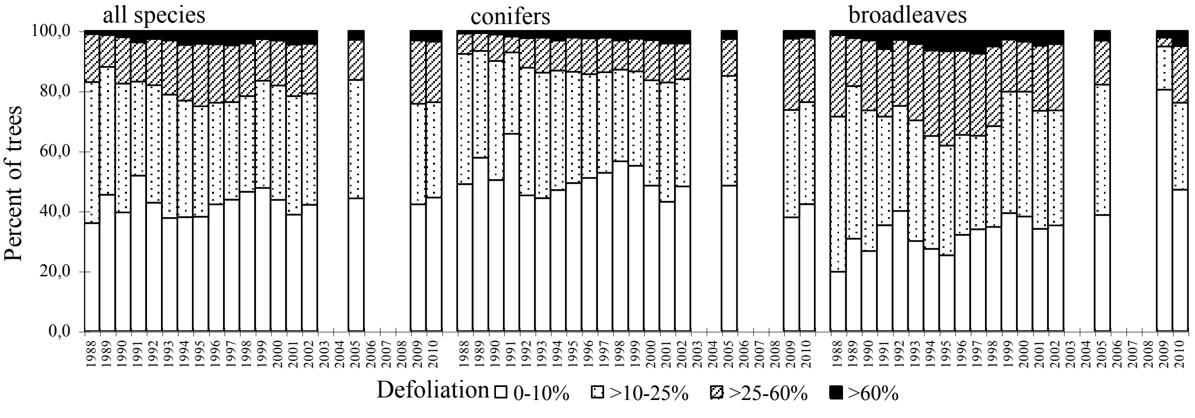
* due to methodological changes, only the time series 1988-94 and 1997-2010 are consistent, but not comparable to each other.

Germany

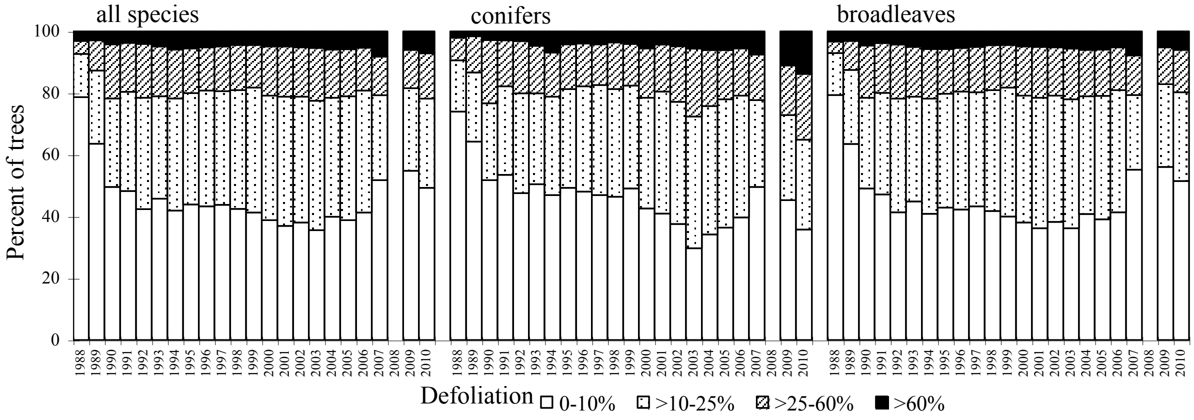


* before 1991 without former GDR

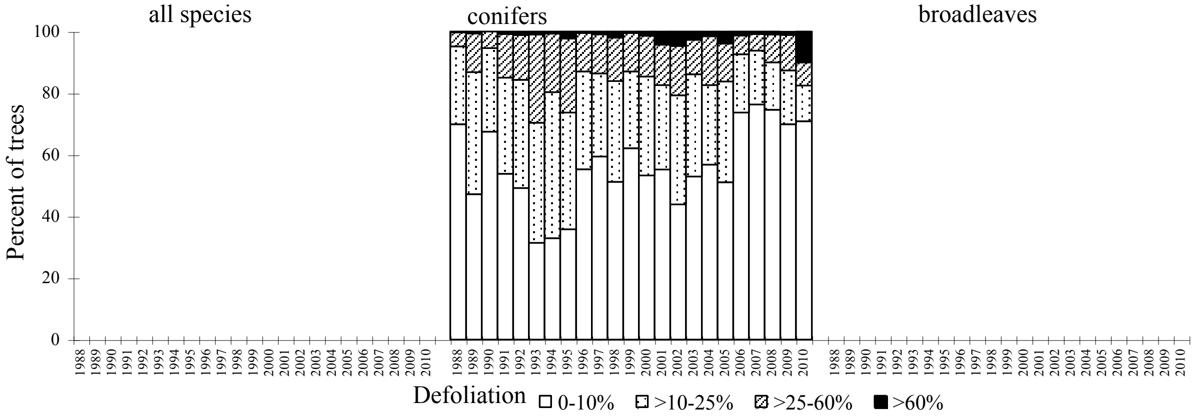
Greece



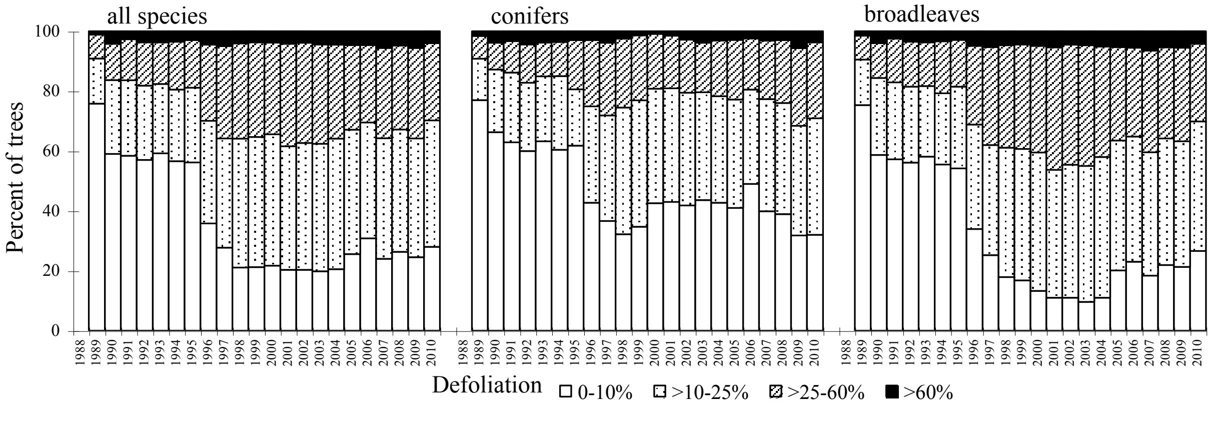
Hungary



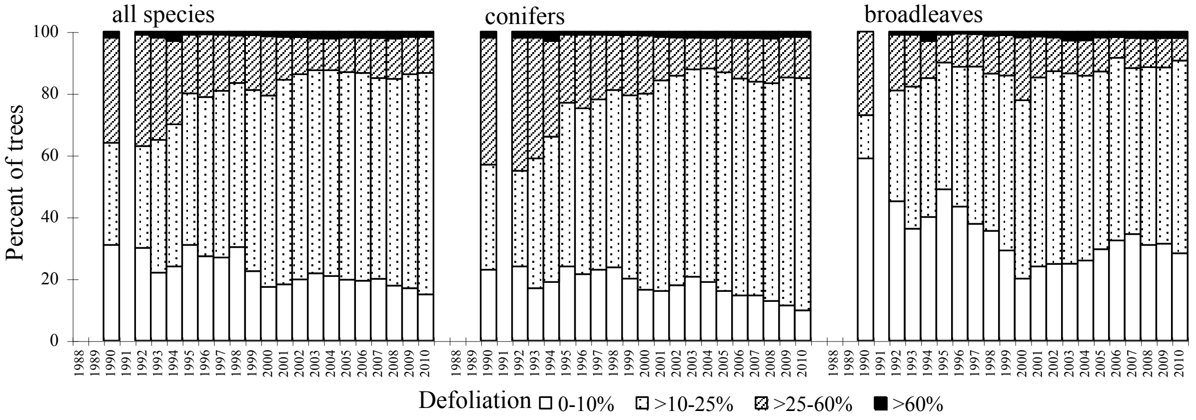
Ireland



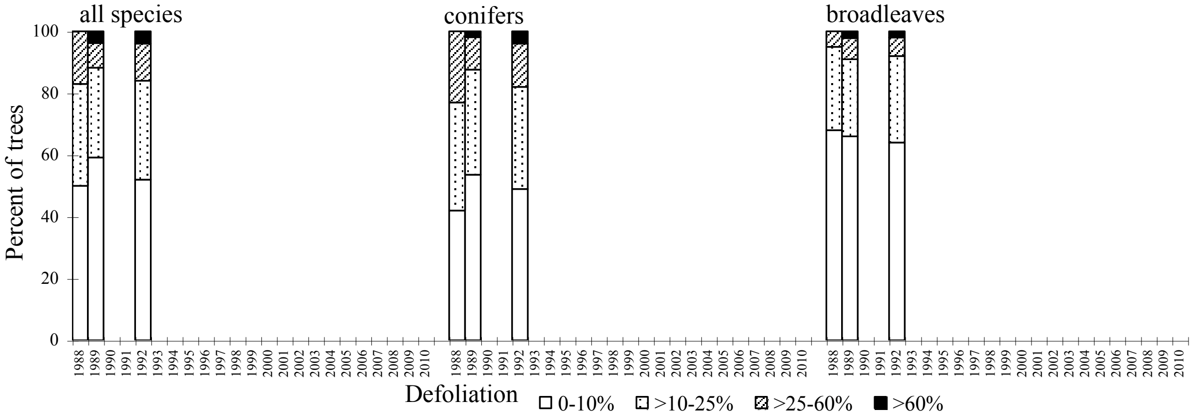
Italy



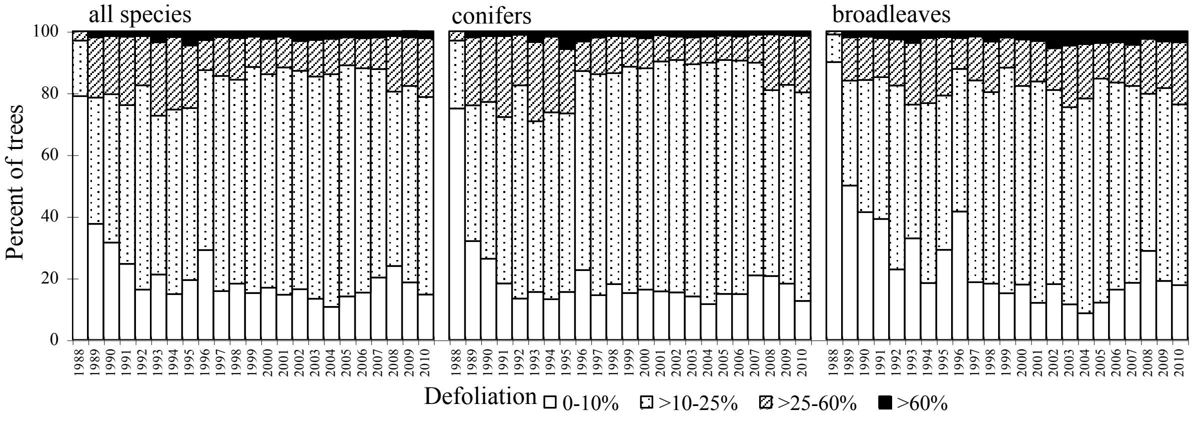
Latvia



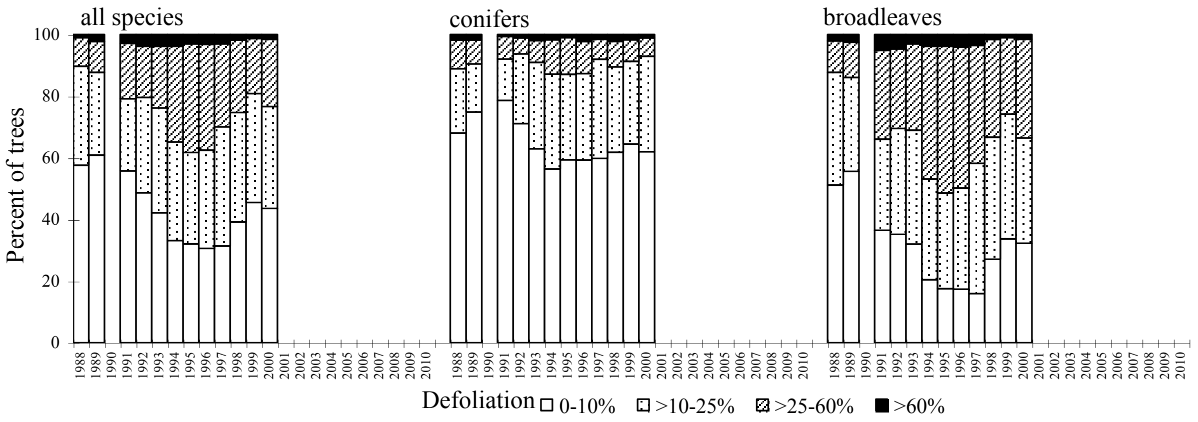
Liechtenstein



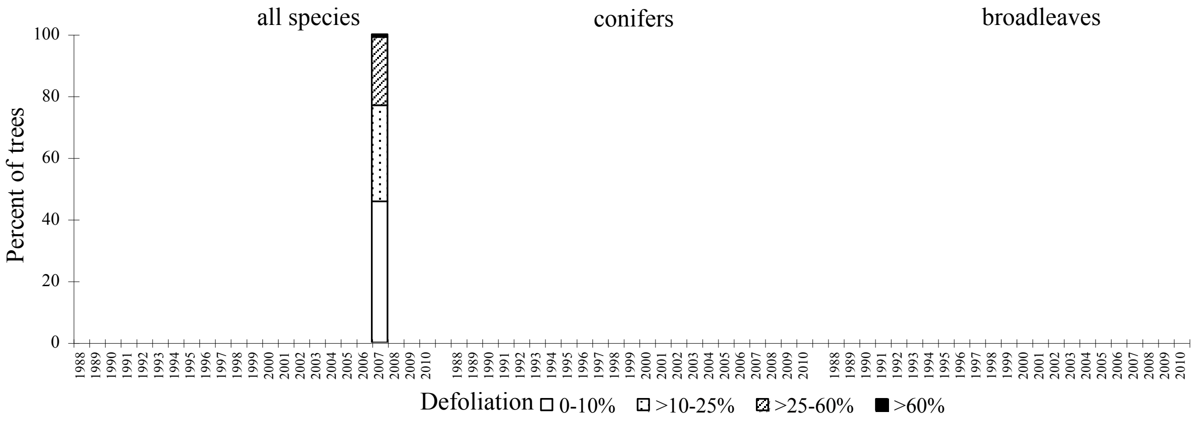
Lithuania



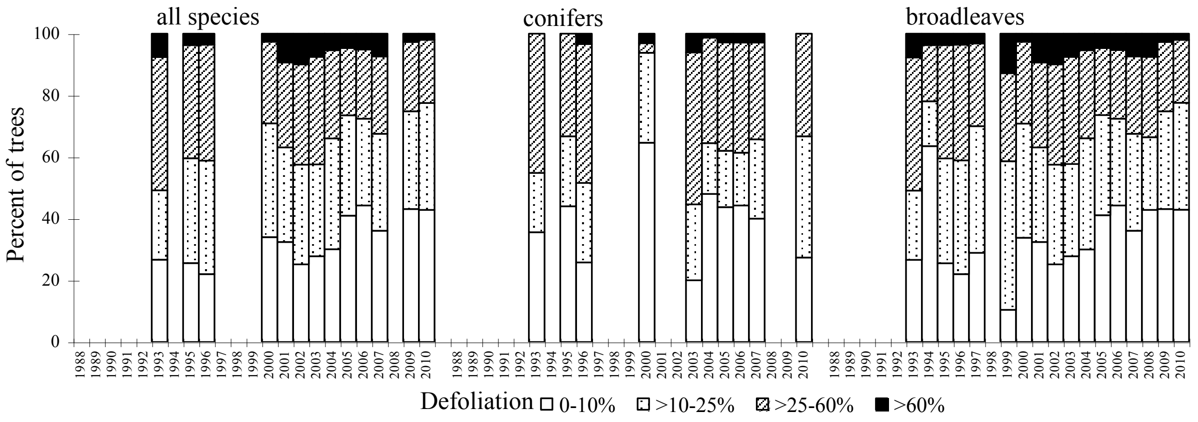
Luxembourg



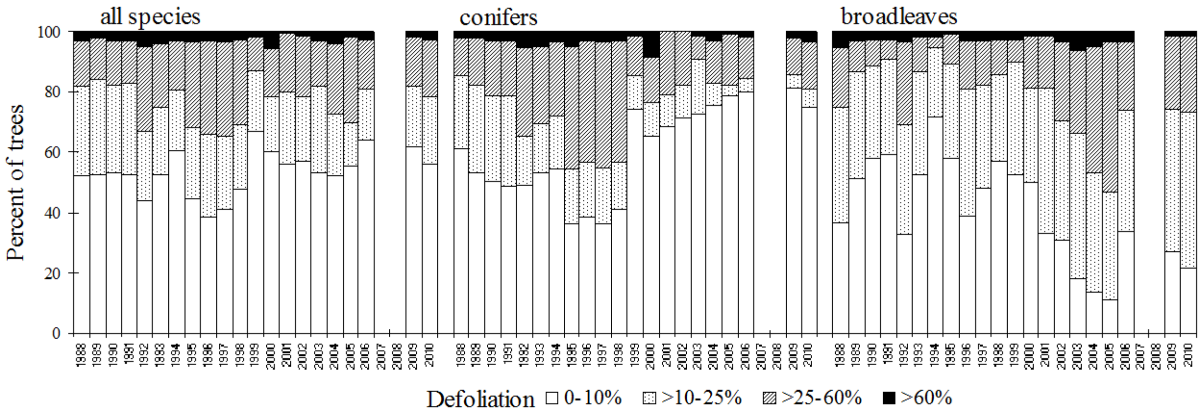
FYR of Macedonia



Republic of Moldova

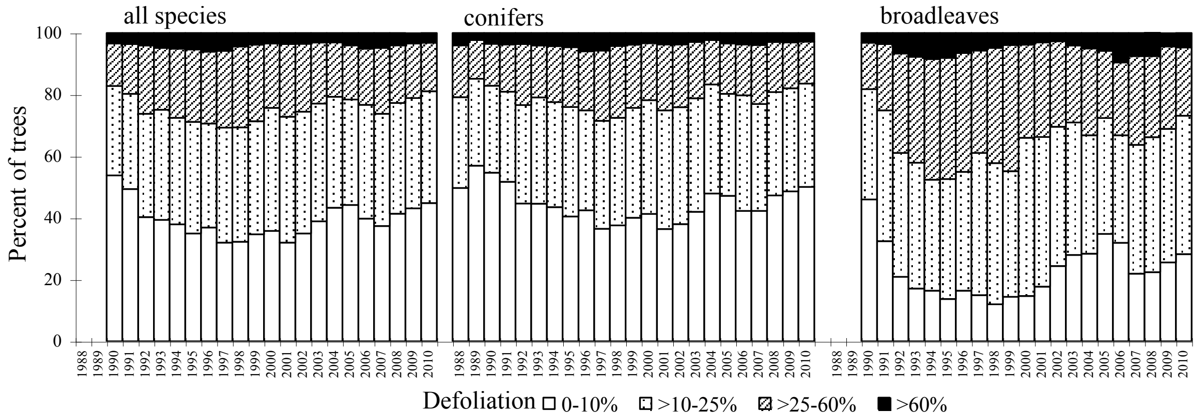


The Netherlands

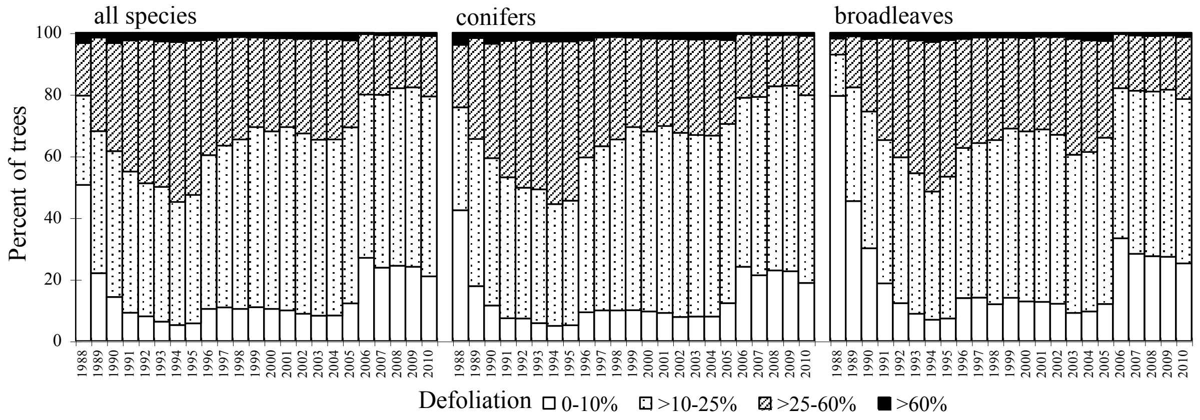


1989-1994: 1500 plots, 1995-1998: 200 plots, since 1999: 11 plots

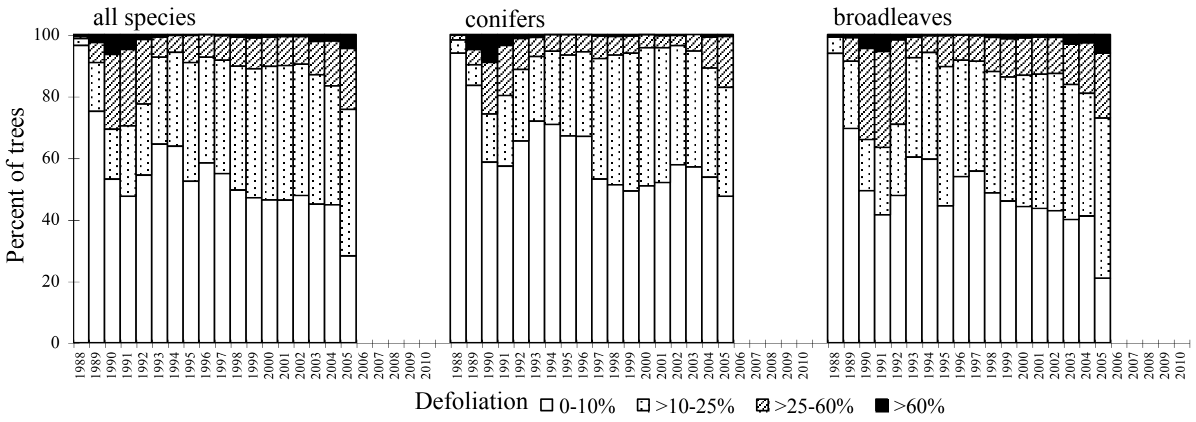
Norway



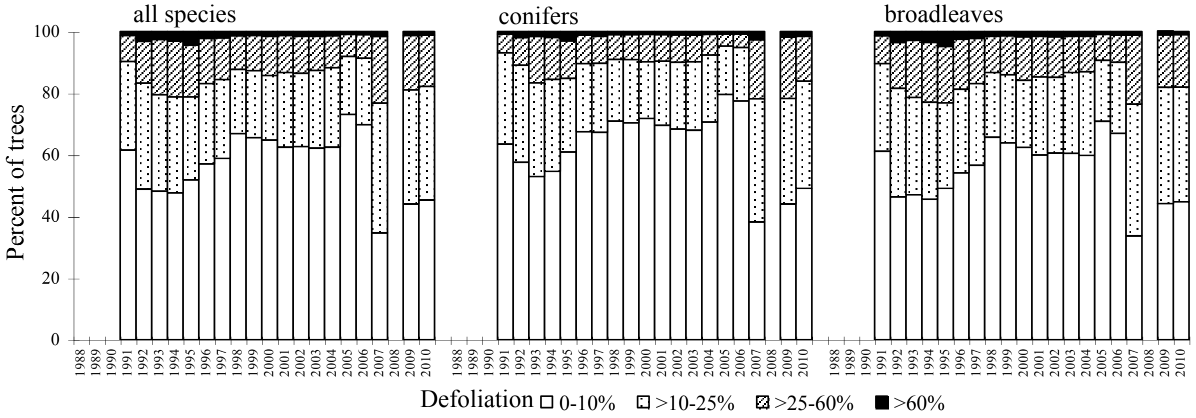
Poland



Portugal

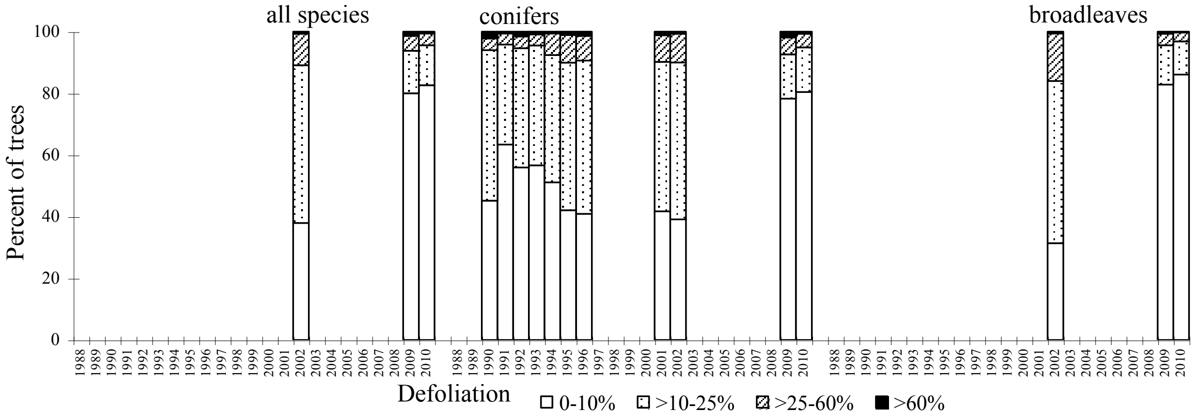


Romania *



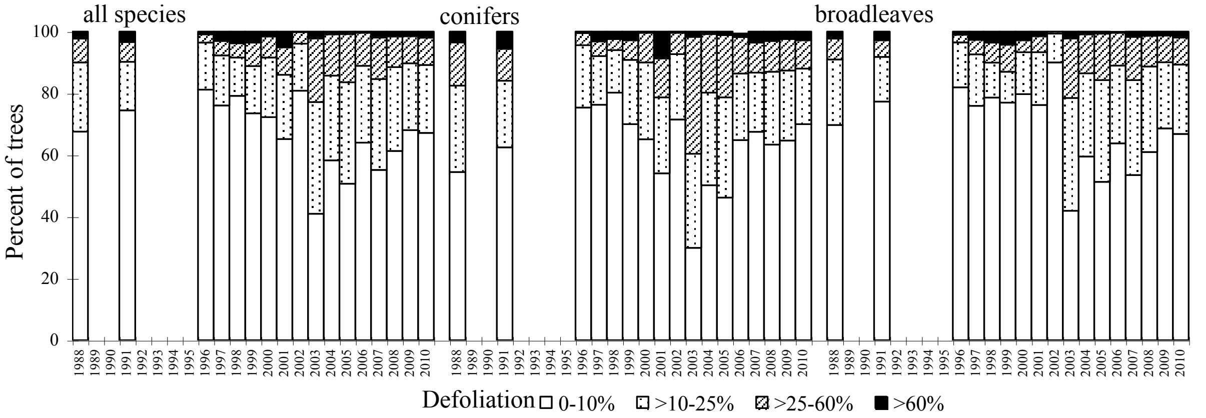
* from 2007 on, results are based on the 16 x 16 km transnational gridnet and must not be compared with previous years.

Russian Federation *

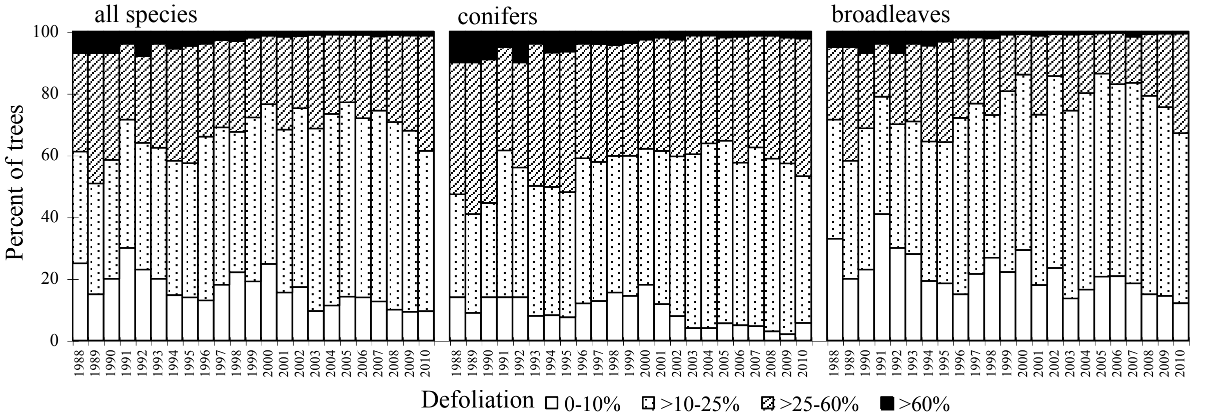


* Only regional surveys in north-western and Central European parts of Russia.

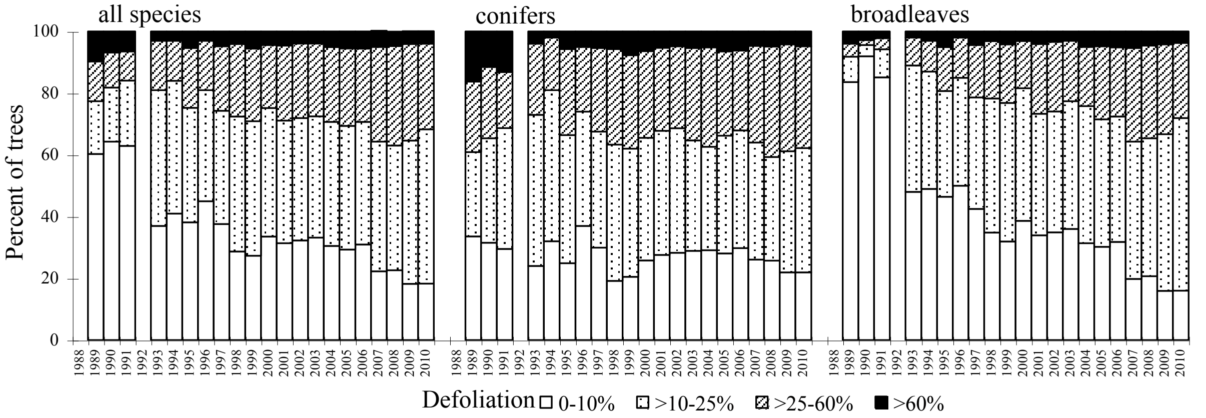
Serbia



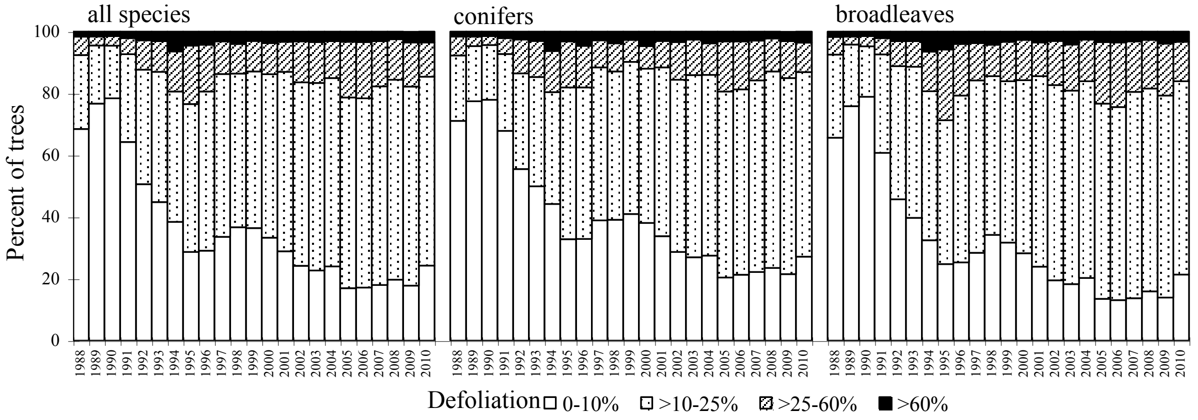
Slovak Republic



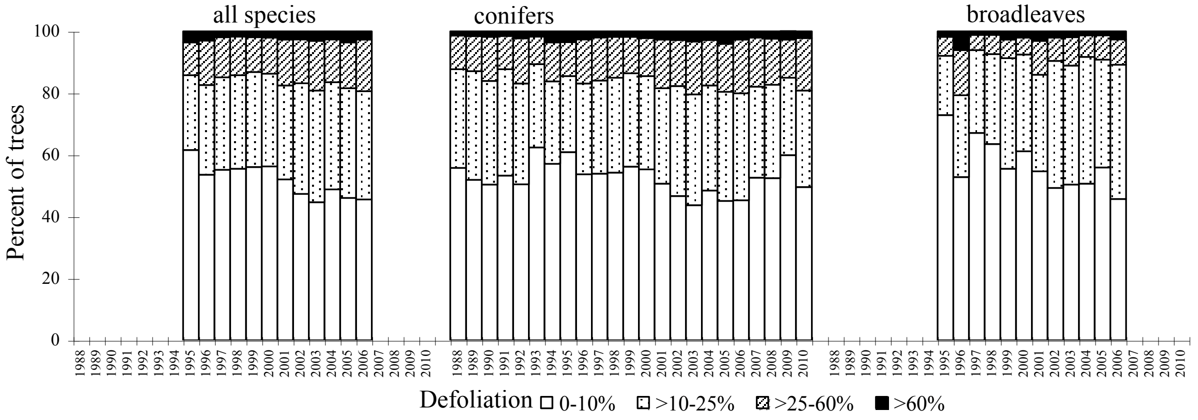
Slovenia



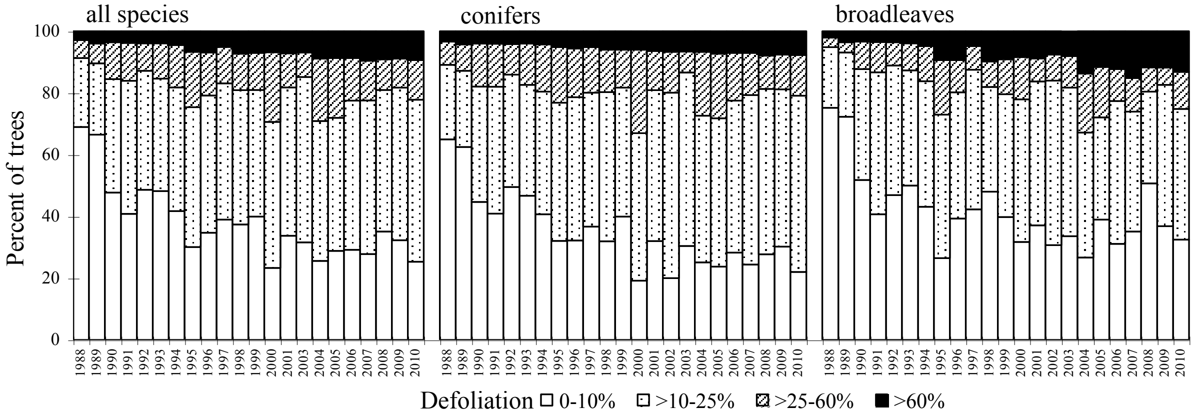
Spain



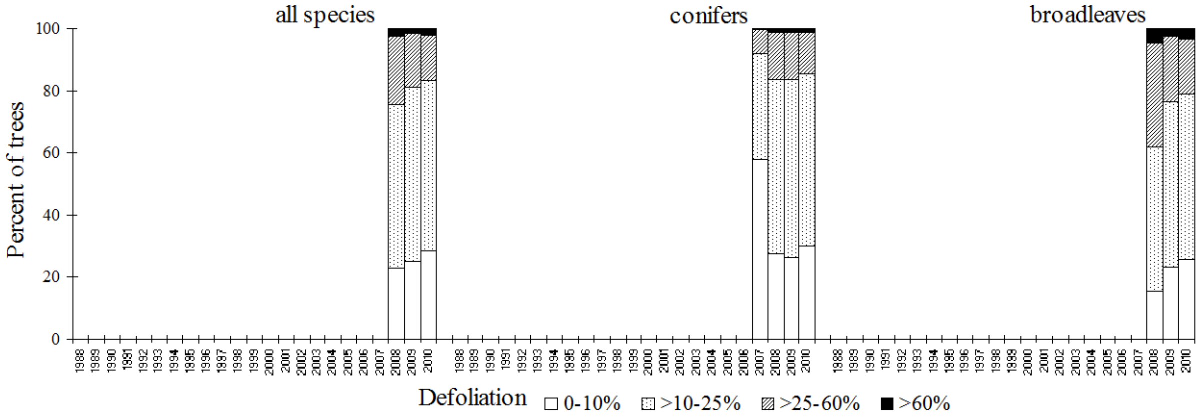
Sweden



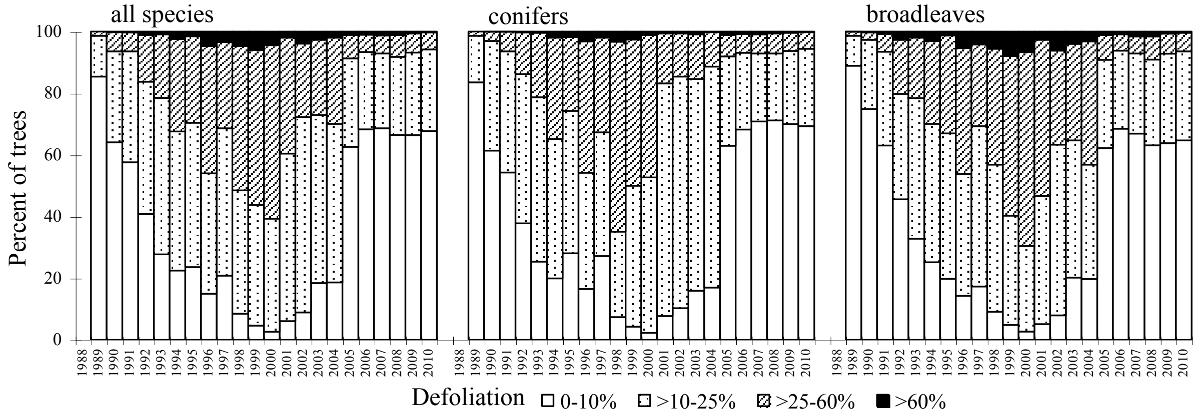
Switzerland



Turkey

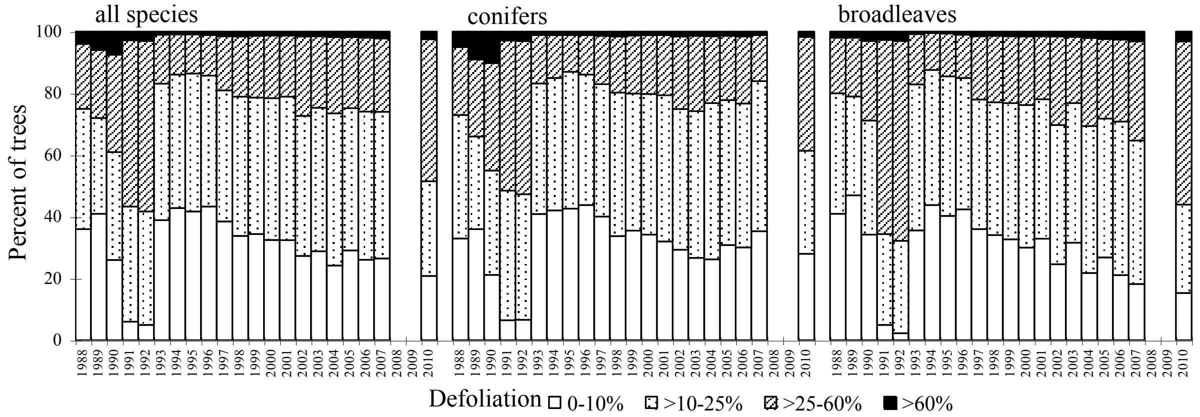


Ukraine



since 2005 change of assessment grid

United Kingdom



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

9.3 Annex: Addresses

9.3.1. UNECE and ICP Forests

UNECE
United Nations Economic Commission for Europe
Environment and Human Settlements Division
Air Pollution Unit
Palais des Nations
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