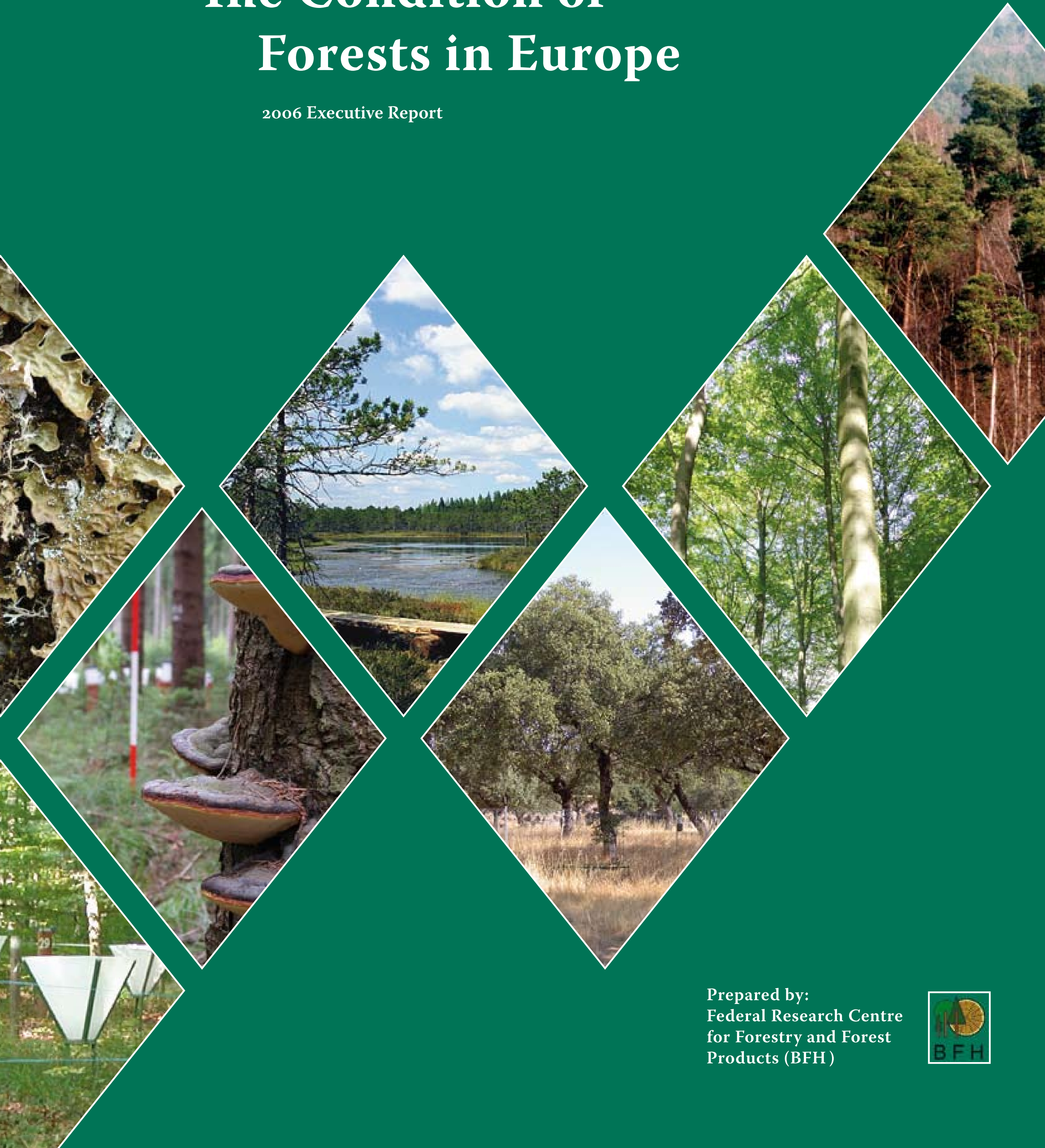
United Nations Economic
Commission for Europe

Convention on Long-range
Transboundary Air Pollution

The Condition of Forests in Europe

2006 Executive Report



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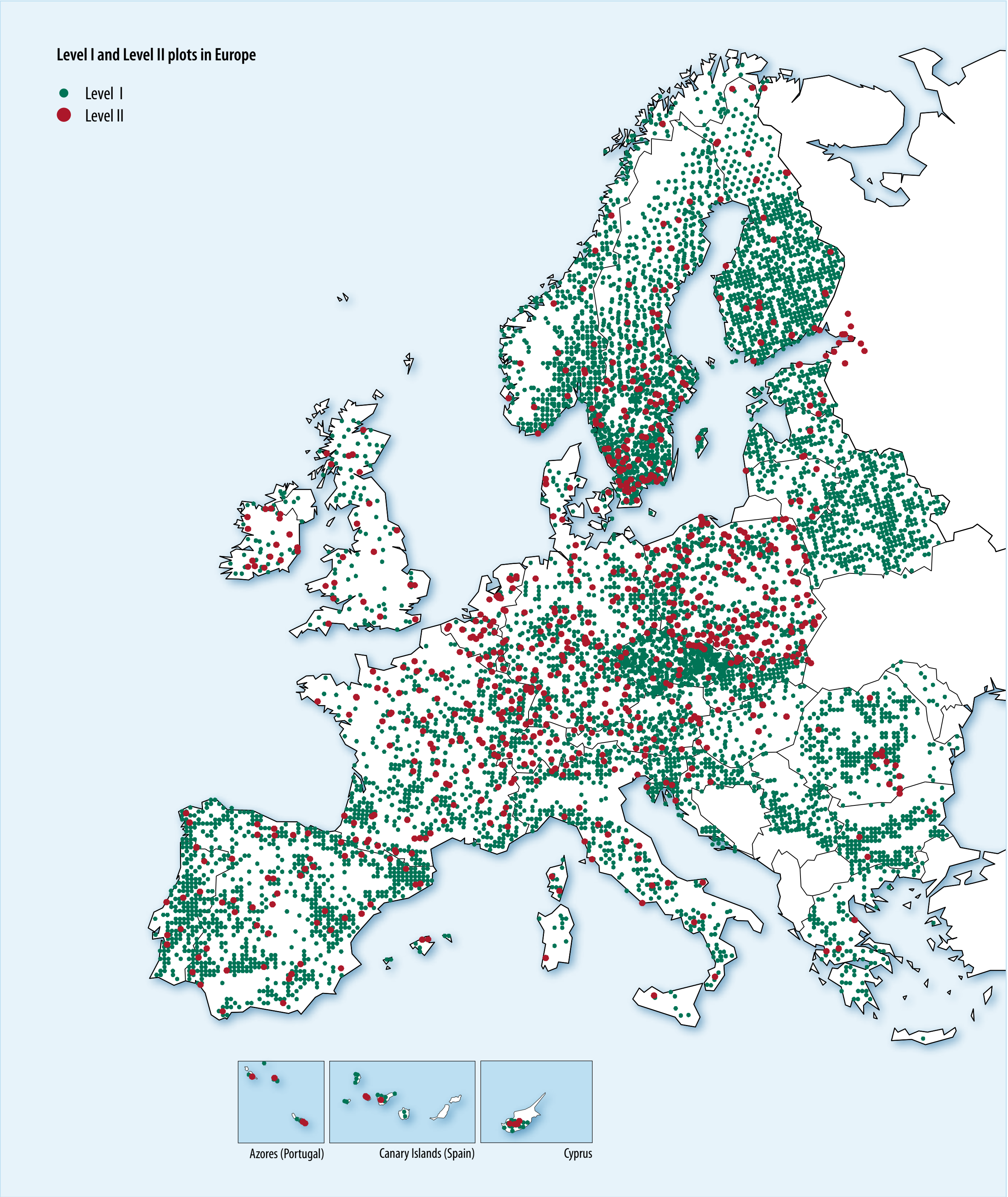

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THE CONDITION OF FORESTS IN EUROPE

2006 Executive Report

United Nations Economic Commission for Europe

Convention on Long-range Transboundary Air Pollution

Working Group on Effects

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

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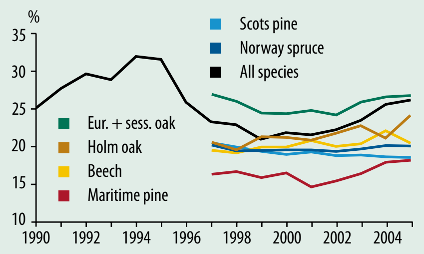

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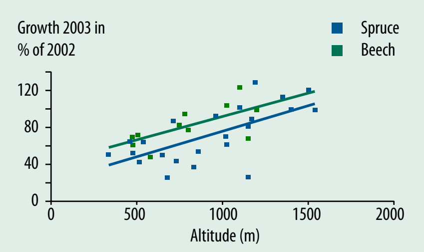

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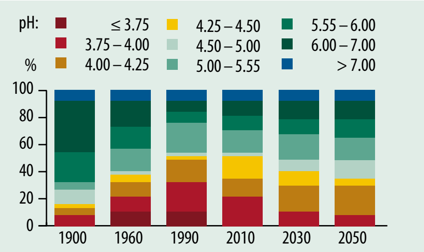
The majority of the evaluated plots show an increase of soil acidification between 1900 and 1990 and a subsequent slight recovery thereafter. However, on many of the evaluated plots the original acidity status will not be reached again until 2050.

Emission reductions are crucial for the recovery of forest soils. Ecosystem reactions depend very much on local stand and site conditions.



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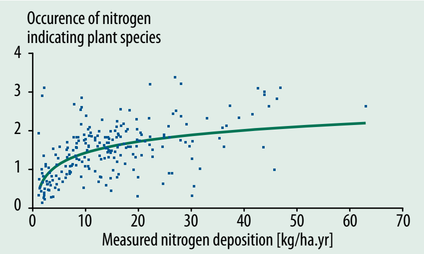
A five year monitoring period was too short to detect significant changes in species composition. Regular monitoring over a long time span is necessary to study the ongoing vegetation dynamics.



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With existing data and newly developed monitoring modules the programme contributes to the harmonized assessment of forest biodiversity in Europe. Stand structure, deadwood occurrence, ground vegetation characteristics and lichen composition differ significantly across forest ecosystems. A forest type classification has proven feasible and necessary as a basis for further investigations. Deadwood volume showed a large variation between the test-plots. Forest management and the age of the stands were significant explanations for the amount of deadwood. Among other influences, air pollution affected composition and numbers of epiphytic lichen species on the plots.

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Scots pine forest in the Baltics.
Forests cover 50% of the land area in Estonia. The total forest area in the country has been continuously increasing over the last decades.

Villu Reiljan

PREFACE

In the early 1980s, already over 20 years ago, Europe was alarmed by the large-scale deterioration of forest condition and the possibility that this was caused by air pollution. Since then, climate change and deterioration of forest biodiversity have also risen up the political agenda.

Trends and development of forest condition and forest damage can be assessed only based on long-term systematic monitoring. Over the years the International Co-operative Programmes on Forests and Integrated Monitoring of Ecosystems (ICP Forests) and the National Focal Centres under the framework of the UN Economic Commission for Europe, in good co-operation with the EC, have provided much relevant information on the large-scale spatial and temporal variation of forest condition. This has been possible by using a European-wide network of Level I plots, as well as studying cause-effect relationships at the ecosystem scale by means of intensive monitoring at Level II plots. At Level II, the nutrient status of soil and trees, increment, vegetation, deposition, soil solution and other parameters are assessed in addition to crown condition.

Today, 40 countries are participating in the programme. The monitoring programme has contributed many and diverse results as a basis for forest and environmental policy. ICP Forests' well-established infrastructure, multidisciplinary monitoring approach and comprehensive database also allow significant contributions to other processes and programmes of international forest and environmental policies.

The annual results of the surveys are summarized in annual Executive Reports. The methods used, as well as results of individual surveys, are described in the Technical Reports and in special issues. There is some evidence that the forest condition is not only influenced by local and long-range transboundary air pollution, but also by climate interrelated with a complex of other abiotic and biotic factors. In some areas, the forests are in better condition and with larger growth increment than before.

The present report refers to the results of the 2005 large-scale crown condition assessment at Level I as well as to the latest results of the intensive monitoring at Level II, specifically in the fields of deposition and biodiversity.

Villu Reiljan
Minister for the Environment
Estonia

Level I plot in Scandinavia.

1. THE PAN-EUROPEAN, LONG-TERM FOREST CONDITION MONITORING PROGRAMME

Data for forest management and policy

One third of Europe's land surface is covered by forests, with important economic and social values. Over large areas they constitute the most natural ecosystems of the continent. Sustainable forest management, as well as environmental policies, must rely upon the sound scientific resource provided by long-term, large-scale and intensive monitoring of forest condition.

Monitoring for the long term

In 1985, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established. The programme operates under the UNECE Convention on Long-range Transboundary Air Pollution and provides a platform for information exchange for forest scientists, managers and politicians of 40 participating countries.

Embedded into a network of cooperations

Since 1986, the ICP Forests has been closely cooperating with the European Union. At present, the "Forest Focus" regulation (EC No 2152/2003) constitutes the legal basis for this cooperation including the co-financing of monitoring activities. 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

	Frequency	Number of plots
Crown condition	annually	6093
Foliar chemistry	once until now	1497
Soil chemistry	Once until now; (repetition launched in most of the EU countries within the BioSoil project)	5289 (5000)
Tree growth	demonstration project launched (BioSoil project)	
Ground vegetation	demonstration project launched (BioSoil project)	
Stand structure, deadwood	demonstration project launched (BioSoil project)	

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

	Frequency	Number of plots
Crown condition	annually	797
Foliar chemistry	every 2 years	767
Soil chemistry	every 10 years	738
Tree growth	every 5 years	769
Ground vegetation	every 5 years	723
Stand structure incl. deadwood	Test phase ongoing	90
Epiphytic lichens	Test phase ongoing	90
Soil solution chemistry	continuously	254
Atmospheric deposition	continuously	545
Ambient air quality	continuously	41
Meteorology	continuously	209
Phenology	several times per year	data validation ongoing
Litterfall	continuously	data validation ongoing
Remote sensing	preferably at plot installation	national data

Table 1-2: Surveys and number of plots on Level II.

too. The programme also maintains close contacts with the Acid Deposition Monitoring Network in East Asia (EANET).

Challenging objectives and a unique monitoring system

One objective of the ICP Forests is to assess the status and development of health and vitality of European forests at a large scale. Air pollution effects are the particular focus of the programme. Data are collected by the participating countries on around 6 100 permanent observation plots called Level I. These plots are located on a 16 × 16 km grid covering 33 countries throughout Europe (see Fig. 1-1, Tab. 1-1). In addition to annual crown condition surveys, the BioSoil demonstration project begun in 2006 facilitates a repeat of an original soil survey undertaken in 1994 in many European countries.

In order to detect the influence of various stress factors on forest ecosystems, intensive monitoring is carried out on 860 Level II plots (see Fig. 1-1, Tab. 1-2). These plots are located in forests that represent the most important forest ecosystems of the Continent.

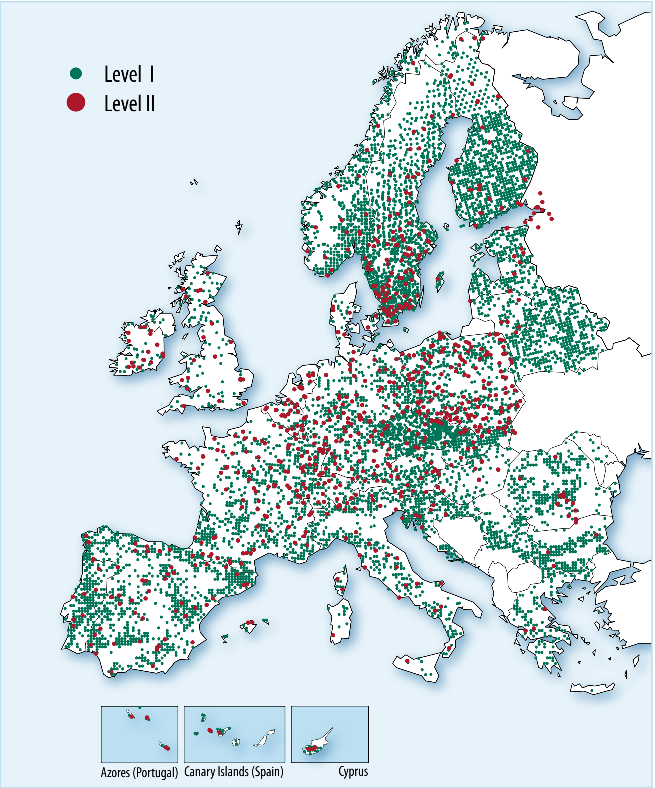


Figure 1-1: Level I and Level II plots in Europe.


Mediterranean evergreen oak woodland in Italy.

2. STATE OF FORESTS IN EUROPE

ICP Forests collects and regularly presents information on forest health in Europe. The time series of almost two decades of forest monitoring is an important baseline upon which to compare present forest condition. Crown condition is the main parameter of the assessments. It responds to many stress factors and is thus a valuable overall indicator (Chapt 2.1). Statistical evaluations have shown that the variation of defoliation is mainly explained by tree age, weather extremes and biotic factors like insect infestation and fungal disease. Air pollution was also found to be correlated with defoliation, but less tightly than the above mentioned natural factors. The recent response of crown condition to the summer heat and drought of the year 2003 in large areas of Europe proves the value of the monitoring programme as an early warning system. The effects of the extreme drought are not only visible in the large scale crown condition data but also in forest growth data of the intensive monitoring programme (Chapt. 2.2).

Tree crown of severely damaged European oak in France. 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.

2.1 Tree crown condition depends from environmental influences

Summary

- *The proportion of damaged trees has increased continuously since 2001 but has not reached the peak of the mid 1990s. In 2005, nearly one quarter of all trees assessed were classified as damaged or dead.*
- *After a marked worsening on many plots in central Europe due to the drought in 2003, beech and spruce trees have recovered in 2005. In contrast, over large regions, European and sessile oak showed no significant recuperation. Scots pine crown condition worsened in south-west Europe and improved in eastern Europe.*
- *Assessments are based on about 134 000 trees annually assessed in 30 countries.*

Defoliation is an operational indicator designed for 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 uses defoliation as one of four indicators for forest health and vitality.

The crown condition survey in 2005 comprised 6 093 plots in 30 countries. In all, 133 840 trees were assessed. Over the years, the number of surveyed plots and trees has increased almost continuously. 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.

Nearly one quarter of all trees assessed were damaged

In 2005, 23.2 % 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. 2-2). In 2004, the respective share amounted to 23.3 %. Of the most frequent tree species, European and sessile oak had the highest share of damaged and dead trees, namely 41.0 %.

The temporal development depends on species and region of observation

In those countries which conducted crown condition surveys since at least 1990, the share of damaged trees reached a maximum of 32.1 % in 1994 and then decreased to 20.7 % in 1999. Since then it has been increasing again, without reaching the 1994 maximum (see Fig. 2-3). From 1997, mean defoliation has increased on 22.1 % of the plots assessed and has decreased on only 9.4 % of them (see Fig. 2-1).

Results for single tree species and regions showed a more differentiated picture. For Norway spruce, there was a sudden increase in defoliation in central European regions in 2004 and a decrease in 2005. This can be interpreted as an effect of the drought in 2003 and subsequent recuperation. Large parts of the monitored spruce plots occur in northern boreal regions of Europe and were not affected by the 2003 drought. Here, an improvement in crown condition has been observed since 2003.

Mean defoliation of Scots pine hardly changed because defoliation decreased in eastern Europe and increased in western and south-western Europe in the years since 1997.

Common beech showed a marked increase in defoliation over all regions in the years before 2004. This was mainly due to the extreme heat and drought in the year 2003. In 2005, however, improved crown condition was observed on many plots in central Europe, showing some recovery from the drought stress in 2003.

Crown condition of European and sessile oak has worsened since 2000. For the period from 1997 to 2005, 20.1 % of the oak plots showed significantly deteriorating crown condition, with an improvement in only 9.4 % of the plots. The deterioration is located on plots in western, central and southern Europe. Damage by defoliating insects was reported from Switzerland, France and Germany. Mediterranean oak trees suffered especially from drought. In eastern Europe no clear trends were observed. Denmark reported recovery of crown condition in 2005.

Further information:

Lorenz, M.; Fischer, R.; Becher, G.; Mues, V.; Seidling, W.; Kraft, P. ; Nagel, H.-D. (2006) Forest Condition in Europe. 2006 Technical Report. Geneva, UNECE, 113 pp, Annexes.

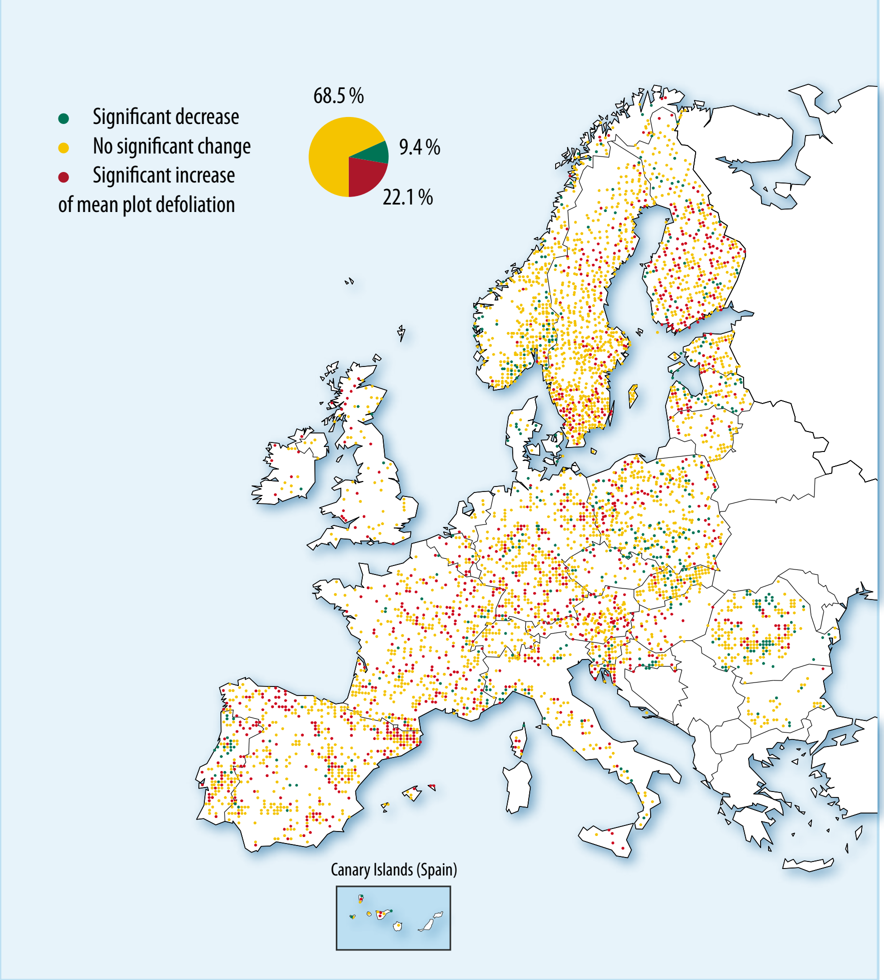


Figure 2-1: Plotwise development of defoliation for all tree species, 1997-2005.

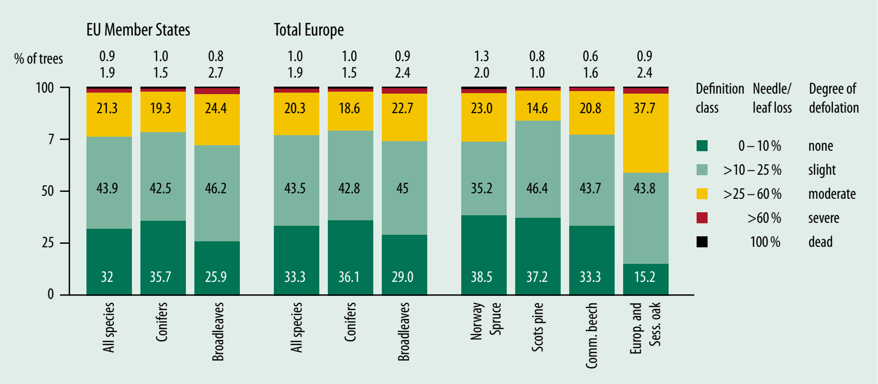


Figure 2-2: Percentage of trees in different defoliation classes. Total Europe and EU, 2005. Sample size for total Europe is 133 840 trees and 107 077 trees for EU.

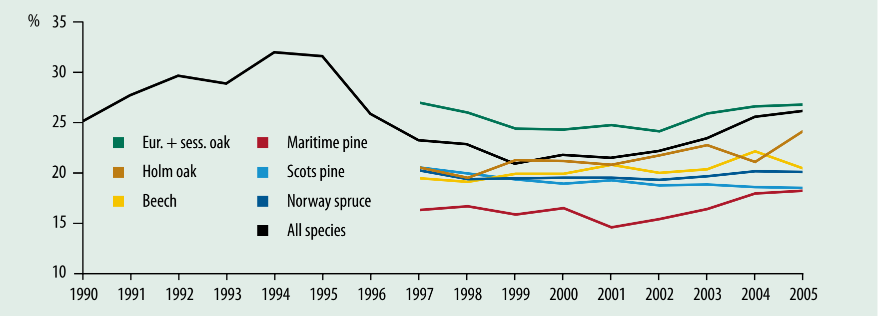


Figure 2-3: Percentage of damaged trees of all tree species and mean defoliation for the most frequent tree species. Samples only include countries with continuous data submission. Sample size for the selected main tree species varies between 3 279 and 37 157 trees per species and year. Time series starting in 1990 are available for a smaller number of countries and trees only. The sample size for all species varies between 42 136 and 49 712 trees per year.

Permanent circumference measurement band on a beech tree.

2.2 Forest growth reacts to the drought in 2003

Summary

- *Extreme drought and heat during the 2003 summer reduced tree growth on intensive monitoring plots in central Europe. Norway spruce was most affected, whilst oak remained comparatively unchanged.*
- *At high altitudes where low temperatures are usually a limiting factor, growth was stimulated by higher summer temperatures.*

Forest growth reductions in 2003

Annual growth data were available from permanent stem circumference bands and tree cores taken from plots in southern Germany, Switzerland, Austria, Slovenia and northern Italy. This central European area had been severely affected by the drought and heat in 2003. The plots cover a large range in altitude and drought stress situations.

Norway spruce showed the strongest growth response to the drought in 2003, common beech reacted less strongly (see Fig. 2-5), and European and sessile oak showed almost no growth reduction. The results for Norway spruce and common beech show that growth reduction in 2003 mostly occurred at low altitudes. At high altitude, due to lower temperatures and possibly higher precipitation, drought was not the limiting factor. Instead, growth was stimulated by higher summer temperatures that extended the tree growing period. This resulted in increased growth rates on plots at high altitudes of the Alpine region (see Fig. 2-6). Crown condition data (see Chapt. 2.1) indicate a recovery of beech and spruce in 2005.

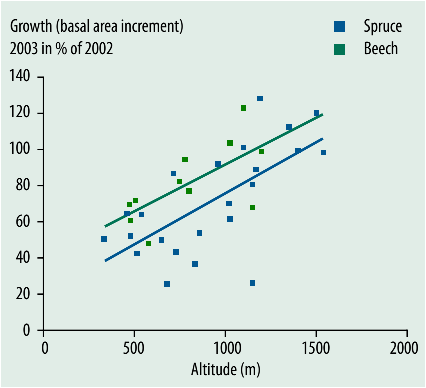


Figure 2-5: Tree growth in 2003 compared to 2002 at different altitudes for Norway spruce and common beech in the Alpine region. Below 1000 m altitude all sites had reduced growth in 2003. For spruce growth reductions of 40 – 80 %, and for beech between 60 – 95 % were common.

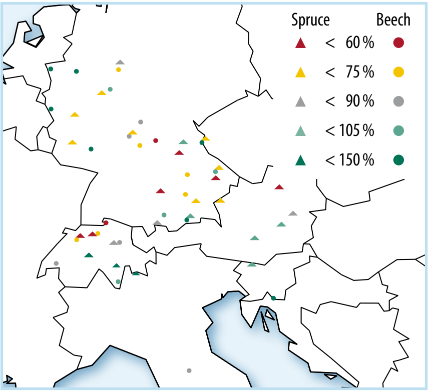


Figure 2-6: Tree growth on spruce and beech plots in central Europe, given as basal area increment of 2003 in percent of 2002.

Hemiboreal pine forests show a low structural diversity with a tree layer that mostly consists of only one, two or three tree species. The forests have low shrub and herb cover, but a considerable moss coverage.

HEMIBOREAL PINE FORESTS

Forest types permit a regional and holistic perspective on forest ecosystems

Forests across the European continent have a highly variable species composition, ecological functioning and structure. A detailed consideration of forest condition therefore requires the region and forest type to be taken into account. Forest type classification has also gained more importance in the context of biodiversity assessments in recent years and a number of classification schemes have been elaborated (see Chapt. 4).

The reporting system of the ICP Forests allows these factors to be integrated into data evaluation. Whereas in previous years, results for one main tree species were presented within a Special Focus, the last year's Executive Report took a more holistic view and presented the condition, dynamics and threats of one specific forest type – namely the Mediterranean evergreen oak forests. This series is now continued with a forest type of northern Europe.

Hemiboreal forests are situated between boreal and central Europe.

Boreal forests exist as a nearly continuous belt of mostly coniferous woodlands across the north of Eurasia and North America. Most of the forests of Fennoscandia as well as those of the Russian Federation belong to boreal forests. Hemiboreal forests are situated in the transition zone between these northern boreal and central European temperate forests. Hemiboreal forests cover southern and central Sweden, southernmost parts of Finland and Norway as well as large parts of Estonia and Latvia. Historically they also occurred in Scotland.

Single layered stands and a low number of tree species are typical characteristics

Conifers prevail in boreal and hemiboreal forests. Scots pine (*Pinus sylvestris*) and Norway spruce (*Picea abies*) are the most important tree species. Scots pine is also native in the Scottish Highlands, from where it carries its name.

Hiking trail along bog and pine forests, Estonia. Forests are increasingly used for recreation purposes.

It is today the most widely distributed pine species in the world. Within the hemiboreal zone, Scots pine is found on nutrient poor and/or dry sites, like shallow soils on crystalline bedrock or deep sandy or ravely soils. On fertile soils, spruce becomes more prevalent and a mixture of different proportions of pine and spruce is rather common.

On the very fertile site types in the south of the hemiboreal zone, conifers are unable to compete with tree species of temperate deciduous forests like small-leaved lime (*Tilia cordata*), ash (*Fraxinus excelsior*), European oak (*Quercus robur*) or elm (*Ulmus glabra*).

Bogs and mires are other common ecosystems of the boreal and hemiboreal zone. They are normally created by hydrophilic plants like sphagnum mosses and are covered with ferns and shrubs such as willows and blueberries. Sphagnum acid bogs and boreal mires are protected habitats under the EU Habitat Directive (92/43/EEC).

Hemiboreal pine forests form 31 % of all forests in Estonia. There, approximately 32 % grow on dry and moderately humid soils, 35 % on gley and peaty soils and 33 % on forest bog soils. In Latvia, pine forests form 37 % of all forests, and 56 % of them occur on dry mineral soils.

Forest fires are important for a natural dynamic

Under natural conditions fire is an important factor in forest ecosystem dynamics, especially in pine forests on sandy and dry substrates, or for trees stocking on organic soils. Forest fires stimulate new successional series, they release nutrients stored in humus and create habitats for many species groups. Scots pine is adapted to forest fire; old pine trees with their thick bark can tolerate low intensity fires and pine seedlings can also spread on newly burnt soils. Early successional stages after forest fire can also be characterised by broadleaved tree species such as birch (*Betula* spp.), aspen (*Populus tremula*), alder (*Alnus* spp.) or rowan (*Sorbus aucuparia*).

Natural and anthropogenic threats

Scots pine is often damaged by fungi, moose (*Alces alces*), frequent fires, storms, insects and industrial air pollution. Considerable damage caused by root rot (*Heterobasidion annosum*) has specifically been reported from dry sandy areas in the Baltic countries. A fungus called scleroderris canker (*Gremmeniella abietina*) caused considerable damage in younger forest stands in 2002 and 2003 in Sweden. Among insects, pine sawfly (*Diprion pini*) can periodically cause large defoliation in pines. Younger stands are especially favoured by moose, which browse the shoots. Wind-throw occurs on wet clay soils where the root system is shallow. Pine stands are also sensitive to atmospheric pollution as well as to soil compaction during harvesting. Defoliation of pine on the hemiboreal ICP Forests Level I plots has been fluctuating in recent years (see Fig. 2-4).

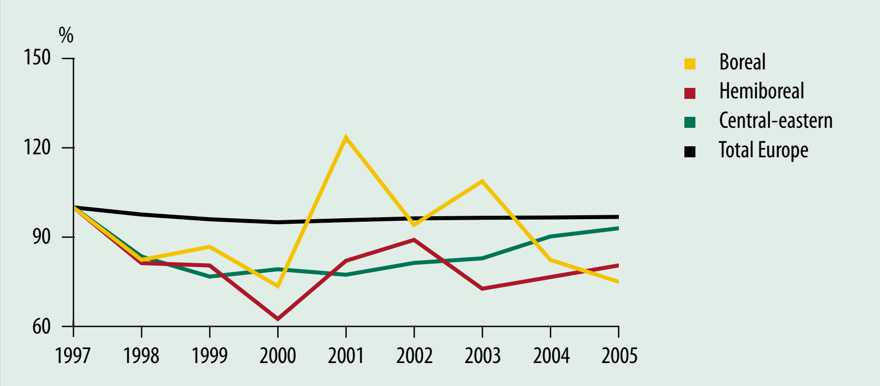


Figure 2-4: Share of damaged Scots pine trees (defoliation classes 2-4) in selected zones of Europe, given as relative deviation from the status in the year 1997. Over total Europe the condition remains comparatively stable. In the different zones there are more pronounced fluctuations (not all zones are depicted).

The pine forests fulfil diverse functions

To a large extent, pine forests are used for multiple purposes, including the production of timber and other goods, environmental protection, recreation and tourism. Forest management practices include scarification and natural regeneration followed by clear cutting. Regeneration of spruce has taken place on many sites in recent decades as this gives advantages in yield production and fewer problems with moose grazing compared to pine. The total growing stock of Scots pine has thus decreased in favour of Norway spruce. Pine forests on dry sandy soils and on dunes in coastal areas are most heavily affected by tourist activities. To protect the biodiversity of these forests, an increasing number of protected areas have been established in recent years, some with a very high level of protection.

Forest canopy of a lowland beech stand. Tree crowns filter large quantities of pollutants from the air. Atmospheric deposition measured in forests is therefore mostly higher as compared to the open field.

3. ATMOSPHERIC DEPOSITION AND ECOSYSTEM RESPONSES

In the 1970s, air pollution effects on human health and the environment became increasingly obvious when the acidification of Scandinavian lakes and later the decline of forest health was linked to the deposition of air pollutants. Under the Convention on Long-range Transboundary Air Pollution, scientists provide a realistic picture about current deposition and its effects on Europe's forests and other ecosystems.

In the last two decades Europe has experienced the first effects of emission reductions, However, large areas still suffer from the exceedance of critical loads for acidity and nutrient nitrogen (see Fig. 3-1). Forests filter pollutants from the air and are thus especially susceptible. 45 % of the forests still suffer from nitrogen inputs that exceed the critical loads.

ICP Forests contributes with findings on specific effects of atmospheric inputs on forest ecosystems and supports the development and application of the above mentioned models with its measured deposition data from forests all over Europe. In previous reports it was shown that forest growth, foliage chemistry and storm damage in forests are related to deposition. The following chapters report on soil acidification and highlight effects of deposition on plant species composition and other aspects of biodiversity. Forests are complex ecosystems and there are many other direct and indirect risks and effects of air pollution.

Further information:

CCE (2005), Posch M, Slootweg J, Hettelingh J-P (eds), European critical loads and dynamic modelling: CCE Status Report 2005. Coordination Centre for Effects, MNP Report 259101016, Bilthoven, Netherlands, 171 pp. www.mnp.nl/cce.

Deposition samplers (red) and litterfall collectors (white) on a Level II plot.

3.1 Decreasing sulphur and fluctuating nitrogen deposition 1998 – 2003

Summary

- *Sulphur deposition has decreased on about one third of 230 evaluated monitoring plots since 1998. This reduction shows the positive effects of pollution abatement strategies.*
- *Atmospheric nitrogen inputs have remained unchanged on around 90 % of the plots. The reduction of nitrogen deposition remains an important task for environmental policy.*
- *The data provide the basis for determination of air pollution effects on forest ecosystems and for the development and application of critical load calculations (see following chapters).*

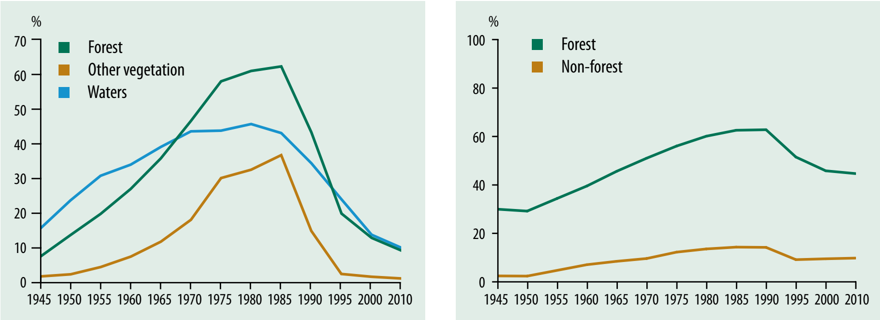


Figure 3-1: Area in Europe with exceeded critical loads of acidity (left) and nutrient nitrogen (right). Calculations are carried out by the ICP on Modelling and Mapping, a partner programme of the ICP Forests and are based on emission inventories and complex models for the long-range transport of air pollutants (CCE, 2005).

Changing importance of different air pollutants

When ICP Forests was founded more than 20 years ago, sulphur oxides, mainly deposited as sulphate (SO_4^{2-}), were the main focus of scientists, politicians and the public. 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. Since the late 1990s, deposition has been collected from Intensive Monitoring Plots and analysed following harmonized methods.

Throughfall deposition samplers in Greece.

Results were derived from deposition measurements within the forest stands (throughfall 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 measured. Thus, throughfall deposition as measured below the forest canopy is not equal to the total deposition that is received by the forest stands. As the forest canopy is not uniformly dense, several deposition samplers are situated at each monitoring plot. Samples are collected weekly, fortnightly or monthly and are analysed by national experts. After intensive quality checks, annual mean depositions for the years 2001 to 2003 were calculated for plots with complete data sets. For the period 1998 to 2003, slopes of plotwise linear regressions of deposition over time were tested for significance.

Fluctuating nitrogen and decreasing sulphur deposition

Mean nitrogen deposition was approximately 10 kg per hectare per year, as the sum of 5 kg of ammonium and 5 kg nitrate deposition, measured for the years 1998 to 2003 and for the mean of around 230 plots in Europe (see Fig. 3-2). Mean annual values were fluctuating and around 90 % of the plots do not reveal any significant changes in nitrogen deposition (see Figs. 3-3 and 3-4). Inputs were mostly higher on plots in central Europe than in alpine, northern and southern European regions (see Figs. 3-6 and 3-7). Between 1998 and 2003, mean annual sulphate inputs decreased from 9.3 kg per hectare to 5.8 kg. One third of the plots showed significantly decreasing sulphur inputs (see Fig. 3-5). Comparatively low sulphate deposition was measured on plots of the alpine region, in Scandinavia and on the Iberian Peninsula (see Fig. 3-8).

Figure 3-2: Development of mean plot deposition of sulphate (SO$_4$-S), nitrate (NO$_3$-N) and ammonium (NH$_4$-N). Although sulphate deposition shows a decrease, the reduction of nitrogen inputs remains an important task.

An array of soil tensiometers designed to assess the variability in soil water tension at a Level II plot in Germany.

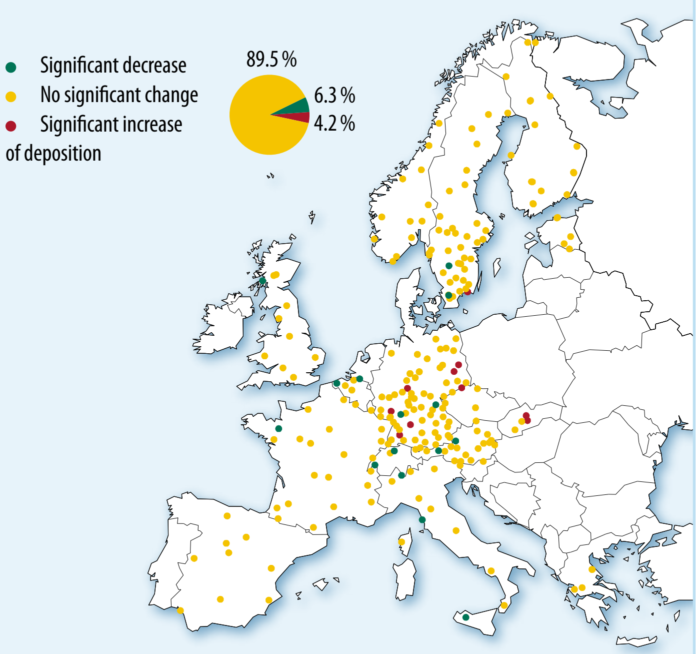


Figure 3-3: Trend of ammonium (NH_4-N) deposition. 1998 – 2003 on 239 plots.

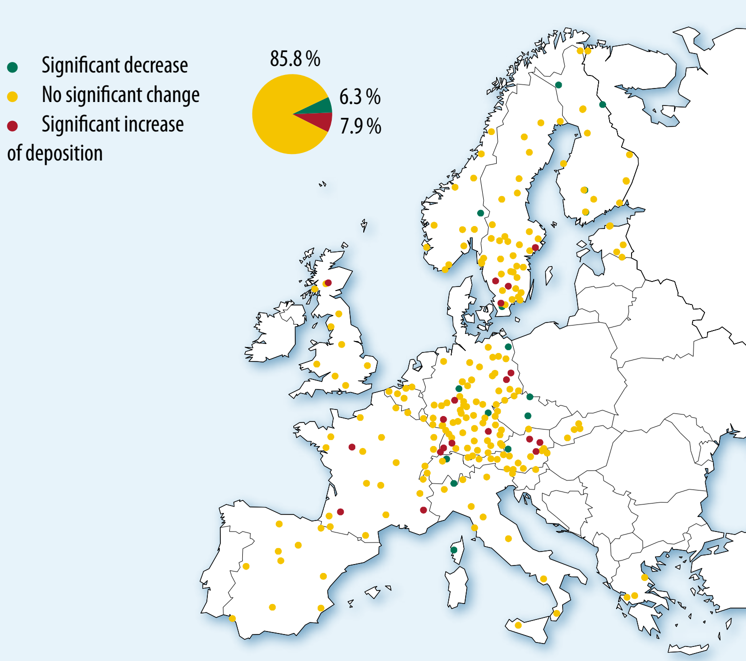


Figure 3-4: Trend of nitrate (NO_3-N) deposition. 1998 – 2003 on 240 plots.

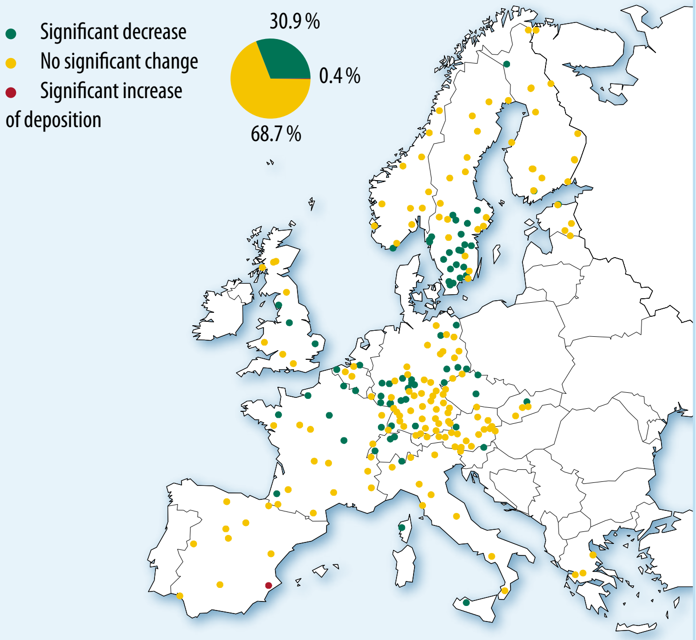


Figure 3-5: Trend of sulphate (SO_4-S) deposition. 1998 – 2003 on 233 plots.

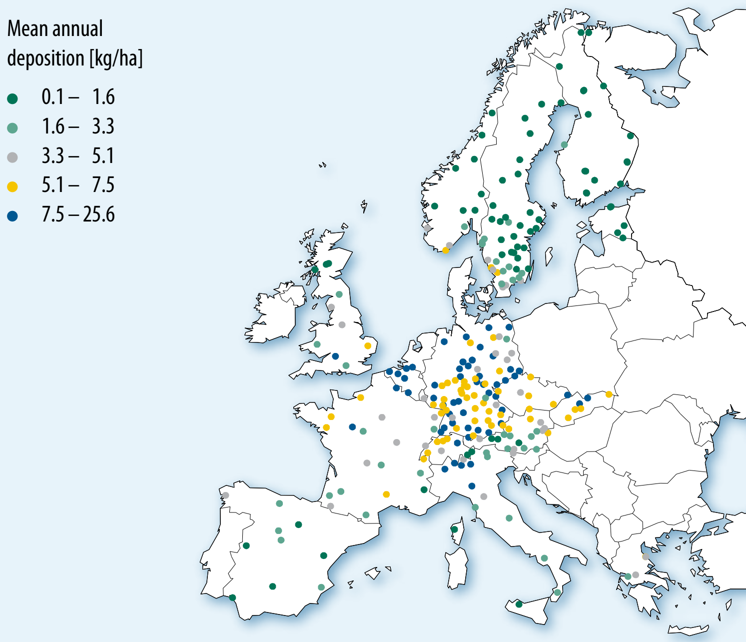


Figure 3-6: Mean ammonium (NH_4-N) deposition. 2001 - 2003 on 264 plots.

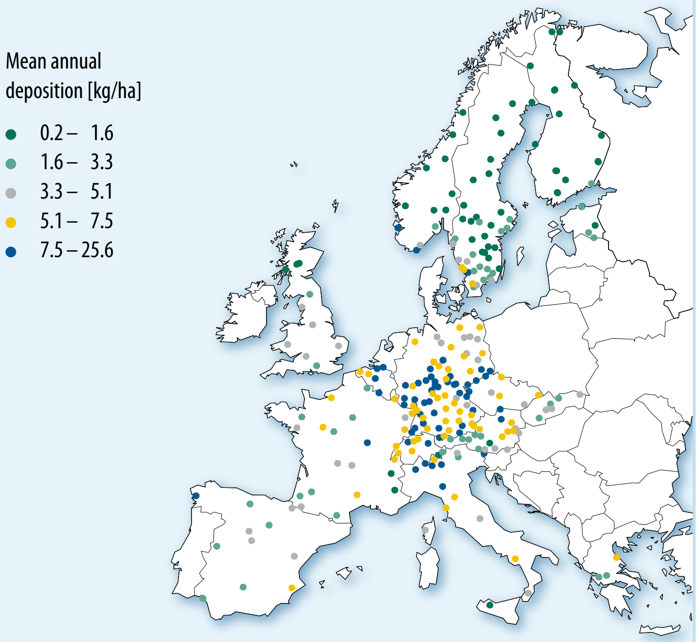


Figure 3-7: Mean nitrate (NO_3-N) deposition. 2001 - 2003 on 265 plots.

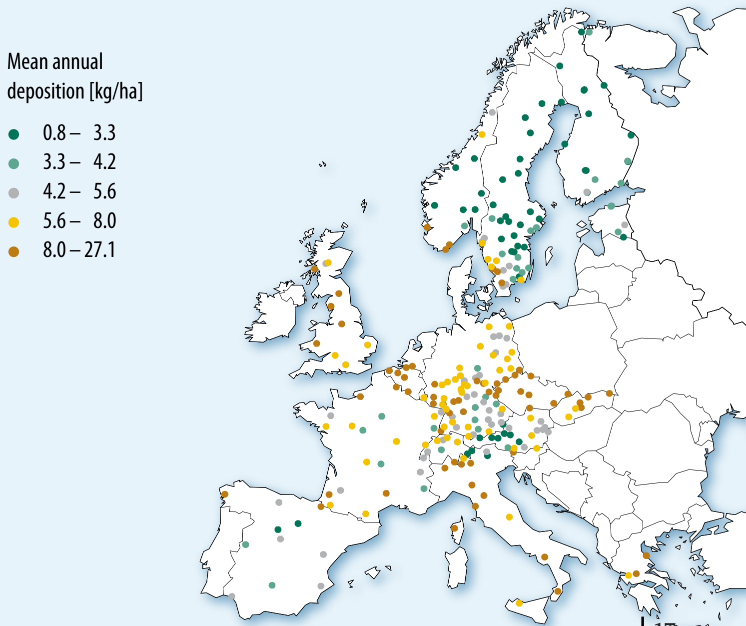


Figure 3-8: Mean sulphate (SO_4-S) deposition. 2001 - 2003 on 257 plots.

Level II plot in Spain.

3.2 Dynamic models reveal a partial recovery of forest soils from acidification

Summary

- *The majority of 37 selected Level II plots show an increase of soil acidification between 1900 and 1990 and a subsequent slight recovery. However, on many of the evaluated plots the original acidity status will not be reached again until 2050.*
- *Ecosystem reactions at specific plots depend very much on local stand and site conditions. Deposition is one factor that can influence the acidity status of forest soils. Emission reductions are thus crucial for recovery.*

Dynamic models can help to evaluate forest ecosystem response to changing deposition scenarios. They allow the future effects of today's clean air policies to be studied, and have been applied to 37 Level II plots. The model calculations specifically estimate the response of the soil solution based on measured soil, meteorological and deposition data. Thus they take into account specific site and stand conditions at each plot, which is a requirement to assess effects of measured deposition.

Air pollution is a main reason for the acidification of soil solution

Many of the plots studied (see Figs. 3-9 to 3-12) show an increase in acidification between 1900 and 1990 and a subsequent slight recovery until 2030.

Dynamic soil chemistry models such as VSD (Very Simple Dynamic Model) show the effects of acid deposition and forestry measures on the soil solution 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. Equilibrium reactions within the soil solution are also taken into account. The calculations rely on Level II data and historical deposition rates 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). The plots depicted are not representative for Europe, but were selected for reasons of data availability.

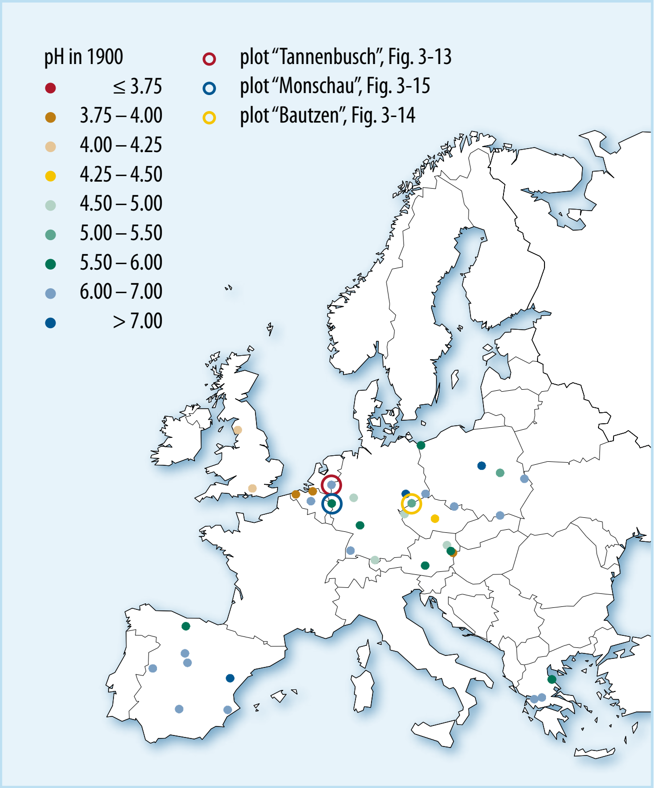


Figure 3-9: pH values at Level II plots for the year 1900. The pH value is a common chemical indicator for acidification. Low values indicate acid conditions. Plots marked with a circle are presented in more detail in Figures 3-13 to 3-15.

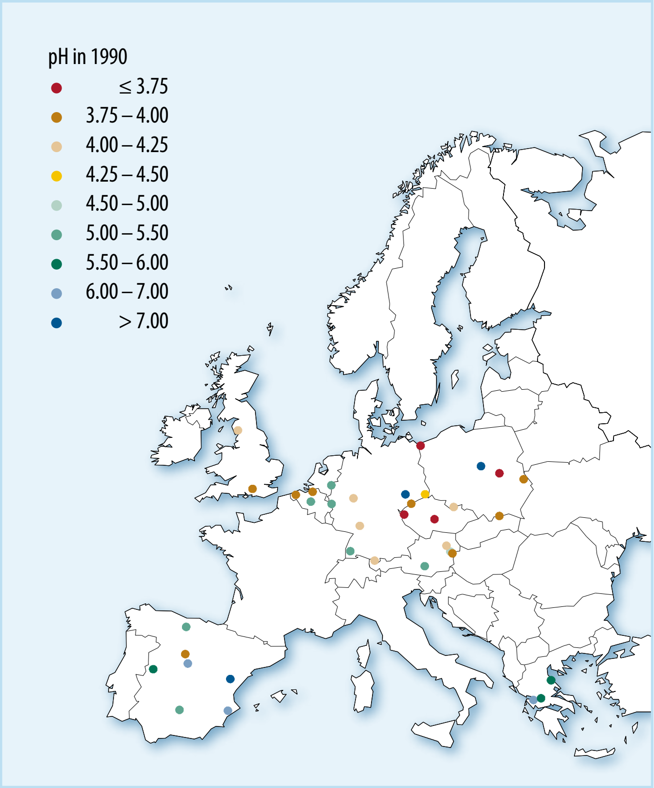


Figure 3-10: pH values at Level II plots for the year 1990.

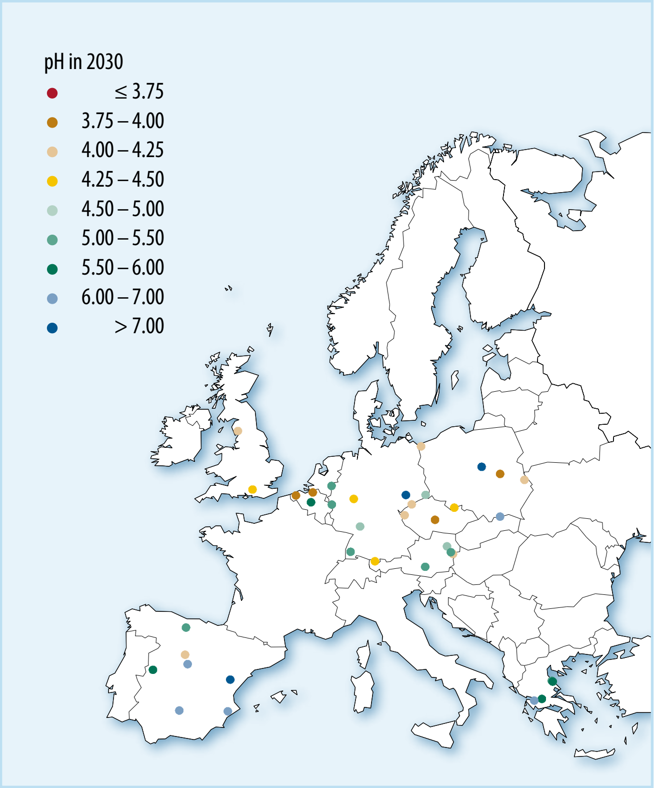


Figure 3-11: pH values at Level II plots for the year 2030.

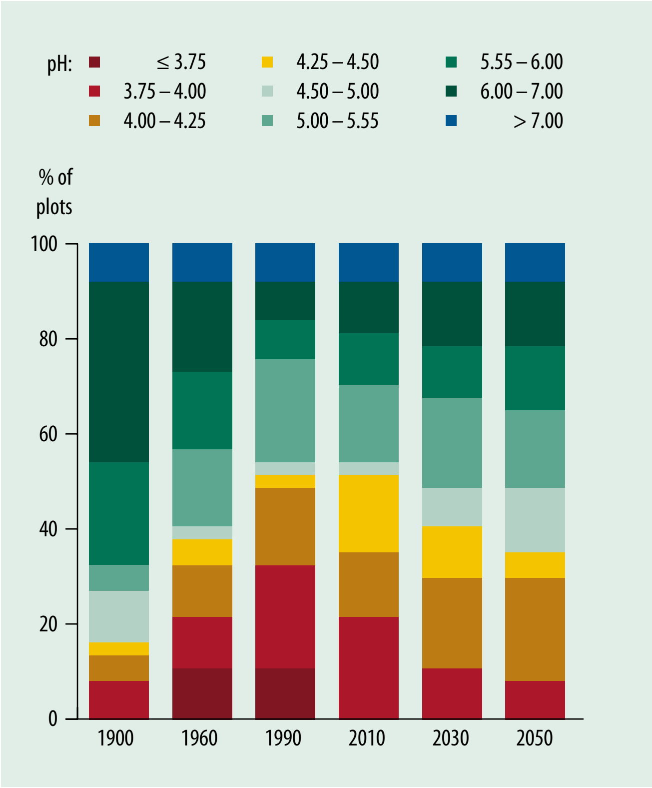


Figure 3-12: Frequency of pH values over time at 37 Level II plots.

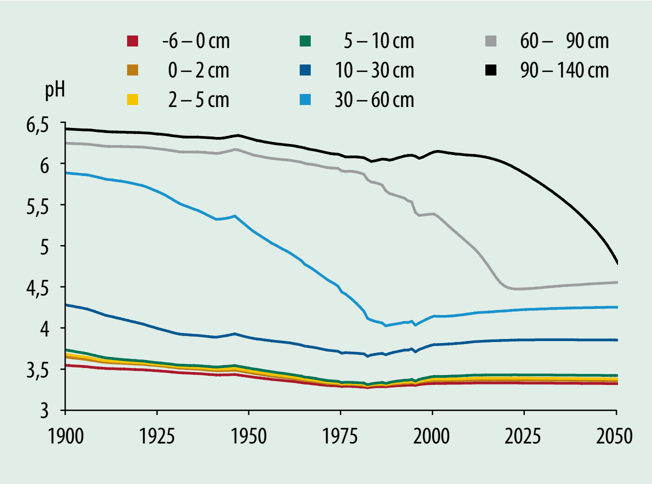


Figure 3-13: pH values of the soil solution at plot „Tannenbusch" in different soil layers over time. At plot „Tannenbusch" 130 year old oaks are growing on moist and sandy soil. Even though that the model calculations assume emission reductions, the three deeper soil layers show a progressive, strong and largely maintained acidification. The poor sandy soil cannot compensate for the previous depletion of nutrients.

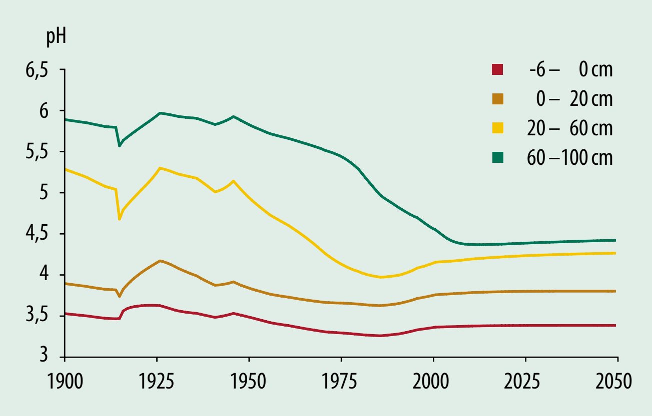


Figure 3-14: pH values of the soil solution at plot „Bautzen" in different soil layers over time. This plot is characterized by a 90 year old spruce stand. The upper three soil layers show a simultaneous acidification and a partial recovery. Below 60 cm soil depth there is a delayed acidification with no recovery.

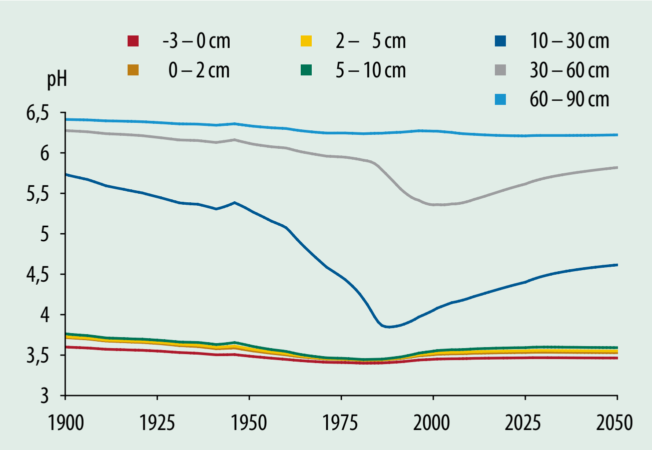


Figure 3-15: pH values of the soil solution at plot „Monschau" in different soil layers over time. Here, a 140 year old beech stand is situated on loamy soils. Reduced deposition in combination with the buffer capacity of the nutrient-rich soil allow for a clear recovery of soil solution pH, as predicted by the dynamic model.

Lysimeters extract water, which is called soil solution, for analysis in the laboratory. Soil solution reacts to deposition and plays an important role in the forest ecosystem. It is, for example, essential for water and nutrient uptake by plants.

However, the prevailing acidity status assumed for the year 1900 will not be reached again on many of the plots until 2050. Atmospheric deposition is the main reason for the observed acidification. Similar trends are confirmed by direct measurements and have also been reported from partner programmes of ICP Forests, showing that across Europe, the area with critical loads exceedances was largest in the 1990s. The partial recovery that is observed since then is a success of emission reductions. The results presented are based on the assumption of further emission reductions following the UNECE Gothenburg Protocol.

Ecosystem reactions depend on local conditions

The plotwise application of a more detailed and layer specific model (SAFE) shows that the ecosystem reaction is not uniform, but instead depends on specific site and stand conditions (see Figs. 3-13 to 3-15). Sensitive soils show a marked decrease in pH. Recovery is observed on plots where pH increases to historical levels after emission reductions have become effective. However, dynamic models focus on the chemistry of soil solution which is closely linked to atmospheric deposition and thus reacts rather quickly to changing inputs. The recovery of the soil solid phase is much slower and can take many decades.

Ground vegetation assessments in Finland.

3.3 Ground vegetation and nitrogen deposition

Summary

- *Management type, the geographic region in which the plots are situated and the soil acidity status are factors that determine the ground vegetation.*
- *There are clear indications that nitrogen deposition also influences ground vegetation species composition on some of the monitoring plots in Europe. Nitrogen-indicating plants occurred more frequently on plots with high nitrogen deposition.*
- *A five year monitoring period was too short to detect significant changes in species composition. The adaptation of vegetation to atmospheric inputs has probably occurred for a much longer time period. Regular monitoring over a long time span is necessary to follow the ongoing dynamics.*

Ground vegetation contributes to the biological diversity of forest ecosystems, and supports a considerable number of insects, animals and fungi. Since ground vegetation itself depends on environmental conditions such as soil and site type, forest type and climate, it is of interest to know whether changing environmental factors like nitrogen deposition can cause changes in ground vegetation composition.

Detrended correspondence analysis (DCA) was used to evaluate the floristic composition of the plots. This statistical method determines certain plant species which specifically account for the differences between vegetation composition of the plots. These species are arranged along synthetic axes. In several cases these species turn out to be typical for certain environmental conditions, such as soil or nutrient status on the plots. The axes can therefore be interpreted as proxy for these environmental factors as well. Plots are given scores on these axes so that they can be ranked (ordinated) according to their floristic composition. Several axes are determined in one DCA and thus allow multiple influences to be evaluated. In all DCAs presented, only around 10 % of total variance in ground vegetation composition is accounted for. This shows that there are numerous additional site and stand specific factors that explain the occurrence of specific plants and that cannot be covered by such a large scale evaluation.

Natural conditions and management mostly differentiate ground vegetation across Europe

Over Europe, the largest differences in ground vegetation species composition were found between Spanish and Portuguese plots on the one hand and plots north and east of the Pyrenees on the other. This difference can be accounted for by natural climatic and phytogeographic reasons. Differing management methods can also play a role in this context, as several plots on the Iberian Peninsula are located in open forests with a low coverage of the tree layer (see Fig. 3-16).

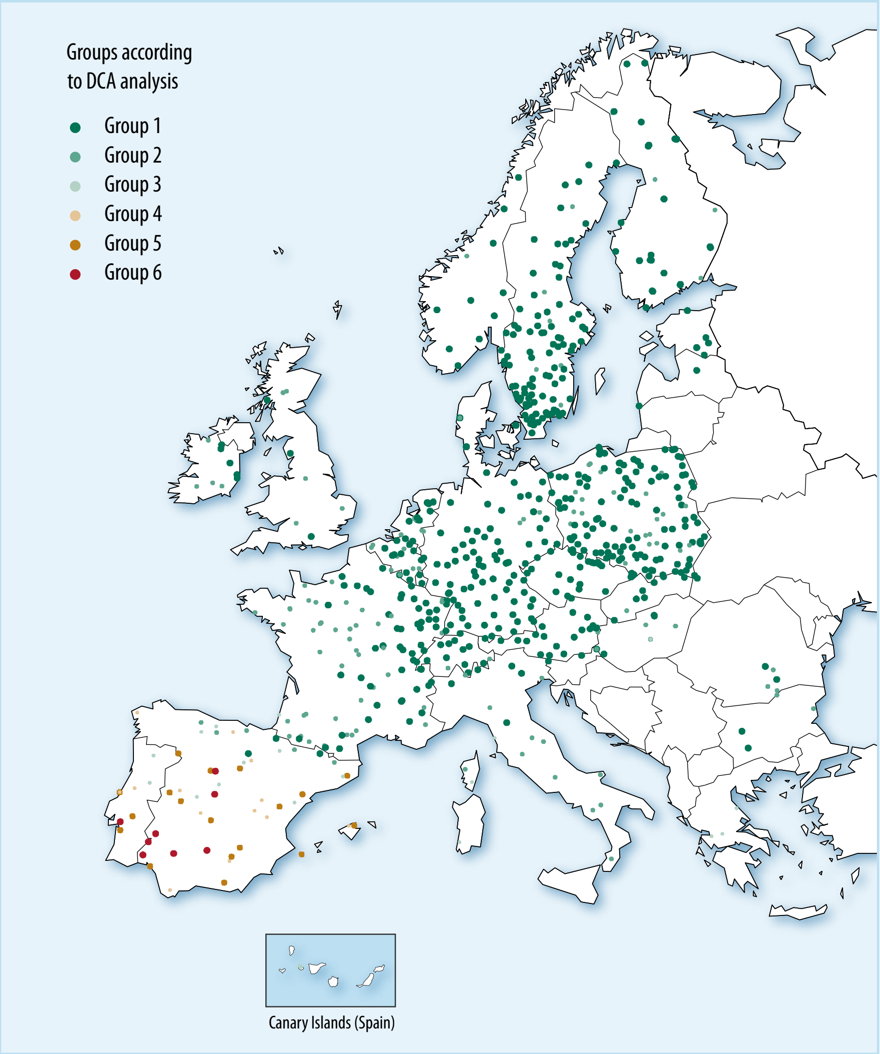


Figure 3-16: Plots classified according to the similarity of their ground vegetation composition (DCA scores, see box, p. 21). Plant composition on the Iberian Peninsula varies considerably from plots north of the Pyrenees. Differing forest management resulting in an open forest canopy, as well as climate and biogeographic reasons result in differing vegetation composition. There are numerous additional site and stand specific factors that explain the occurrence of specific plants and that cannot be covered by such a large scale evaluation.

There is some evidence for the effects of nitrogen deposition

In a specific study focussing on plots in central and southern boreal regions of Europe, the natural acid-base state of the organic soil layer was a main driving factor for the composition of ground vegetation.

Nitrogen availability also seems to affect the vegetation composition of the plots, because plots with a large component of nitrogen-indicating species are located in regions with high nitrogen deposition, such as in The Netherlands, Flanders, northern Germany and Denmark, southern Poland, Slovakia and Hungary (see Fig. 3-17).

The Level II data offer the opportunity to relate these ground vegetation characteristics to measured soil and deposition data. Results show that plots with acidity-indicating species have more acid soils as characterised by pH (see Fig. 3-18). In addition, air pollution can explain part of the variation in species composition, as there is a significant relationship between the occurrence of nitrogen-indicating species and nitrogen deposition (see Fig. 3-19).

National evaluations can provide a more detailed picture. In Italy the number of plant species increased with the content of nitrogen in the soil, a situation that mainly occurred on beech forests in the south of the country. In contrast, the number of species decreased when nitrogen deposition exceeded critical loads. This mostly occurred in beech forests in northern Italy.

No short term changes in ground vegetation over time

Plots with repeated vegetation assessments allow the analysis of possible changes in plant composition over time. They can also be used to examine whether nitrogen deposition has caused changes in species composition.

Mean Ellenberg indicator values (see box p.23) reflect nitrogen availability at the plots. However, a comparison of these values between the first and most recent assessments did not reveal significant differences (see Fig. 3-20). One reason for this might be the fact that the time intervals between measurements of around five years are rather short.

Further information:

Lorenz, M.; Fischer, R.; Becher, G.; Mues, V.; Seidling, W.; Kraft, P. ; Nagel, H.-D. (2006) Forest Condition in Europe. 2006 Technical Report. Geneva, UNECE, 113 pp, Annexes.

Climbing corydalis (*Ceratocapnos claviculata*) is a herb species that indicates nitrogen availability in the soil and that is fostered by atmospheric nitrogen deposition. Out of 488 Level II plots it occurred on 14 plots situated in areas with high nitrogen deposition.

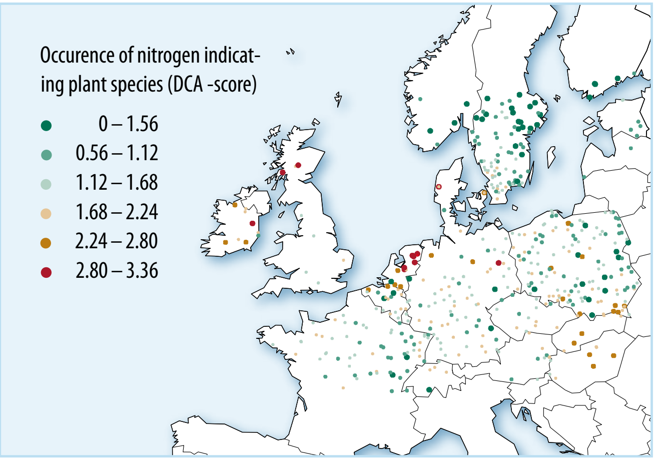


Figure 3-17: Level II plots grouped according to the occurrence of nitrogen-indicating plant species (4th DCA axis). Plots with a stronger occurrence of nitrogen indicators are located in regions with high nitrogen deposition. On the plots in Scotland and Ireland, species that are typical for Atlantic climate prevail. In the statistical evaluation, these species are grouped together with nitrogen-indicating plants.

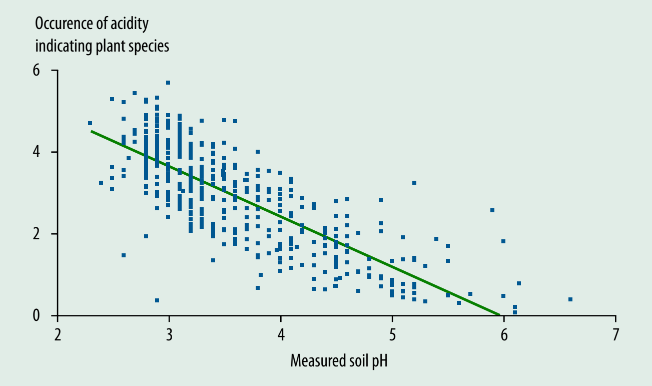


Figure 3-18: Relationship between the occurrence of acidity-indicating plants (1st DCA axis) and pH in the organic soil layer for 472 plots. Ground vegetation significantly reflects the measured acidity status of the soil organic layer. The graph shows a large number of plots with very low pH.

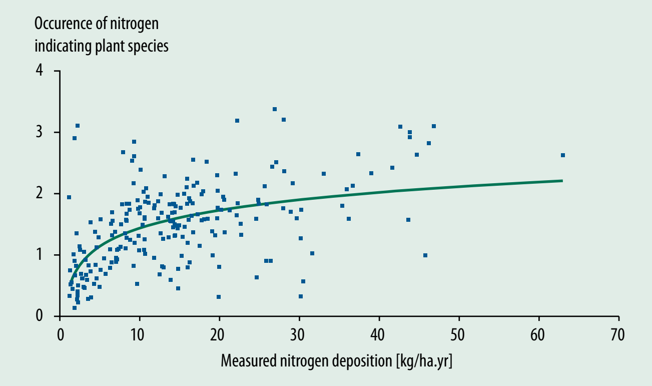


Figure 3-19: Relationship between the occurrence of nitrogen-indicating plants (4th DCA axis) and nitrogen deposition for 224 plots. Ground vegetation significantly reflects the measured nitrogen deposition under the forest canopy of the plots.

Ellenberg indicator values are a common tool to express the ecological behaviour of plant species. Plant species that usually only grow on sites with a poor nitrogen supply are assigned low nitrogen indicator values. Plants that require high nitrogen supply are given high indicator values of up to 9. Means of all Ellenberg nitrogen indicator values per plot thus give information on the nitrogen availability at the plots.

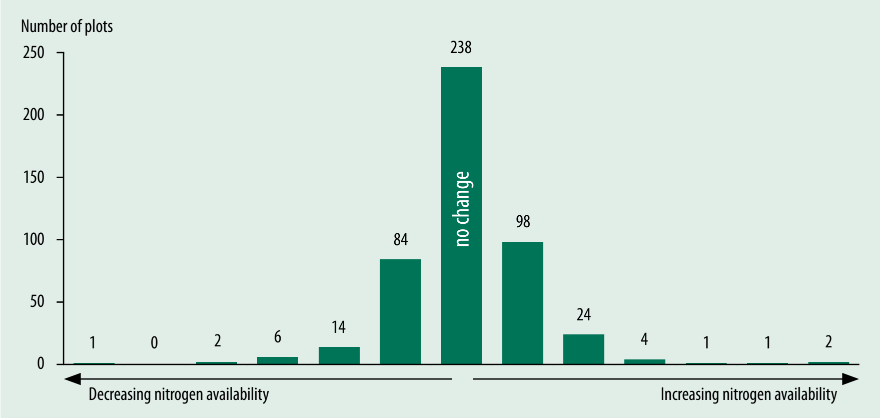


Figure 3-20: Differences between mean Ellenberg nitrogen indicator values at the most recent and first assessments for 475 plots with repeated surveys. Most of the plots do not show any changes. The short time intervals between the assessments are probably a major reason for this. It can also be assumed that vegetation was already adapted to the nitrogen deposition at the time of the first assessments.

The lichen species *Lobaria pulmonaria* indicates old growth-forests with a long ecological continuity. Although distributed over all Europe, the species is on the red lists of most countries.

4. A NEW CHALLENGE: FOREST BIODIVERSITY ASSESSMENTS

Summary

- *Selected key indicators were successfully assessed on more than 100 plots in 12 European countries to develop suitable methods for the monitoring of biological diversity in forests.*
- *Forest management and the age of the stands significantly affected the amount of deadwood.*
- *A new forest type classification proved to be feasible as regional approach for the investigation of forest biodiversity.*
- *The first results of the study confirm that air pollution, among other factors, affected composition and numbers of epiphytic lichen species.*

Biodiversity is high on the political agenda

The UNCED conference in Rio de Janeiro in 1992 and the adoption of the Convention on Biological Diversity were political milestones in bringing forward the concept of biodiversity. At the World Summit and the Environment for Europe Ministerial Conference in 2002, participating states committed themselves to reduce and halt the loss of biodiversity by 2010. The Ministerial Conference for the Protection of Forests in Europe in 2003 adopted 35 indicators for the sustainable management of forests, among which nine are biodiversity indicators. In 2004, the Council of the European Union decided to "enhance biodiversity research and monitoring with the aim to contribute to the implementation of the Convention on Biological Diversity".

The concept of biodiversity does not only refer to species composition and diversity, it also encompasses functions and structures of ecosystems and takes into account scales from the genetic level to forest stands and landscapes.

Deadwood assessment in Germany. Decaying wood offers a wide range of habitats for many insects, birds and fungi.

Monitoring of biological diversity is presently extended

Ground vegetation has been assessed on Level II plots since the 1990s, in order to serve as a biological indicator for deposition effects (see Chapt. 3-3). Today, these data are also recognized as a core contribution to biodiversity monitoring. Under the Forest Focus regulation of the EU and in line with the ICP Forests strategy, new projects and developments have been initiated recently with the aim of contributing to monitoring some aspects of forest biodiversity.

The project "Forest Biodiversity Test-phase Assessments (ForestBIOTA)" aims at harmonized monitoring methods for the assessment of stand structure, deadwood, and for lichens growing on the tree bark (epiphytic lichens). A scheme for the classification of the forests into forest types has also been applied. The new methods were successfully tested on 107 plots located in 12 European countries.

Above all: a diversity in forest types

A detailed assessment of forest biodiversity aspects needs to take into account the differing composition, structure and functioning of forest ecosystems across Europe. A classification into 28 forest types was therefore tested (see Fig. 4-1 and Special Focus p. 12/13). First results show significant relations of all the newly assessed parameters to the forest type of the re-

Workshop for the development of harmonized monitoring methods.

spective plots. Forest stand structure characterised by diameter variation and deadwood occurrence differed between forest types. The same was true for ground vegetation characteristics and for the number of epiphytic lichen species per plot.

Stand structure and deadwood are key factors

Variation in tree diameter (see Fig. 4-2) is a valuable indicator for the structure of the forest stands. Deadwood provides habitats for many species, for example insects and fungi. The volume of deadwood per hectare showed a large variation between the test-plots. The occurrence of deadwood was significantly related to the age of the stands. Forest management was an important factor affecting the amount of deadwood in European forests. The results from this harmonized approach are a valuable basis for sustainable forest management.

Sulphur and nitrogen deposition significantly affect lichens.

In total, 276 epiphytic lichen species were recorded on sample trees of 83 test-plots. In many countries the assessments include valuable records of threatened and endangered species. Plots with a lower number of epiphytic lichen species had significantly higher sulphur and nitrogen deposition. There are clear indications that air pollution does not only affect species number, but as well forest lichen species composition (see Fig. 4-3).

Outlook

The results of the ForestBIOTA project support the demonstration project BioSoil that is presently being carried out on a larger number of Level I plots. Links to the national forest inventories of many counties are also being intensified, in order to provide reliable and comparable information on the biological diversity of European forests.

Further information:
www.forestbiota.org

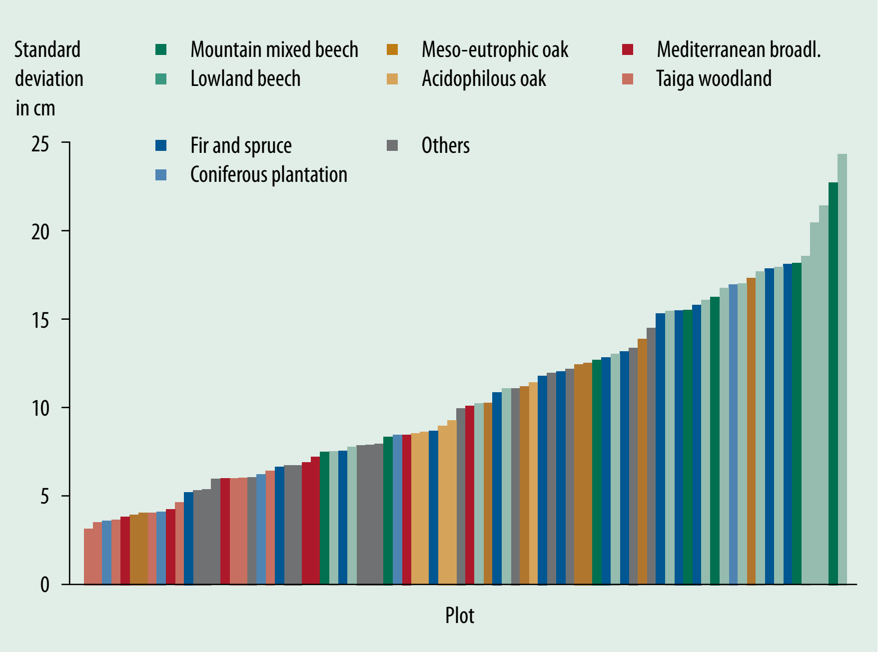


Figure 4-2: Tree diameter variation at breast height per plot in cm. Plots with beech woodlands in central Europe had mostly higher variations compared to Scandinavian and southern European plots.

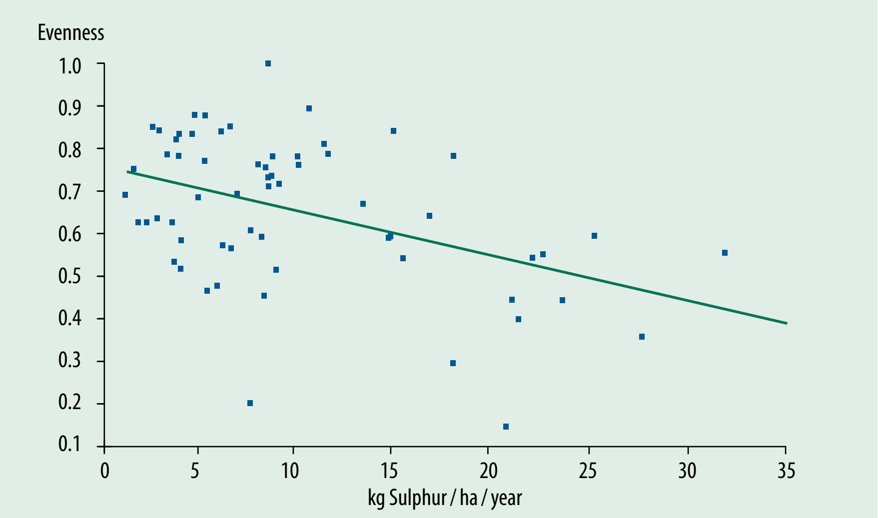
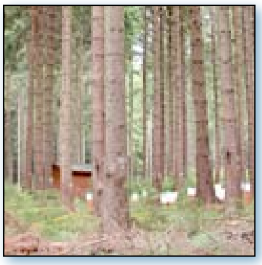


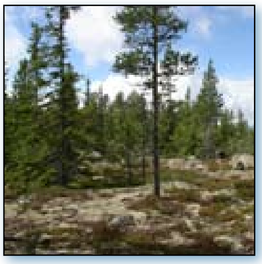
Figure 4-3: Eveness of epiphytic lichens in relation to sulphur inputs. Decreasing eveness of lichen species composition indicates that on plots with high sulphur inputs a few sulphur tolerant species become predominant.

● Lowland beech forest

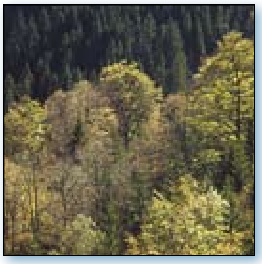


▲ Spruce forest

▲ Scots pine forest



△ Taiga woodland-pine



● Mountain mixed beech forest

● Meso-eutrophic oak forest

● Natural mediterranean broadleaved woodland

● Semi-natural mediterranean broadleaved woodland

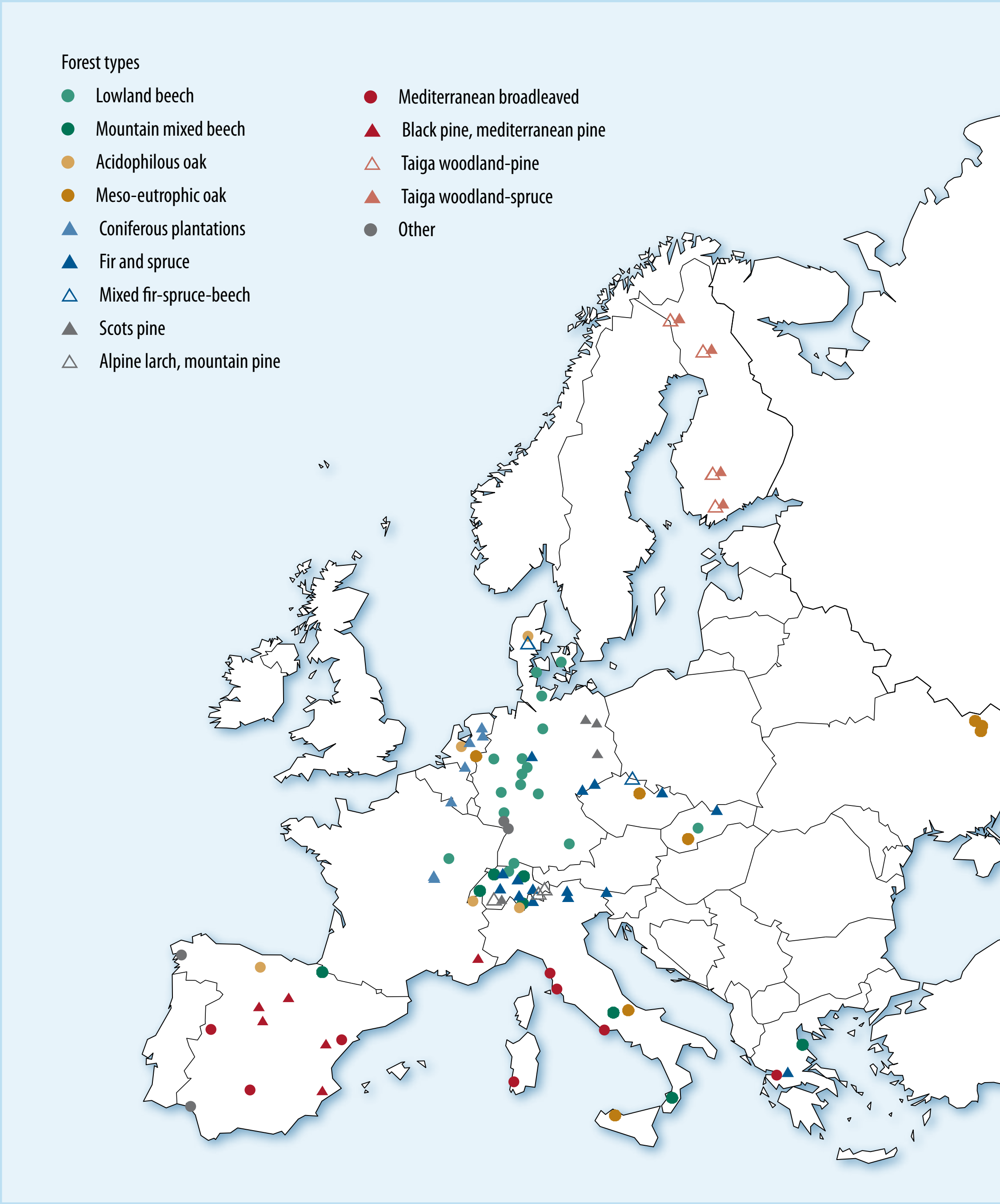


Figure 4-1: ForestBIOTA plots classified according to forest types.

5. CONCLUSIONS

In the 1980s, media headlines about air pollution causing forest decline alarmed politicians and the public. Today, climate change and forest biodiversity issues are high on the political agenda. A holistic view reveals these topics as different aspects of the same underlying anthropogenic pressures. Continuous monitoring is necessary to serve the information needs of environmental policy.

Over more than 20 years, ICP Forests in close cooperation with the European Commission, has established a unique monitoring system that combines both a harmonized and regular inventory and an intensive monitoring approach. The inventory provides representative information on the condition of forests in Europe, supported by intensive monitoring which enables the investigation of the complex relations between deposition fluxes and ecosystem responses. ICP Forests thus provides an ideal combination of monitoring, early warning system and analyses of cause effect relationships.

The monitoring programme has contributed many and diverse results as a basis for environmental policy. Atmospheric deposition is in the particular focus of the programme. Earlier results revealed some significant relations between deposition and tree crown condition. In addition, it was shown that the risk of storm damage is higher on acidified soils. Current evaluations show decreasing sulphur inputs on one third of around 200 Intensive Monitoring Plots since 1998 which is a clear indication of the success of clean air policies under UNECE and the European Union. Dynamic models show that acidification at many of the investigated plots reached a maximum in the 1990s. Since then, a slight recovery has taken place following emission reductions. However, critical loads are still exceeded on large forest areas and acidification will, among other factors, remain a driving force for the disturbance of forest condition.

Nitrogen inputs remained unchanged at most of the plots and effects of nitrogen inputs are of major public concern. Results presented in this report show that the composition of ground vegetation on the evaluated forest plots is influenced by nitrogen deposition. In addition, among other influences air pollution affected composition and numbers of epiphytic lichen species. These are indications that the biological diversity in forests is altered through atmospheric inputs. A forest biodiversity monitoring test phase has been successfully implemented on more than 100 monitoring plots. Harmonized methods for the assessment of stand structure, deadwood and epiphytic lichens are now available.

The dramatic deterioration of forest condition that was observed at some locations in Europe in the 1980s was stopped, not least as an impact of the Convention on Long-range Transboundary Air Pollution. Nevertheless, forest condition remains an issue of specific concern. Accumulations of previous inputs, nitrogen deposition and ozone concentrations are burdens to forests today. Weather extremes like the drought in the Mediterranean in the mid 1990s and the extremely warm and dry summer across large areas of Europe in 2003 led to increased defoliation. Even though the condition of beech and spruce recovered in 2005, the overall level of defoliation remains high with one quarter of all trees assessed classified as damaged or dead.

In view of current climate change scenarios, ICP Forests gains increased importance. Forests are unrivalled bioindicators for environmental change and the monitoring programme can contribute information on possible future adaptations of European forests. The extreme drought in 2003 is an example showing that the early warning system of ICP Forests is reliable. The existing data of the programme are a baseline for the comparison of future forest condition in a changing environment.

Further information:
www.icp-forests.org

Intensive monitoring plot in a central European lowland beech forest.

ANNEX I: FORESTS AND SURVEYS AND DEFOLIATION CLASSES IN EUROPEAN COUNTRIES (2005)

- 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			no survey in 2005			
Andorra	17				no survey in 2005			
Austria	3878	46.2	16 × 16	136	3528	50.5	34.7	14.8
Belarus	7812	37.8	16 × 16	406	9490	37.7	53.3	9.0
Belgium	691	22.8	$4^2/8^2$	132	3126	38.4	41.7	19.9
Bulgaria	4064	29.9	$4^2/8^2/16^2$	139	4817	22.4	42.6	35.0
Croatia	2061	36.5	16 × 16	86	2046	36.3	36.6	27.1
Cyprus	298	32.2	16 × 16	15	360	20.0	69.2	10.8
Czech Republic	2630	33.4	$8^2/16^2$	138	6128	11.6	31.3	57.1
Denmark	468	10.9	$7^2/16^2$	22	528	68.8	21.8	9.4
Estonia	2285	49.9	16 × 16	92	2167	54.2	40.4	5.4
Finland	20302	65.8	$16^2/24 \times 32$	609	11535	57.6	33.6	8.8
France	14591	26.6	16x16	509	10129	30.5	35.3	34.2
Germany	11076	28.9	$16^2 / 4^2$	451	13630	29.1	42.4	28.5
Greece	2512	19.5	16 × 16	72	1697	44.2	39.5	16.3
Hungary	1851	19.4	4 × 4	1218	28506	38.8	40.2	21.0
Ireland	680	6.3	16 × 16	22	382	51.1	32.7	16.2
Italy	8675	28.8	16 × 16	238	6573	25.6	41.5	32.9
Latvia	2944	44.9	8 × 8	349	8208	19.7	67.2	13.1
Liechtenstein	8	50.0					no survey in 2005	
Lithuania	2091	31.3	8 × 8 / 16 × 16	262	6315	14.1	74.9	11.0
Luxembourg	89	34.4					no survey in 2005	
Rep. of Moldova	318	9.4	2 × 2 / 2 × 4	528	14575	41.0	32.5	26.5
The Netherlands	334	9.6	16 × 16	11	229	55.2	14.6	30.2
Norway	12000	37.1	$3^2/9^2$	1595	8497	44.2	34.2	21.6
Poland	8756	28.0	16 × 16	1298	25960	12.2	57.1	30.7
Portugal	3234	36.4	16 × 16	119	3570	28.2	47.5	24.3
Romania	6244	26.3	4 × 4	6132	100718	73.1	18.8	8.1
Russian Fed.	8125	73.2					no survey in 2005	
Serbia Montenegro	2360		16 × 16 / 4 × 4	129	2995	50.7	32.9	16.4
Slovak Republic	1961	40.0	16 × 16	108	4111	14.2	62.9	22.9
Slovenia	1099	54.2	16 × 16	44	1056	29.3	40.1	30.6
Spain	11588	30.9	16 × 16	620	14880	17.0	61.7	21.3
Sweden	23400	57.1	varying	3954	17610	46.1	35.5	18.4
Switzerland	1186	28.7	16 × 16	48	1031	28.8	43.1	28.1
Turkey	20199	25.9					no survey in 2005	
Ukraine	9400	15.4	16 × 16	1329	26720	62.6	28.7	8.7
United Kingdom	2825	11.6	random	345	8280	29.1	46.1	24.8
Total	203088		varying	21156	349397			

Russian Federation: North-western and Central European parts only.
Serbia and Montenegro: Serbia 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 (1994-2005)

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

Participating countries	All species, defoliation classes 2-4												change % points
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2004/2005
Albania					9.8	9.9	10.1	10.2	13.1		12.2		
Andorra											36.1		
Austria	7.8	6.6	7.9	7.1	6.7	6.8	8.9	9.7	10.2	11.1	13.1	14.8	1.7
Belarus	37.4	38.3	39.7	36.3	30.5	26.0	24.0	20.7	9.5	11.3	10.0	9.0	-1.0
Belgium	16.9	24.5	21.2	17.4	17.0	17.7	19.0	17.9	17.8	17.3	19.4	19.9	0.5
Bulgaria	28.9	38.0	39.2	49.6	60.2	44.2	46.3	33.8	37.1	33.7	39.7	35.0	-4.7
Croatia	28.8	39.8	30.1	33.1	25.6	23.1	23.4	25.0	20.6	22.0	25.2	27.1	1.9
Cyprus								8.9	2.8	18.4	12.2	10.8	-1.4
Czech Rep.	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.1	53.4	54.4	57.3	57.1	-0.2
Denmark	36.5	36.6	28.0	20.7	22.0	13.2	11.0	7.4	8.7	10.2	11.8	9.4	-2.4
Estonia	15.7	13.6	14.2	11.2	8.7	8.7	7.4	8.5	7.6	7.6	5.3	5.4	0.1
Finland	13.0	13.3	13.2	12.2	11.8	11.4	11.6	11.0	11.5	10.7	9.8	8.8	-1.0
France	8.4	12.5	17.8	25.2	23.3	19.7	18.3	20.3	21.9	28.4	31.7	34.2	2.5
Germany	24.4	22.1	20.3	19.8	21.0	21.7	23.0	21.9	21.4	22.5	31.4	28.5	-2.9
Greece	23.2	25.1	23.9	23.7	21.7	16.6	18.2	21.7	20.9			16.3	
Hungary	21.7	20.0	19.2	19.4	19.0	18.2	20.8	21.2	21.2	22.5	21.5	21.0	-0.5
Ireland	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	20.7	13.9	17.4	16.2	-1.2
Italy	19.5	18.9	29.9	35.8	35.9	35.3	34.4	38.4	37.3	37.6	35.9	32.9	-3.0
Latvia	30.0	20.0	21.2	19.2	16.6	18.9	20.7	15.6	13.8	12.5	12.5	13.1	0.6
Liechtenstein													
Lithuania	25.4	24.9	12.6	14.5	15.7	11.6	13.9	11.7	12.8	14.7	13.9	11.0	-2.9
Luxembourg	34.8	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	-7.5
The Netherlands	19.4	32.0	34.1	34.6	31.0	12.9	21.8	19.9	21.7	18.0	27.5	30.2	2.7
Norway	27.5	28.8	29.4	30.7	30.6	28.6	24.3	27.2	25.5	22.9	20.7	21.6	0.9
Poland	54.9	52.6	39.7	36.6	34.6	30.6	32.0	30.6	32.7	34.7	34.6	30.7	-3.9
Portugal	5.7	9.1	7.3	8.3	10.2	11.1	10.3	10.1	9.6	13.0	16.6	24.3	7.7
Romania	21.2	21.2	16.9	15.6	12.3	12.7	14.3	13.3	13.5	12.6	11.7	8.1	-3.6
Russian Fed.	10.7	12.5						9.8	10.9				
Serbia Montenegro			3.6	7.7	8.4	11.2	8.4	14.0	3.9	22.8	14.3	16.4	2.1
Slovak Rep.	41.8	42.6	34.0	31.0	32.5	27.8	23.5	31.7	24.8	31.4	26.7	22.9	-3.8
Slovenia	16.0	24.7	19.0	25.7	27.6	29.1	24.8	28.9	28.1	27.5	29.3	30.6	1.3
Spain	19.4	23.5	19.4	13.7	13.6	12.9	13.8	13.0	16.4	16.6	15.0	21.3	6.3
Sweden		14.2	17.4	14.9	14.2	13.2	13.7	17.5	16.8	19.2	16.5	18.4	1.9
Switzerland	18.2	24.6	20.8	16.9	19.1	19.0	29.4	18.2	18.6	14.9	29.1	28.1	-1.0
Turkey													
Ukraine	32.4	29.6	46.0	31.4	51.5	56.2	60.7	39.6	27.7	27.0	29.9	8.7	-21.2
United Kingdom	13.9	13.6	14.3	19.0	21.1	21.4	21.6	21.1	27.3	24.7	26.5	24.8	-1.7

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 1993-94 and 1997-2005 are consistent, but not comparable to each other. *Italy:* Due to methodological changes, only the time series 1993-96 and 1997-2005 are consistent, but not comparable to each other. *Russian Federation:* North-western and Central European parts only. *United Kingdom:* The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States. *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

Tree species referred to in the text

Black pine	*Pinus nigra*
Common beech	*Fagus sylvatica*
European oak	*Quercus robur*
Greek fir	*Abies cephalonica*
Holm oak	*Quercus ilex*
Maritime pine	*Pinus pinaster*
Norway spruce	*Picea abies*
Scots pine	*Pinus sylvestris*
Sessile oak	*Quercus petraea*
Silver fir	*Abies alba*

Annex IV

Photo references

Name	Page
D. Aamlid	6, 25 bottom
P. Busselen	23
R. Fischer	8, 16 top, 20, 24, 27 (Scots pine forest, Mountain mixed beech forest)
O. Granke	11, 14, 15, 16 bottom, 25 top, 27 (Spruce forest), 29
K. Karoles	12, 13
M. Lorenz	4
Ministry of the Environment, Estonia	5
L.M. Nageleisen	9, 27 (Meso-eutrophic oak forest)
M. Salemaa	21
G. Sanchez	18

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