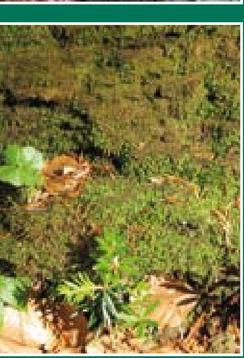
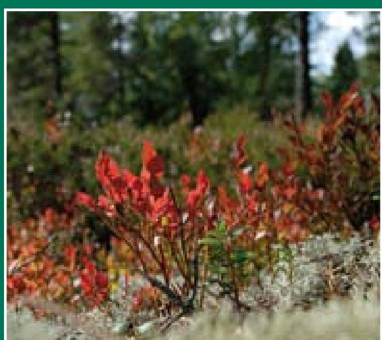
International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects and Forests (ICP Forests)

European Comission

The Condition of Forests in Europe

2007 Executive Report





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The Condition of Forests in Europe

2007 Executive Report

United Nations Economic Commission for Europe,
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International Co-operative Programme on Assessment and
Monitoring of Air Pollution Effects on Forests (ICP Forests)

European Commission

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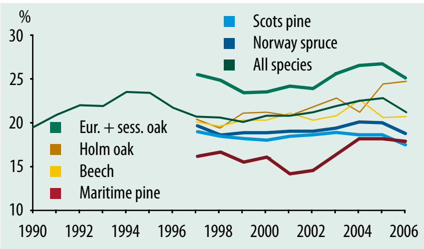
Summary and table of contents

The ICP Forests monitoring programme was established in 1985 under the auspices of the Convention on Long-range Transboundary Air Pollution. A close collaboration with the European Commission began in 1986. Today, 41 countries participate in the programme. Results are based on around 6 000 Level I and 800 Level II plots.

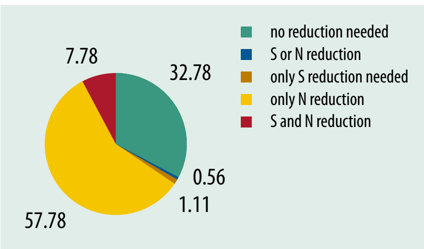


Development of defoliation

After a number of years with a general deterioration of forest condition across Europe, 2006 was characterized by clear improvements. In many regions this is interpreted as recovery from sustained drought effects. One fifth of all trees assessed were rated as damaged, though the situation differs between the main tree species and regions of Europe.


Virgin forest in the Carpathian Mountains

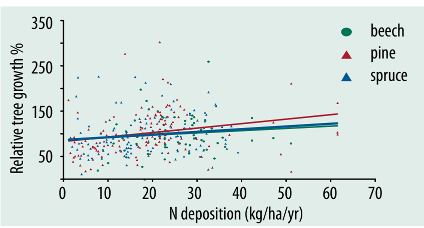
In the Carpathian mountains, beech forests with a natural composition of tree species still cover large areas. A number of virgin forests still exist which serve as study areas for natural forest dynamics. Even though the health condition of beech is comparatively good, several factors including drought, ozone and exceedances of critical loads for acid deposition were demonstrated to affect crown condition.



Percentage of plots with deposition reduction needed in order to be below critical loads

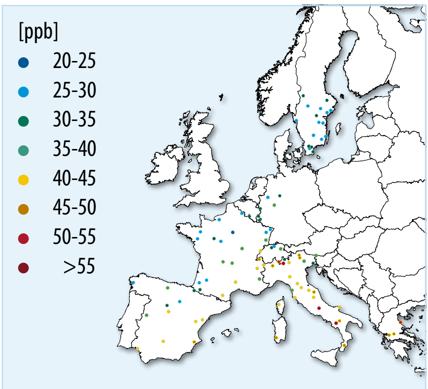
Critical loads for nitrogen deposition were exceeded on two thirds of nearly 200 monitoring plots, mostly located in Central Europe. Deposition remained unchanged on 80 % of the plots between 1999 and 2004.

It is predicted that even if emission reductions are implemented according to the existing agreements the soil acidity status will not reach pre-industrialisation levels on most of the plots in the next few decades.



Relative tree growth in relation nitrogen deposition

Nitrogen deposition was linked to increased tree growth for Scots pine, Norway spruce and beech trees. Continued high nitrogen deposition may in the long run have negative effects on forest ecosystems and cause declining tree growth or increased tree mortality. Tree growth was as well linked to deviations from long term mean temperatures.



Mean ozone concentrations (Apr. - Sept.) 2000 - 2004

Scots pine tree with stemrust infestation

Bilberry shrubs with autumn colouring

Further information:
http://www.icp-forests.org
http://ec.europa.eu/environment/index_en.htm
http://forest.jrc.it

Preface

Miroslav Jureňa
Minister of Agriculture of the Slovak Republic

Talking about European forests means talking about almost half of Europe´s land area. The annual increment of wood in Europe´s forests amounts to 2.287 million m^3. This equals 73 cubic metres per second. About 12 % of the forest area is designated as protective forests - for protection of soil, water or other components and function of forests. But we can hardly measure, quantify and value the real benefits of non-commercial forests, especially their ecological functions. These large statistics and crucial facts should make all decision makers and the public aware that we still have invalueable natural wealth and real fortune in Europe, and also that we have to understand it and to take care of this wealth.

In the early 1980´s, Europe was for the first time alarmed by the large-scale forest decline or deterioration of forest condition. In the meantime 51 parties have signed the Convention on Long-range Transboundary Air Pollution (CLRTAP, Geneva 1979). The CLRTAP was crucial for launching forest monitoring in the framework of the International Co-operative Programme on Assessment and Monitoring of Air Pollution on Forests (ICP Forests) in 1986. The fear of forest decline in Europe and the uncertain role of air pollutants were driving forces of forest monitoring at that time. The monitoring was set up to assess the health status and development of European forests on a large scale and to regularly inform policy makers, scientists and the public on the results. The initiatives of the European Union, from the first Regulations on crown condition assessment during the 1980s until the Regulations on intensive monitoring of forest ecosystems starting in the 1990s, have created a complex forest monitoring system for the assessment of air pollution effects on forests. The results of ICP Forests provided not only a realistic picture of the extent and development of forest damage, but increased our knowledge on the status of forest ecosystems in Europe, on the effect of atmospheric deposition and other stress factors on forests and contributed to the elucidation of the complex causes and effects involved. ICP Forests promotes the wide use of its data for scientific evaluation. Upon request and in agreement with the data owners, data are free for external users.

Forest condition and health are now perceived in a wider context, and the programme has developed into a unique multifunctional monitoring system. ICP Forests today provides a platform for information exchange for forest scientists, managers and politicians of 41 participating countries.

The considerable reduction of industrial emissions, sulphur emissions in particular, and the resulting notable improvement of air quality in Europe was partly achieved due to the successful work of ICP Forests and the other ICPs under the CLRTAP. However, further emission reductions are necessary in order to ensure soil status that provides long-term forest ecosystem stability. In contrast to the relatively fast reacting soil solution, the chemistry of the soil solid phase, and even more the soil fauna and flora, react much more slowly. Here, recovery processes can take many decades.

New and old hazards are threatening and damaging European forest ecosystems. Among these factors, a relatively new threat is damage due to increased ground level ozone in many regions. The main cause is a large increase in the transport of people and goods by road with related nitrogen oxide emissions which contribute to the increase of tropospheric ozone. In addition, the increase in deposition of nitrogen to forest soils, at least partly due to the same cause, is threatening the integrity and functioning of forest ecosystems.

Globally a major threat is climate change. According to most climate models, predicted changes in average temperature and precipitation will

Forest and mountain landscape in the Slovak Republic.

strongly affect ecological conditions of forests and their plant communities. In addition, extreme weather events like storms, high temperatures, and long lasting droughts will probably occur much more often in the future.

The environmental risks are reflected in several international conventions and processes. The Framework Convention on Climate Change (FCCC), the Kyoto Protocol and the Convention on Biological Diversity (CBD) reflect, beside other obligations, a need for new and broadened datasets about forests.

The Sixth Community Environment Action Programme of the European Union has defined key environmental priority areas such as climate change, nature and biodiversity, environmental health and quality of life and natural resources and wastes. Forestry can be considered a key sector in relation to all priority areas of the programme. A forestry-specific key process is the Ministerial Conference on the Protection of Forests in Europe (MCPFE).

In addition to the above mentioned commitments and reporting obligations, the EU and its member states also have commitments to supply forest related data for the UN-ECE/FAO Forest Resources Assessment (FRA).

As a result of the above mentioned obligations and processes, teams of experts have prepared lists of indicators relevant to these issues. The multifunctional monitoring programme of the ICP Forests programme offers a very good tool to record the extent and intensity of risk factors and to monitor and assess the reactions of the forest ecosystems. The high spatial coverage and long time series for many of the data make the monitoring system especially unique and the data can be further utilised for modelling and prediction of future developments. The evaluation of existing and newly collected data concerning additional indicators and parameters is an exceptional chance to obtain a clear picture of the state, risk and current change in forest ecosystems. On the other hand, some inevitable change is required in the current forest monitoring programme in order to meet all these monitoring needs.

We have to keep in mind that besides the joint EU and ICP Forests monitoring activities there are National Forest Inventories and also specific or regional environmental programmes in forests. The integration and combination of information of all relevant monitoring systems seems to be the best and most effective solution.

Representative surveys (Level I monitoring) provide information on the current state and changes taking place in forests over extensive areas, while intensive monitoring (Level II Monitoring) investigates the ecological processes and cause-effect relationships. National forest inventories provide the most representative information also at national and regional level. It is desirable to improve the coherency and efficiency of the existing monitoring activities and networks under the umbrella of an European Forest Monitoring System, to improve reliability, comparability and accuracy of all forest related information, and last but not least, to increase the cost-effectiveness of data reporting on all forest related commitments at national, European and international level.

Miroslav Jureňa

Newly established Level I plot with *Pinus brutia* in Turkey.

1. A pan-European forest monitoring programme

Data for forest management, nature conservation and policy

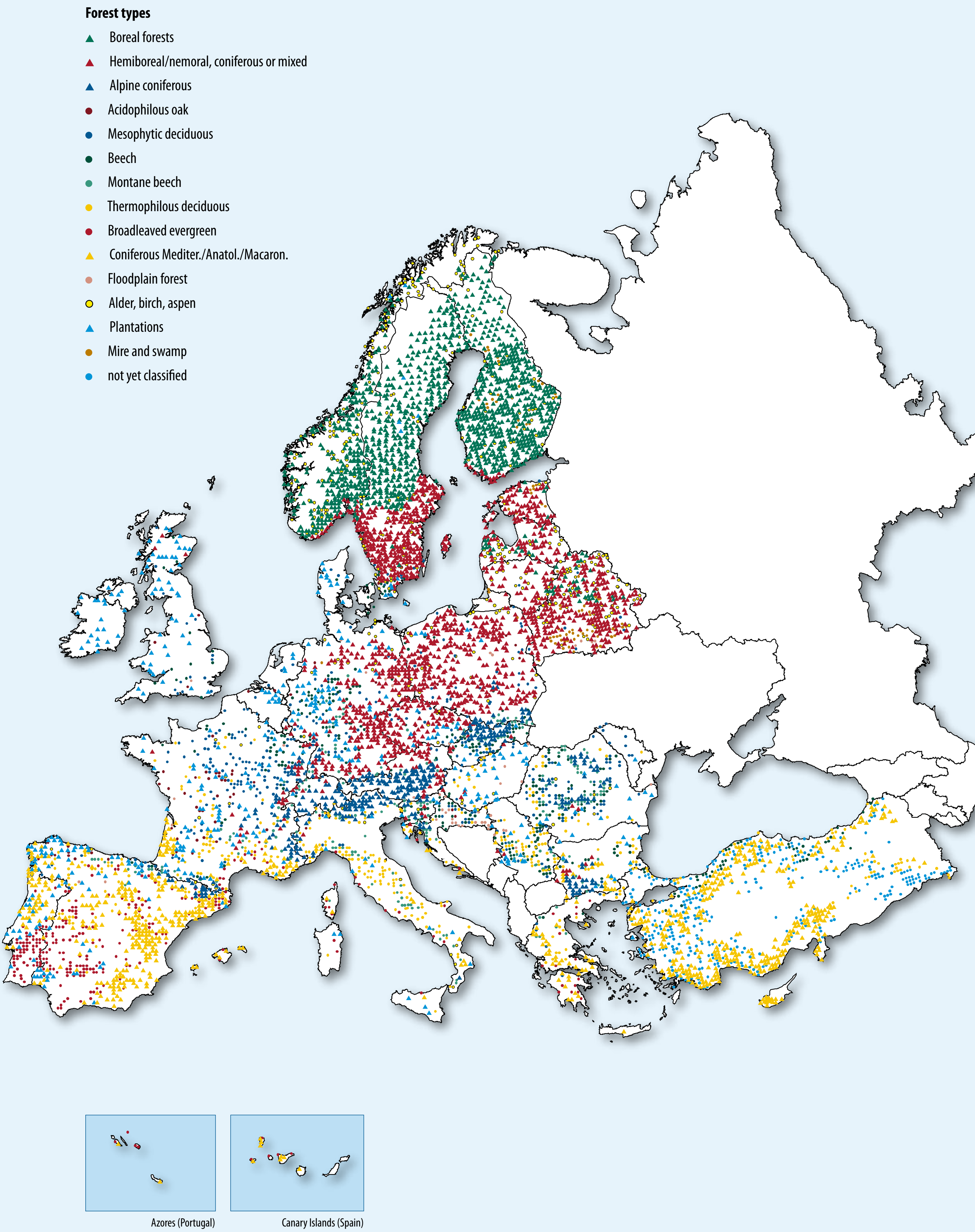
Throughout Europe, forests have many important functions. They are a basis for economic activity, and play a significant role in the development of rural areas and for recreational purposes. Forests also have major value for nature conservation and environmental protection and are significant carbon sinks, and thus relevant in the context of climate change. Forests also represent a controlling factor within the hydrological cycle. Sustainable forest management, as well as environmental policies, relies upon the sound scientific resource provided by long-term, large-scale and intensive monitoring of forest condition.

In 1985, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP). In 1986 the European Union (EU) adopted the Scheme on the Protection of Forests against Atmospheric Pollution and with the Council Regulation (EEC) No. 3528/86, the legal basis for the co-financing of the assessments was provided. In 2003, this regulation was prolonged and modified through the "Forest Focus" Regulation (EC No 2152/2003) which expired in 2006. Since 2007 there is no more legal basis for obligatory forest monitoring in the EU, even though under the "LIFE+" Regulation (EC No. 614/2007) co-financing for the future development of forest monitoring may be provided. ICP Forests and EU have been closely co-operating in monitoring the effects of air pollution and other stress factors on forests. Today 41 countries participate in the ICP Forests which contributes to the implementation of clean air policies at European and national level.

Embedded into a network of co-operations

The data and results of the monitoring activities provide information for a number of criteria and indicators for sustainable forest management as defined by the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Contributions to the Framework Convention on Climate Change (FCCC) and to the Convention on Biological Diversity (CBD) have been made as well. The programme also maintains close contacts with the Acid Deposition Monitoring Network in East Asia (EANET).

Figure 1-1: Level I plots classified according to forest types (National data validation is ongoing in the course of the BioSoil project, see Chapt. 4).


Forest types
Boreal forests
Hemiboreal/nemoral, coniferous or mixed
Alpine coniferous
Acidophilous oak
Mesophytic deciduous
Beech
Montane beech
Thermophilous deciduous
Broadleaved evergreen
Coniferous Mediter./Anatol./Macaron.
Floodplain forest
Alder, birch, aspen
Plantations
Mire and swamp
not yet classified
Azores (Portugal)
Canary Islands (Spain)

	Frequency	Number of plots	Number of plots data submission 2006:
Crown condition	annually	6093	6045
Foliar chemistry	once until now	1497	
Soil chemistry	Once until now; (repetition launched in most of the EU countries within the BioSoil project)	5289 (4000)	
Tree growth	demonstration project ongoing (BioSoil)	(4000)	
Ground vegetation	demonstration project ongoing (BioSoil)	(4000)	
Stand structure, deadwood	demonstration project ongoing (BioSoil)	(4000)	

Table 1-1: Surveys and number of plots on Level I.

	Frequency	Number of plots with data	Number of plots; data submission 2004
Crown condition	annually	822	676
Foliar chemistry	every 2 years	795	127
Soil chemistry	every 10 years	742	1
Tree growth	every 5 years	781	338
Ground vegetation	every 5 years	757	105
Stand structure incl. deadwood	once	90	-
Epiphytic lichens	once	90	-
Soil solution chemistry	continuously	262	221
Atmospheric deposition	continuously	558	434
Ambient air quality	continuously	100	98
Meteorology	continuously	227	212
Phenology	several times per year	145	145
Litterfall	continuously	114	114
Remote sensing	preferably at plot installation	national data	

Table 1-2: Surveys and number of plots on Level II (see Annex III for more details).

Challenging objectives and a unique monitoring system

The mandate of the ICP Forests is

- to monitor effects of anthropogenic (in particular air pollution) and natural stress factors on the condition and development of forest ecosystems in Europe, and
- to contribute to a better understanding of cause-effect relationships in forest ecosystem functioning in various parts of Europe.

Data are collected by the participating countries. Presently data are stored from over 6 000 permanent observation plots called Level I (see Fig. 1-1). In addition, 805 plots have been selected in Turkey in 2006. Level I plots are located on a 16*16 km grid covering 35 countries throughout Europe. In addition to annual crown condition surveys, the BioSoil demonstration project begun in 2006 under the Forest Focus Regulation allows a repeat of an original soil survey on Level I plots undertaken in 1994 in many European countries (Tab. 1-1, see Chapt 4).

In order to detect the influence of various stress factors on forest ecosystems, intensive monitoring is carried out in over 800 Level II plots. A larger number of surveys are carried out on these plots which are located in forests that represent the most important forest ecosystems of the Continent. (see Tab. 1-2). Due to the large annual data numbers and intensive data validation routines implemented within a new data platform, results from intensive monitoring plots can only be presented up to the year 2004 in this report.

Further information:
http://www.icp-forests.org
http://ec.europa.eu/environment/index_en.htm
http://forest.jrc.it

Forest types and environmental conditions differ greatly across Europe. Overgrazing can constitute a major pressure for open holm oak forests in Spain.

Significant data volumes require complex data base applications and quality checks

Within the monitoring programme 600-700 data files are submitted by the National Focal Centres each year, amounting to over three quarters of a million single data records annually.

Under the Forest Focus Regulation the European Commission Directorate General Joint Research Centre (DG JRC) has implemented a Forest Focus Monitoring Database System to manage the data. The system was developed and realized under contract by a Consortium, coordinated by I-MAGE Consult with Nouvelles Solutions Informatiques s.a. (NSI) as consortium partner and the Federal Research Centre for Forestry and Forest Products (BFH) as sub-contractor.

The database contains data from all Level I and Level II surveys.

Data are first checked for adherence to the format specifications stipulated in the Technical Specifications of DG JRC. These tests are performed on-line and generate immediate feedback to the National Focal Centre submitting the data. The feedback report allows NFCs to check their data and if necessary make corrections before submitting the survey.

To maintain a full audit trail of the process, all previously submitted files and reports remain within the system, but are flagged as obsolete if superseded by a new submission of the same survey. Data that pass the first suite of tests are then subjected to further evaluation. These checks are performed off-line because some of the tests require relatively intense processing and direct access to the data already stored within the database. Individual values are examined for plausibility either within expected general ranges (single parameter), depending on values of other parameters (multiple parameter), or depending on values from former years (multiple years). Data values that generate warning messages are reported to the originating National Focal Centre, who can then correct the data if necessary, or otherwise confirm the submitted values as valid. Values confirmed in this way are flagged within the database system as extreme events.

All of the prior group of tests assess plot-specific conditions. The final stage in the validation process is intended to ascertain the suitability of the data for further temporal and spatial analyses, and to identify inconsistencies in the data that could not be found during any of the previous checks. This is done by comparing the data values with information from other plots. These checks are more qualitative and constitute a first step into data evaluation. The results are presented as tables, graphs and maps, which require expert interpretation and may also include comparisons with external data as far as available. Data are stored within the database only after they pass all the tests or are confirmed extreme events.

The programme of verification of all submitted data from 2002 onwards is ongoing and expected to be complete by the end of 2007. Until then, all results reported should be taken as provisional, as they include data that have not yet passed all the validation stages.

Further information:
http://forestfocus.nsi-sa.be/

Moderately defoliated tree crowns of maritime pine and Pyrenean oak in the Mediterranean. The main parameter assessed within the extensive forest condition survey is defoliation. This is an estimate of the lack of needles or leaves in comparison to a fully foliated reference tree. Defoliation responds to many stress factors and is reliably assessable over large areas.

2. State of forests in Europe

2.1 After some years of worsening, forest condition has stabilized in 2006

Summary

- *Mean defoliation for all tree species has been fluctuating since 1990. However, there was a slight overall decrease in forest condition over the past 10 years. Only in 2006 was some recuperation recorded. Around one fifth of the trees assessed in 2006 were rated as damaged or dead.*
- *Whereas beech had shown some improvements in 2005 and a stable mean defoliation in 2006, deciduous oak species showed a marked recuperation in the most recent assessments. For Scots pine and Norway spruce slight improvements were registered. Mean defoliation of holm oak and maritime pine remained unchanged in 2006.*

Defoliation is an operational indicator designed for monitoring large areas

The health condition of forest trees in Europe is monitored over large areas by a survey of tree crown defoliation. Trees that are fully foliated are regarded as healthy. The Ministerial Conference on the Protection of Forests in Europe (MCPFE) uses defoliation as one of four indicators for forest health and vitality.

In 2006, crown condition data were submitted from 6 045 plots in 32 countries. In all, 129 880 trees were assessed. Since the beginning of the 1990s, the number of surveyed plots and trees has increased. Larger samples of trees are therefore available for the analysis of short and medium term changes, whereas the evaluation of long term changes is based on a smaller number of plots and countries.

One fifth of all trees assessed were damaged

In 2006, 21.9 % of all trees assessed had a needle or leaf loss of more than 25 % and were thus classified as either damaged or dead (see Fig. 2-1). In 2005, the respective share amounted to 23.2 %. Of the most frequent tree species, European and sessile oak had the highest share of damaged and dead trees, namely 34.9 %.

In the last year there were more improvements in crown condition than deterioration

Over the last ten years the development of crown condition has been mainly characterized by an increase in defoliation. This is not only reflected by a rather constant increase of mean defoliation of all species between 1997 and 2005 (see Fig. 2-2), but also by a much larger share of plots with increasing defoliation compared to plots with a decrease (see Fig. 2-3). In 2006, however, improvements prevailed. Beech trees had already shown some recuperation from sustained drought effects in 2005. Mean defoliation of beech

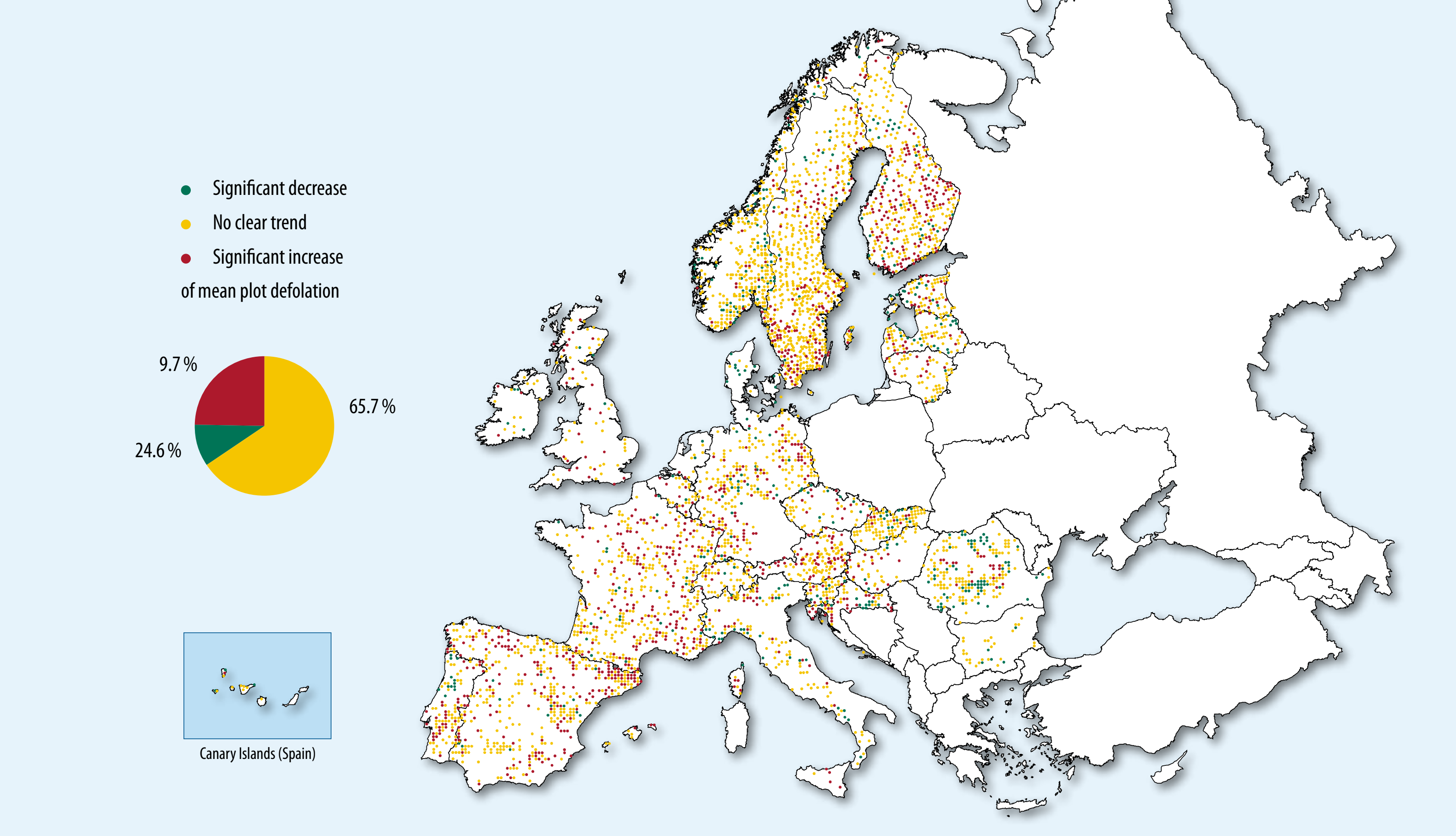


Figure 2-3: Plot wise development of defoliation for all tree species, 1997-2006. In some countries and regions of Europe shifts in plot locations hinder the calculation of plot wise changes.

hardly changed in 2006 because some worsening in the Atlantic regions was balanced by improvements in mountainous regions of the Mediterranean. European, and sessile oaks showed a marked improvement in most regions in 2006. Defoliation in holm oak stabilised after a lengthy worsening trend and maritime pine did not show much change in comparison to the previous year. There were slight overall improvements in the condition of Scots pine and Norway spruce. Exceptions were Scots pine in the mountainous regions in the Mediterranean and Norway spruce in the Boreal region.

Further information:

Lorenz, M.; Fischer, R.; Becher, G.; Granke, O.; Riedel, T.; Roskams, P.; Nagel, H.-D.; Kraft, P. (2007) Forest Condition in Europe. 2007 Technical Report. BFH, Hamburg, 91pp, Annexes.
http://www.icp-forests.org/RepTech.htm

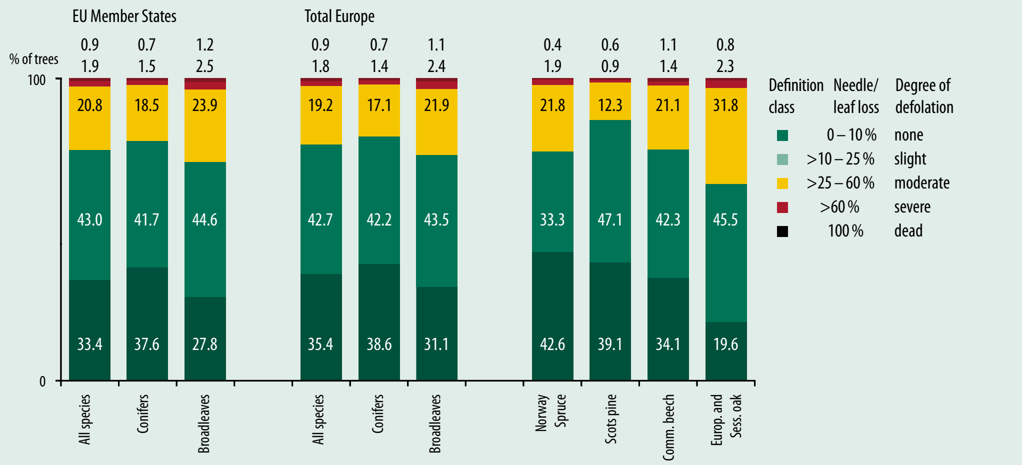


Figure 2-1: Percentage of trees in different defoliation classes. Total Europe and EU, 2006. Sample size for total Europe is 129 880 trees and 109 085 trees for EU.

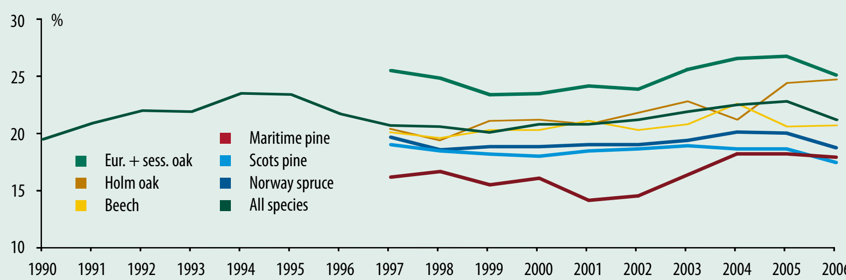


Figure 2-2: Mean defoliation for the most frequent tree species and for the total of all tree species. Samples only include countries with continuous data submission. Sample size for the selected main tree species varies between 3 166 and 31 790 trees per species and year. The time series starting in 1990 is available for a smaller number of countries and is based on between 41 484 and 49 712 trees depending on the year.

Sycamore maple and silver fir are characteristic admixtures in montane beech forests.

Special Focus

Carpathian Montane Beech Forests

The natural range of Beech forests covers most of Europe

The natural habitat of European beech (*Fagus sylvatica*) covers large areas of Europe, ranging from southern Scandinavia to Sicily and from the Iberian Peninsula to the East Carpathians. Throughout the wide geographic range the natural dominance of beech is mainly explained by its high shade tolerance and its ability to grow on a wide range of site types. In general, as one moves to the south, beech forests occupy increasingly higher altitudes, their limit being at 1 250 m in the West Carpathians and northern Alps, 1 500 m in the Pyrenees and 1 850 m in the Apennines. According to the "European Forest Types" classification (EEA Technical Report 9/2006), there are two main categories with the dominance of beech: beech forests and montane beech forests. One of the forest types included under the latter category are Carpathian montane beech forests.

Carpathian montane beech forests adapt to differing site conditions

With an area of about 210 000 km², the Carpathian Mountains represent one of the most significant natural forest regions in Europe. They are more than 1 500 km long and are located in Czech Republic, Slovakia, Poland, Ukraine, and Romania. They still comprise over 300 000 ha of primary forests. Large parts of these are virgin beech forests. In the Carpathians, beech grows in pure stands or can be mixed with silver fir, Norway spruce or broadleaves like sycamore, Scotch elm and rowan depending on the site type. Plant communities in this forest type can differ quite considerably, depending on site condition. A number of units are included in the EU Habitat Directive (92/43/EEC) like *Luzulo-Fagetum* beech forests on poor and acid soils and *Asperulo-Fagetum* beech forests on richer soils. Limestone beech forests of the *Cephalanthero-Fagion* occur exclusively on calcareous parent materials and often on steep stony slopes. Here, tree, shrub layer and herb layer are usually very diverse, including whitebeam (*Sorbus aria*), and in a few areas yew (*Taxus baccata*).

Remnants of primary forests are nuclei for larger protected areas and research

Carpathian montane beech forests have undergone less intensive exploitation by humans and tree species composition is generally much less changed than in western Europe. Nevertheless, in the Carpathians the percentage of beech has decreased in favour of conifers due to the demand for softwood. At present, the forests are usually managed by different shelterwood systems. In some cases clear-cutting is still used.

Semi-natural and natural Carpathian beech forests are dominant parts of natural parks, nature and biosphere reserves. Clusters of "Carpathian Primeval Forests" in Slovakia and later also "Beech Primeval Forests of the Carpathians" in Romania and Ukraine have been proposed to be added to the UNESCO World Natural Heritage List. Studies in primeval forests in the Carpathians have been crucial for the scientific study of the evolution of European virgin forests and have significantly influenced modern silvicultural techniques.

A well-balanced mosaic of segments representing all growth stages can be recognised in primeval forests: the juvenile phase, the mature phase and the phase of disintegration. A primeval forest has a typical structure of trees of different species, age, volume and height. The cycle of one generation of beech is about 220 years, while the life cycle of fir is about 350 – 400 years. Among others, the Dobročský primeval forest, Badín primeval forest (both declared strict reserves in 1913), Hrončecký grúň and Stužica (the largest of them – about 760 ha) became increasingly valued and were studied in great detail. The standing wood volume in these forests varies between 750 and 1300 m³ per hectare and dead wood amounts to between 100 and 350 m3 per hectare, depending on the dominating phase and site condition. The height of older trees is usually about 35 – 45 m, but the height of the biggest fir trees was 58 m, and the total volume of a single tree amounted to about 55 m³.

The mixed Carpathian forests provide suitable conditions for many animal species including big animals that became extinct in western Europe in the last centuries: brown bear (*Ursus arctos*), lynx (*Lynx lynx*) and wolf (*Canis lupus*). In the Poloniny National Park (Slovakia) and Vânători Neamț National Park (Romania) the European bison (*Bison bonasus*) was reintroduced. The bird fauna is also very diverse. Thus, besides the productive function and water and soil protection, the preservation of biodiversity is one of the very important functions of Carpathians montane beech forests.

Monitoring is the basis for the assessment of possible threats and damages

In a specific study aiming on the detection of air pollution effects on Carpathian forests between 1997 – 2002, there were between 17.9 % (1997) and 27.9 % (2001) of damaged beech trees. This tree species had the best health condition and the lowest average defoliation, followed by Norway spruce, with 42.9 (2001) and 46.6 % (1997) and silver fir with about 50 % damaged trees. Several factors, such as tree age, drought, ozone and exceedances of critical loads for acid deposition were shown to affect crown condition. Several fungi and insect species occur, and can locally become damaging agents, but they do not destabilize the forests. It seems that direct or indirect effects of human activities, including improper forest management are much more important. Beech as a thin-bark tree is sensitive to mechanical damage by logging operations and following rot infections. Despite the relatively good situation concerning forest legislation and nature conservation status, the pressure of tourism can locally have negative effects. Over the long-term, climate change seems to be the most important threat for Carpathian montane beech forests as it can affect growth and health conditions.

The discussion above indicates strongly that detailed monitoring is urgently needed in order to detect stress factors and their impact on beech forests. An holistic scientific evaluation of results is an indispensable basis for decision making at the operative and political levels.

In virgin mountain beech forests, deadwood can constitute up to one fifth of the total wood volume.

Intensive monitoring plot in Germany with permanent circumference measurement tapes (two oak trees in the foreground), throughfall samplers (three white round samplers in the middle) and stemflow collectors (green barrel).

3. Environmental influences and ecosystem reactions

3.1 Some improvements in deposition; critical nitrogen loads are still exceeded

Summary

- *Nitrogen deposition is generally higher on plots in Central Europe compared to Northern and Southern regions. This leads to the exceedance of critical loads on two thirds of the plots mainly located in central Europe. Nitrogen deposition and the resulting nitrogen enrichment in the soil thus remain a widespread threat. Studies are based on nearly 200 monitoring plots.*
- *Model calculations show that on nearly 60 % of the plots, reduction of nitrogen deposition is needed in the coming years in order to be below critical loads. Between 1999 and 2004, however, nitrogen inputs remained unchanged on around 80 % of the plots.*
- *Critical loads for acidity were only exceeded on one third of the plots. However, it is predicted that even in 2050 the soil acidity status will not reach pre-industrialisation levels on most of the plots.*
- *The reduction of sulphur inputs and soil acidification show some real success of clean air policies. Plots with comparatively low sulphur inputs are mainly located in central Europe, in the far North and South-West of the Continent.*

Changing importance of different air pollutants

When ICP Forests was founded more than 20 years ago, sulphur oxides, mainly deposited as sulphate (SO_4), were an important focus for scientists, politicians and the public concerned with forest health and sustainability. However, additional compounds such as nitrate (NO_3) and ammonium (NH_4) have gained in importance. Sulphate and nitrate deposition mainly originate from the combustion of fossil fuels through vehicular traffic, and industry and domestic energy use. Ammonium deposition is largely related to ammonia emissions from agricultural fertilizers and animal husbandry.

Central and Eastern European forest plots receive highest nitrogen inputs

Nitrogen deposition is comparatively high in central Europe. Plots with annual nitrate inputs above 6.3 kg per hectare and with ammonium deposition above 7.5 kg are concentrated in Central Europe.
For sulphate, plots with annual deposition below 3.3 kg per hectare can be found in Alpine regions and in the north (see Figs. 3-1 – 3-3).

Plots in the Mediterranean and in the North are more sensitive to high nitrogen inputs

Critical loads are calculated in order to estimate possible harmful effects of atmospheric deposition to forest ecosystems. Low critical nitrogen loads on many plots in Scandinavia, northern Germany, the Netherlands as well as in the Mediterranean (see Fig. 3-4) characterize ecosystems that are sensitive to high nitrogen inputs. In Scandinavia and Spain, this is due to slow growth rates and small wood volumes removed at harvest resulting in a small export of nitrogen from the ecosystem. In the Mediterranean there is also little export of nitrogen through leaching, due to low precipitation. Thus, more nitrogen is assumed to remain in the ecosystem resulting in higher risks of harmful effects. On Alpine plots with high precipitation, more nitrogen deposition is leached thus leading to higher critical

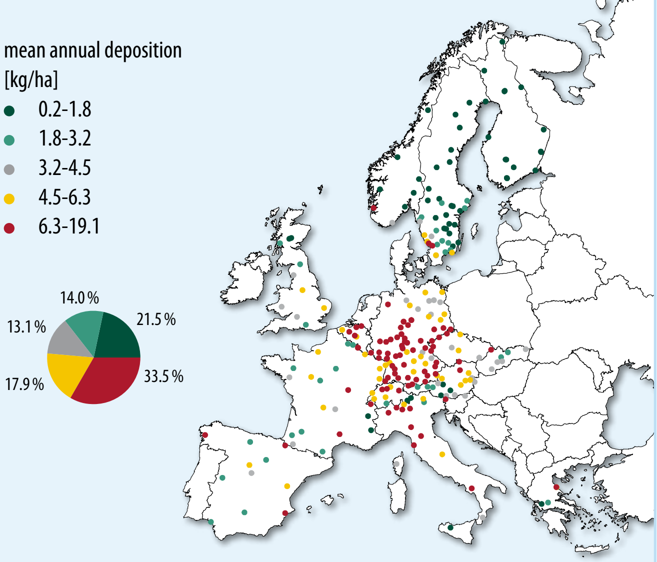


Figure 3-1: Mean throughfall deposition of nitrate (NO_3-N) 2002-2004 on 219 plots.

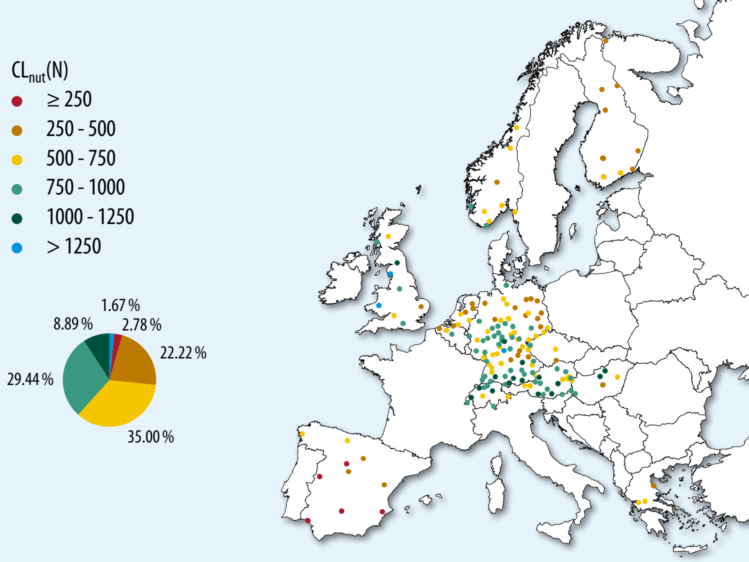


Figure 3-4: Critical loads for nutrient nitrogen on 186 plots. The assessment of soil data necessary for critical load calculation was optional until recently. Data are available for more plots; the submission from national data bases is still ongoing.

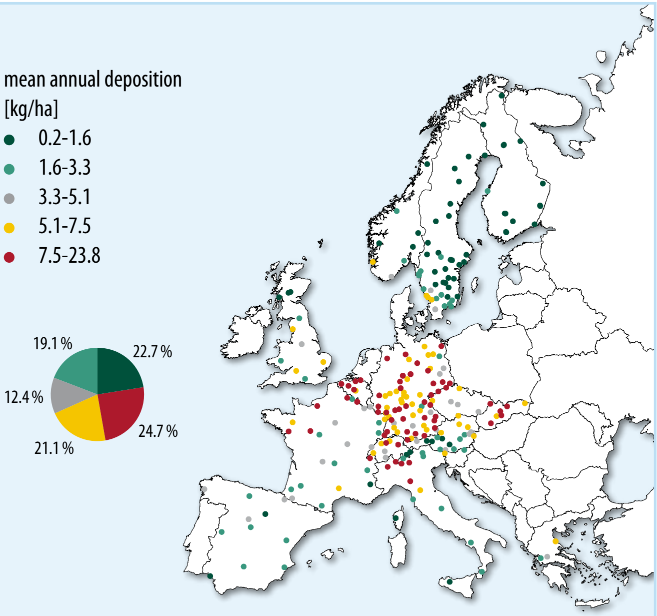


Figure 3-2: Mean throughfall deposition of ammonium (NH_4-N) 2002- 2004 on 219 plots.

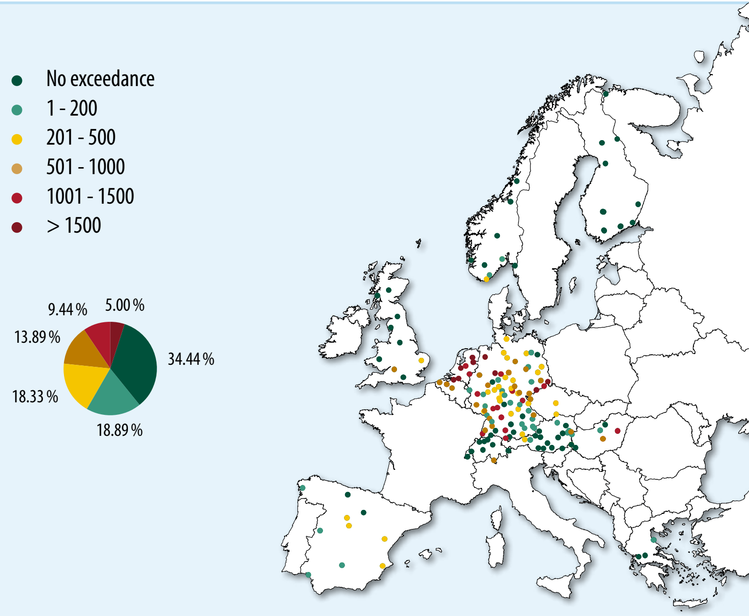


Figure 3-5: Exceedance of critical loads for nutrient nitrogen in $mol_c ha^{-1} a^{-1}$ by present deposition. *)

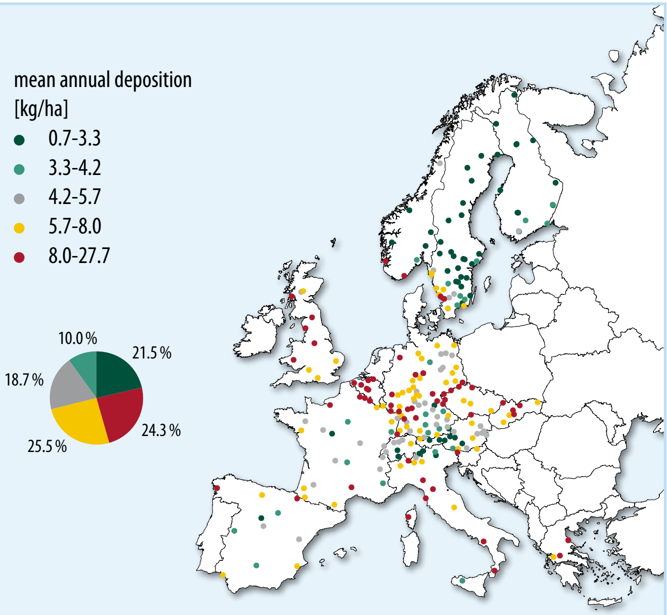


Figure 3-3: Mean throughfall deposition of sulphate (SO_4-S) 2002- 2004 on 219 plots.

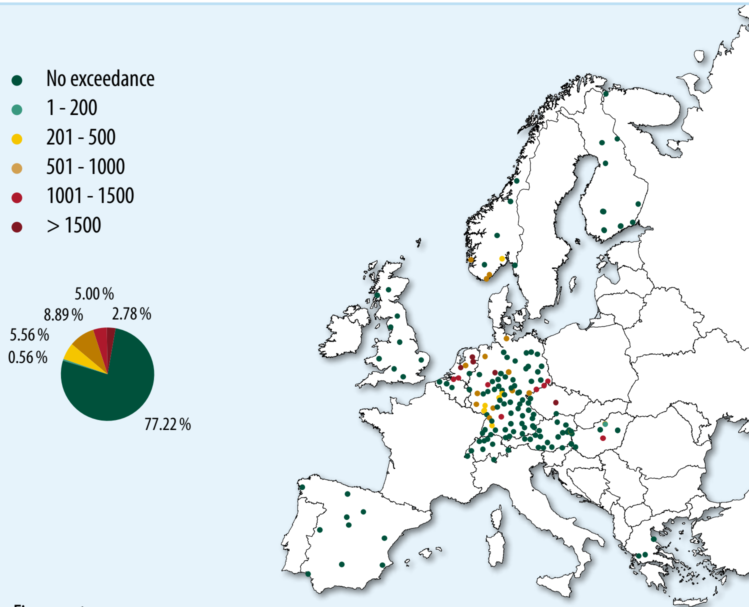


Figure 3-6:
Exceedance of critical loads for acidity in $mol_c ha^{-1} a^{-1}$ by present deposition. *)

*) The assessment of soil data necessary for critical load calculation was optional until recently. Data are available for more plots; the submission from national data bases is still ongoing.

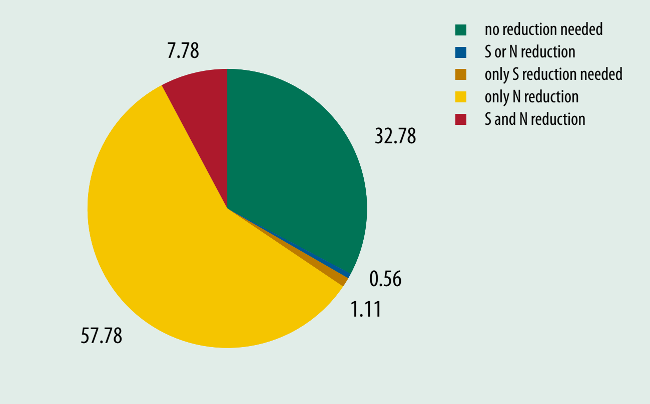


Figure 3-7: Required reduction to reach deposition below critical loads (S = sulphur, N = nitrogen).

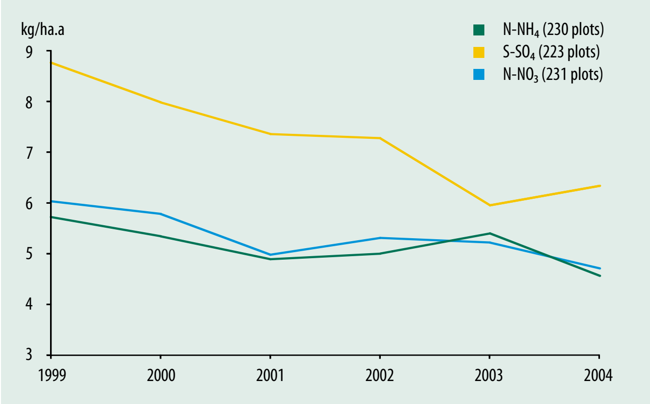


Figure 3-11: Development of measured mean plot troughfall deposition of sulphate (SO_4-S), nitrate (NO_3-N) and ammonium (NH_4-N).

loads. Critical load calculations only take into account effects to the forest stands. Possible negative effects of nitrogen leached into the ground water are not considered by the models. In Central Europe the model calculations assume higher nitrogen uptake by forest trees and thus a lower sensitivity of the forest ecosystems.

Nitrogen deposition is above critical thresholds on almost all plots in central Europe

Critical loads for nitrogen inputs were exceeded on almost all plots in central Europe and to a lesser extent on the Spanish plots (see Fig. 3-5). Nitrogen deposition, and the resulting nitrogen enrichment (eutrophication) in the soil, is a widespread risk. Negative effects of nitrogen deposition have to be expected in large parts of Europe. Accelerated tree growth can occur (see Chapt. 3.2), but there remains the possibility of destabilisation of forest stands and the loss of ability for the soil to buffer and help prevent water pollution, an important function of many forest soils. Shifts in ground vegetation composition can also be related to nitrogen deposition. There were only a few plots with exceedances in the Alps, in Scandinavia, United Kingdom and Greece.

Critical loads for acidity were exceeded on a much smaller proportion of the evaluated plots than critical loads for nitrogen (see Fig. 3-6). This is a result of clean air policies. However, the acidity status of many plots is still influenced by historical sulphur and nitrogen depositions in the years 1960 – 2000 from which the forest soils have not yet recovered. Present exceedances of critical acidity are caused by a combination of nitrogen and sulphur deposition.

In order to be below critical loads, nitrogen deposition needs to be reduced on nearly 60 % of the evaluated plots. Both nitrogen and sulphur deposition need to be reduced on around 8 % of the plots, whereas no reduction is needed on 33 % of the plots (see Fig. 3-7).

Sulphur deposition shows stronger decreases as compared to nitrogen inputs

On over 80 % of around 200 evaluated plots, no significant change in nitrogen deposition was observed between 1999 and 2004. On the remaining plots improvements prevailed. There were hardly any plots with increasing deposition (see Figs. 3-8, 3-9). Mean nitrate deposition decreased from 6.0 kg nitrogen per hectare in 1999 to 4.7 kg

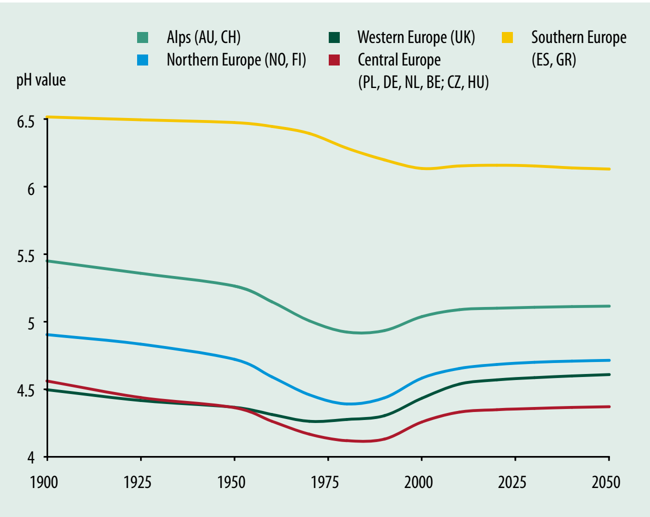


Figure 3-12: Development of modelled soil pH for 158 Level II plots located in 13 countries acidification. Low values indicate acid conditions.

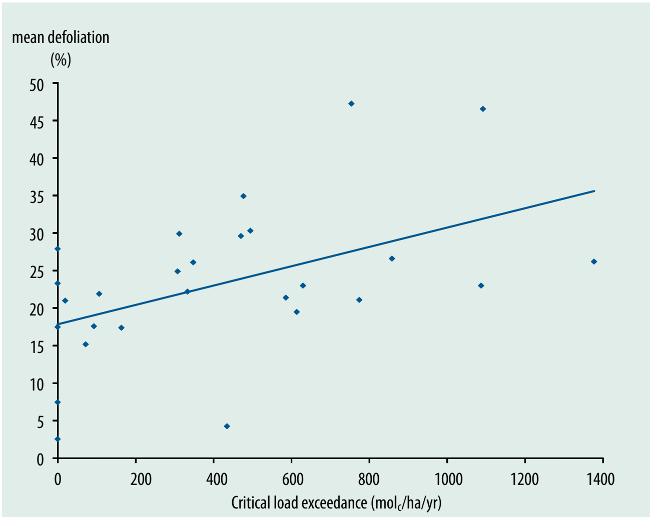


Figure 3-16: Defoliation of beech at Level II plots related to exceedances of critical loads for nutrient nitrogen.

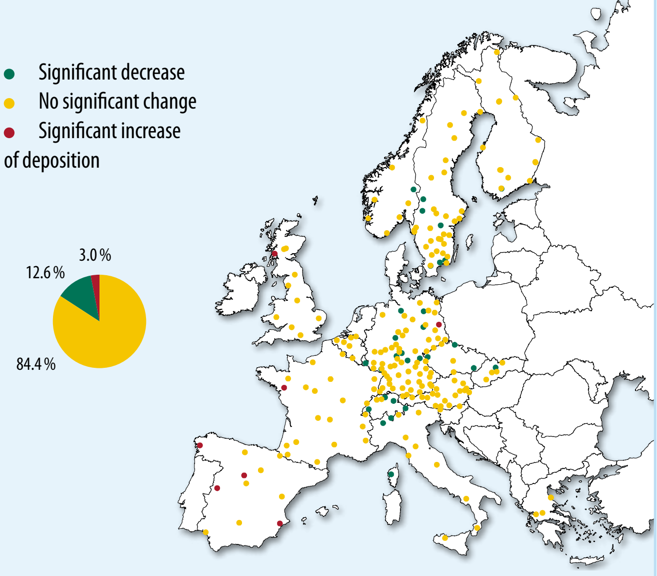


Figure 3-8: Trend of measured nitrate (NO_3-N) throughfall deposition. 1999 – 2004 on 206 plots.

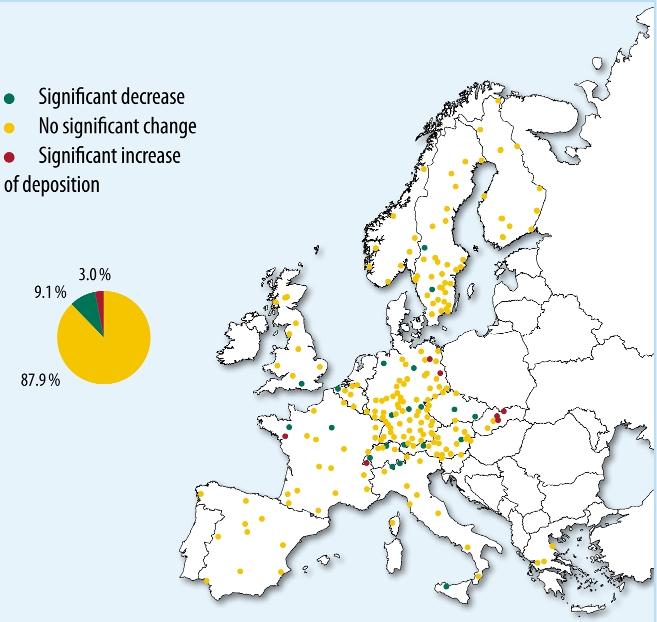


Figure 3-9: Trend of measured ammonium (NH_4-N) throughfall deposition. 1999 – 2004 on 205 plots.

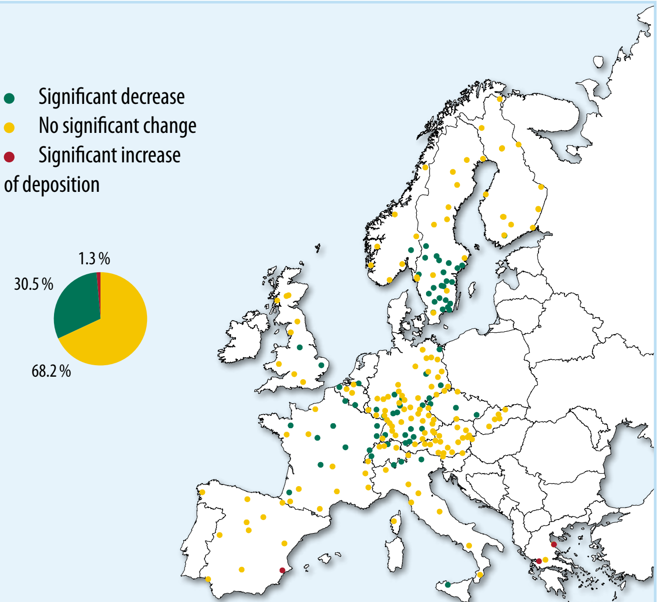


Figure 3-10:
Trend of measured sulphate (SO_4-S) throughfall deposition. 1999 – 2004 on 198 plots.

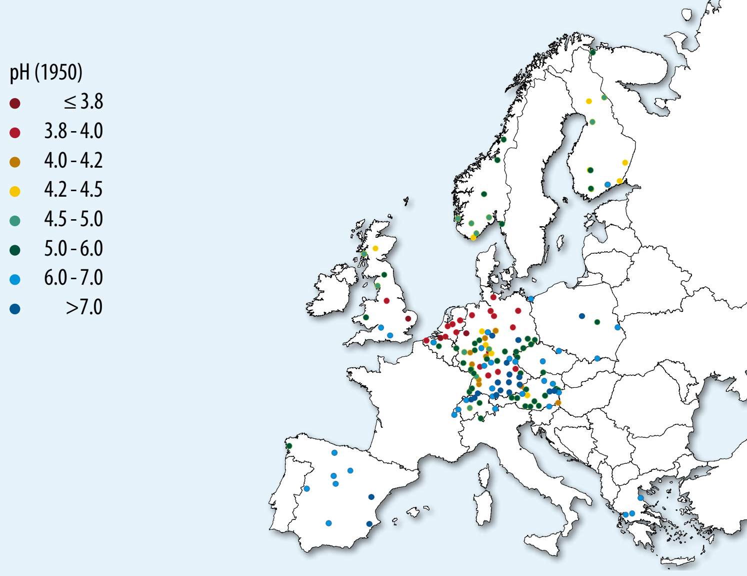


Figure 3-13: Modelled pH values at Level II plots for 1950. The pH value is a common chemical indicator for acidification. Low values indicate acid conditions*).

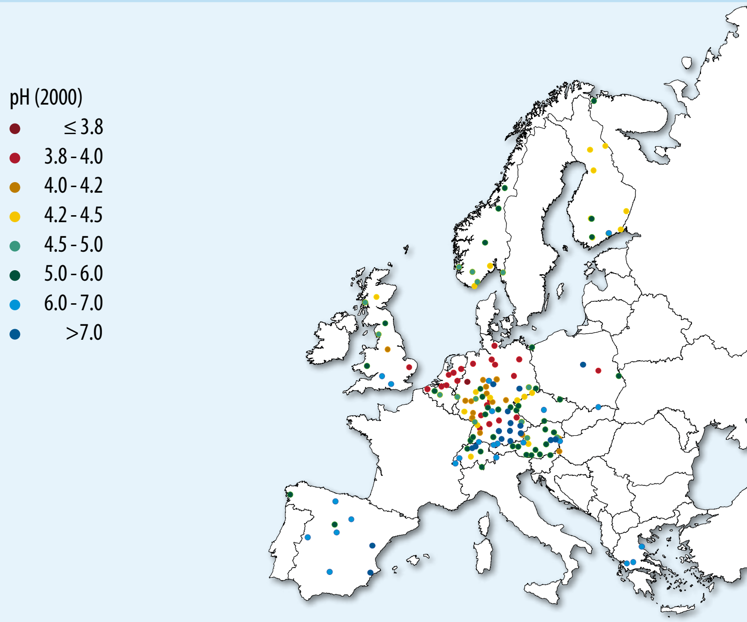


Figure 3-14: Modelled pH values at Level II plots for 2000.*)

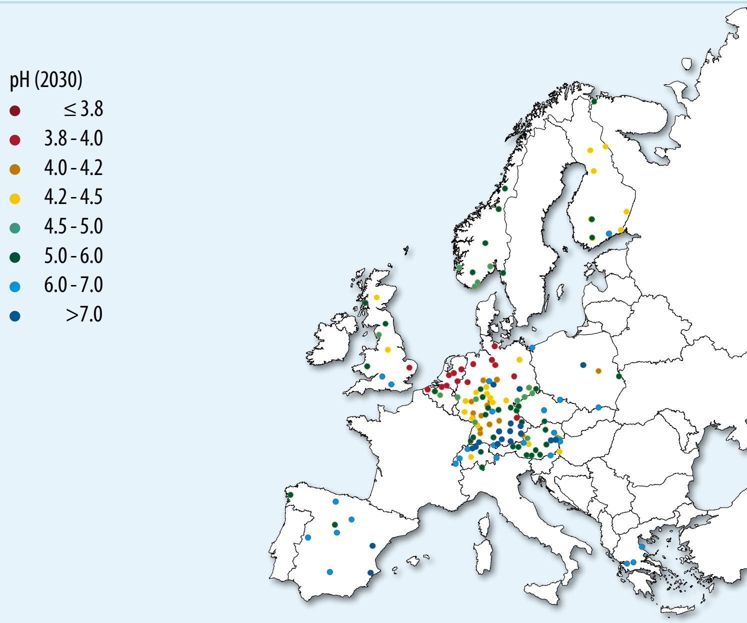


Figure 3-15: Modelled pH values at Level II plots for 2030.*)

*)The assessment of soil data necessary for pH modelling was optional until recently. Data are available for more plots; the submission from national data bases is still ongoing.

in 2004 (see Fig. 3-11). Mean ammonium deposition decreased from 5.7 kg nitrogen to 4.6 kg per hectare on the plots monitored in the same period. For sulphate deposition there were stronger reductions observed, with around one third of the plots showing significantly decreasing sulphur inputs (see Fig. 3-10). The evaluated monitoring plots are mainly located in central Europe.

Reduced deposition leads to some recovery from soil acidification

Dynamic models can help to evaluate forest ecosystem responses to changing deposition scenarios. They take into account specific site and stand conditions at each plot and allow the study of future effects of today's clean air policies. Results show that acidifying effects of the atmospheric deposition are widespread (see Figs. 3-13 to 3-15). Until the mid 1990s, decreasing soil pH indicates acidification of soil water in all regions studied. The reduction of sulphur and to a lesser extent nitrogen deposition has been shown for the Level II plots to lead to a recovery of pH on most of the plots. However, it is predicted that the original pH modelled for the beginning of the last century will not be reached again until 2050 (see Fig. 3-12). A full recovery of pH was only calculated for the plots in the United Kingdom. Due to prevailing calcareous parent materials, the pH on Spanish and Greek plots is generally higher. Industrialisation and thus soil acidification started later in these regions.

Beech trees show increased defoliation on plots with higher exceedances of critical loads

The above mentioned exceedances of critical loads for acidity and nutrient nitrogen calculated for a given year were compared with defoliation of the main tree species as assessed in the same year on the same Level II plots. Of these species, only beech revealed a statistical relationship between defoliation and the exceedance of critical loads for nutrient nitrogen (see Fig 3-16). For the other species no such relations could be verified. The fact that nearly no relations to damage symptoms were substantiated on plots showing critical loads exceedances is not contradictory to the concept of critical loads. Forests are able to store nitrogen up to a certain degree, so that today's exceedance of CL is not necessarily linked to direct and immediate damage to trees.

Further information:
Lorenz, M.; Fischer, R.; Becher, G.; Granke, O.; Riedel, T.; Roskams, P.; Nagel, H.-D.; Kraft, P. (2007) Forest Condition in Europe. 2007 Technical Report. BFH, Hamburg, 91pp, Annexes.
http://www.icp-forests.org/RepTech.htm

Deposition measurements are carried out within the forest stands (throughfall deposition) and in nearby open fields (bulk deposition). In the forest canopy, some elements can be leached from the foliage and increase the measured deposition load, whereas others are taken up by leaves and needles and are thus not detected in throughfall. Bulk deposition is not influenced by element fluxes in the canopy but is mostly lower because the forest canopy filters additional deposition loads from the air. Thus, neither throughfall nor bulk deposition is equal to the total deposition that is received by the forest stands. On the plots, samples are collected weekly, fortnightly or monthly and are analysed by national experts. After intensive quality checks, annual mean depositions for the years 1999 to 2004 were calculated for plots with complete data sets. Slopes of plotwise linear regressions of deposition over time were tested for significance. Throughfall deposition was used to calculate exceedances of critical loads.

Dynamic soil chemistry models such as VSD (Very Simple Dynamic Model) show the effects of acid deposition and forestry measures on the soil water over time. The key processes included in the model are element fluxes in deposition, nutrient uptake by trees, nutrient cycling including mineralization, weathering processes for base cations and aluminium, and leaching of elements to groundwater. The calculations rely on soil data from Level II. As chemical and physical soil properties change rather slowly, all data submitted since the beginning of the Intensive Monitoring Programme have been used. In addition, historical deposition rates were available from the literature. Future deposition scenarios based on the UNECE Gothenburg Protocol were applied as calculated by the International Institute for Applied Systems Analysis (IIASA). Dynamic models were applied to 158 Level II plots.

Critical loads define thresholds for the effects of air pollution. If pollution is below the critical values, it is assumed that no environmental damage will occur and a long-term stability of the ecosystem is achieved. Critical loads are derived using the principal of a scale balance to compare the quantity of mainly anthropogenic pollutants as inputs on one side and the removal, acceptable storage and outputs of these substances on the other. The system remains in balance as long as critical loads are not exceeded. Any additional input of pollutants may cause harmful effects.

Acidity is given in $\mathbf{mol_c.ha^{-1}.yr^{-1}}$ ("mol of charge per hectare per year"). Mols of charge allow comparisons of the deposition of different substances. The simpler unit of $\mathbf{kg.ha^{-1}.yr^{-1}}$ does not allow this comparison. 1000 mol_c is equivalent to 14 kg of nitrogen and 16 kg of sulphate sulphur.

3.2 Nitrogen deposition and high temperatures accelerate forest tree growth

Summary

- *Results suggest that nitrogen deposition leads to increased tree growth. On plots with high inputs, growth of pine, spruce and beech trees was consistently higher than expected for given site conditions, stand age and density.*
- *Higher growth increase occurred on sites with a low original nitrogen status. These sites with limited nitrogen availability are responding stronger to the atmospheric inputs, as expected. Further research will test whether prolonged high nitrogen deposition will have negative effects such as declining growth or increased tree mortality.*
- *Temperatures above the long term mean during the growing season also correlated with increased tree growth.*

Level II plots are a basis to investigate increased tree growth

Previous reports have suggested that forest growth in Europe has been increasing in recent decades. Data from Intensive Monitoring Plots over a five years period have been used to examine the influence of environmental factors on forest growth (see Fig. 3-17). Evaluation focussed on the influence of nitrogen, sulphur and acid deposition, temperatures, precipitation and on a drought index calculated as the deviation from the long-term mean. The study included the main tree species Norway spruce, Scots pine and common beech as well as European and sessile oak and was based on data from 363 plots.

Main tree species react to environmental influences

Relative growth of spruce and pine trees was significantly higher on plots with high nitrogen deposition. For beech trees there was also a positive relation with nitrogen deposition, but it was not statistically significant (see Fig. 3-18). On sites that were already nitrogen saturated this effect was smaller whereas a stronger influence of nitrogen deposition could be substantiated on sites with a low nitrogen status. These results indicate an accelerating effect of nitrogen deposition on forest tree growth. On sites that were overexploited in the past and with a good supply of nutrients other than nitrogen, these inputs may compensate for former nitrogen losses. On other sites it is possible that, while nitrogen deposition increases growth at first, it may cause nutrient imbalance and may in the long-run lead to a destabilisation of forest stands. The appraisal of these findings is still ongoing.

Temperatures above the long term mean in the growing season also correlated with higher relative growth for all three of the main tree species (see Fig. 3-19). However drought may offset the effects of increased temperature at least for pine and spruce at sites with low water availability. For oak with only 32 available plots results were neither consistent nor significant.

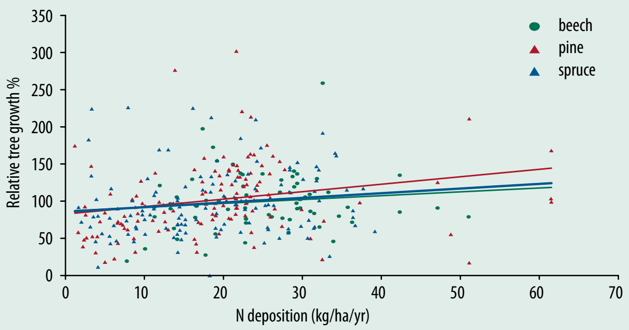


Figure 3-18: Relative tree growth in relation to nitrogen deposition. Overall, an increase of 1 kg nitrogen deposition per hectare and year accounted for an increase of 1 % in stem growth. (Dobbertin and Solberg, 2007)

Calculation of relative growth

As many other factors besides nitrogen and temperature influence tree growth, expected growth was modelled using site productivity, stand age and a stand density index. Relative tree growth was then calculated as actual growth in % of expected growth. The model explained between 18 % and 39 % of the variance with site productivity being positively related and age negatively related to actual growth. The site productivity was either taken from expert estimates or computed from site index curves.

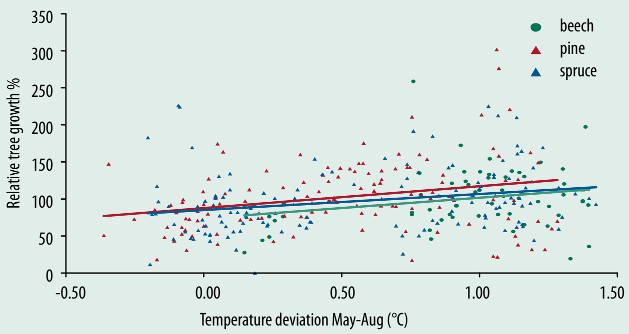


Figure 3-19: Relative tree growth in relation to temperature deviation from the long term mean. A temperature deviation of 0.1°C accounted for an increase of between 2 to 4 % in growth. (Dobbertin and Solberg, 2007)

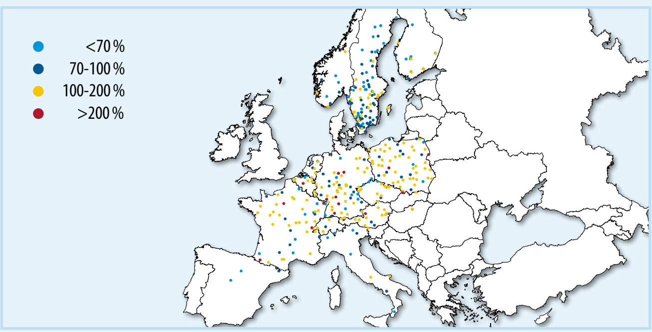


Figure 3-17: Relative tree growth on Level II plots in Europe given as deviation of measured from modelled growth. Increased tree growth was more often observed on plots in central Europe (Dobbertin and Solberg 2007).

Examples of different passive sampler devices exposed in Intensive Monitoring Plots across Europe. A) France, B,C) Switzerland, D) Spain. Passive samplers provide an accurate and inexpensive method for measuring cumulative exposures of different air pollutants such as ozone and do not require any electric power. The ozone molecules diffuse into the sampler where they are absorbed. After the analysis in a laboratory they give a mean concentration value over time.

3.3 After an extreme year 2003, ozone concentrations were again lower in 2004.

Summary

- *Ground level ozone is the most important toxic air pollutant for plants worldwide and contributes to global warming.*
- *The passive samplers of the ICP Forests Level II monitoring network constitute the only transnational harmonized measurement campaign for a wide selection of remote forest areas in Europe.*
- *Over the measurement periods of 2000-2004, concentrations were higher in 2003 and relatively low in 2004, probably due to contrasting weather conditions during the respective seasons.*
- *Critical ozone levels for sensitive forest species (AOT 40) were frequently exceeded during summer seasons in all years.*
- *Ozone flux to forests was successfully modelled based on the intensive monitoring data.*

Ground level ozone is toxic for plants and contributes to global warming

Current ground level (tropospheric) ozone (O_3) concentrations are considered to be by far the most important gaseous air pollutant for plants worldwide. In addition, tropospheric ozone has been recognized as an important greenhouse gas and is a significant contributor to the "global warming". Elevated CO_2 concentrations in the atmosphere stimulate plant growth and thus the carbon sink strength of plants, but these mitigating effects are potentially curtailed by ozone toxicity. The formation of ozone takes place under intensive solar radiation and elevated air temperatures and is enhanced by the presence of pollutants such as nitrogen oxides and volatile organic compounds. Ozone concentrations in remote areas are predicted to remain high or even increase, underlining the need to continuing monitoring across Europe.

Passive samplers provide a cost effective monitoring method for remote areas

'Passive' samplers used in the ICP Forests Level II monitoring network constitute the only transnational harmonized measurement campaign for a wide selection of remote forest areas in Europe. This method provides data on ambient ozone levels and exposures across Europe which also play an important role for the validation of large-scale modeling for European forest ecosystems.

Ozone concentrations over the period 2000-2004

The highest ozone concentrations in forest areas across Europe are typi-

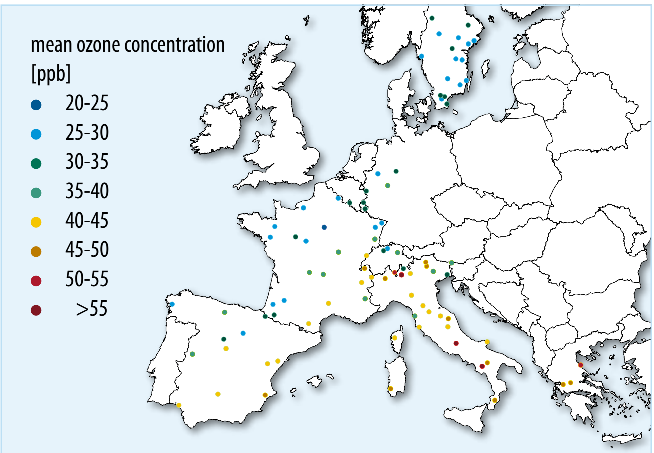


Figure 3-20: Mean ozone concentrations for April-September in 2000 – 2004. Due to the higher solar radiation, concentrations typically increase from North to South Europe.

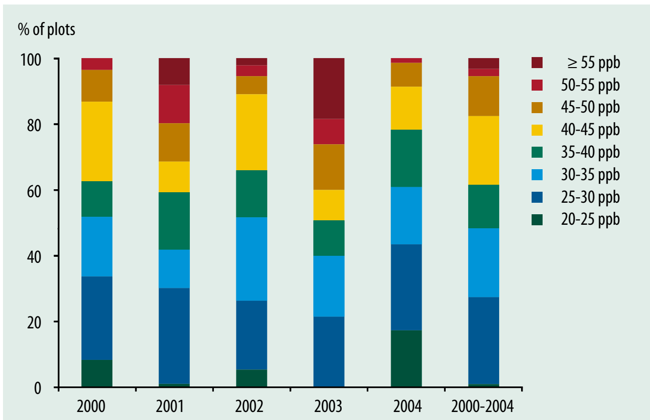


Figure 3-21: Shares of plots belonging to 8 classes of ozone concentrations based on the mean ozone values (April-September) 2000-2004. Only plots with at least 70 % data cover during the observation period were considered.

cally found in the South (see Fig 3-20). Over the period from 2000 to 2004 highest concentrations were measured in 2003, a year with one of the hottest summers on record for Europe. The high air temperatures measured during the summer of 2001 are also reflected in the higher ozone levels during that year. In the five year study period, concentrations were lowest in 2004, due to the relatively low solar radiation recorded during April-September 2004 (see Fig 3-21).

Critical ozone levels for sensitive vegetation are frequently exceeded

Data from passive sampling have been successfully used to model the AOT40 (Accumulated Over a Threshold of 40 ppb ozone), i.e. the index used to identify a possible risk for sensitive vegetation. A recent run of the model for 24 Italian plots over the period 2000-2004 revealed a continuous exceedance of the UNECE Critical Level for sensitive vegetation under sensitive conditions (5000 ppb*h) on all plots. However, the extent to which these exceedances lead to adverse effects on forest vegetation remains subject to further investigation.

Ozone flux studies are an advanced approach to evaluate ozone effects on forest vegetation

Recent research has focussed on how much of the gaseous pollutant is taken up by plants. This so-called ozone flux can be estimated by process models which are based on data from Level II intensive monitoring plots. The models are data hungry (see Fig. 3-22) as they need to predict complex physiological processes which in turn depend on environmental factors such as climatic, soil and site conditions and forest structure including plant age, species composition and other factors., The further development and validation of ozone flux models is currently being undertaken in collaboration with the International Cooperative Programme on Effects of Air Pollution on Natural Vegetation and Crops (ICP-Vegetation).

A standardized assessment approach is being developed

To evaluate the effects of ozone on forest ecosystems, the assessment of ozone-induced visible injury on needles and leaves has been shown to be a useful and inexpensive method. In order to standardize the assessment of ozone visible injury and its flux-relevant onset, clones of an ozone sensitive poplar genotype (*Populus x berolinensis*) are currently being tested for their suitability as bio-indicators at a subset of Level II sites. Such a bio-indicator approach provides valuable, standardized reference data for ozone effects which may be very useful for a better understanding of an ozone-risk assessment for forest ecosystems across Europe (e.g. determination of critical flux).

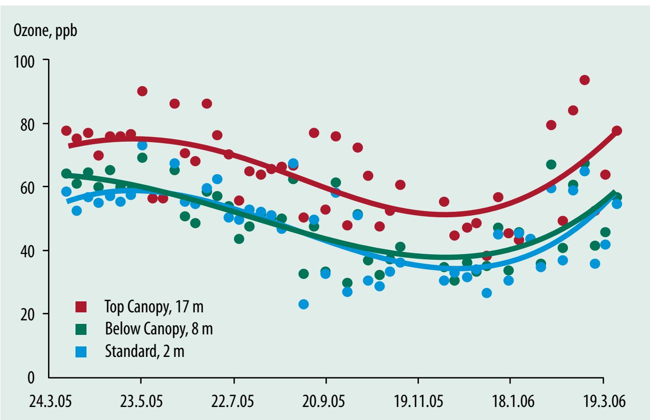
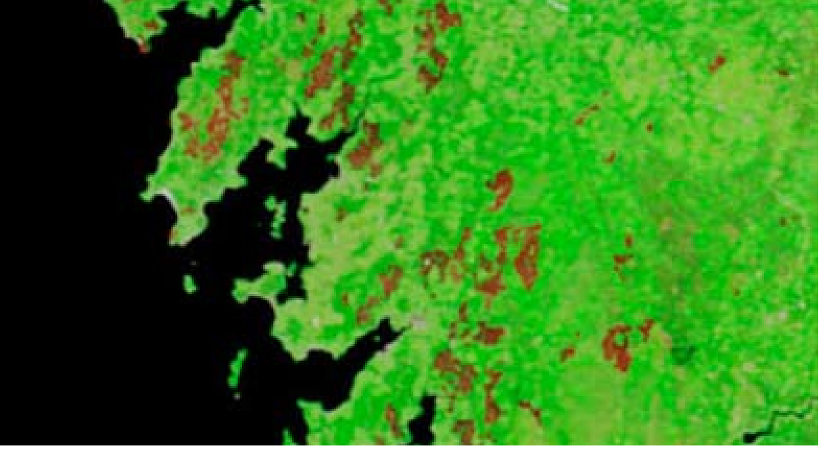


Figure 3-22: Ozone concentration at different canopy heights at one Italian Level II plot between March 2005 and March 2006 (Bussotti and Ferretti, 2007). In order to estimate the ozone uptake by forest trees very detailed and data intensive assessments are required.

Typical ozone-induced visible symptoms on a poplar leave.



Satellite image with visible burned areas showing the situation in Galicia, Spain by the 21 August 2006.

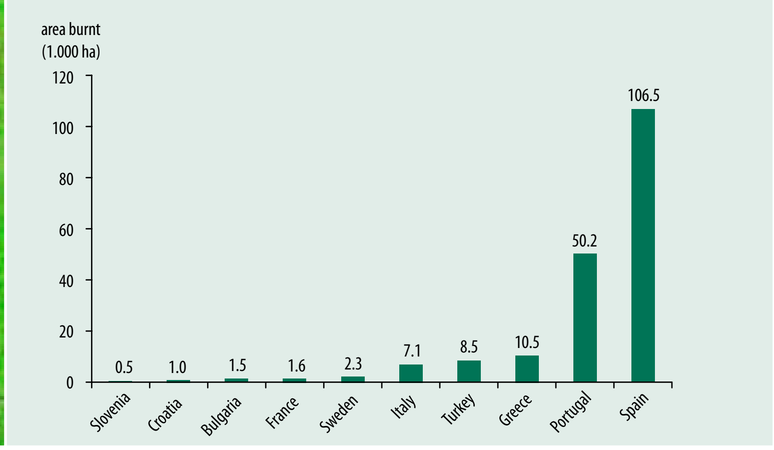


Figure 3-24: Burnt forest area in a number of countries in summer 2006 as mapped by the use of satellite images.

3.4 2006 was an unexceptional year for forest fires

Summary

- *The 2006 summer fire season has been characterized by average fire danger conditions in the Mediterranean region. The largest forest fires occurred in Galicia, Spain.*
- *The occurrence of forest fires largely depends on specific weather conditions. The Fire Weather Index as calculated by the European Commission is based on meteorological data and can provide reliable information on actual fire risk in different areas of Europe.*

Fire risk can be calculated based on weather data

Through the Fire Danger Forecast module of EFFIS the fire risk level is continuously analyzed and mapped. The Fire Weather Index (FWI) is used as fire risk indicator (see Fig. 3-23).

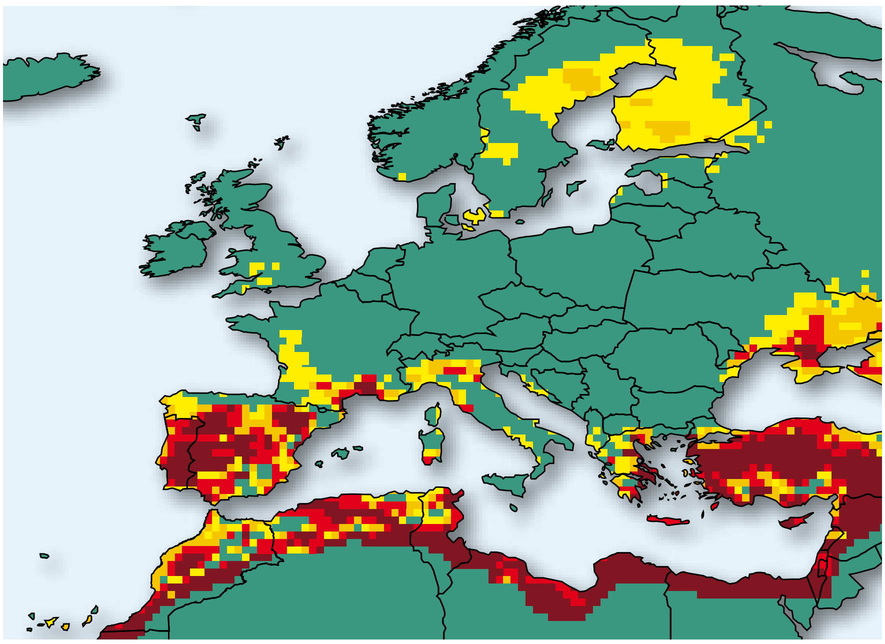
Satellite images are an important basis for the analysis of the forest fire situation

The mapping of fire burned forest areas in Europe is carried out through the analysis of satellite images (MODIS). This Rapid Damage Assessment corresponds only to the burnt areas of 50 ha or larger. Official statistics on the total burnt area and the number of fires, based on field information, are released annually by Member States and are compiled in the fire reports published by the Joint Research Centre.

Spain had the largest area affected by forest fires

The European Forest Fire Information System (EFFIS) has been developed at the Joint Research Centre and provides up to date information on the forest fire situation in Europe. The 2006 summer fire season was characterized by average fire danger conditions in the Mediterranean region with localized high fire danger conditions during the month of August in North-west Spain and Northern Portugal. This resulted in a large number of fires that led to an unusual large burned area in the region of Galicia, Spain. In Central and Northern Europe there were quite a few unusual periods of fire danger that led, for example, to an increase in the number of fires in Norway and to exceptionally large fires in Sweden (see Fig. 3-24).

Further information:
http://effis.jrc.it/



Fire Danger (1 day(s) forecast
2006.08.08.)

- Very low risk
- Low risk
- Moderate risk
- High risk
- Very high risk

Figure 3-23: Fire Weather Index (FWI) for Europe on the 8 of August 2006 as calculated by the European Forest Fire Information System of the Joint Research Centre. In 2006, the risk indicator correlated closely with the regions where fires actually occurred.

Stemrust infestation on a Scots pine tree.

Larvae of the oak splendour beetle (*Agrilus biguttatus*) feeding on the wood beneath the bark of European oak.

Drought symptoms on holm oak in Spain.

3.5 Insects and fungi are important factors influencing tree condition

Summary

- *A new system involving a more detailed assessment of influences on tree condition has been successfully implemented in the last two years.*
- *Oak and beech had the highest proportion of trees with damage symptoms and had the highest mean defoliation scores. Insects and fungi were the most commonly reported causes.*
- *When time series become longer the data will not only be an important basis for the interpretation of tree health but will contribute species information to the ongoing biodiversity discussions, and will reflect ecosystem reactions to climate change.*

In addition to defoliation, many other symptoms like discolouration of leaves, dead branches or stem wounds can provide information on tree health and vitality. Knowledge about their occurrence is essential for the study of cause-effect mechanisms. From the start of the ICP Forests, monitoring programme information on the presence or absence of eight easily identifiable damage causes has been collected on Level I plots. In 2004, a new method for the assessment of damage causes was implemented, allowing for more detailed information to be collected.

Oak and beech trees had highest shares of trees with damage symptoms

Data from 2006 were evaluated from 80 093 trees on 4 464 Level I plots located in 19 countries. Oak and beech trees had the highest share of trees with observed symptoms (see Fig. 3-25). Defoliators were important for these symptoms in both tree species. This helps to explain the mean defoliation values of these species which are higher than those of the conifers (see Fig. 2-2). For around half of the assessed symptoms damage causes could be identified. Insects and abiotic factors like drought, snow and storm constituted the largest shares of observed damage causes (see Fig. 3-26). For oak species it is well known that a large number of insects naturally live and depend on them. Thus, the information on factors influencing tree condition also reflects aspects of biodiversity and the observed symptoms are not exclusively interpreted as damage.

Baseline data for tree health, biodiversity and climate change aspects

The new system of damage cause assessments has been successfully implemented and first evaluations have begun. Results so far indicate that only a few symptoms are common and their relative importance varies between tree species. Keeping records of damage symptoms and causal factors over the years will provide baseline data for quantifying their influence on tree health as well as their role in stand dynamics. The system will also contribute knowledge on aspects of biodiversity and on reactions of forest ecosystems to climate change.

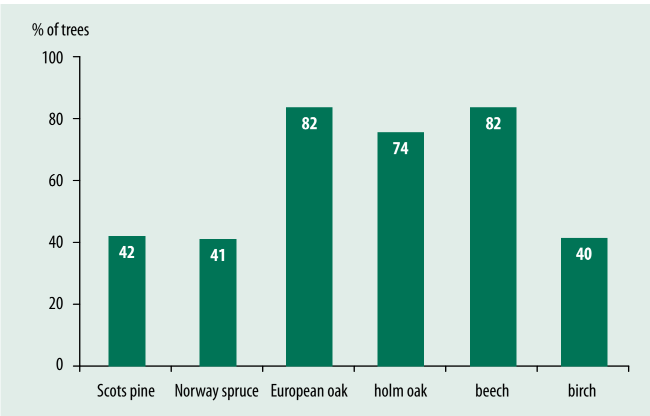


Figure 3-25: Percentage of trees with recorded symptoms. Oak species and beech had the highest shares of trees with reported damage causes.

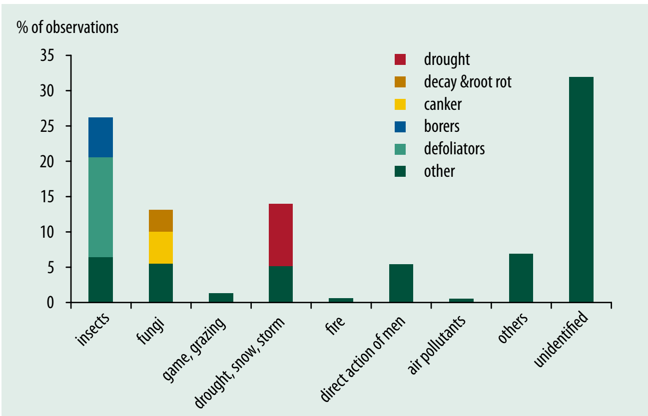


Figure 3-26: Percentage of observed damage causes. Insects, fungi and weather influences were most frequent.

Deadwood in a central European lowland beech forest.

Structured maritime pine stand with species rich shrub and herb layer in the Mediterranean region.

4. Biological diversity is under observation

Summary

- *Communicating about European forests has to embrace the large diversity of forest types across the continent. A new forest type classification proved to be very valuable in this context.*
- *Forest type and site factors strongly determine the species richness of forest vegetation. Stand structure and forest management also influence the occurrence of epiphytic lichens and to a lesser extent the plants in the herb layer.*
- *High loads of sulphur and nitrogen deposition are man-made impacts related to low diversity of herbs and epiphytic lichens on nearly 100 plots across Europe. However, this may at least be partly due to naturally low species numbers in beech and plantation forests located in areas with high deposition.*
- *Within the BioSoil demonstration project, large scale representative forest biodiversity information is presently collected on over 4 000 Level I plots.*

Assessments of biodiversity gain importance

In 2002, the environment ministers of Europe declared a halt to the loss of biodiversity by 2010. This ambitious aim clearly needs to be supported by representative and reliable information on the biological state of forests in Europe. Within the European forest monitoring programme, some indicators related to biological diversity, such as tree species and ground vegetation, have been assessed from its inception. With co-financing from the European Commission under the Forest Focus Regulation, a specific biodiversity test phase was completed on 96 Intensive

Indicators for Biodiversity

Biological diversity is assessed by means of a number of indicators, as it is practically impossible to assess the diversity of all living organisms.

Deadwood

The occurrence of deadwood is regarded as a key parameter for forest biodiversity as it provides nutrition and habitats for many species, specifically for insects, fungi, mosses and lichens. Its presence or absence is strongly related to forest management and timber harvesting.

Stand structure

Structurally diverse forest stands contain more vertical tree and shrub layers and show a more random horizontal distribution tree pattern. It is assumed that a greater range of habitat types is associated with such stands. For example, a close relationship has been shown between forest stand structure and the occurrence of bird species.

Epiphytic lichens

Epiphytic lichens grow on the bark of trees. Lichens are long-living organisms with a high sensibility to environmental influences including air pollution. Lichen occurrence has been shown to depend on specific climatic parameters and on stand structure.

Ground vegetation

Many plants depend on specific soils and site types. Plant species composition can be related to environmental conditions. Ground vegetation assessments have been conducted since the beginning of the Intensive Monitoring Programme.

Lichen species *Hypogamnia physodes*.

Autumn colouring of bilberry shrubs in a typical combination with ground occurring lichens in Scandinavia.

Monitoring Plots (ForestBIOTA). A related demonstration project (BioSoil) on Level I plots was started in 2006. The application of a new forest type classification was an important basis for the evaluations (see Fig. 4-1).

Above all: a diversity in forest types

A regional perspective is essential in understanding, evaluating and reporting indicators of sustainable forest management. Intensive monitoring plots were thus assigned to a new forest type classification proposed by the European Environment Agency (see Figs. 1-1 and 4-1). Means per forest type were calculated for a number of indices. As expected, results showed

Forest type	Number of plots (varying per survey)	Tree species per plot	Soil pH	Plant acidity index*	Plant nitrogen index*	Plant temp. index*	Critical Load Exceed. nitrogen ($mol_c.ha^{-1}.a^{-1}$)	Deposition NH4 ** ($kg.ha^{-1}.a^{-1}$)	Deposition NO3 ** ($kg.ha^{-1}.a^{-1}$)
Boreal	17-136	2.1	3.6	2.8	2.8	4.0	0.01	0.7	0.8
Hemiboreal/ nemoral conif. and mixed	30-190	2.2	3.4	3.4	3.9	5.0	729.5	5.1	5.3
Alpine coniferous	34-196	3.1	3.8	4.6	4.6	4.4	439.0	5.5	6.3
Acid. oak	9-59	3.2	3.5	4.2	4.4	5.3	682.8	5.2	3.8
Mesophyt. deciduous	13-97	4.5	3.9	5.6	5.1	5.3	410.6	8.1	5.9
Beech	29-152	2.9	4.0	5.0	5.2	5.1	216.3	6.8	6.9
Montane beech	9-84	2.9	4.2	5.3	5.3	4.9	237.0	6.8	7.4
Thermoph. deciduous	13-29	2.1	5.3	6.3	4.6	6.0	-	-	
Broadleav. evergreen	21-32	2.3	5.2	5.7	3.6	6.3	-	-	
Mediterran. coniferous	7-30	1.3	5.4	5.8	3.5	6.2	196.4	2.7	5.7
Plantations	23-129	1.7	3.6	3.5	3.9	5.3	592.2	6.4	5.4

Table 4-1: Means of selected key parameters per forest type, calculated for intensive monitoring plots. Shaded boxes indicate higher values. All parameters differ significantly between forest types. A regional perspective is essential for monitoring and reporting for sustainable forest management.

* Mean Ellenberg indicator ** sum of throughfall and stemflow

significant differences in plant species composition, soil properties and critical load exceedances across Europe (see Tab. 4-1). Boreal forests are located in the north of Europe. Here, plant species and measured soil pH indicate a naturally more acidic soil. Deposition and exceedance of critical loads are low in this area. Beech forests are mostly located in central Europe. Nitrogen inputs are among the highest in this forest type. In evergreen broadleaved forests located in Mediterranean areas, soils are less acidic and plants are adapted to higher temperatures.

The occurrence of mosses, herbs and lichens naturally differs in forests across Europe

Herb species, lichens and mosses constitute an important part of the biological diversity in many forest types. In depth assessments were therefore carried out in the ForestBIOTA project. In boreal forests mosses and lichens usually dominate the ground vegetation. Ground vegetation of lowland beech forests is naturally species poor. Large numbers of epiphytic lichens are typical for montane beech plots. Alpine and Mediterranean plots showed highest numbers of herb species (see Fig 4-2).

Epiphytic lichens are more sensitive to stand structure then ground vegetation

Compared to geographical and other site factors, stand structure, and thus forest management, had less influence on the richness of the observed species groups at all. Diversity of the moss layer was not related to stand structure at the European scale. For herbs, higher species numbers were observed in stands with more tree layers. Large numbers of epiphytic lichen species were observed in stands with a greater tree density and with a clumped and irregular tree distribution. This suggests that they are more sensitive to stand structure than ground vegetation. Deposition of both ammonium and sulphate was negatively related to the number of herb species and epiphytic lichens.

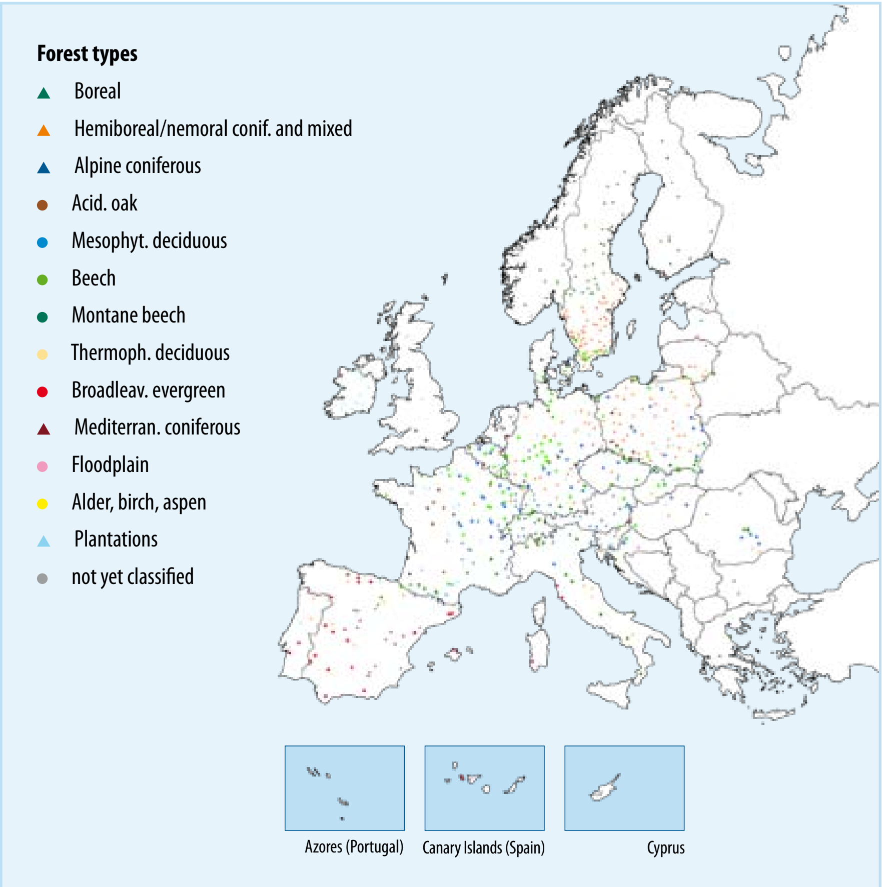


Figure 4-1: Level II plots classified according to forest types.

For herbs, this effect may at least partly be due to naturally low species numbers in beech forests and plantations which are located in areas with high inputs of atmospheric ammonium. Additional influences, like natural and anthropogenic disturbances, were not the subject of the present study (see Tab. 4-2).

Large scale representative biodiversity information is presently collected

The results presented above are based on around 100 selected intensive monitoring plots. Until recently, there has been no large scale monitoring system of forests biodiversity in Europe. However, the Level I survey platform of the monitoring programme represents an ideal opportunity to measure and describe forest biodiversity at stand level and to collect harmonised information relevant to forest biodiversity at the European level. The so-called BioSoil initiative, co-financed under Forest Focus, aims to assess and demonstrate the efficacy of the systematic Level I network as a representative tool of European forest biodiversity monitoring. The BioSoil project also aims to support both international and national policy on forest biodiversity by testing selected internationally recognised, robust and practical biodiversity indicators on a large scale survey, and to develop a practical methodology in a manual. Another important aim of the project is to establish an improved common baseline framework to integrate other information and the ongoing projects (including the soil initiative of BioSoil) on forest biodiversity in order to achieve maximum added value.

The project was conducted over the 2006 and 2007 summers. Characterisation and monitoring includes general plot design and description, forest category classification and verification of actual forest type, structural forest diversity (tree diameters, species composition of all

		Moss layer		Herbs and shrubs		Epiphytic lichens	
		Species number	Evenness	Species number	Evenness	Species number	Evenness
Geographic location	North/South gradient (°latitude)	++		--		--	--
	East/West gradient (°longitude)						
	Altitude (m a.s.l.)			++		++	++
Site	Soil pH (organic layer)	--		++		++	++
Stand structure	Number of tree layers			++			
	Number of trees per ha.					++	
	Area covered by tree stems (basal area)			--			
	Regularity of horizontal tree distribution (mean contagion)					++	++
	stand age						
	Density of tree crowns (canopy closure)						
Atmosph deposition	Ammonium (NH4-N)			--			--
	Nitrate (NO3-N)						
	Sulphur (SO4-S)			--			--

Table 4-2: Correlations between species diversity and different environmental and stand structural parameters (-- significant negative correlation; ++ significant positive correlation). On the European scale, geographic and site factors show more relations to species richness than stand structures. Epiphytic lichens were most sensitive to the evaluated environmental factors. Evenness describes whether a few species are dominant or whether species occur with similar frequencies.

woody plants, canopy closure, tree layering, and deadwood) and compositional forest diversity as a vascular plant species list. Twenty one EU countries are carrying out field assessments on more than 4 000 Level I plots. First results of a forest categorisation based on the complete transnational data set are available (see Fig 1-1). The data will be submitted to the Joint Research Centre and after validation will be entered into the Forest Focus database.

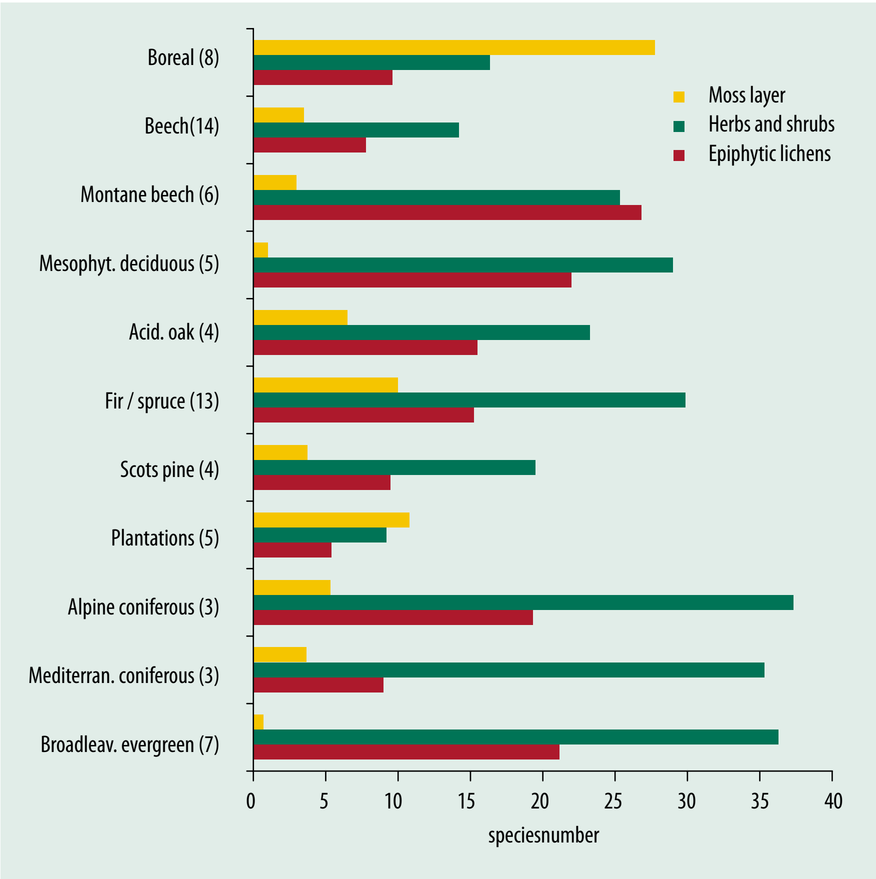


Figure 4-2: Number of species on plots in different forest types (in brackets: number of plots). Ground vegetation was mostly sampled on areas of 400m², epiphytic lichens on 12 randomly selected trees. Different numbers of moss, herb and lichen species are typical for different forest types.

Forest landscape in Norway.

5. Conclusions

A unique forest monitoring system has been implemented in 41 countries

For more than 20 years forest condition has been monitored jointly by ICP Forests and the European Commission. Today the joint programme is one of the largest bio-monitoring networks in the world. The system combines an inventory approach with intensive monitoring. It provides reliable and representative data on forest ecosystem health and vitality and helps to detect responses of forest ecosystems to the changing environment. The data collected so far provide a major input for several international programmes and initiatives, such as the Convention on Long-range Transboundary Air Pollution (CLTRAP) and the Ministerial Conference for the Protection of Forests in Europe (MCPFE).

The programme provides an early warning system for stress factors like air pollutants and climate change

In the early 1980s a dramatic deterioration of forest condition was observed in Europe and initiated the implementation of forest condition monitoring under CLRTAP. The annual assessment of forest condition allows for a holistic picture of the current state and changes in space and time. Results show effects of acidifying deposition on tree crown condition, which are accentuating the influence of other stress factors like insects, fungi and weather effects. The drought in the Mediterranean region in the mid 1990s and the extremely warm and dry summer across large parts of Europe in 2003 led to increased defoliation as a natural reaction of trees to this kind of stress. Some overall recovery of crown condition occurred in 2006 , the first year after many when deterioration was recorded. However, it is very likely that Europe may have to face the effects of climate change in the near future, including the alteration of natural ecosystems, changing agricultural, forestry and fisheries productivity, increased risk of floods, erosion, and wetland loss. Although (forest) species have responded to environmental changes throughout their evolutionary history, a primary concern for wild species and their ecosystems is the rapid rate of human induced changes.

Nitrogen inputs remain a driving force for the change of forest condition

Atmospheric deposition has been the specific focus of the programme since its inception. Current evaluations show decreasing sulphur inputs on 30 % of around 200 Intensive Monitoring Plots since 1999, which is a result of clean air policies under the Convention on Long-range Transboundary Air Pollution and European Union legislation. However, nitrogen depositions are still exceeding critical loads on a large number of plots. In addition, the legacy of previous inputs still affects today's forest condition. Studies have shown that the risk of storm damage

is increased on acidic soils. An effect of nitrogen depositions on the abundance of herbal vegetation as well as on increased tree growth could be found on intensive monitoring plots across Europe.

Biological diversity is among the most complex and challenging items to be monitored

Recently launched monitoring campaigns contribute information to policy processes under the Convention on Biological Diversity. A new forest type classification which was proposed by the European Environment Agency has been applied to Level I and Level II plots and might be considered in further reporting. Methods for the assessments of indicators such as deadwood, stand structure, ground vegetation and epiphytic lichens have been developed. Related assessments on around 4 000 Level I plots are presently ongoing within the EU-funded project “BioSoil” and constitute the first large scale monitoring approach for forest biodiversity in Europe. Relationships between stand structure and the diversity of species groups like epiphytic lichens, plants or mosses on the forest floor have been quantified. In order to facilitate the interpretation of the results an expert group has started to elaborate methods for the application of the naturalness concept. Additional species groups like birds and beetles might be monitored on the programme’s plots in the future.

Cooperation remains important for the future development of the monitoring system

The long cooperation of ICP Forests and the European Commission has enabled the implementation of a harmonized and operational monitoring system. Most countries of the pan-European region participate in the programme, which became one of the main data providers for the Ministerial Conference for the Protection of Forests in Europe. Contributions to the Forest Resource Assessment, the Convention on Biological Diversity, and other international initiatives and programmes have been realised.

Currently activities are ongoing to link the Level I network with national forest inventories. A first joint workshop with the European National Forest Inventory Network (ENFIN) has been held.

Major keystones of the success of the programme are the strong national commitments, the engagement and commitment of national experts and their active involvement in Expert Panels and Working Groups, as well as the exemplary collaboration of ICP-Forests Programme Coordinating Centre and the European Commission services.

New challenges arising from air pollution, biodiversity loss and climate change effects on forests and the increasing importance of forests as a source for renewable resources render joint efforts necessary to maintain the programme and enhance it for future needs.

Annex I: Forests and surveys and defoliation classes in European countries (2006)

- Results of national surveys as submitted by National Focal Centres -

Participating countries	Forest area (× 1000 ha)	% of forest area	Grid Size (km × km)	No. of sample plots	No. of sample trees	Defoliation of all species by class (aggregates), national surveys		
						0	1	2-4
Albania	1036	35.8	10x10	299	8970	44.0	45.0	11.0
Andorra	17		16 x 16	3	74	18.9	58.1	23.0
Austria	3878	46.2	16 x 16	135	3425	57.8	27.2	15.0
Belarus	7812	37.8	16 x 16	398	9373	37.4	54.7	7.9
Belgium	691	22.8	4^2 / 8^2	121	2841	33.1	49.0	17.9
Bulgaria	4064	29.9	$4^2/8^2/16^2$	141	5069	17.3	45.3	37.4
Croatia	2061	36.5	16 x 16	88	2108	41.6	33.6	24.8
Cyprus	298	32.2	16x16	15	360	11.7	67.5	20.8
Czech Republic	2630	33.4	$8^2/16^2$	135	5661	12.3	31.5	56.2
Denmark	468	10.9	$7^2/16^2$	22	528	64.2	28.2	7.6
Estonia	2264	49.4	16 x 16	92	2191	46.6	47.2	6.2
Finland	20338	65.9	16^2 / 24x32	606	11506	55.3	35.1	9.6
France	14591	26.6	16 x 16	498	9950	28.5	35.9	35.6
Germany	11076	28.9	16^2 / 4^2	423	10327	31.8	40.6	27.6
Greece	2512	19.5					no survey in 2006	
Hungary	1853	19.4	4 x 4	1220	28386	41.3	39.5	19.2
Ireland	680	6.3	16 x 16	37	455	73.7	18.9	7.4
Italy	8675	28.8	16 x 16	251	6941	30.8	38.7	30.5
Latvia	2950	45.0	8 x 8	342	8116	19.4	67.2	13.4
Liechtenstein	8	50.0					no survey in 2006	
Lithuania	2121	31.7	8x8/16x16	203	4872	15.3	72.7	12.0
Luxembourg	89	34.4					no survey in 2006	
Rep. of Moldova	318	9.4	2x2/2x4	528	12729	44.3	28.1	27.6
The Netherlands	334	9.6	16 x 16	11	230	64.0	17.0	19.0
Norway	12000	37.1	$3^2/9^2$	1669	9004	39.8	36.9	23.3
Poland	9200	29.4	16 x 16	376	7520	27.0	52.9	20.1
Portugal	3234	36.4	16 x 16					
Romania	6244	26.3	4 x 4	3879	97626	69.8	21.6	8.6
Russian Fed.	8125	73.2					no survey in 2006	
Serbia	2360		16 x 16/4 x 4	130	2935	63.9	24.8	11.3
Slovak Republic	1961	40.0	16 x 16	107	3975	13.9	58.0	28.1
Slovenia	1099	54.2	16 x 16	45	1080	31.0	39.7	29.3
Spain	11588	30.9	16 x 16	620	14880	17.2	61.2	21.6
Sweden	23400	57.1	varying	4315	17326	45.6	35.0	19.4
Switzerland	1186	28.7	16 x 16	48	1025	29.2	48.3	22.5
Turkey	21188	27.2					no survey in 2006	
Ukraine	9400	15.4	16 x 16	1518	35900	68.3	25.1	6.6
United Kingdom	2825	11.6	random	341	8184	26.1	48.0	25.9
Total	203612		varying	18616	333567			

Russian Federation: North-western and Central European parts only.
Note that some differences in the level of damage across national borders may be at least partly due to differences in standards used. This restriction, however, does not affect the reliability of the trends over time.

Annex II: Defoliation of all species (1994-2006)

- Results of national surveys as submitted by National Focal Centres -

Participating countries	All species, defoliation classes 2-4												change % points
	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2005/2006
Albania				9.8	9.9	10.1	10.2	13.1		12.2		11.1	
Andorra										36.1		23.0	
Austria	6.6	7.9	7.1	6.7	6.8	8.9	9.7	10.2	11.1	13.1	14.8	15.0	0.2
Belarus	38.3	39.7	36.3	30.5	26.0	24.0	20.7	9.5	11.3	10.0	9.0	7.9	-1.1
Belgium	24.5	21.2	17.4	17.0	17.7	19.0	17.9	17.8	17.3	19.4	19.9	17.9	-2.0
Bulgaria	38.0	39.2	49.6	60.2	44.2	46.3	33.8	37.1	33.7	39.7	35.0	37.4	2.4
Croatia	39.8	30.1	33.1	25.6	23.1	23.4	25.0	20.6	22.0	25.2	27.1	24.9	-2.2
Cyprus							8.9	2.8	18.4	12.2	10.8	20.8	10.0
Czech Rep.	58.5	71.9	68.6	48.8	50.4	51.7	52.1	53.4	54.4	57.3	57.1	56.2	-0.9
Denmark	36.6	28.0	20.7	22.0	13.2	11.0	7.4	8.7	10.2	11.8	9.4	7.6	-1.8
Estonia	13.6	14.2	11.2	8.7	8.7	7.4	8.5	7.6	7.6	5.3	5.4	6.2	0.8
Finland	13.3	13.2	12.2	11.8	11.4	11.6	11.0	11.5	10.7	9.8	8.8	9.7	0.9
France	12.5	17.8	25.2	23.3	19.7	18.3	20.3	21.9	28.4	31.7	34.2	35.6	1.4
Germany	22.1	20.3	19.8	21.0	21.7	23.0	21.9	21.4	22.5	31.4	28.5	27.6	-0.9
Greece	25.1	23.9	23.7	21.7	16.6	18.2	21.7	20.9			16.3		
Hungary	20.0	19.2	19.4	19.0	18.2	20.8	21.2	21.2	22.5	21.5	21.0	19.2	-1.8
Ireland	26.3	13.0	13.6	16.1	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	-8.8
Italy	18.9	29.9	35.8	35.9	35.3	34.4	38.4	37.3	37.6	35.9	32.9	30.5	-2.4
Latvia	20.0	21.2	19.2	16.6	18.9	20.7	15.6	13.8	12.5	12.5	13.1	13.4	0.3
Liechtenstein													
Lithuania	24.9	12.6	14.5	15.7	11.6	13.9	11.7	12.8	14.7	13.9	11.0	12.0	1.0
Luxembourg	38.3	37.5	29.9	25.3	19.2	23.4							
Rep. of Moldova	40.4	41.2				29.1	36.9	42.5	42.4	34.0	26.5	27.6	1.1
The Netherlands	32.0	34.1	34.6	31.0	12.9	21.8	19.9	21.7	18.0	27.5	30.2	19.5	-10.7
Norway	28.8	29.4	30.7	30.6	28.6	24.3	27.2	25.5	22.9	20.7	21.6	23.3	1.7
Poland	52.6	39.7	36.6	34.6	30.6	32.0	30.6	32.7	34.7	34.6	30.7	20.1	-10.6
Portugal	9.1	7.3	8.3	10.2	11.1	10.3	10.1	9.6	13.0	16.6	24.3		
Romania	21.2	16.9	15.6	12.3	12.7	14.3	13.3	13.5	12.6	11.7	8.1	8.6	0.5
Russian Fed.	12.5						9.8	10.9					
Serbia		3.6	7.7	8.4	11.2	8.4	14.0	3.9	22.8	14.3	16.4	11.3	-5.1
Slovak Rep.	42.6	34.0	31.0	32.5	27.8	23.5	31.7	24.8	31.4	26.7	22.9	28.1	5.2
Slovenia	24.7	19.0	25.7	27.6	29.1	24.8	28.9	28.1	27.5	29.3	30.6	29.4	-1.2
Spain	23.5	19.4	13.7	13.6	12.9	13.8	13.0	16.4	16.6	15.0	21.3	21.5	0.2
Sweden	14.2	17.4	14.9	14.2	13.2	13.7	17.5	16.8	19.2	16.5	18.4	19.4	1.0
Switzerland	24.6	20.8	16.9	19.1	19.0	29.4	18.2	18.6	14.9	29.1	28.1	22.6	-5.5
Turkey													
Ukraine	29.6	46.0	31.4	51.5	56.2	60.7	39.6	27.7	27.0	29.9	8.7	6.6	-2.1
United Kingdom	13.6	14.3	19.0	21.1	21.4	21.6	21.1	27.3	24.7	26.5	24.8	25.9	1.1

Austria: From 2003 on, results are based on the 16×16 km transnational gridnet and must not be compared with previous years. *Czech Republic:* Only trees older than 60 years assessed until 1997. *France:* Due to methodological changes, only the time series 1997-2006 are consistent. *Italy:* Due to methodological changes, only the time series 1995-96 and 1997-2006 are consistent, but not comparable to each other. *Russian Federation:* North-western and Central European parts only. *Ukraine:* Due to a denser gridnet since 2005, results must not be compared with previous years.

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

Annex III: Numbers of Intensive Monitoring Plots in the Forest Focus / ICP Forests data base

Country	all	Crown condition	Soil	Foliar	Growth	Deposition	Meteorol.	Soil solution	Ground vegetation	Phenology	Litterfall	Ozone injury	Air quality
Austria	20	20	20	20	20	20	2	2	20				
Belgium	21	21	20	21	20	10	6	8	20	1	*		
Bulgaria	3	3	3	3		3	3	1			3		3
Croatia	7	7	7	7	7	1							
Cyprus	4	4				2	2		4				1
Czech Republic	21	14	11	14	12	11	2	3	15				
Denmark	22	22	16	20	15	18	4	22	15		8		5
Estonia	8	8	7	8	8	6		2	7				
Finland	31	31	31	31	31	24	12	16	32				
France	100	100	100	100	100	25	25	15	99	89	94	16	25
Germany	95	95	87	92	91	92	75	83	85				*
Greece	4	4	4	4	3	4	4	2	4		2		1
Hungary	15	14	14	15	14	15	11		15	*		9	
Ireland	16	15	15	15	15	4	9	4	9				
Italy	29	27	20	26	24	28	16	2	19	15		4	29
Latvia	3	3	1	1	3	1		1	3			1	
Lithuania	9	9		9	9	1		1	9		1	9	2
Luxembourg	2	2	2	2	2	1	2		2	2	2		2
Netherlands	14	14	14	14	14	14		14	14				
Norway	19	19	17	19	19	19	2	19	12				
Poland	150	150	150	148	148	150			148				
Portugal	13	13	4	13	12	2			12				
Romania	13	13		11	13	4			7	4	4		
Russia	12		12										
Slovak Republic	9	9	8	9	9	9			8				
Slovenia	11	11				5	11	2	11	11			
Spain	58	58	53	58	56	14	13	2	53	13	*	12	13
Sweden	100	100	100	99	100	51	10	48	98				
Switzerland	16	16	16	16	16	14	16	8	16			16	*
United Kingdom	20	20	10	20	20	10	2	7	20			14	19
	845	822	742	795	781	558	227	262	757	145	114	81	100

Note: Table shows total numbers of plots with data submitted, irrespective year of data submission. Data base includes abandoned plots as well.

*This survey is measured in this country but data are still undergoing validation. Some country totals may increase if they have recently set up surveys in new plots - the latest survey may still be undergoing validation.

Air quality counts plots with passive samplers and active stations separately. Where there is an active plot at the same place it is not counted again.

Denmark and Bulgaria have only active samplers in the validated database.

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