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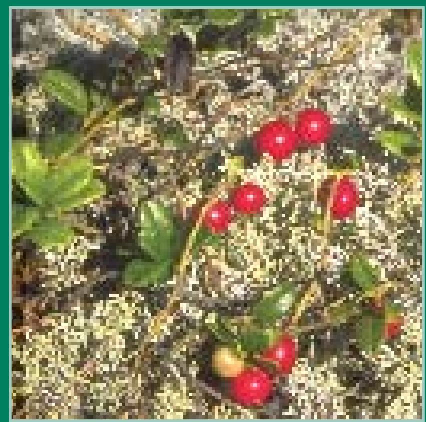

2002 Executive Report

The Condition of Forests in Europe

Convention on Long-range Transboundary Air Pollution: International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests

European Union Scheme on the Protection of Forests against Atmospheric Pollution

Federal Research Centre for Forestry
and Forest Products (BFH)

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The views expressed in this report are the author's and do not necessarily correspond with those of the European Commission.

After approval by the Task Force of ICP Forests this report was derestricted by the Working Group on Effects of the Convention on Long-range Transboundary Air Pollution

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Contents

Preface

It is a great privilege and pleasure for me to contribute with this preface to the 2002 Executive Report on Forest Condition in Europe. As a representative of the research community I strongly believe that sustainability can only be guaranteed with the use of sound scientific information when developing public policies.

The forest monitoring programme of EU and ICP Forests has become an essential source of information for the formulation of clean air policy. The Programme has effectively increased awareness in the scientific, political and public areas of the effects of the depositions of atmospheric pollutants on forests.

This Report presents for the first time a Europe-wide assessment of critical deposition loads based on measurements from monitoring plots. These results are an important cornerstone in the production of areal maps for Europe.

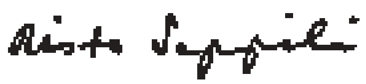
Another novel feature of the Report is the assessment of species diversity. It shows clearly that soil acidity has a negative influence on ground vegetation diversity in the forests. The inclusion of the measurement of species diversity in the ICP Forests is also important because species diversity serves as an indicator of biological diversity in forest ecosystems e.g. for the Ministerial Conference of Protection of Forests in Europe (MCPFE).

The ICP Forests is very much oriented towards empirical natural sciences. This is understandable and acceptable as a starting point. However, the original reason for forest condition problems is usually to be found in economic development and human behaviour. Consequently, solutions to the problems are almost always connected with socio-economic and political factors. This suggests that the ICP Forests should also include socio-economic and policy research in its agenda.

Although changes in the condition of forests in Europe can only be traced by means of continuous monitoring and the collection of data, it is timely to ask whether sufficient attention has been paid to the efficient use of existing information and knowledge. Collecting more and more data often begins to dominate activities to the extent that there are not enough time and resources left for analyzing all information available. In addition, policy makers and other users of research results do not always consider the results and conclusions produced by the research community in their deliberations. In many cases a major step forward would be made if that what we already know were implemented properly.

Despite the warning note above, I do not suggest that the ICP Forests should stop collecting new data. We need continuous monitoring, e.g. to see how the implementation of clean air policies has succeeded. My understanding is that scientists and organizations also outside the Programme have extensively utilized collected data, and many results have been efficiently adopted in political decision-making. However, as an external observer, I cannot help asking whether it is still necessary to collect so many new data. Shouldn't more emphasis, at least temporarily, be placed on compiling, analyzing and synthesizing existing information at the expense of getting new figures?

Finally, I would like to congratulate the ICP Forests and the EC on this excellent work and offer the collaboration of IUFRO - the International Union of Forest Research Organizations. In addition to its almost 300 discipline-based Research Groups and Working Parties, IUFRO has established problem-oriented Task Forces that cover many of the key issues of the ICP Forests. In fact, several scientists who currently work in the Programme are also active within the IUFRO framework.



Risto Seppälä
President
International Union of Forest Research Organizations

Further information is available at: http://www.iufro.org

Timberline in the mountains of northern Finland.

Impacts of environmental stress factors on European forests - overview and summary –

- The crown condition of the forests in Europe deteriorated considerably during the first decade of monitoring. After some recuperation in the mid-1990s the deterioration resumed. In 2001 more than 20 % of the sample trees were rated as damaged.
- The defoliation of Scots pine and beech is mainly related to the effects of weather extremes, in particular precipitation, age, insects, fungi, and air pollution. Defoliation of these species is correlated with atmospheric inputs of sulphur.
- Depositions of nitrogen, acidity and heavy metals exceed critical loads over a large proportion of the Intensive Monitoring Plots, indicating enhanced risks for leaching of aluminium and base cations, tree root damage, crown damage by drought, frost and pests and changes in the plant diversity of ground vegetation.
- Plant diversity is mainly determined by actual soil condition, specifically acidity, as well as nitrogen deposition, temperature, precipitation and tree species.
- The monitoring programme can substantially contribute to environmental policies in the context of biodiversity and sustainable forest management.

The United Nations Economic Commission for Europe (UNECE) and the European Union (EU) have been monitoring forest condition in Europe jointly for 16 years. The above outlines main results and conclusions of the programme as presented in this annual report.

The monitoring system
Large-scale variations of forest condition over space and time are assessed in relation to natural and anthropogenic factors for more than 6 000 monitoring plots spread over a systematic 16 x 16 km grid throughout Europe (Level I). Detailed causal relationships are studied on 860 Intensive Monitoring Plots covering the most important forest ecosystems in Europe (Level II). Changes to the condition of forests in Europe, their reaction to environmental stress and the effects of environmental policies can only be traced by means of continuous systematic and intensive monitoring. With its large number of plots and parameters and the participation of 39 countries, the programme operates one of the world's largest biomonitoring networks.

Crown condition
Crown condition is a visible reaction on numerous environmental factors affecting tree vitality. Changes in crown condition are therefore assessed annually for both Level I and Level II plots. This provides in addition an indication of the forest health criterion for the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Fifteen years of large-scale monitoring of crown condition has revealed that after initial deterioration followed by some recuperation in the mid-1990s, the deterioration has resumed.

The results of statistical evaluations described in the present report confirm earlier findings explaining the variation of defoliation mainly in terms of the effects of weather extremes, in particular precipitation, insects, fungi, and age. Also, relationships between defoliation of Scots pine and beech and sulphur deposition are substantiated by the recent statistical evaluations of the transnational data set.

Atmospheric deposition
Of the various environmental factors influencing forest condition, the programme pays particular attention to air pollution, in accordance with its objectives. Sulphur depositions have been reduced on many plots. This is a clear success of the drastic reductions of sulphur emissions in Europe under the Convention on Long-range Transboundary Air Pollution (CLRTAP) and other pollution abatement strategies.

With regard to air pollution control, a factor of particular concern is how much pollution a particular environment can tolerate in the long term (critical loads). For the first time this report presents a European-wide assessment of critical loads of forest soils based on measurements from the Intensive Monitoring Plots. Critical loads for nitrogen accumulation in the soil were exceeded at 92% of the plots investigated. In earlier reports it was shown that nitrogen accumulations in the soil are the predominant source of potential soil acidification. From saturated ecosystems they can be released again, now increasing nitrate concentrations in the ground water. Calculations of critical loads related to nitrogen concentrations in the foliage of trees show that on 45% of the conifer plots there is an increased risk of drought stress, frost and pests, whereas risks for ground vegetation changes occur on more than half of the evaluated plots. Critical loads for acidity that are related to effects on tree roots were exceeded at 33% of the investigated plots. Base cations or aluminium pools in the soil might be declining on up to 64% of the Intensive Monitoring Plots. Critical loads for lead and cadmium related to possible impacts on soil organisms were exceeded on 92% and 29% of the plots, respectively. It has to be taken into account that the presented critical loads refer to a steady state. Therefore the time before effects become visible can take several years to decades.

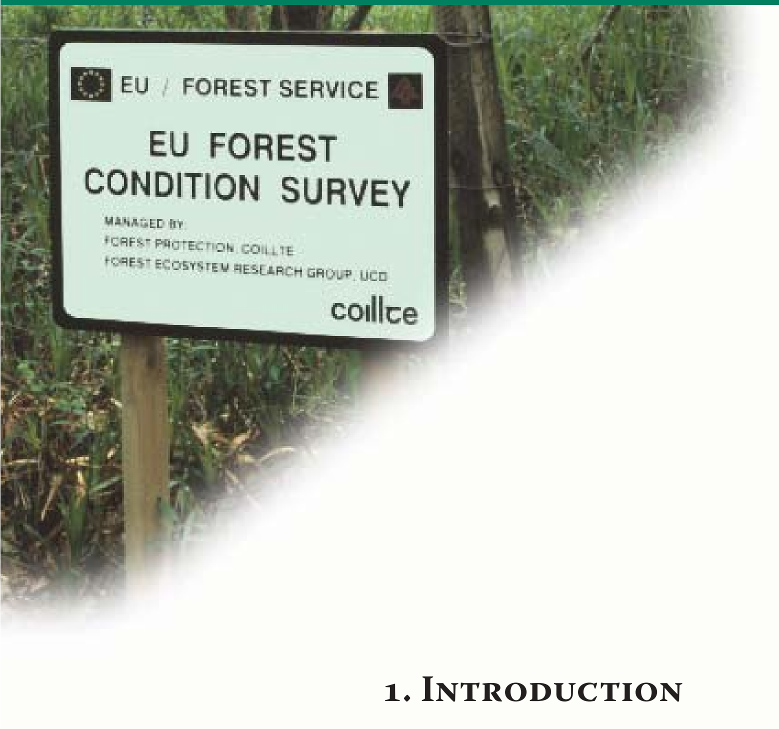
Ground vegetation
The plant diversity has been related to environmental factors on nearly 200 Level II plots. The results show large differences in plant diversity on the monitored plots. The present occurrence of species is mainly determined by actual soil condition, specifically acidity, temperature, precipitation, and tree species. In the statistical models also nitrogen deposition had a significant influence on ground vegetation. The programme has recognised the importance of the biodiversity issues and a newly established working group is now responsible for intensified assessments and evaluations that might in the future make it possible to quantify environmental impacts on floristic biodiversity in forests.

Mountain forest, Italy.

Future directions
Having set out to assess the effects of air pollution on forests, the programme has provided important information for the implementation of clean air policies under the UNECE and EU and will continue to do so in the future. However, its well-established infrastructure, its multidisciplinary monitoring approach and its comprehensive database mean that it also has significant contributions to make in other areas of international environmental politics.
It pursues the objectives of several of the resolutions of the MCPFE and provides information on some of the quantitative indicators for sustainable forest management. In addition, the soil data of the programme is expected to be important for the assessment of carbon sinks in the frame of the Kyoto Protocol under the Framework Convention on Climate Change (FCCC). Contributions of the programme to the United Nations Forum on Forests as well as to the implementation of the Convention on Biological Diversity, including the expanded work programme on forest biological diversity, are expected. In addition, the programme is receiving increasing attention from research institutions and policy-making bodies outside Europe. An example is its recently initiated co-operation with the Acid Deposition Monitoring Network in East Asia (EANET) and the close co-operation with forest monitoring programmes in Canada and the USA.

Further information is available at:

http://www.icp-forests.org
(ICP Forests)
http://europa.eu.int/comm/agriculture
(European Commission)
http://www.fimci.nl
(Forest Intensive Monitoring Co-ordinating Institute)



Intensive Monitoring Plot, Ireland.

1. Introduction

The forest monitoring programme in an international context

In the early 1980s a severe deterioration of forest condition was observed in large areas of Europe. As a response to growing concern about the role of air pollution in this decline, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 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 was provided for the co-financing of the assessments. Since then, ICP Forests and the EU have been co-operating closely in monitoring the effects of air pollution and other stress factors on forests. The activities pursue the objectives of resolutions Ministerial Conference on the Protection of Forests in Europe (resolution S1 - Strasbourg, H1 - Helsinki, L2 - Lisbon).
Today 39 countries are participating in the monitoring programme, which contributes to the implementation of clean air policies under UNECE and EU as well as at national levels.

Programme objectives

The objectives of the monitoring programme are:

- to provide a periodic overview on the spatial and temporal variation in forest condition in relation to anthropogenic and natural stress factors for a European and national large-scale systematic network (Level I);
- to contribute to a better understanding of the relationships between the condition of forest ecosystems and stress factors, in particular air pollution, through intensive monitoring of a number of selected permanent observation plots spread over Europe (Level II);
- to contribute to the calculation of critical levels, critical loads and their exceedances in forests;
- to collaborate with other environmental monitoring programmes in order to provide information on other important issues, such as climate change and biodiversity in forests and thus contribute to the sustainable management of European forests;
- to compile information on forest ecosystem processes and to provide policy makers and the public with relevant information.

Monitoring arrangements

The objectives of the programme are implemented by a systematic large scale monitoring network (Level I) and an Intensive Forest Monitoring Programme (Level II) (see Tab. 1-1).
At Level I approximately 6 000 permanent plots are systematically arranged in a 16 x 16 km grid throughout Europe. At these sites crown condition is assessed annually. In addition, soil and/or foliage surveys were conducted on most of the plots. A new soil survey is under discussion.
For intensive monitoring, more than 860 Level II plots have been selected in the most important forest ecosystems of the countries participating. A larger number of key factors are measured on these plots; the data collected can be used for case studies of the more common combinations of tree species and sites.
Key factors measured at both levels form the basis for an extrapolation of results. The inclusion of further parameters and surveys is currently being considered.

Surveys conducted	Level I	Level II	
Crown condition	annually	annually	all plots
Foliar condition	once so far[1]	every 2 years	all plots
Soil chemistry	once so far[2]	every 10 years	all plots
Soil solution chemistry	-	continuously	some plots
Tree growth	-	every 5 years	all plots
Ground vegetation	-	every 5 years	some plots
Atmospheric deposition	-	continuously	some plots
Ambient air quality		continuously	some plots
Meteorological condition	-	continuously	some plots
Phenology (optional)	-	according to phenophases	some plots
Remote sensing (optional)	-		some plots

Table 1-1: Surveys carried out on Level I and Level II plots. [1] on 1497 plots | [2] on 5289 plots

This year's report

This year's report provides the results for the annual crown condition survey as well as in-depth evaluations for specific tree species. The focus on holm oak is the continuation of a series that has dealt with European and sessile oak, common beech and Aleppo pine in previous years. (Chapter 2). As far as intensive monitoring is concerned, the focus in last year's report was on the effect of sulphur and nitrogen in the forest ecosystem and the response of the soils. Chapter 3 of this year's report focuses on critical deposition loads in comparison to present loads, whereas for next year's report it is planned to consider impacts under various emission scenarios on forest ecosystem condition in the future.
Since the objectives of the monitoring programme were widened in 2001, evaluations in the field of biodiversity have been intensified. Chapter 4 presents interim results on the relationships between ground vegetation and environmental factors. Once again, evaluations are continuing and more details are expected in the coming years.

Co-operating partners were invited to illuminate the context of the ongoing work. The contributions of the ICP on Modelling and Mapping and of the European Environmental Agency are included in Chapters 3 and 4, respectively.

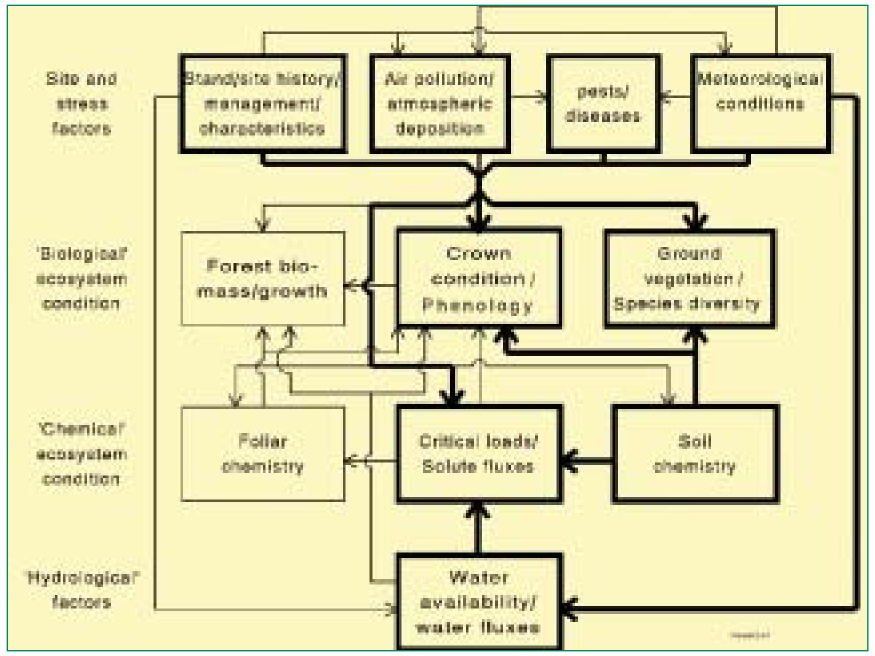
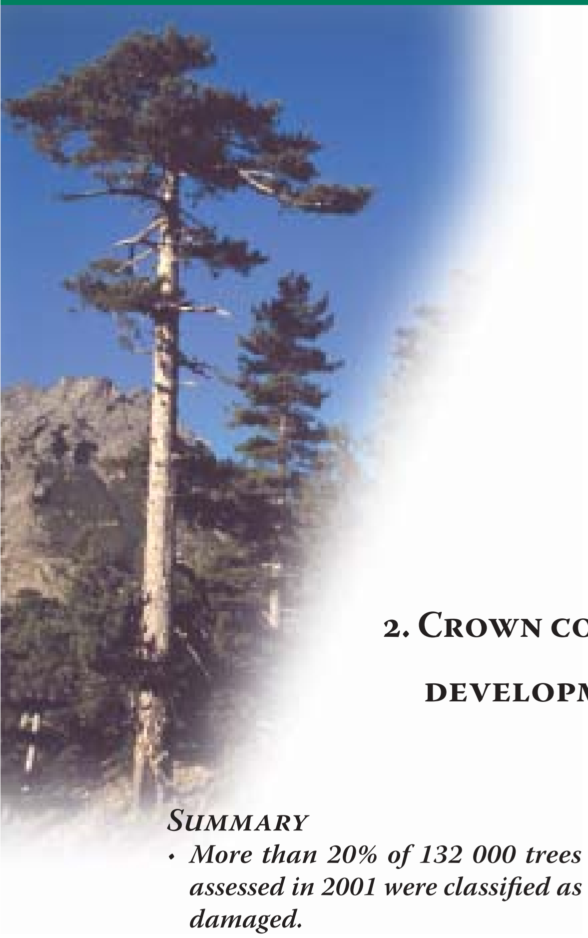


Figure 1.1: Flow diagram illustrating the relationships between site and stress factors and the forest ecosystem condition. Boxes and arrows in bold are specifically investigated in this year's report.



Corsican pine, France.

2. Crown condition in 2001 and past developments

Summary

- ***More than 20% of 132 000 trees assessed in 2001 were classified as damaged.***
- ***Trees that have been monitored since the start of the survey show continuous deterioration from 1986 to 1995. After a marked recuperation in the mid-1990s the deterioration resumed at a lower level.***
- ***In-depth evaluations for Scots pine and common beech show that there is no uniform trend of defoliation throughout Europe. Rather, they reveal changing conditions in different regions.***
- ***High or low precipitation, insect and fungi attacks as well as air pollution are among the most important influencing factors. Whereas sulphur deposition correlates with high defoliation, nitrogen has ambiguous effects: depending on soil and forest type, either its fertilising or its acidifying effects seem to prevail.***

2.1 Introduction

The annual crown condition survey is the main tool of the programme to obtain a large scale overview on the condition of forests in Europe. In 2001 the assessments were conducted in all EU member states and in 15 non-EU countries on the transnational 16 x 16 km grid. Some 132 000 trees were assessed on nearly 6 000 plots during the summer months. Quality assurance measures were routinely applied in the countries and extensive plausibility and consistency checks were carried out by the Programme Co-ordinating Centre in Hamburg, Germany. Due to changes in the assessment methods French and Italian datasets were excluded from the time series.

The crown condition is assessed in terms of defoliation. This parameter describes the lack of foliage for each sample tree. Defoliation depends on many stress factors and is therefore a valuable measure to describe the overall forest condition.

2.2 Crown condition in 2001 and trends

22.4% of all trees assessed in 2001 were classified as moderately or severely defoliated or dead. Crown condition in the EU Member States was slightly better than in Europe as a whole. Of the four tree species most frequently occurring on the plots, European and sessile oak were still the most severely defoliated species and also showed the highest proportion of dead trees (Fig. 2-1).

The temporal development of defoliation was analysed for a sample of all continuously monitored trees. With the exception of the holm oak, mean defoliation of all main tree species increased in 2001 (Fig. 2-2). The share of damaged and dead trees (defoliation classes 2-4) of all species was highest in 1995 (25.8%) and decreased in the following two years. Since then a steady but slow increase in damage has been recorded.

The mid-term development of defoliation not only varies between tree species, but also between regions. The plot-

Tree crowns of undamaged, moderately damaged and dead Scots pine.

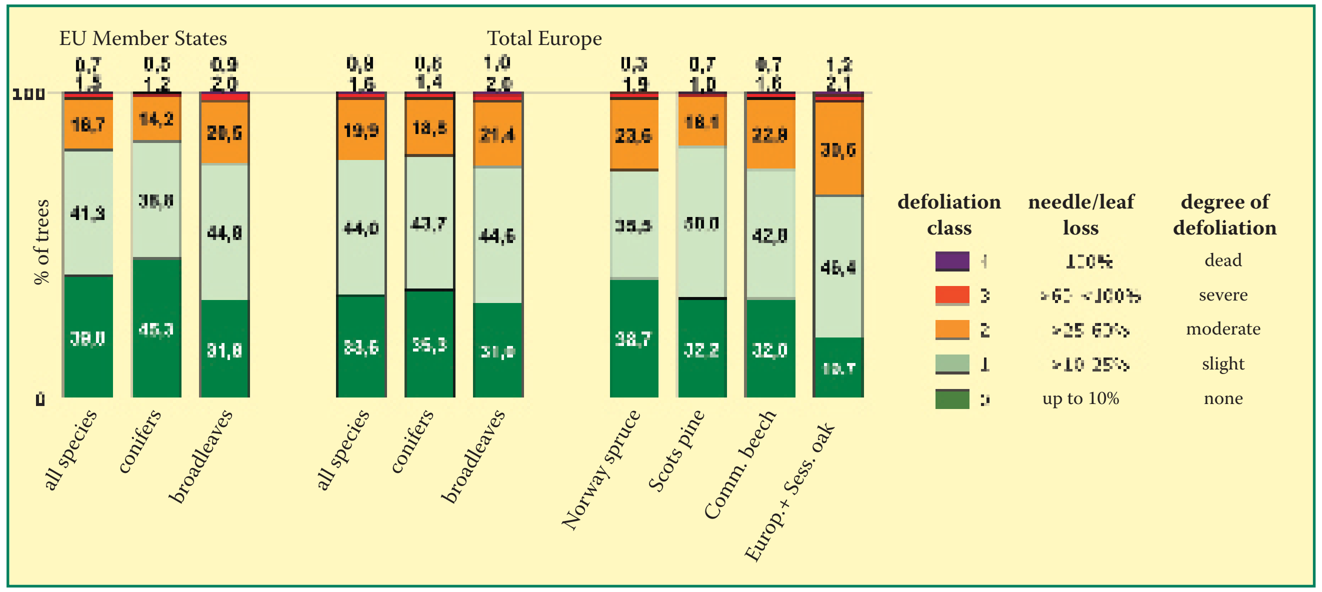


Figure 2-1: Percentage of trees in different defoliation classes for main tree species (-groups). Total Europe and EU, 2001.

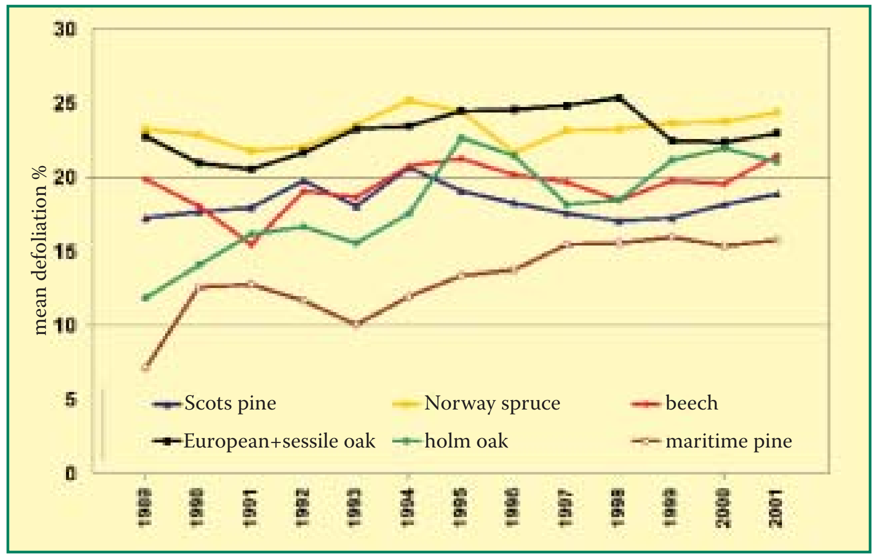
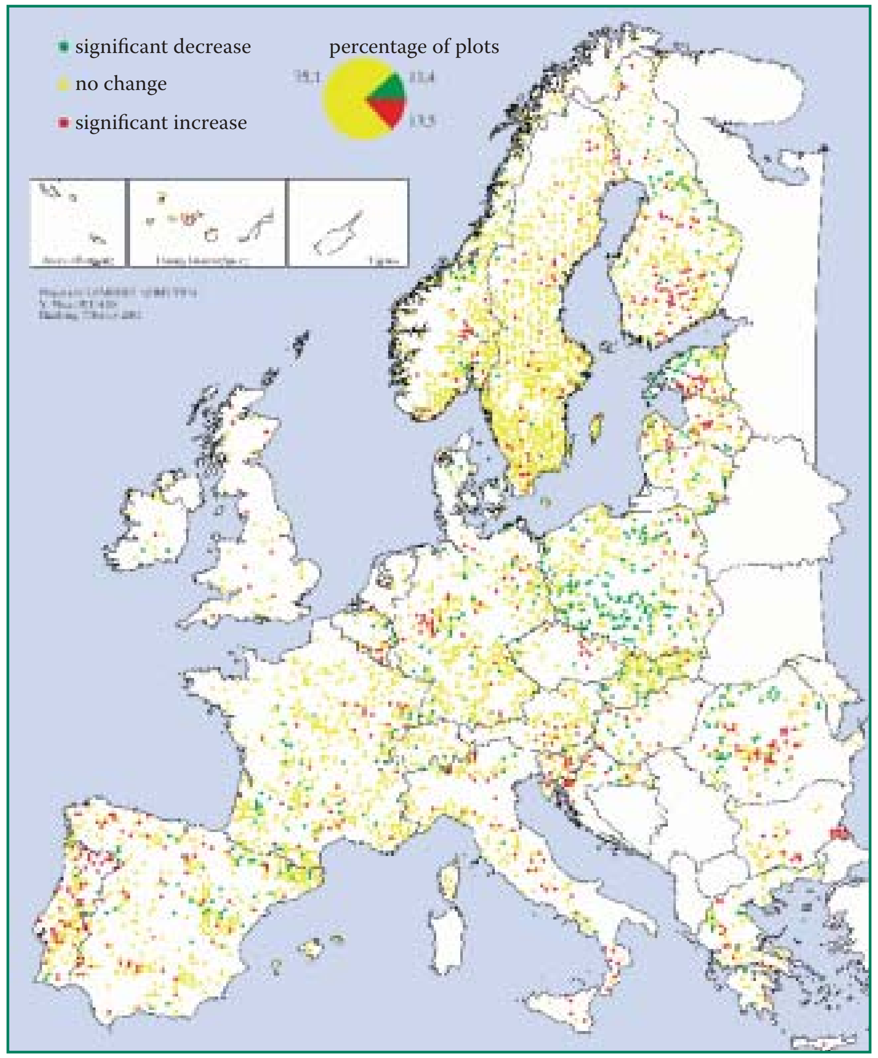


Figure 2-2: Development of mean defoliation for European main tree species, calculated for continuously monitored trees. Sample sizes vary between 1 215 trees for European and sessile oak and 3 012 for spruce.

wise mapping (Fig. 2-3) shows that the number of plots with a significant increase (565) is slightly larger than the number of plots with an decrease of mean defoliation (500).

Regions with prevailing improvements of crown condition are southern Poland and south-western France. Deterioration took place mainly in eastern Bulgaria and southern Italy. Local experts explain the observed deterioration in southern Europe mainly by unfavourable weather conditions. For Bulgaria, extensive forest fires were also reported and the damaged areas in southern Italy are among the regions with the highest ozone concentrations in Europe during the observation period. In addition, beech and chestnut plots suffered from severe insect and fungal attacks. The improvement in southern Poland is ascribed to a reduction of air pollution emissions and favourable weather conditions, especially in the period from 1994 to 1999.

Figure 2-3: Development of defoliation for all species.
Plot wise linear trends for 1994 – 2001 were tested for significance. The evaluation period for France, Italy and Sweden is 1997 to 2001.



2.3 Influences on crown condition

The data and the statistical analysis

- **Data basis:** In-depth evaluations for Scots pine and beech are based on those Level I plots for which data on at least three pine or beech trees were continuously reported from 1994 to 1999. The evaluation period ended in 1999 as later deposition data was not available.
- **Levels of defoliation:** Defoliation field estimates throughout Europe are strongly influenced by stand age (older trees are usually more defoliated) and by the country in which the Level I plot is located (assessment methods sometimes vary between countries). The levels of defoliation presented were therefore evaluated as differences between field estimates and modelled plot values which take into account the variables 'stand age' and 'country' and hence compensate for their influence.
- **The development of defoliation** was calculated as the plot wise linear gradient of a regression through all annual mean plot values of the years 1994 to 1999. Age and country influences were negligible for time trend evaluations.
- **The geostatistical method kriging** was used to interpolate levels and trends of defoliation, based on the available Level I plots. Interpolated values were only calculated for grid points with more than 4 plots available in a radius of 100 km.
- **Multivariate models** were used to explain defoliation by different environmental influences. A coincidence of high defoliation with certain stress factors can be interpreted as damaging effect.

Scots pine
In Estonia, southern Poland as well as north eastern Spain there are regions with a comparatively high mean defoliation. However, crown condition has improved in these regions (Fig. 2-4; 2-5). Also, in middle Norway a decrease of the rather high mean defoliation has been observed, whereas in southern Norway the comparatively good crown condition has deteriorated. The deteriorating trend in Bulgaria is based on the limited number of 21 pine plots of which 19 show a worsening trend.

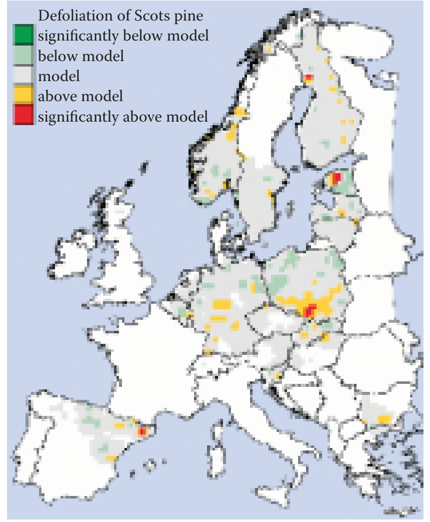


Figure 2-4: Differences between medium term mean defoliation of Scots pine and model value; interpolation based on 1313 plots continuously assessed from 1994 to 1999.

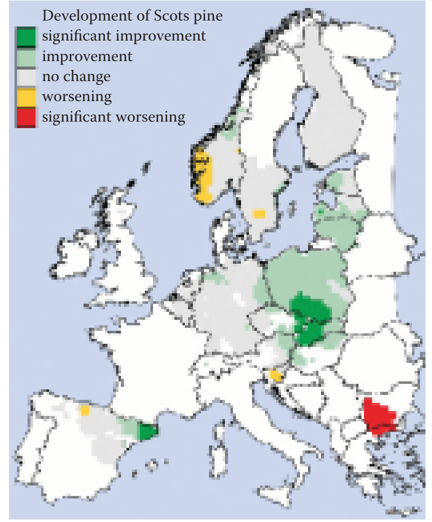


Figure 2-5: Linear time trends of mean defoliation of Scots pine; interpolation based on 1313 plots continuously assessed from 1994 to 1999.

Common beech
Southern Germany shows a comparatively high mean defoliation of beech which has worsened towards the end of the observation period (Fig. 2-6; 2-7). Romania is characterised by obviously high fluctuations in beech crown condition. The high defoliation in central Romania has decreased until 1999 whereas the comparatively low defoliation in the middle east and middle west of the country has clearly increased. Other European regions with deteriorating crown condition for beech trees are north-western Germany and the region along the border between Slovenia and Croatia. Improvements have been registered for Slovakia and regions in Germany.

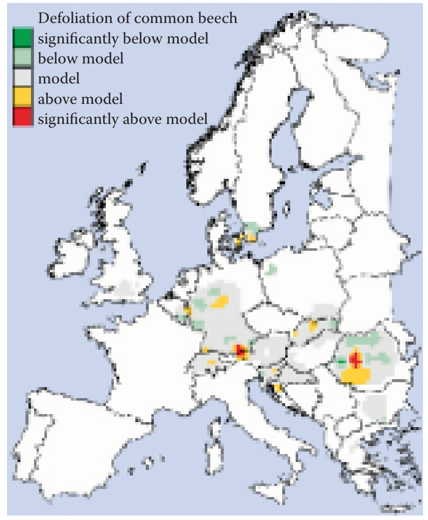


Figure 2-6: Differences between medium term mean defoliation of common beech and model value; interpolation based on 399 plots continuously assessed from 1994 to 1999.

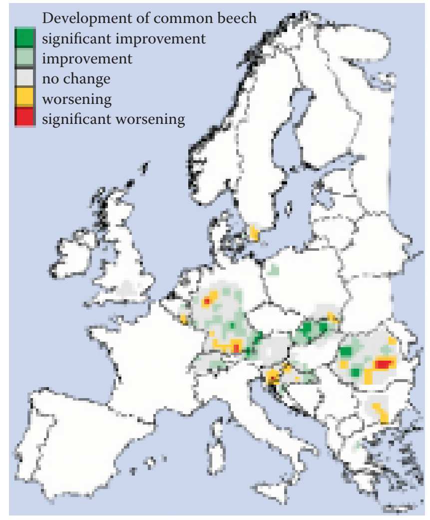


Figure 2-7: Linear time trends of mean defoliation of common beech; interpolation based on 399 plots continuously assessed from 1994 to 1999.

Multiple influences on crown condition
Model results show that high precipitation is related to relatively healthy tree crowns (Tab. 2-1). In addition, pine plots show a plausible interaction of site characteristics and precipitation: on plots with low and medium water availability there is a positive correlation between precipitation and crown condition. It seems that on these plots an increased water supply improves forest condition, whereas the reverse is true for sites with more than enough water available in the soil. With respect to biotic damage factors, insects (and on beech plots also fungi) are related to high or increasing defoliation. Sulphur deposition was also correlated in all four models with high or increasing defoliation. Research results on the damaging effects of sulphur inputs are thus supported. The correlations between nitrogen inputs and forest condition are not significant and reveal ambiguous conditions. This might confirm current knowledge, as nitrogen inputs on one hand eutrophy forest ecosystems but on the other hand may have acidifying effects. Interaction terms of deposition and soil pH in the model (not depicted) show that effects of deposition in general depend on the acidity status of the soil. A linear trend could explain parts of the temporal variation of defoliation for pine as well as for beech. This shows that there are linear trends which are independent from the other explanatory variables of the model. As already shown on the maps, however, there is not a uniform Europe-wide trend, but varying conditions on different plots.

FURTHER READING:
UNECE AND EC. 2002. LORENZ, M., MUES, V., BECHER, G., SEIDLING, W., FISCHER, R., LANGOUCHE, D., DURRANT, D., BARTELS, U.: THE CONDITION OF FORESTS IN EUROPE. 2002 TECHNICAL REPORT. UNECE AND EC, GENEVA AND BRUSSELS, 69 P.

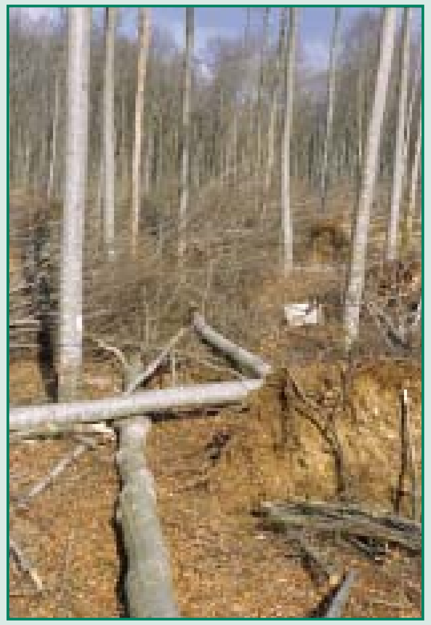
Defoliation		R^2	No. of plots	Variables									
				precip index	site*precip[a] interaction	insect	fungi	deposition[b]			linear trend	age	country
								S	NH_x	NO_y			
Spatial variation	pine	60.9	1313	-	*	**+**		**+**	+	-		*****	*****
	beech	41.1	399	**-**		+	**+**	+	-	+		*****	*****
Temporal variation	pine	44.5	1313	-	*	+		**+**	+	-	*		
	beech	39.3	399	-		+	+	+	-	+	*		

-	negative correlation	**-**	significant negative correlation	+	positive correlation	**+**	significant positive correlation	*	correlation	*****	significant correlation

a data source: Global Precipitation Climatology Centre (www.dwd.de/research/gpcc)
b data source: EMEP 150 x 150 km grid (www.emep.int)

Table 2-1: Relations between temporal and spatial variation of defoliation of Scots pine and common beech and various explaining variables as results of multivariate regression analyses. The R^2 value indicates the percentage of variance explained by the model.

THE INFLUENCE OF STORMS ON FOREST ECOSYSTEMS



Storm damage in France.

Introduction
Storm damage is one of the most important economic factors of forest damage in Europe. Over the past decades, damage severity has increased. The storms in December 1999 caused the highest damage ever reported in Europe (nearly 200 million m^3 merchantable timber). The severity of the storms is reflected in the damage that occurred on the plots of ICP Forests and EU: 3% of all Level I plots and 12% of the Level II plots were damaged. In the main storm areas these percentages were much higher. In France and Switzerland the monitoring plots were used to investigate the factors that contributed to the damage in 1999. In general the results are in line with earlier evaluations carried out in Germany, Austria and other countries after the severe storms in 1990.

Wind exposure
In France and Switzerland wind speed was linked to increased damage. Forests growing in the plains or on gentle slope suffered the highest damage.

Tree species
For both countries earlier findings were confirmed showing that conifers are in general more susceptible to wind than deciduous trees. During winter evergreen conifers offer more resistance to wind than deciduous trees, which increases their vulnerability to storms.

Stand structure and management
Storm damage increased substantially with tree height. For the French plots, higher ratios of stand height to stand mean diameter meant higher damage for some species. Unevenly structured stands seemed to be more resistant than single or multi-storey stands in Switzerland. Thinning increased the susceptibility to wind damage in the first few years.

Previous damage and biological condition
In Switzerland, stands damaged by the 1990 storms were also more often damaged by the 1999 storms, indicating either a higher susceptibility of these sites or increased vulnerability to wind as a result of the prior storms. Crown defoliation was not found to be a significant factor. Root and stem rot seem to increase the chances of uprooting or stock-breakage of Norway spruce in Switzerland and red oak in France.

Soil condition
Water saturated and water-logged soils increased the danger of storm damage in Switzerland, whereas the stability of stands increased with rooting depth in France. The influence of soil acidification and increased nitrogen deposition is currently being investigated.

Consequences and outlook
Since the 1999 storms, bark beetle populations have increased and the mortality of susceptible tree species, such as Norway spruce and various pine species, is expected to rise in many of the affected areas in the coming years. Total area and stocking volume of European forests and the proportion of older and taller stands are currently increasing due to change in management practice. Although ecologically beneficial, this will increase the vulnerability of forests and therefore also the risk of wind damage in the future. The role of climate change and possibly increasing storm intensities and frequencies is still unclear. However, various scenarios indicate a higher probability of unfavourable weather conditions such as extreme wind speeds and heavy rainfalls.

The condition of the holm oak (Quercus ilex)

Summary

- ***Holm oak forests are important elements of the Mediterranean vegetation.***
- ***They are characterised by a wide ecological range and a high adaptability, by their biodiversity richness and protective value. The great variety of products which they offer and the historical links to the Mediterranean culture make holm oak forests an essential forest formation of this region.***
- ***A process of decline detected throughout its natural range seems to be caused by the combined effects of climatic, biotic and human factors.***

Holm oak stands are among the most characteristic elements of the Mediterranean vegetation. Together with other oak forests they are very complex and diverse natural ecosystems in Europe. Their natural range spreads from Portugal to Turkey. From northern Spain and southern France they reach south to the African Magreb. They can be found from sea level to altitudes of more than 1 500 m (2 800 m in Morocco).

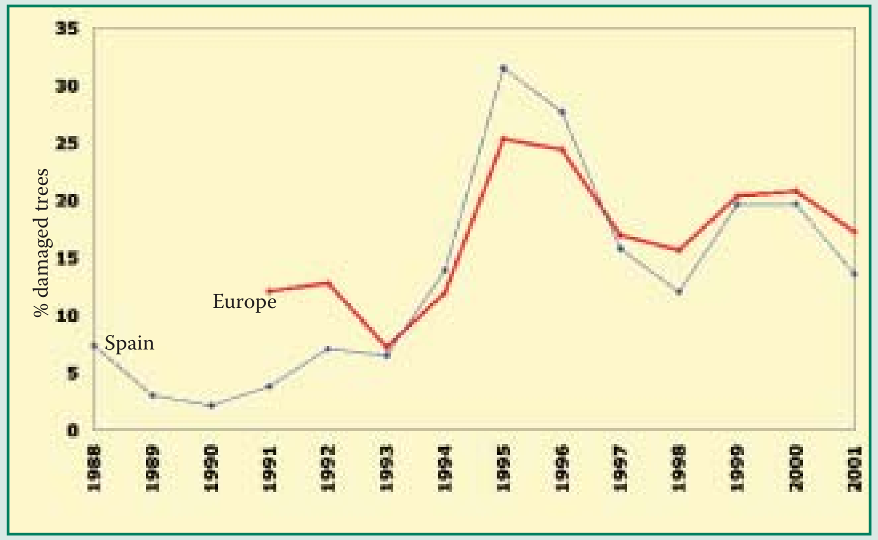
Holm oak is regarded as undemanding as far as soil is concerned. It normally shows an extraordinary resistance to drought, continental conditions and very dry winds. It is known as a slow growing species and an effective colonizer of marginal soils where pure and dense stands can be found, which are very typical for the Mediterranean landscape. The species reproduces very successfully from seed, and its root and stump sprouting capability remains active even after the age of 200 years. Holm oaks can live to more than 700 years.

The species and the forests it forms are closely connected to the cultural development of the Mediterranean region. Its longevity, adaptability and the variety of products that it is able to produce, together with the great capability to protect soil and ground vegetation, were the basis for what can be considered as the first historical example of sustainable forest management: the “dehesa” in Spain and the “montado” in Portugal. These are ecosystems with a low density of trees (but good crown coverage of soil) under which a fairly sparse maquis and herbal natural species develop together, creating ideal conditions for rich animal wildlife. Their essential functions in terms of nature and landscape preservation recently led to the development of official codes for the defence and promotion of these ecosystem types. In other countries holm oak occurs in dense stands forming semi natural forests managed mostly for protective functions.

„Dehesa“ - „Montado“ forest formations.

In the last 10 years, 7 countries have monitored holm oak on Level I plots (Romania, Greece, Croatia, Italy, France, Spain and Portugal). Most plots are located in Spain, with almost 3 200 trees, and Portugal, with more than 650 trees. The development of the percentage of damaged trees (defoliation classes 2 + 3) shows a significant increase after 1994 with more than 20% of the trees damaged in some years (Fig. 2-8). Recuperation has been observed since 1997, although the level of damage is higher than at the beginning of the observation period.

Percentage of damaged holm oak (defoliation classes 2+3) in Europe and Spain.



Closed holm oak forest, Spain.

Progressive decline of holm oak.

Sudden death of holm oak.

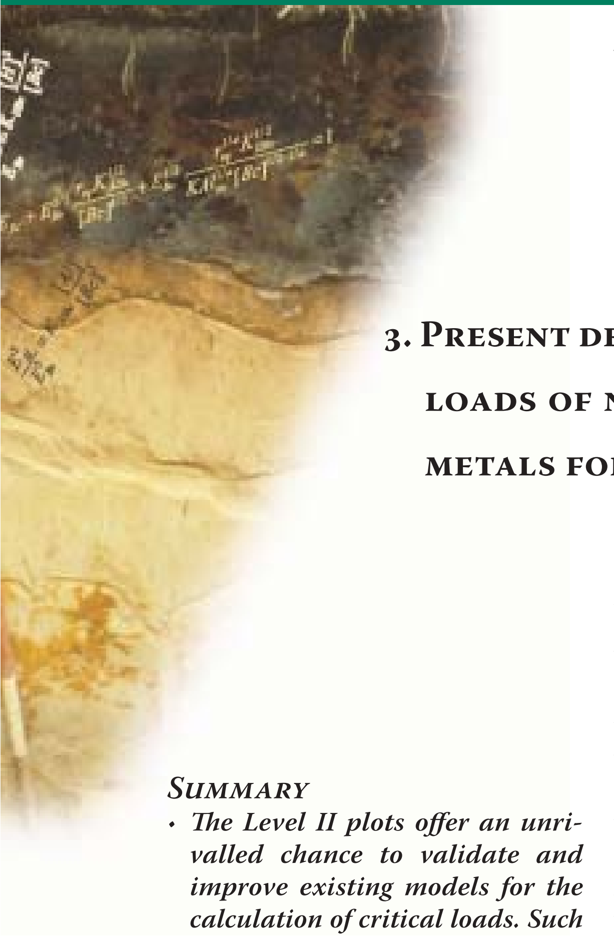
The decline process

The oak decline can be observed at varying degrees of intensity and, mostly without one single identifiable cause. For holm oak stands, three types of decline processes have been identified:

- **Sudden death,** when an apparently healthy tree without any signs of damage dies in a short period of time;
- **Progressive decline,** when the stand shows debility symptoms, losing crown density, and at the same time, showing dead branches and twigs. This process mostly ends with the death of trees with a decline period lasting from two to several years;
- **Loss of vitality of trees,** the symptoms are the same as in the case of progressive decline, nevertheless the trees continue to survive, though in a decrepit state.

Causes of damage are assessed in the European wide Level I survey and additional national surveys like the Spanish Forest Damage Inventory (IDF).
Results show a complex of predisposing, triggering and ancillary causes of damage. The damage is often influenced by soil type and soil capacity to retain water. Climatic factors, in particular drought stress caused by low precipitation and/or warm temperatures, often trigger outbreaks of oak decline. Inappropriate human intervention ranging from complete absence of silvicultural management to abusive use of the resources may have increasing effects. Once the process has started, a lot of opportunistic biotic agents can speed it up, sometimes leading to the death of a tree or tree group within a short period of time.

The most common biotic agents include fungi (Phythophtora, Armillaria, Ophiostoma, Cryphonectria, Fusarium, Biscogniauxia), insects (Platypus, Coroebus, Cerambix, Lymantria, Tortrix), bacteria (Brennia), nematodes and viruses.
The interplay of harmful factors as described above is a simplified scheme. In many cases a different course of the decline can be observed and there are cases when the deteriorating crown condition or death of holm oak trees remains unexplained.
The only possible action in the mid term seems to be the implementation of tried and tested silvicultural and conservative management techniques including an even closer survey of the holm oak stands in order to enable timely interventions and sanitary fellings. Also, it will become increasingly important to create stable stands, including mixed stands. This will hopefully minimise the impact of the oak decline and strengthen the species’ resistance to adverse environmental conditions.



Soil profile, formulas.

3. Present deposition and critical loads of nitrogen, acidity and metals for forest ecosystems

Summary

- ***The Level II plots offer an unrivalled chance to validate and improve existing models for the calculation of critical loads. Such loads have been calculated referring to different parts of the forest ecosystem.***
- ***Critical loads for nitrogen aiming at no further nitrogen accumulation in the soil are exceeded at 92% of the investigated plots. Critical loads taking into account effects on trees are exceeded at 45% of the plots. At these plots an increased vulnerability to drought stress, frost, pest and diseases is to be feared. The plant diversity of the ground vegetation is potentially endangered at 58% of the plots.***
- ***For 33% of the investigated plots critical loads for acidity referring to effects on tree roots are exceeded. Leaching of base cations or aluminium already occurs at lower acidity inputs. Related critical loads are exceeded at 64% of the plots.***
- ***In general, highest excess acid depositions occur in central Europe and for nitrogen also in western Europe, where present loads are high and critical loads are relatively low.***
- ***Critical loads of cadmium and lead were exceeded on 91% of the plots for lead and on 29% of the plots for cadmium. These results are based on very stringent criteria for possible impacts on soil organisms.***

3.1 Introduction

For most European countries critical load maps for nitrogen and acidity are available based on estimated data (see box on p. 20). The large number of Level II plots, their comparatively wide extend and the extensive database offer the possibility to validate and improve existing models and to contribute to the development of new methods. A Europe-wide assessment of critical loads based on measured data of Intensive Monitoring Plots in comparison with measured present loads has not yet been available and is presented for the first time in this report. As data collection, submission and validation is rather time consuming, data up to 1999 were used. Evaluations were conducted after intensive checks on data reliability and consistency. Critical loads were calculated for approximately 230 Intensive Monitoring Plots where all relevant data on deposition, meteorology, forest growth and soil and soil solution chemistry were available. Results for nitrogen are reported as the sum of nitrate (NO_3) and ammonium (NH_4). Acidity is defined as the sum of sulphate (SO_4) and nitrogen.

Definition of critical limits and loads

Atmospheric inputs affect different parts of the forest ecosystems simultaneously. Therefore various related critical loads can be calculated that take into account these different effects. The lowest of these is the critical load relevant for the protection of the specific ecosystem. It has to be taken into account that the presented critical loads refer to a steady state. An excess implies an increase in the concentration of nitrogen and acidity ultimately reaching the critical limit. In practice the time before effects become visible can take several years to decades.

In this report critical loads for nitrogen were calculated which aim at no further net accumulation of nitrogen in the soil. The calculations are based on a nitrogen threshold in the soil solution of 0.28 $g.m^{-3}$ (0.02 $mol_c.m^{-3}$). For sites with higher values, increased leaching is to be expected. In addition, critical nitrogen loads are included which aim at ensuring that concentrations of nitrogen in the foliage of trees stay below a critical limit of 18 $g.kg^{-1}$. Above this limit, effects on trees can be expected such as an increased vulnerability to drought stress, frost, pest and diseases. Another approach aims at determining effects of nitrogen deposition on ground vegetation. Here, the limits are based on empirical data.

The critical loads for acidity take into account the impact on tree roots of free aluminium in the soil solution. They were calculated by aiming that ratios of toxic aluminium to base cations in the soil solution stayed below a critical limit of 0.8 for pine and spruce and 1.6 for oak and beech. Other critical loads for acidity assume no further loss of exchangeable base cations in base rich forest soils (loess, clay and peat soils) and no further loss of readily available aluminium in base poor sandy forest soils.

Critical loads for heavy metals were calculated which ultimately lead to concentrations in soil solution that may affect soil organisms. For cadmium a concentration of 0.8 $mg.m^{-3}$ was used; for lead the limit was 8 $mg.m^{-3}$.

3.2 Nitrogen

The average nitrogen deposition from 1995 to 1999 on all 234 plots is 19 $kg.ha^{-1}.yr^{-1}$. Lowest loads were found for pine, followed by spruce, reflecting their location in mostly low deposition areas, such as Scandinavia (Tab. 3-2). High nitrogen inputs above 22.4 $kg.ha^{-1}.yr^{-1}$ (1 600 $mol_c.ha^{-1}.yr^{-1}$) only occur on plots in central Europe (Fig. 3-1). Total nitrogen input is generally found to be much lower on plots in northern and southern Europe.

Critical loads and levels – a tool for environmental policy

Critical loads and levels 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. The critical load of sulphur and nitrogen acidity was defined in 1994 in the UNECE Protocol on Further Reduction of Sulphur Emissions:

"Critical Load" means a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur, according to present knowledge.

Direct effects on plants, due to mostly gaseous concentrations of air pollutants, are defined in a similar way using critical levels.

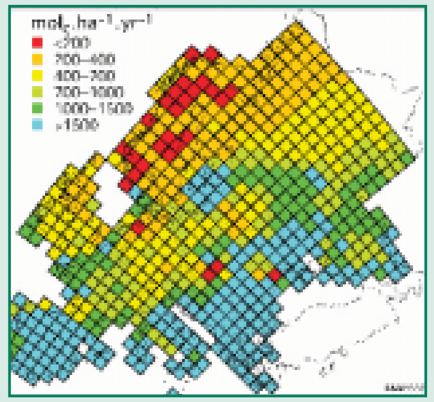
Critical loads are derived by comparing the quantity of mainly anthropogenic pollutants as inputs on one side and the removal, acceptable storage and outputs of these substances on the other side. The outputs include the harmless or tolerable transfer of the pollutants to other parts of the environment. Critical loads are not exceeded as long as the system remains in balance, but any additional input of pollutants may cause harmful effects. The comparison between critical loads and the actual deposition makes it possible to determine excess deposition values. Mapping the extent of excess depositions for given receptors provides an important policy tool for the development of optimised pollution abatement strategies.

An effective policy tool

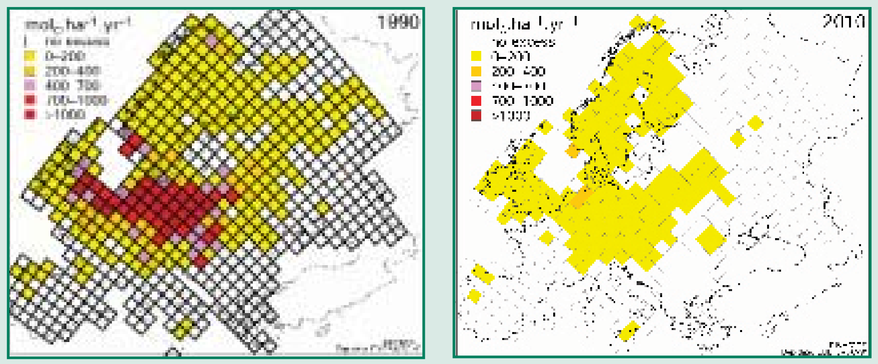
Two effects-based protocols, the 1994 Sulphur Protocol and the 1999 Gothenburg Protocol were adopted under the UNECE Convention. The 1999 Gothenburg Protocol aims at curbing the emissions of sulphur, nitrogen and volatile organic compounds and is an example for the use of critical load maps. For the most recent maps, 24 countries calculated and submitted data estimates for 1.3 million gridcells to the International Co-operative Programme (ICP) on Modelling and Mapping, which were used to produce the latest maps on critical loads for forests, crops, natural vegetation, soils, water and materials.

The current critical loads methodology describes a steady-state condition, and thus aims towards a long-term stability of ecosystems. In order to map and evaluate present damage as well as predicted changes it is important to apply dynamic modelling. Recently, ICP Modelling and Mapping developed a dynamic modelling approach in collaboration with ICP Forests to be applied on the Level II plots. It is anticipated to complete the effort on 200 forest plots by 2004 and to up-scale it to the whole of Europe afterwards.

Further information is available at: http://www.icpmapping.com



Sensitivity to sulphur expressed in terms of critical loads. Red indicates areas with ecosystems most sensitive to acid deposition, whereas areas in blue are least sensitive.



Excess deposition of acidity over critical loads (CL) in 1990 (left) and 2010 (right) if the Gothenburg protocol is fully implemented. The scenario shows a decrease in excess depositions due to a substantial sulphur reduction. However, the emission of nitrogen oxides and ammonia will continue to contribute to acidification and eutrophication.

Deposition measurements and units

Within the Intensive Monitoring Programme atmospheric deposition is measured below the forest canopy *(throughfall)*, directly at the tree trunks *(stemflow)* and in nearby open fields *(bulk deposition)*. Total deposition on forest stands was derived by adding throughfall and stemflow values, while correcting for the effects of element interactions with the canopy (uptake and leaching through leaves and needles). This correction requires data on bulk deposition.

Acidity is given in $mol_c.ha^{-1}.yr^{-1}$ (read "mol of charge per hectare per year"). Chemicals are usually deposited into soils in the form of charged particles or ions. Ions can carry different charges and the chemical reactions in the soil depend among other things on the charges received. Mol of charge is a way of expressing the total charges deposited into the ecosystem and allows comparisons of the deposition of different substances. The simpler unit of $kg.ha^{-1}.yr^{-1}$ does not allow this comparison. For example: 1000 mol_c is equivalent to 14 kg of nitrogen and 16 kg of sulphur.

Throughfall sampler in a beech stand, Belgium.

The average critical load aiming at no further nitrogen accumulation in the soil was near 8 $kg.ha^{-1}.yr^{-1}$ (Fig. 3-1). These critical loads were exceeded on 92% of the evaluated Level II plots (Tab. 3-1 and 3-2). Critical loads are lower for pine with a lower nitrogen uptake, than for the other tree species. High critical loads characterise ecosystems which are less sensitive to high nitrogen inputs. Such plots are mainly located in southern Europe, where forest ecosystems, specifically broadleaf forests, have a higher nitrogen uptake. Results confirm that forests in northern Europe are more sensitive to nitrogen inputs as the net uptake of nitrogen by trees is low in these regions.

Critical nitrogen loads related to effects on tree foliage were higher. Thus reactions of trees are expected at higher nitrogen inputs only. The average was near 14 $kg.ha^{-1}.yr^{-1}$ for pine and near 20 $kg.ha^{-1}.yr^{-1}$ for spruce. These loads were exceeded at 45% of the evaluated conifer plots indicating an increased vulnerability to drought stress, frost, pests and disease.

Critical loads requiring no changes in the ground vegetation were exceeded on 58 % of the plots. This shows that changes in plant diversity are very likely in European forests.

Table 3-1: Percentage of Level II plots with deposition above critical loads related to different compartments of the forest ecosystem.

Ecosystem compartment concerned	% of Level II plots with excess of	
	critical nitrogen loads	critical acidity loads
Soil	92	64
Tree	45	33
Ground vegetation	58	-

Species	No. of sites	PDL kg	CL kg	CLex (%)
Pine	57	15 (1074)	6 (419)	96
Spruce	96	19 (1359)	9 (618)	86
Oak	28	21 (1476)	9 (623)	93
Beech	42	22 (1540)	9 (659)	98
Other	11	17 (1198)	9 (670)	91
All	234	19 (1329)	8 (580)	92

Table 3-2: Average total present nitrogen deposition load (PDL kg) and critical load (CL kg) in $kg.ha^{-1}.yr^{-1}$ as well as percentage of plots with excess deposition (CLex %). Critical loads are related to effects in the soil. Values in brackets are given in $mol_c.ha^{-1}.yr^{-1}$.

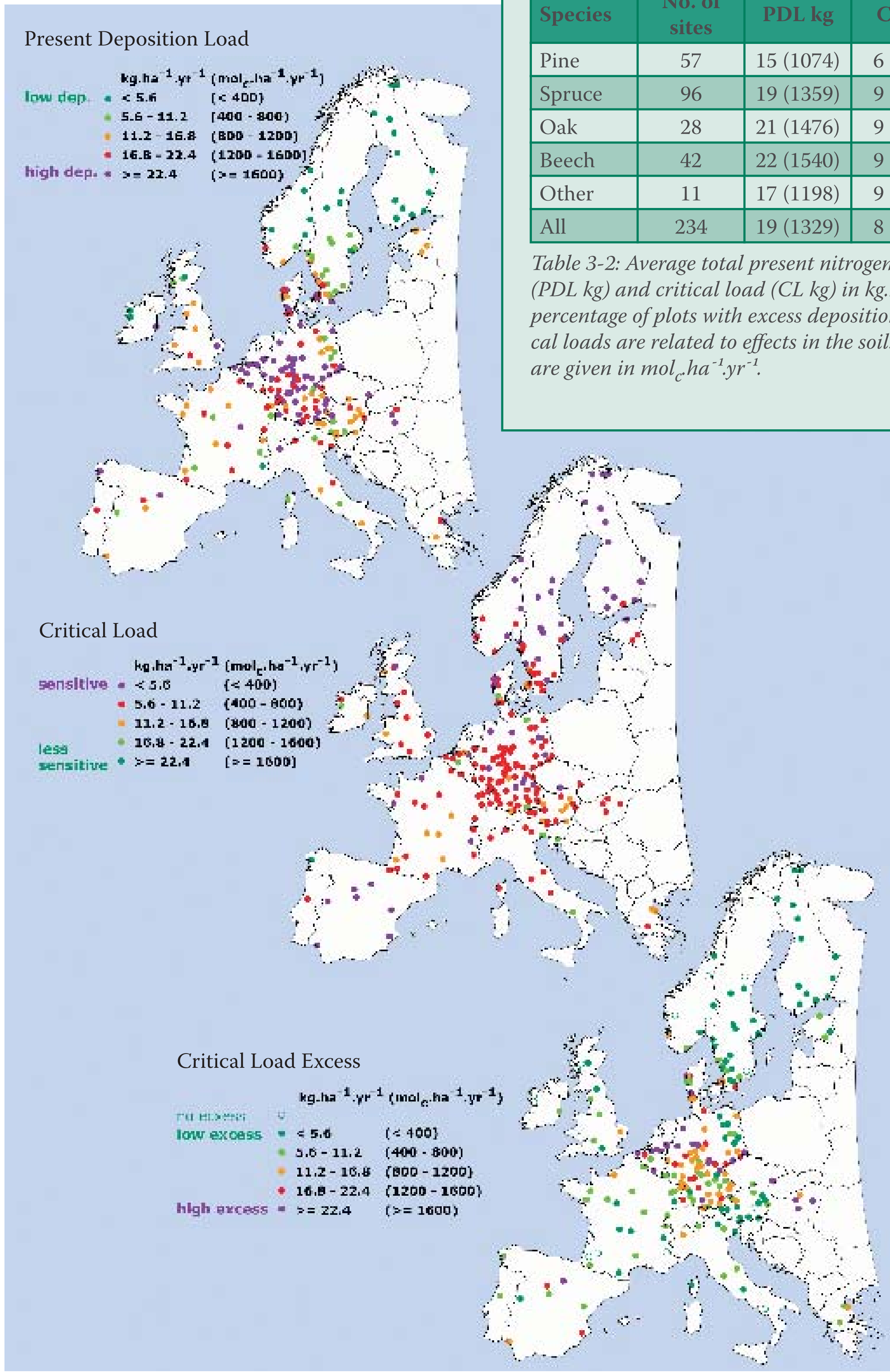


Figure 3-1:
Top map: average present deposition load of nitrogen (N = NH_4-N plus NO_3-N)
Middle map: critical nitrogen loads related to nitrogen concentration in the soil.
Bottom map: excess deposition above critical loads.
234 Intensive Monitoring Plots, average 1995-1999.

Number of sites for all tree species	PDL ($g.ha^{-1}.yr^{-1}$)		CL ($g.ha^{-1}.yr^{-1}$)		CLex (%)	
	lead	cadmium	lead	cadmium	lead	cadmium
242	26	0.38	3.8	0.33	91	29

Table 3-4: Average total present deposition load (PDL), critical load (CL) and excess deposition (CLex excess) of lead and cadmium (in $g.ha^{-1}.yr^{-1}$).

3.3 Acidity

The average acid load (nitrogen plus sulphate) on 226 plots is nearly 2 100 $mol_c.ha^{-1}.yr^{-1}$. As with nitrogen, lowest loads were found for pine, followed by spruce (Tab. 3-3). Relatively high acid inputs can be found everywhere in Europe, except in central and northern parts of Scandinavia, but most sites with highest acid inputs (up to 3 000 $mol_c.ha^{-1}.yr^{-1}$) are situated in central Europe (Fig. 3-2).

Critical loads, which take into account the impact on tree roots through free aluminium in the soil solution, are clearly lower for pine and spruce. These species are more sensitive to aluminium than oak or beech. In general, the critical acid load increases from the northern boreal regions to southern Europe, which shows that forest ecosystems in the south are less sensitive to acidic inputs. This is firstly due to higher neutralising base cation inputs from the atmosphere and from soil weathering and secondly to a higher nitrogen uptake by the vegetation in the south. The critical loads are exceeded at 33% of the plots (Tab. 3-1 and 3-3).
Critical loads related to base cation and aluminium pools in the soil are lower. They are exceeded at 66% of the plots.

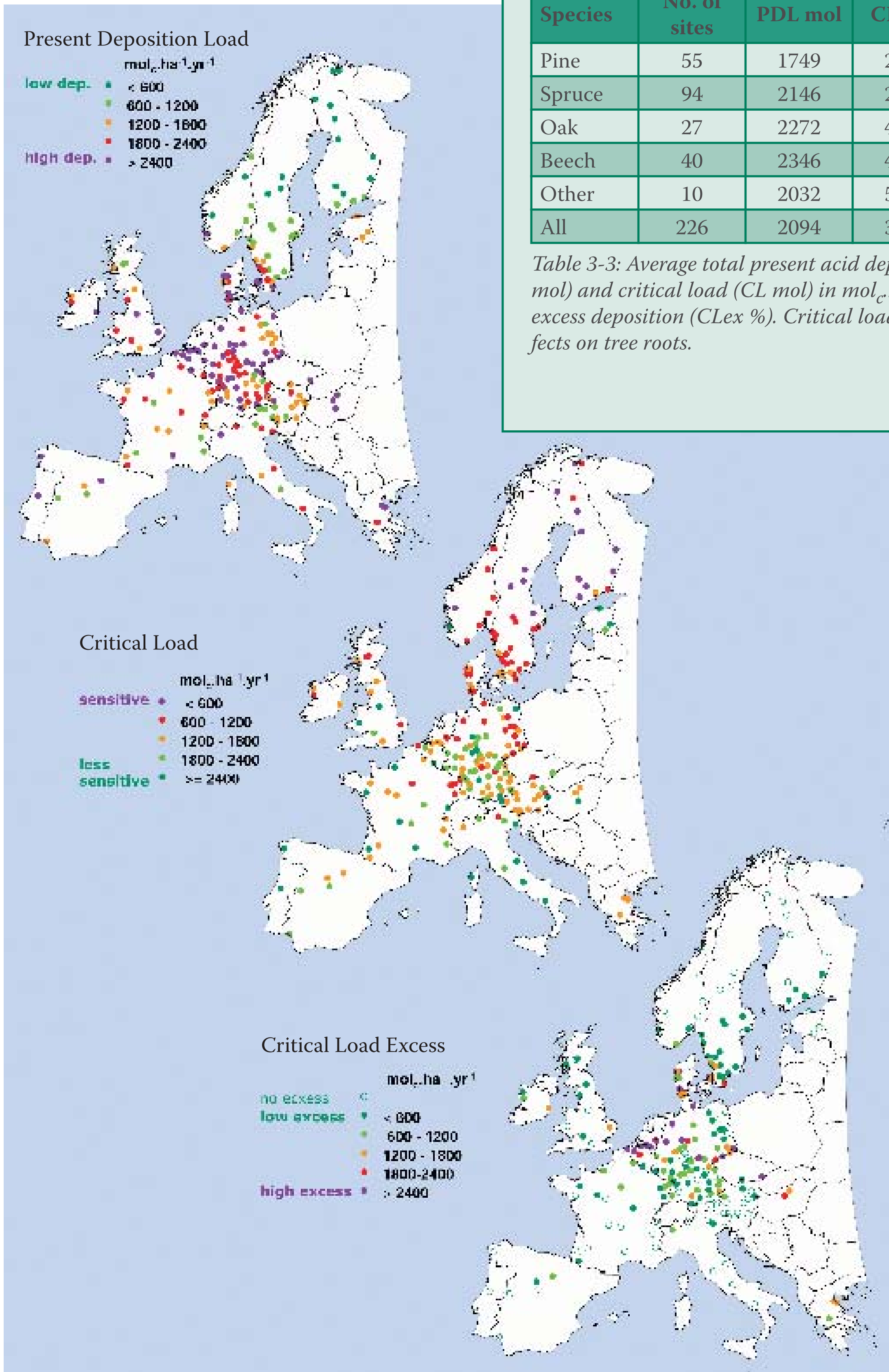
3.4 Heavy metals

On average the present lead deposition is much higher than the critical load, whereas the excess is small for cadmium. The share of plots where critical loads were exceeded was 91% for lead and 29% for cadmium (Tab. 3-4). These results are, however, based on very stringent criteria related to possible impacts on soil organisms.

3.5 Outlook

Apart from critical loads, present deposition thresholds were calculated. They take into account the present plot specific situation and do - in contrast to critical loads - not assume a steady-state. Thus they are an even more precise instrument to evaluate risks to the forests. Preliminary calculations indicate that present deposition thresholds are higher than critical loads for nitrogen, whereas the reverse is true for acidity. This aspect will be considered in greater detail in next year's Executive Report, when dynamic models will be applied to predict impacts of acid deposition scenarios on forest soils. The further development of critical loads needs a continuation of the close co-operation with other bodies and programmes under the Convention on Long-range Transboundary Air Pollution.

FURTHER READING:
UNECE AND EC, 2002; DE VRIES, W., G.J. REINDS, H. VAN DOBBEN, D. DE ZWART, D. AAMLID, P. NEVILLE, M. POSCH, J. AUEE, J.C.H. VOOGD AND E. VEL. INTENSIVE MONITORING OF FOREST ECOSYSTEMS IN EUROPE. TECHNICAL REPORT 2002. UNECE AND EC, GENEVA AND BRUSSELS, 173 PP.



Species	No. of sites	PDL mol	CL mol	CLex (%)
Pine	55	1749	2906	40
Spruce	94	2146	2726	34
Oak	27	2272	4721	25
Beech	40	2346	4624	31
Other	10	2032	5282	18
All	226	2094	3469	33

Table 3-3: Average total present acid deposition load (PDL mol) and critical load (CL mol) in $mol_c ha^{-1}.yr^{-1}$ as well as excess deposition (CLex %). Critical loads are related to effects on tree roots.

Figure 3-2:
Top map: average present deposition load of acidity (SO_4 + NH_4 + NO_3)
Middle map: critical loads of acidity related to effects on tree roots
Bottom map: excess depositions
226 Intensive Monitoring Plots, average 1995-1999.

Cranberries and lichens, Finland.

4. Ground vegetation and forest biodiversity

Summary

- ***Ground vegetation records from 674 plots offer a unique chance for biodiversity evaluations and reveal large variations in plant diversity throughout Europe's forests.***
- ***Plant diversity was found to be less in acid conditions which are now widespread in Europe. Actual soil acidity is clearly influenced by previous depositions.***
- ***Nitrogen deposition had a small but significant direct influence on ground vegetation.***
- ***Nutrient rich soils, southern climates, and oak stands are correlated with diverse and species rich ground vegetation.***
- ***Future data collection will allow a more appropriate assessment of deposition impacts on vegetation changes.***

4.1 Introduction

The species composition of the ground vegetation assessed at Intensive Monitoring Plots is an indication of the plant diversity of forest ecosystems. Level II offers a unique opportunity to relate the species composition of the ground vegetation to environmental factors, including atmospheric deposition. This was done to identify where possible those environmental factors that most strongly determine the plant diversity of the ground vegetation, specifically in view of the hypothesis that the deposition of nitrogenous compounds is an important threat. If such factors are known, it may be possible to assess more precisely threats to plant diversity, to which local governments might respond proactively.

4.2 Plant diversity at plot level

An evaluation of plant diversity, indicated by the Simpson index, was carried out with the available data from 674 plots (Fig. 4-1). The value of this index is higher when more species occur. The results show that there are large differences on the plots throughout Europe.

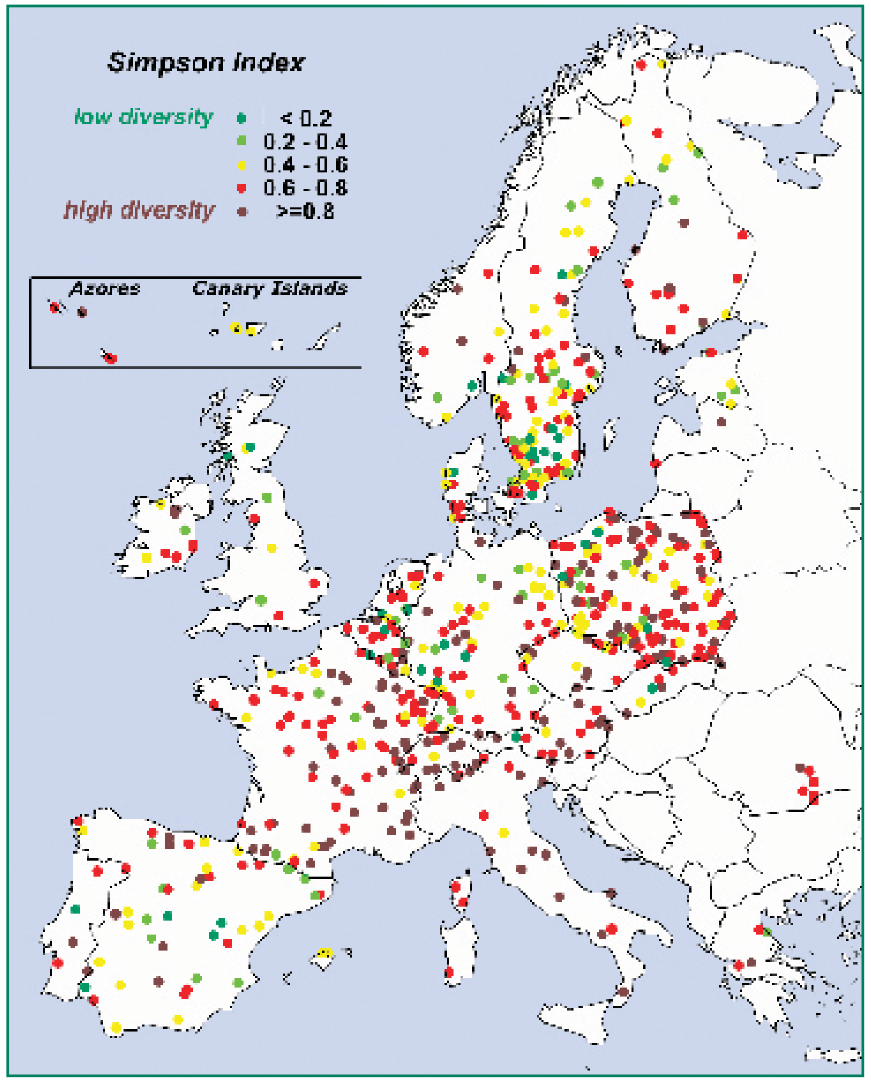


Figure 4-1
Diversity of vascular plants. Case studies at 674 unfenced Intensive Monitoring Plots, assessed in 1998-1999.

Biodiversity in European forests

Forests, the natural potential land-cover in most of Europe, offer diverse habitats for plants, animals and micro-organisms and hold the vast majority of the terrestrial species. Many species contribute towards the functioning of the forest ecosystem, including such diverse groups of organisms as mycorrhizal fungi, herbs, trees and insects. Forests with a good biodiversity status are considered to particularly provide ecological, economic and social functions and benefits to the society. They maintain the water balance, and protect soils against erosion. Today, in regions of Europe with long industrial and agricultural heritage and high population density forest cover has mostly been reduced. Furthermore, also in the remaining forest regions, forestry and other uses of forests may have impoverished the biodiversity. Especially the disappearance of old growth forest has significantly contributed to this loss. On the other hand, traditional forest use has not generally been negative from a biodiversity point of view and even created specific ecosystems that nowadays are considered to have particular biodiversity values. Examples are forms of coppicing and forest grazing systems, uneven-aged mixed forests in central Europe, and Mediterranean agro-forestry systems.

Further information is available at:
http://www.biodiv.org

Dead wood not only provides food and shelter for numerous insect and fungi species, it can also be important for the growth of new young trees.

Structured forests provide a great range of habitat types. The depicted intensively managed mixed mountain forest offers high ecological, economic and recreational values.

International processes and projects

Biodiversity was a priority issue at the UN Conference on Environment and Development in Rio de Janeiro 1992 resulting in the "Convention on Biological Diversity" *(CBD)* and a set of "Forest Principles". In this convention biodiversity is defined as

"the variability among living organisms from all sources including inter alia, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems."

In a follow up, most European countries, and also the EU, have elaborated biodiversity strategies and plans and have integrated the biodiversity considerations in their legal framework (in EU e.g. in the *"Habitats Directive"* an the *"NATURA 2000"*). Activities in line with the Forest Principles have most notably been implemented in regional processes of which one is the "Ministerial Conference of Protection of Forests in Europe" *(MCPFE).*

A necessary first step in the assessment of biodiversity is to develop valid and cost-effective indicators. Related projects funded by the European Union include "Indicators for monitoring and evaluation of forest biodiversity in Europe" *(BEAR)*, the "European Biodiversity Assessment Tools" *(BioAssess)* and the "Nature-based management of beech in Europe" *(Nat-Man).* Additional research projects address various aspects of forest genetic biodiversity.

Ideally, efforts should be coordinated. Without doubt, the pan-European monitoring system of ICP Forests and the EU collects data that have the potential to contribute to the assessment of air pollution effects on forest biodiversity in Europe.

Further information is available at:
http://biodiversity-chm.eea.eu.int

Variable group	Explained variance
Actual soil situation	7.6%
Temperature, precipitation	5.6%
Tree species	4.1%
Deposition	3.3%
Total	20.6%

Table 4-1: Percentage explained variance of the species abundances that could be ascribed to the four main groups of variables based on 194 plots.

Relationships between plant diversity and species numbers of the ground vegetation on one hand and environmental factors on the other hand were evaluated for approximately 200 plots for which combined datasets were available, including soil and tree species information, climatic data, and atmospheric deposition (throughfall).
Part of the variation in the abundance of the various species occurring in the ground vegetation could be explained by tree species, actual soil situation and climate, mainly in terms of precipitation and temperature. (Tab. 4-1). 'Rich' soils with high pH, high base saturation and high availability of base cations, as well as southern climates and oak forests seem to determine high plant diversity. The impact of nitrogen deposition was lower but statistically significant. Deposition effects may partly be hidden because of the relationship between acid deposition and actual soil pH on the plot, which was an important variable explaining ground vegetation composition. In addition, the results are only related to the spatial distribution of species. Related studies show that temporal changes in ground vegetation composition can be influenced by atmospheric deposition. This suggests a stronger influence of deposition on ground vegetation then presented in these results. Future data collection will allow a more appropriate assessment of deposition impacts on vegetation changes.

4.3 Single species in relation to environmental factors
Relationships between the occurrence probability of individual species and environmental factors were investigated for 332 different species. This was done by relating the species occurrence to more than 10 000 possible combinations of measured Level II data. Also these results show a predominant influence of soil chemistry, in particular pH, on the occurrence of single species and confirm the above presented findings. An example for 36 selected species against soil pH is given in Figure 4-2. Results show that most species occur on alkaline conditions whereas on acid sites only a few specially adapted species will predominate. This is in line with current views which accept acidification as a factor that negatively affects biodiversity. Models are to be developed in the coming years based on the evaluations presented. They will allow simulations that predict changes in ground vegetation composition under changing environmental conditions.

4.4 Contribution of the monitoring programme to forest biodiversity assessments - a future focus
Recently, ICP Forests has amended its mandate to include contributions to biodiversity assessments in forests by means of the monitoring activities. In collaboration with the European Commission, a Biodiversity Working Group has been formed to address the issue of forest biodiversity within the pan-European Monitoring Programme and to establish links to other processes related to biodiversity such as e.g. the Ministerial Conference for the Protection of Forests in Europe (MCPFE), the European Environmental Agency (EEA) and the Convention on Biological Diversity (CBD).

The programme's Working Group on Biodiversity has revised the wealth of approaches and methodologies presently available in the field of forest biodiversity assessment. As a contribution of the programme, the group has suggested to adopt the stand-scale structural approach to characterise plant diversity in forests. Important consideration is also given to its relationships to measured environmental factors.
The stand-scale structural approach uses the description of the forests stand as an indicator of forest biodiversity. The assumption behind this is that the more structurally diverse a forest stand is (e.g. in terms of the presence or absence of vertical and horizontal layers), the greater the range of habitat types that may be associated with that stand, thus suggesting a greater biodiversity potential. Necessary data for structural descriptions including forest growth, stand age, number of tree species and remote sensing already exist in the present database. Others like stand history, canopy closure and management regime might be subject of additional assessments. These parameters may be related to the occurrence and distribution of plant communities recorded at the plots. The importance of forest deadwood to biodiversity is now widely recognised and a measurement of this too may be added as an assessment parameter.
The Task Force of ICP Forests agreed to conduct a test phase aiming to specify the possible contributions of the programme in the field of forest biodiversity assessments. As a first step, the possible use of existing data that may contribute to the issue of biodiversity in forests will be examined at national and European level.

FURTHER READING:
UNECE AND EC, 2002; DE VRIES, W., G.J. REINDS, H. VAN DOBBEN, D. DE ZWART, D. AAMLID, P. NEVILLE, M. POSCH, J. AUEE, J.C.H. VOOGD AND E. VEL. INTENSIVE MONITORING OF FOREST ECOSYSTEMS IN EUROPE. TECHNICAL REPORT 2002. UNECE AND EC, GENEVA AND BRUSSELS, 173 PP.

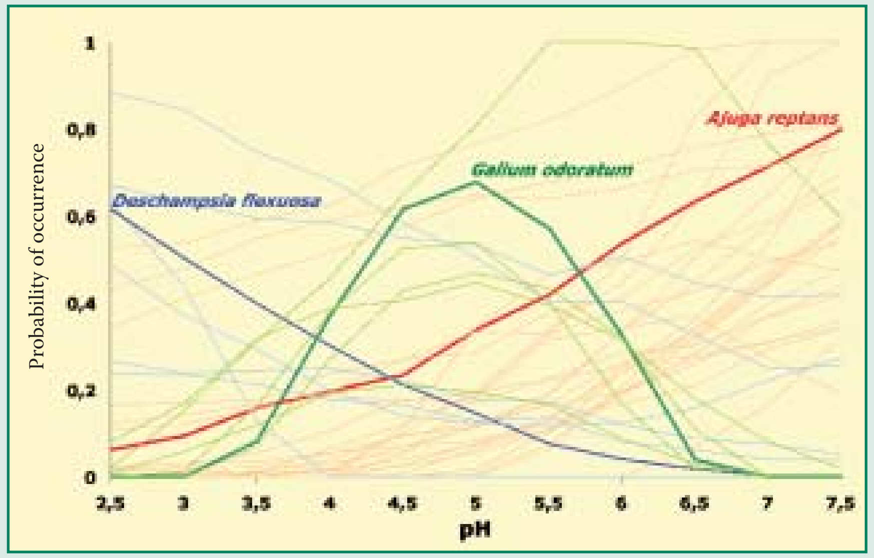


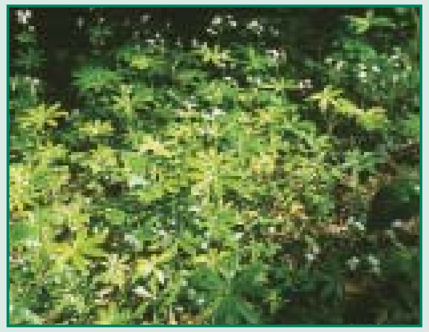
Figure 4-2: Response curves showing the probability of occurrence of 36 species at different pH. The species can be grouped into three species classes with an optimum at low, intermediate, and high pH; assessed in the period from 1998 to 1999 for 366 Intensive Monitoring Plots.

Species that prevail at acid soils (low pH) are: *Deschampsia flexuosa, Calluna vulgaris, Calamagrostis villosa, Vaccinium myrtillus, Vaccinium vitis-idaea, Picea abies, Sorbus aucuparia.*

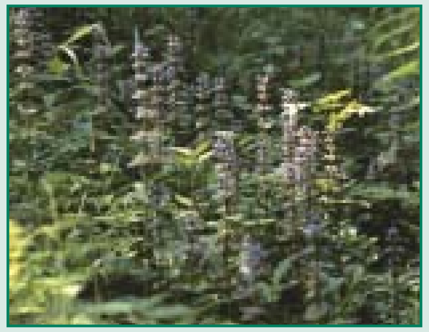
Species that prevail at intermediate soils are: *Galium odoratum, Melica uniflora, Anemone nemorosa, Veronica officinalis, Hedera helix, Carex sylvatica.*

Species that prevail at alkaline soils (high pH) are: *Ajuga reptans, Viola alba, Melittis melissophyllum, Dactylis glomerata, Sorbus domestica, Cardamine bulbifera, Silene italica, Digitalis lutea, Festuca heterophylla, Daphne laureola, Cruciata glabra, Ruscus aculeatus, Carex flacca, Stachys officinalis, Rubus caesius, Poa nemoralis, Carpinus betulus, Mercurialis perennis, Solidago virgaurea, Rosa arvensis, Luzula forsteri, Rubus idaeus, Prunus spinosa, Rubus ulmifolius, Arum maculatum.*

Deschampsia flexuosa forms typical grass vegetation in open pine stands on acid soils.



Galium odoratum is a characteristic species in many beech and mixed deciduous forests.



Ajuga reptans growing on a moist and base cation rich site.

5. Conclusions

Approximately a third of Europe is covered by forests. These extensive ecosystems are partly affected by the deposition of atmospheric pollutants. These inputs act within a complex of other anthropogenic and natural stress factors.

The **monitoring programme** of EU and ICP Forests joins experts from 39 countries. It operates nearly 7 000 plots throughout Europe and maintains effective communication infrastructures to policy players and the public. It has become an essential source of information in the fields of clean air policy and atmospheric pollution also taking into account their relations to sustainable forest management, biodiversity and climate change.

Time trends of its large-scale data on **forest condition** show an overall deterioration in crown condition again over the past five years, although the level of damage is lower compared to the peak in the mid-1990ies. More than 20% of all trees assessed in 2001 were classified as damaged. For the first time correlations between deposition and deteriorating crown condition of the trees were clearly shown in large-scale evaluations based on 1 300 plots of pine trees and nearly 400 beech plots. Furthermore, insect and fungi attacks and unfavourable weather conditions have had an impact on forest condition.

Under the Intensive Monitoring Programme, **total deposition** has been calculated for more than 200 plots. Inputs of nitrogen from 1995 to 1999 mostly range between 3.5 and 39 kg per hectare and year with an average value of 19 kg. Average sulphur inputs are around 12.5 kg and range mostly between 3 and 29 kg. The effects of these depositions depend on the sensitivity of the ecosystems. **Critical loads** for nitrogen and acidity have been calculated which express the highest quantity of inputs tolerable for specific plots. Results show that the forests in Scandinavia are particularly sensitive. Critical loads for nitrogen and acidity were exceeded by present depositions on large parts of the plots. Based on the official UNECE manual for calculation of critical loads, the plotwise results largely based on measurement data are important cornerstones for the partner programme of ICP on Modelling and Mapping, which produces area related maps for Europe largely based on estimated data.

The UNCED conference in Rio de Janeiro in 1992 expressed a serious concern about the world-wide loss of biodiversity and considered atmospheric deposition as one of the factors that might be responsible for this. The **ground vegetation** data of the monitoring programme in relation to the measured environmental influences now shows that the present acidity status of the soil is clearly related to the species occurrence. Impacts of nitrogen deposition were found for some species. Additional important environmental influences were precipitation, temperature and the tree species growing on the plots. The programme has recognised the importance of the biodiversity issues and a newly established working group is now responsible for intensified assessments and evaluations that might in the future make it possible to quantify environmental impacts on floristic biodiversity in forests.

In the 16 years of its existence the forest monitoring programme of ICP Forests and EU has been effective as a promoter, supporter and creator of awareness in the scientific, political and public areas. Its growing datasets and its infrastructure have become increasingly interesting for other organisations and projects and at the same time the widened scope of activities require competent partners. In particular in the Nordic countries the programme's monitoring data are linked to the national forest inventories. Also, their use for monitoring Natura 2000 habitat types is under discussion. The work of ICP Forests and EU takes into account international processes like the Convention on Biodiversity (CBD) and the Framework convention on Climate Change (FCCC) and benefits, for example, from co-operation with the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and with deposition monitoring networks in other parts of the world.

Beech Forest, Germany.

Annex I: Forests, surveys and defoliation classes in European countries (2001)

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

Participating countries	Forest area (1000 ha)	% of forest area	Grid size (km x km)	No. of sample plots	No. of sample trees	Defoliation o all species by class (aggregates), national surveys		
						0	1	2-4
Albania	1028	35.8	10 x 10	216	6480	51.5	38.3	10.2
Austria	3878	46.2	8.7 x 8.7	260	7002	57.7	32.6	9.7
Belarus	6001	28.9	16 x 16	407	9652	18.0	61.3	20.7
Belgium	691	22.8	4^2 / 8^2	142	3374	42.1	40.0	17.9
Bulgaria	3314	29.9	$4^2/8^2/16^2$	120	4323	31.6	34.6	33.8
Croatia	2061	36.5	16 x 16	81	1941	36.1	38.9	25.0
Cyprus	298	32.2	16x16	15	360	25.8	65.3	8.9
Czech Republic	2630	33.4	$8^2/16^2$	139	6808	11.3	36.6	52.1
Denmark	445	10.3	$7^2/16^2$	52	1248	58.6	34.0	7.4
Estonia	2249	45.7	16 x 16	89	2136	49.0	42.5	8.5
Finland	20032	65.8	16^2 / 24x32	454	8579	56.8	32.3	10.9
France	14591	26.6	16 x 16	519	10373	44.2	35.5	20.3
Germany	10264	28.9	16^2 / 4^2	446	13478	35.7	42.4	21.9
Greece a)	2512	19.5	16 x 16	76	1792	38.8	39.5	21.7
Hungary	1787	19.2	4 x 4	1141	26808	37.0	41.8	21.2
Ireland	436	6.3	16 x 16	21	420	55.2	27.4	17.4
Italy	8675	28.8	16 x 16	265	7351	20.3	41.3	38.4
Latvia	2888	44.7	8 x 8	365	8695	18.2	66.2	15.6
Liechtenstein	8	50.0		no survey in 2001				
Lithuania	1858	28.5	8x8/16x16	286	6664	14.6	73.7	11.7
Luxembourg	89	34.4		no survey in 2001				
Rep. of Moldova	318	9.4	2 x 2	580	14058	32.4	30.7	36.9
The Netherlands	334	9.6	16 x 16	11	231	56.3	23.8	19.9
Norway	12000	37.1	$9^2/18^2$	1647	7891	32.0	40.8	27.2
Poland	8756	28.0	16 x 16	1180	23600	9.9	59.5	30.6
Portugal	3234	36.4	16 x 16	144	4320	46.3	43.6	10.1
Romania	6244	26.3	4 x 4	4221	110190	62.5	24.2	13.3
Russian Fed. b)	7610	72.2	varying	130	2966	41.7	48.5	9.8
Slovak Republic	1961	40.0	16 x 16	110	4241	15.5	52.8	31.7
Slovenia	1099	54.2	16 x 16	41	984	31.4	39.7	28.9
Spain	11792	23.4	16 x 16	620	14880	28.9	58.1	13.0
Sweden	23400	57.1	varying	4139	16442	52.1	30.4	17.5
Switzerland	1186	28.7	16 x 16	49	1073	33.7	48.1	18.2
Turkey	20199	25.9		no survey in 2001				
Ukraine	9316	15.4	16 x 16	71	1685	6.1	54.3	39.6
United Kingdom	2156	8.9	random	341	8184	32.4	46.5	21.1
Yugoslavia	2858	2.8	16 x 16	114	2674	65.2	20.8	14.0
TOTAL	198198	26.7	varying	18492	340903			

a) Excluding maquis. b) Leningrad and Pskov regions.

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 (1990-2001)

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

Participating countries	All species												change % points
	Defoliation classes 2-4												
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2000/ 2001
Albania									9.8	9.9	10.1	10.2	0.1
Austria	9.1	7.5	6.9	8.2	7.8	6.6	7.9	7.1	6.7	6.8	8.9	9.7	0.8
Belarus	54.0		29.2	29.3	37.4	38.3	39.7	36.3	30.5	26.0	24.0	20.7	-3.3
Belgium	16.2	17.9	16.9	14.8	16.9	24.5	21.2	17.4	17.0	17.7	19.0	17.9	-1.1
Bulgaria	29.1	21.8	23.1	23.2	28.9	38.0	39.2	49.6	60.2	44.2	46.3	33.8	-12.5
Croatia			15.6	19.2	28.8	39.8	30.1	33.1	25.6	23.1	23.4	25.0	1.6
Cyprus												8.9	
Czech Rep. a)		45.3	56.1	51.8	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.1	0.4
Denmark	21.2	29.9	25.9	33.4	36.5	36.6	28.0	20.7	22.0	13.2	11.0	7.4	-3.6
Estonia	only conifers assessed								8.7	8.7	7.4	8.5	1.1
Finland	17.3	16.0	14.5	15.2	13.0	13.3	13.2	12.2	11.8	11.4	11.6	11.0	-0.6
France b)	7.3	7.1	8.0	8.3	8.4	12.5	17.8	25.2	23.3	19.7	18.3	20.3	2.0
Germany c)	15.9	25.2	26.4	24.2	24.4	22.1	20.3	19.8	21.0	21.7	23.0	21.9	-1.1
Greece d)	17.5	16.9	18.1	21.2	23.2	25.1	23.9	23.7	21.7	16.6	18.2	21.7	3.5
Hungary	21.7	19.6	21.5	21.0	21.7	20.0	19.2	19.4	19.0	18.2	20.8	21.2	0.4
Ireland	5.4	15.0	15.7	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	2.8
Italy e)	16.3	16.4	18.2	17.6	19.5	18.9	29.9	35.8	35.9	35.3	34.4	38.4	4.0
Latvia	36.0		37.0	35.0	30.0	20.0	21.2	19.2	16.6	18.9	20.7	15.6	-5.1
Liechtenstein			16.0										
Lithuania	20.4	23.9	17.5	27.4	25.4	24.9	12.6	14.5	15.7	11.6	13.9	11.7	-2.2
Luxembourg		20.8	20.4	23.8	34.8	38.3	37.5	29.9	25.3		23.4		
Rep. of Moldova				50.8		40.4	41.2				29.1	36.9	7.8
The Netherlands	17.8	17.2	33.4	25.0	19.4	32.0	34.1	34.6	31.0		21.8	19.9	-1.9
Norway	17.2	19.7	26.2	24.9	27.5	28.8	29.4	30.7	30.6	28.6	24.3	27.2	2.9
Poland	38.4	45.0	48.8	50.0	54.9	52.6	39.7	36.6	34.6	30.6	32.0	30.6	-1.4
Portugal	30.7	29.6	22.5	7.3	5.7	9.1	7.3	8.3	10.2	11.1	10.3	10.1	-0.2
Romania		9.7	16.7	20.5	21.2	21.2	16.9	15.6	12.3	12.7	14.3	13.3	-1.0
Russian Fed. f)					10.7	12.5						9.8	
Slovak Rep.	41.5	28.5	36.0	37.6	41.8	42.6	34.0	31.0	32.5	27.8	23.5	31.7	8.2
Slovenia	18.2	15.9		19.0	16.0	24.7	19.0	25.7	27.6	29.1	24.8	28.9	4.1
Spain	4.7	7.4	12.3	13.0	19.4	23.5	19.4	13.7	13.6	12.9	13.8	13.0	-0.8
Sweden	only conifers assessed					14.2	17.4	14.9	14.2	13.2	13.7	17.5	3.8
Switzerland	15.5	16.1	12.8	15.4	18.2	24.6	20.8	16.9	19.1	19.0	29.4	18.2	-11.2
Turkey													
Ukraine	2.9	6.4	16.3	21.5	32.4	29.6	46.0	31.4	51.5	56.2	60.7	39.6	-21.1
United Kingd. g)	39.0	56.7	58.3	16.9	13.9	13.6	14.3	19.0	21.1	21.4	21.6	21.1	-0.5
Yugoslavia		9.8					3.6	7.7	8.4	11.2	8.4	14.0	5.6

a) Only trees older than 60 years assessed until 1997; only conifers assessed in 1990 b) Due to methodological changes, only the time series 1990-94 and 1997-2001 are consistent, but not comparable to each other. c) For 1990, only data for former Federal Republic of Germany. d) Excluding maquis. e) Due to methodological changes, only the time series 1989-1996 and 1997-2001 are consistent, but not comparable to each other f) Only Kaliningrad and Leningrad Regions. g) The difference between 1992 and subsequent years is mainly due to a change of assessment method in line with that used in other States.

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

Common beech	*Fagus sylvatica*
Corsican pine	*Pinus nigra var. maritima*
European oak	*Quercus robur*
Holm oak	*Quercus ilex*
Maritime pine	*Pinus pinaster*
Norway spruce	*Picea abies*
Red oak	*Quercus rubra*
Scots pine	*Pinus sylvestris*
Sessile oak	*Quercus petraea*

Annex IV

Photo, page	Author
title	top left, bottom right: R. Fischer top right: W. Seidling bottom left: P. Roskams
6	E. Oksanen
7, 12, 26, 27 top	R. Fischer
9, 27 bottom	Institute for World Forestry, Hamburg, Germany
10, 28 left	W. Seidling
17	E. Ulrich
18, 19	General Directorate of Nature Conservation, Madrid, Spain
19, big photo	Antonio Moreno. CENEAM. Ministerio de Medio Ambiente, Madrid
20, 22	P. Roskams
28 middle and right	A. Reif
31	R. Schönemund

Participating countries:

Albania	Lithuania	Portugal
Austria	Luxembourg	Romania
Belarus	Republic of Moldova	Russian Federation
Belgium	The Netherlands	Slovak Republic
Bulgaria	Norway	Slovenia
Canada	Poland	Spain
Croatia	Germany	Sweden
Cyprus	Greece	Switzerland
Czech Republic	Hungary	Turkey
Denmark	Ireland	Ukraine
Estonia	Italy	United Kingdom
Finland	Latvia	United States
France	Liechtenstein	Yugoslavia

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