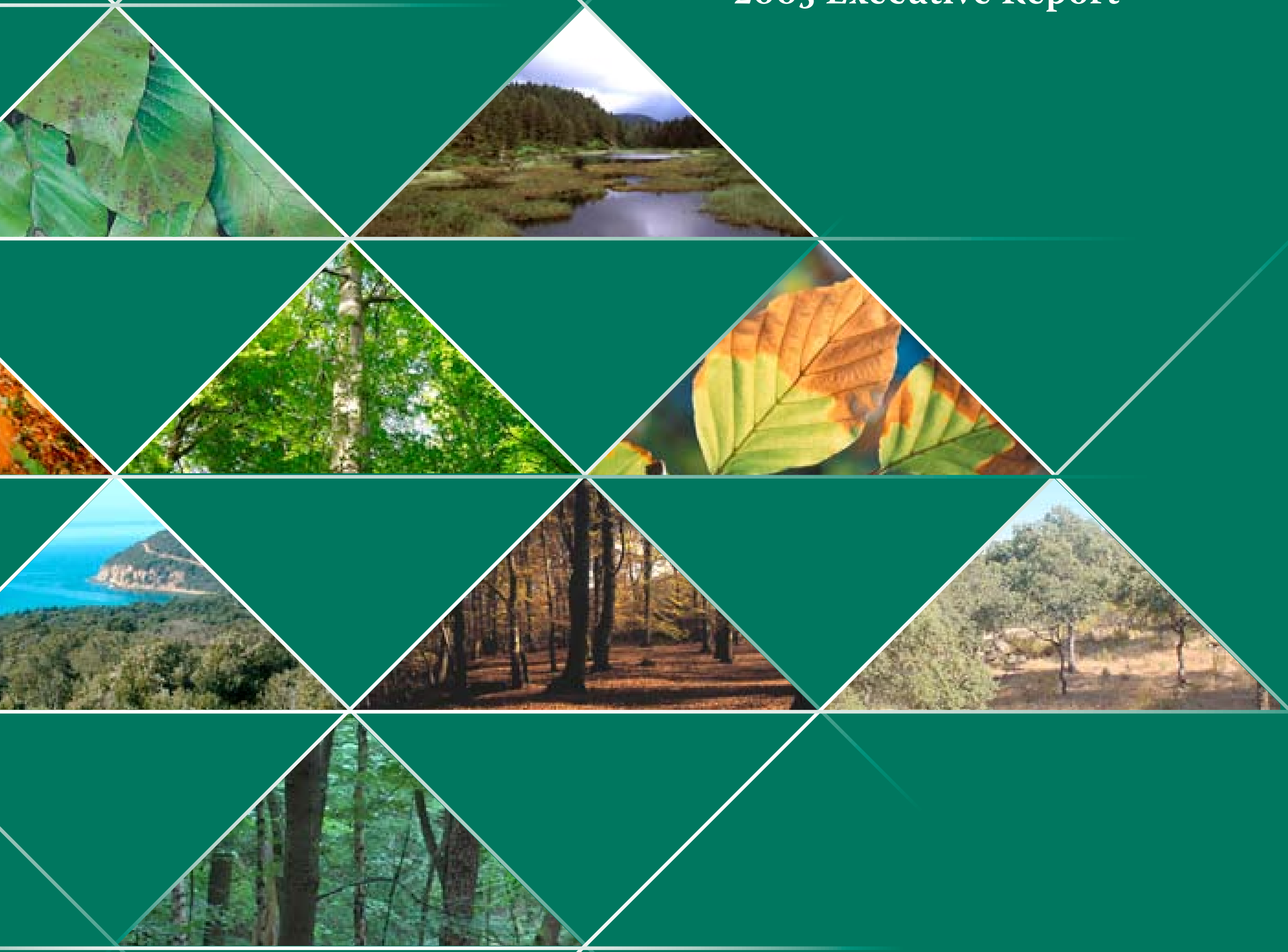
United Nations Economic Commission for Europe

The Condition of Forests in Europe

2005 Executive Report



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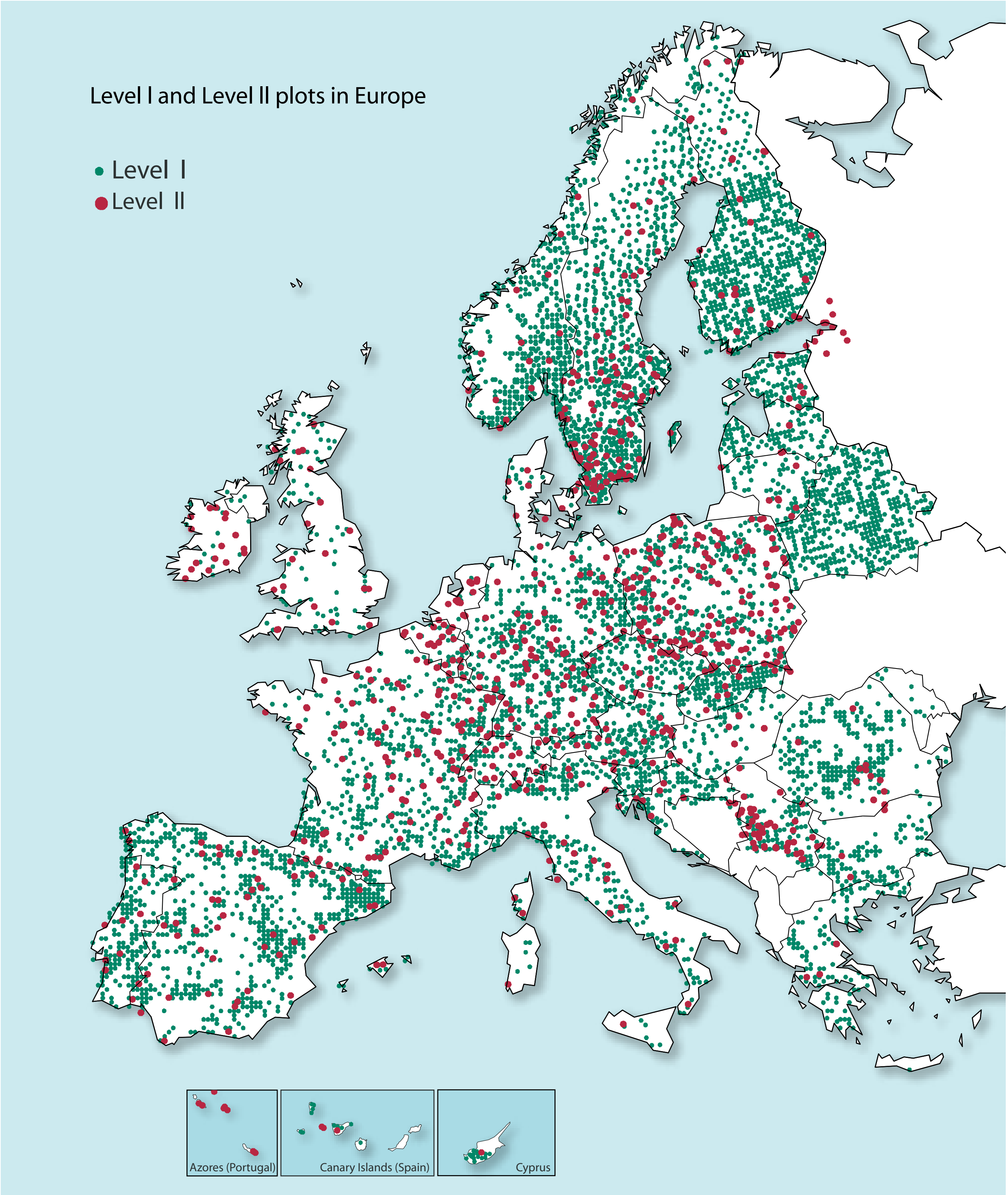
Level I and Level II plots in Europe

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THE CONDITION OF FORESTS IN EUROPE

2005 Executive Report

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

United Nations

Economic Commission for Europe

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The ICP Forests monitoring programme was established in 1985 under the auspices of the UNECE and has recently celebrated its 20th anniversary. Today, 41 countries are participating. Results are based on around 6 000 Level I and 860 Level II plots.

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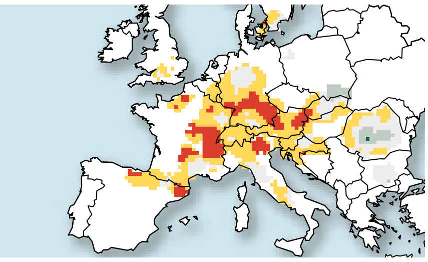
In 2004, the main tree species showed a clear worsening of crown condition as compared to the previous years. A plausible explanation is delayed effects of the extreme heat and drought in summer 2003. The only exception was Scots pine, which occurs on many plots not affected by the extreme weather conditions. In 2004, one quarter of around 135 000 trees assessed was classified as damaged.



Deviation of mean plot defoliation of common beech in 2004 from the average defoliation of 1997 to 2003.

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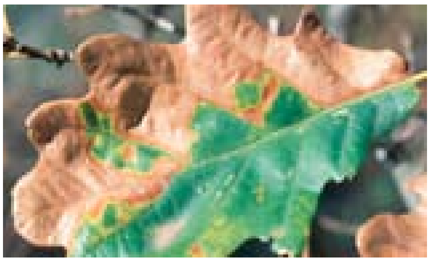
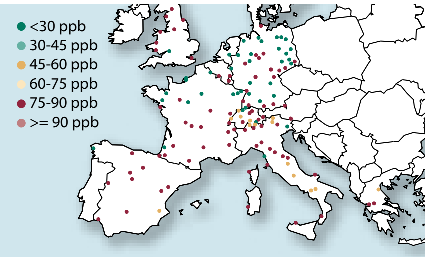


Summer heat symptoms on oak leaves.

3.2 Successful ozone monitoring implemented 19

The need for ozone data from remote and forested areas was successfully met by the installation of ozone samplers at around 100 Level II plots in 2001 – 2003. In addition, visible ozone injury assessments have been trained for and carried out.

Ozone concentrations increased in 2003, mainly due to the intensive solar radiation. They were higher in the south of Europe and at high altitudes.



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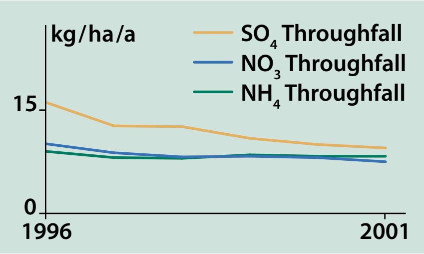
3.3 Decreasing sulphur and fluctuating nitrogen deposition............ 21

Mean annual sulphur inputs decreased by 40% from 16 kg to 9.5 kg per hectare per year in the period from 1996 to 2001. Total nitrogen deposition under the canopy was reduced by around 15%. These results are based on 169 Intensive Monitoring Plots mostly located in central Europe. Present deposition varies to a large extent across the plots and there are still many locations with too high inputs. Forest trees continue to filter large quantities of sulphate and other pollutants from the air.



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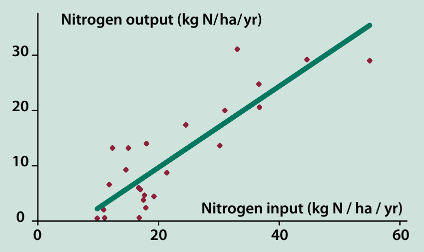
Nitrogen leaching into the ground water is strongly related to atmospheric nitrogen inputs. This is particularly true for sites that are already nitrogen enriched. For sites with a lower nitrogen status, mean annual temperature plays an additional important role.



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Litterfall assessments have been carried out for years by many countries. A harmonized methodology for the survey is available since 2004. The surveys give important information on the functioning of the ecosystem, on nutrient cycles and on phenological events like fruiting, flowering and leaf and needle fall.

Litterfall collectors.

PREFACE

In Western Europe, levels of air pollution from the industrial sector have been drastically reduced in the last 20 years, due to the successful implementation of protocols for emission cuts adopted at national levels by the signature countries of the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP, Geneva, 1979). These results have also been obtained through the study and monitoring of forest condition, launched in 1986 in the framework of the International Cooperative Programmes on Forests and Integrated Monitoring of Ecosystems (ICP Forests), and following the related initiatives of the European Union, from the first regulations on crown condition during the 1980s until the most recent regulations on intensive monitoring of forest ecosystems during the 1990s. In comparison with the 1970s, sulphur and nitrogen emissions coming from the industrial sector have been reduced by 20-30%, generating a significant improvement of the condition of all ecosystems over the European continent. The famous "acid rains", which in the past contributed to a strong deterioration of forest health, in particular in central Europe, are today only a bad memory in most European countries.

New and old hazards are damaging and threatening the delicate European forest ecosystems, utilised for centuries for their precious and irreplaceable economic resources. Among these factors, an alarming new threat is damage due to the increased ground level of ozone. The main cause is a very fast increase of transportation of people and goods by road with the related nitrogen oxide emission, which increases tropospheric ozone. In addition, the increase in deposition of nitrogen to forest soils, due at least in part to the same cause, is threatening the integrity and functioning of the forest ecosystems. Finally, our forests are threatened by the observed changes in climate and by an important loss of biodiversity, both of which are occurring over the entire European continent, in particular in the south.

Before the establishment of the European network for the intensive monitoring of forest ecosystems, the available knowledge on air pollution levels in remote forest areas was very limited: monitoring facilities were located, in almost all cases, in urban or suburban areas and only in a very few cases in really remote areas. The large amount of data on air pollution, generated through the monitoring activities performed on the EU/ICP Forests Level II plots since the ‘90s, forms the first significant and reliable data bank established at pan-European level on the ecological condition of land ecosystems. The integrated and combined evaluation of these data is an exceptional chance to obtain a clear picture of state, risk and current change in European forest ecosystems. First results clearly indicate that forest ecosystems of southern Europe are exposed to very high ozone levels, well over the risk threshold accepted at international level. Several vascular species have been documented as particularly sensitive to ozone damage, with observed effects on growth and crown defoliation. The effects of ozone on forests are also potentially dangerous for the conservation of biodiversity (decrease of competitive ability for sensitive species), for forest vitality (increase of crown defoliation), for carbon uptake and storage (decrease of tree growth) and in general for the sustainable management of forests.

In Italy, the ICP Forests programme is carried out in the framework of the LRTAP Convention and EC Regulation no. 2152/2003 on forest monitoring and environmental interactions (Forest Focus). Corpo Forestale dello Stato (the Italian National Forest Service) is the responsible body at national level, under the authority of the Minister for Agriculture and Forestry. The CONECOFOR programme (Intensive Monitoring of Forest Ecosystems) is the first and uniquely successful long-term ecological network that it has been possible to establish, maintain and develop over such a long time in Italy. In the framework of the new tasks required by the EC Regulation Forest Focus, a test phase for biodiversity assessment was launched in 2004, based on the same key indicators detected in selected Level II permanent plots and according to a methodology harmonised at international level. First results show the effectiveness and reliability of the applied methods, obtaining important signals for forest condition. In a few months of surveying of lichens and insects, several new species for science and new or very rare species for Italy were discovered. The results obtained provide a good background for the starting phase of the international project ForestBIOTA, a co-operative project that involves 13 European countries and 120 Level II plots from 2005 onwards. Within this framework, Italy organised two international workshops on forest biodiversity in 2003, and has in 2004 been designated to represent ICP Forests in the initiatives coordinated by the European Environment Agency for the establishment of a pan-European network for biodiversity monitoring (SEBI2010), implementing the Convention on Biological Diversity.

Gianni Alemanno
Minister for Agriculture and
Forestry
Italy

Forest landscape in Norway.

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

A 20 years' success story

On 4 October 1985, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established at its first Task Force Meeting, which was held in Freiburg, Germany, with 26 participating countries. The fear of a large-scale forest decline in Europe and the uncertain role of air pollutants were driving forces at that time. Operating under the UNECE Convention on Long-range Transboundary Air Pollution, the programme has not changed this main focus until today. Nevertheless, forest condition and health are now perceived in a wider context, and the programme has developed into a multifunctional monitoring system. ICP Forests today provides a platform for information exchange for forest scientists, managers and politicians of 40 participating countries.

Political links and cooperation

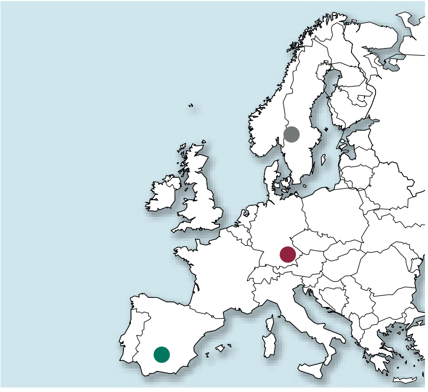
In the year 2003, the European Union adopted the "Forest Focus" regulation (EC No 2152/2003). This prolongs the basis for the close cooperation with ICP Forests that has lasted since 1986. The monitoring activities also pursue the objectives of several resolutions of the Ministerial Conference on the Protection of Forests in Europe (MCPFE). Possible contributions to the Framework Convention on Climate Change (FCCC) and to the Convention on Biological Diversity (CBD) have been specified. The programme maintains close contacts to the Acid Deposition Monitoring Network in East Asia (EANET).

ICP Forests promotes the wide use of its data for scientific evaluation. Upon request and in agreement with the data owners, data are free for external users. Previous users are listed in Annex III.

A monitoring system tailored for challenging objectives

The programme has been set up to assess the health status and development of European forests on a large scale and to inform policy makers, scientists and the public regularly of the results. The necessary data are collected by the participating countries on permanent observation plots called Level I (see Fig. 1-1). These are arranged on a 16*16 km grid covering 33 countries throughout Europe. In addition to annual crown condition surveys the repetition of a first soil survey is foreseen in the coming years.

Intensive monitoring is carried out at 860 Level II plots in order to detect how various stress factors influence forest ecosystems. Air pollution effects are the particular focus of the programme. The activities require to some extent expensive technical equipment for a larger number of surveys, like crown condition, foliar chemistry, soil and soil solution chemistry, tree growth, ground vegetation, atmospheric deposition, ambient air quality, meteorology, phenology, litterfall, and remote sensing. A number of biodiversity assessments are presently being tested within the ForestBIOTA project (see www. forestbiota.org).



Lugar Nuevo, Freising, Blåbärskullen:

Examples of Level II plots across Europe

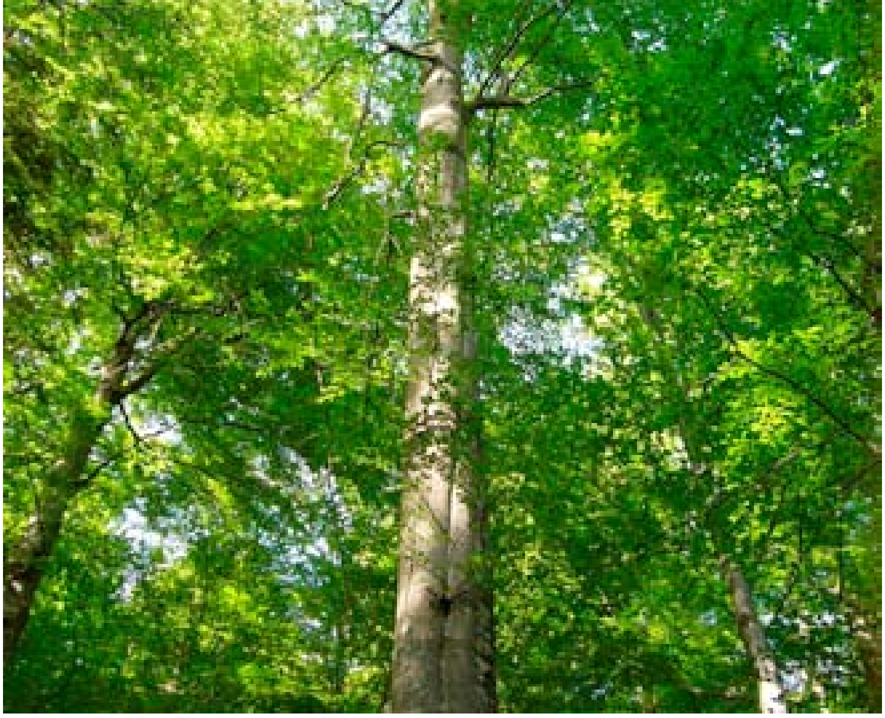
Level II plots have been selected in the most important forest types of 30 participating countries in Europe, and the setting up of comparable installations is ongoing in East Asia and North America. The selection of the plot locations is not statistically representative. Instead, the plots enable case studies and can give insight into complex forest ecosystem processes that differ across Europe. The present report emphasizes this by using three plots throughout several chapters as illustrative examples.

● Lugar Nuevo is located in the Sierra Morena mountain range, in the south of Spain at an altitude of 605 m a.s.l. It is covered by open holm oak forest mixed with pasture (dehesa). In other parts dense bushes form the typical maquia. Brown soils with a moderate nutrient supply have developed over a parent material of solid granite. The dry Mediterranean climate is characterized by mean annual rainfall below 500 mm and regular summer temperatures of up to 35°C. Monitoring activities started in 1994 and include fortnightly sampling and assessment of deposition, meteorology, phenology, air quality (passive samplers), and ozone - like symptoms.

● Freising is an ancient city naming the closely located Level II plot in Bavaria, southern Germany - 30 km north of Munich at an altitude of around 500 m a.s.l. The 153 year old mixed beech and oak stand is well nourished and the beech trees are healthy. Soils have developed from loess over upper Miocene sediments. In combination with a fairly high mean annual precipitation of 880 mm and a moderate mean annual temperature of 7.7 °C, they create favourable site conditions for forest growth resulting in a standing wood volume of 550 m^3 per hectare and an annual increment of 19.5 m^3 per hectare. Monitoring activities started in 1994 and all mandatory and optional measurements of ICP Forests are carried out. In a nearby open field, meteorology, deposition, air quality and ozone - like symptoms are measured and a phenological garden has been installed.

● Blåbärskullen (Bilberry Hill) is situated in central Sweden just 30 km from the Norwegian border. The altitude is 355 meters a.s.l. Mean annual temperature is 4.1°C and mean annual precipitation is reported to amount to slightly more than 1000 mm. The soil is on a quite fine textured morainic material and has no distinct horizons, since the site has probably been cultivated in earlier times.

The pure spruce stand was planted in the early 1950s. No management operations have been carried out since the plot was established in 1995. Deposition and soil water have been sampled since then and a mini meteorological station started measurements of temperature, precipitation and humidity in 2003.



Tree crowns in a beech forest of the Ukraine.

2. STATE OF EUROPE'S FORESTS IN 2004 AND CHANGES OVER TIME

Summary

- *More than 23% of around 135 000 trees assessed in 31 countries in 2004 were classified as damaged. Defoliation varied greatly between species and regions. European and sessile oak had the highest and Scots pine the lowest defoliation.*
- *The trends in defoliation differ also with species and region. As of last year, most of the main tree species show a clear worsening of crown condition as compared to the previous year. This effect was particularly pronounced for common beech. Plausible explanations are delayed effects of the extreme heat and drought in summer 2003. While defoliation of several main species has increased since 1990, defoliation of Scots pine is now clearly lower than in the mid 1990s.*

Introduction

The state of forests in Europe became a matter of particular concern in the early 1980s, as the condition of forest tree crowns was observed to deteriorate in large parts of Europe. This gave rise to a continuous monitoring of crown condition under ICP Forests and the EU. The key parameter of the monitoring of crown condition is defoliation. Defoliation can be assessed with reasonable effort at the European scale. The Ministerial Conference on the Protection of Forests in Europe (MCPFE) has chosen it as an indicator for forest health and sustainable forest management. On the large-scale transnational 16*16 km grid, defoliation was assessed in 2004 on 135 372 trees on 6 133 plots in 31 countries as a fast reacting indicator for numerous natural and anthropogenic factors affecting tree vitality. In many countries, additional assessments were performed on denser national grids. The present report focuses on those tree species represented most frequently on the transnational grid, i.e. Scots pine, Norway spruce, common beech, and European and sessile oak (which are considered jointly).

Large-scale defoliation status

The share of trees classified as damaged or dead was 23.3% in total Europe and 24.2% in the participating EU Member States. These figures involved a share of dead trees of 0.7 % in both cases. Of the tree species assessed most

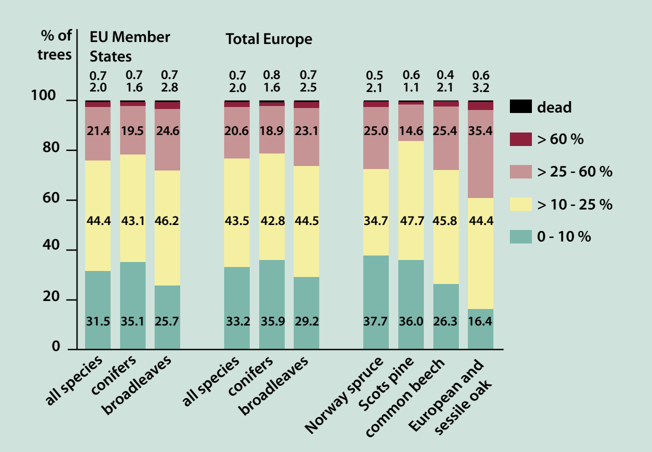


Figure 2-1: Percentage of trees in different defoliation classes. Total Europe and EU, 2004.

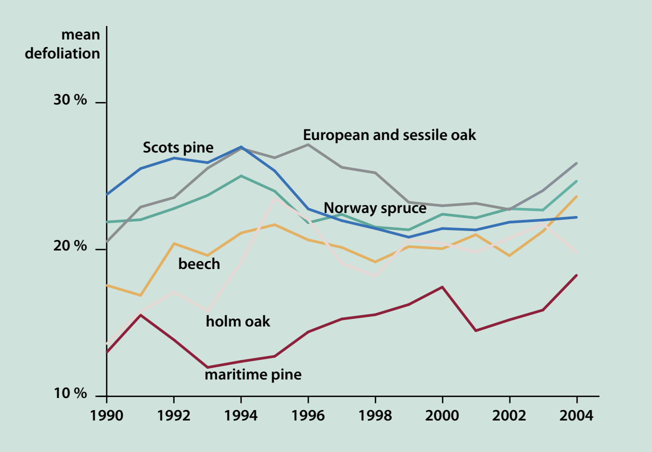


Figure 2-2: Development of mean defoliation of major tree species in Europe. Sample sizes vary between 11 924 and 2 332 trees per year and species. Results are based on data from 12 countries with continuous data submission.

frequently in total Europe, European and sessile oak had the highest and Scots pine the lowest defoliation (see Fig. 2-1).

Temporal development

Mean defoliation of common beech, of European and sessile oak and to a smaller degree also of Norway spruce increased during an evaluation period from 1990 to 2004. These species had recovered from high defoliation in the mid 1990s, but now show a clear increase in defoliation between 2002 and 2004 (see Fig. 2-2). It is obvious that all species except holm oak and Scots pine show a sharp increase in defoliation in 2004 and to some extent already in 2003. Scots pine defoliation has decreased compared to 1995.

The trends in defoliation vary considerably across Europe (see Fig. 2-3). On 18.8% of all plots a statistically significant increase in defoliation was observed during the period from 1997 to 2004. This reflects the deterioration of crown condition of the main tree species described above. A decrease in defoliation occurred on 12.4% of the plots. These are largely Scots pine plots concentrated mainly in Belarus and in parts of Poland and of the Baltic States.

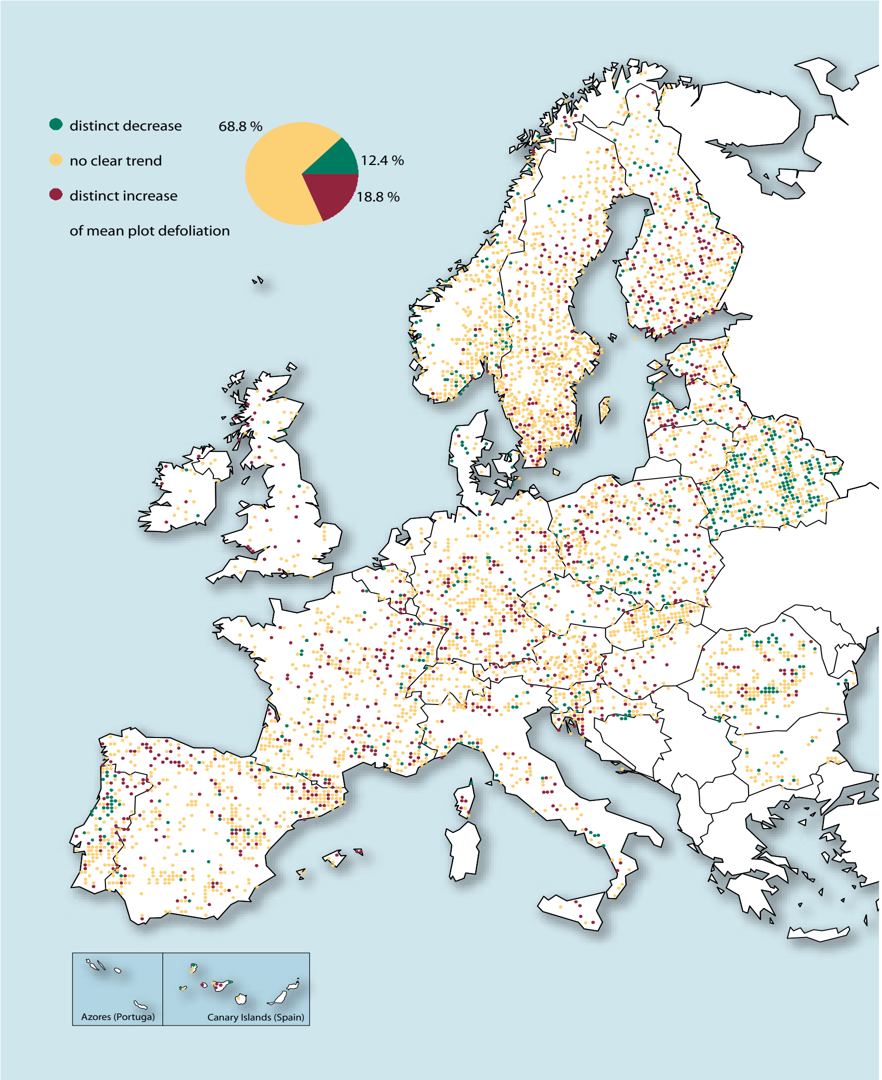


Figure 2-3: Plot-wise development of defoliation for all tree species, 1997-2004.

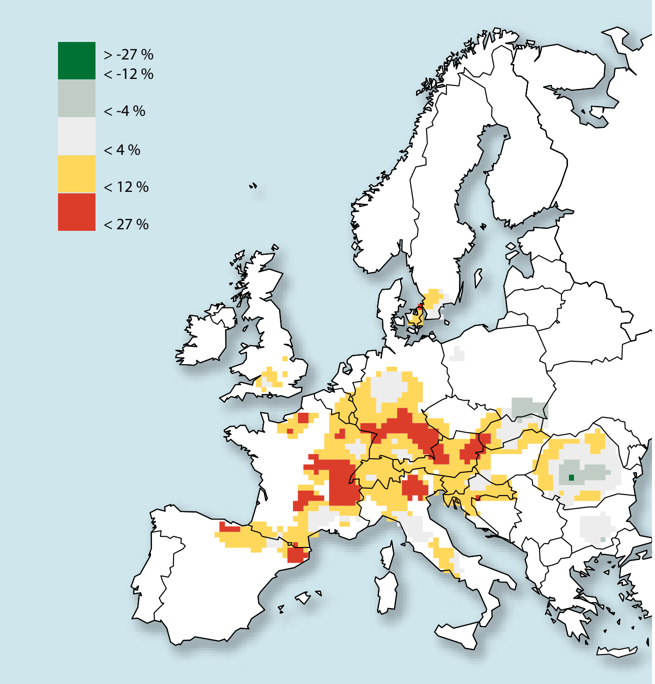


Figure 2-4: Deviation of mean plot defoliation of common beech in 2004 from the average defoliation from 1997 to 2003. Kriging interpolation based on 564 plots continuously assessed from 1997 to 2004. Classes in percent points of defoliation.

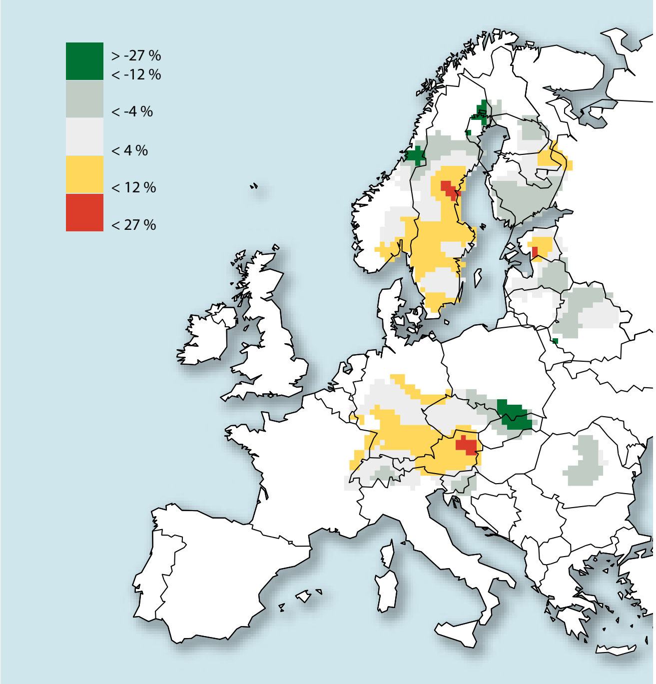
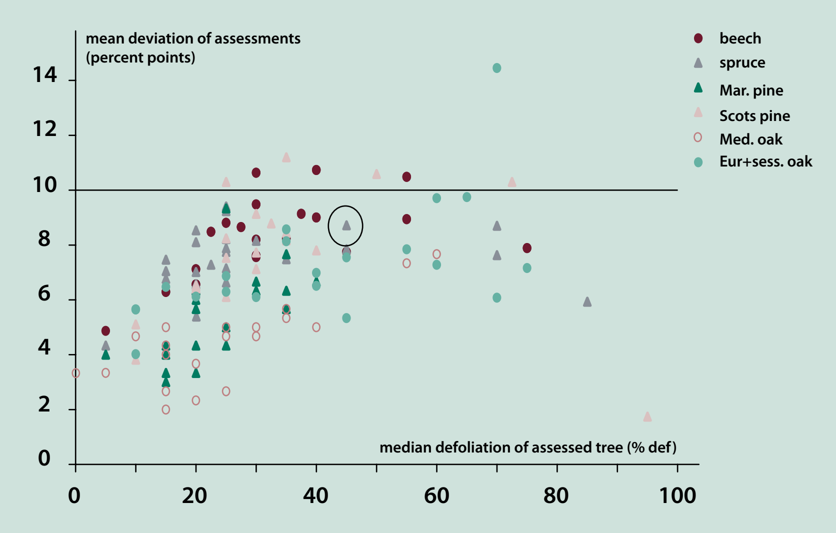


Figure 2-5: Deviation of mean plot defoliation of Norway spruce in 2004 from the average defoliation from 1997 to 2003. Interpolation based on 1 463 plots continuously assessed from 1997 to 2004. Classes in percent points of defoliation.

Quality control in defoliation assessments has for many years been ensured by field exercises, at which national team leaders meet in the forests and assess the same trees. As an additional measure, photos of tree crowns were circulated by postal mail and decentralised assessments were conducted for the first time in 2004. The re-assessment of the same photos in coming years is an excellent tool to guarantee temporal consistency of the assessments. For each main tree species, the exercise was based on 20 tree crown photos from various regions of Europe. In all, 84 experts and teams participated. For trees with extremely low and high defoliation, the deviations were lower. Tree species that are growing in smaller parts of Europe only, like Mediterranean oaks and maritime pine, were assessed more homogeneously than Norway spruce and Scots pine, which were assessed by a larger number of experts.



Deviation of the photo assessments from the mean defoliation of the assessed trees. The variation in the assessments was mostly below 10%. The marked spruce tree, for example, had a mean defoliation of 45% and the assessments by the experts deviated on average by 8.7 percentage points.

In 2004, common beech deteriorated in all regions monitored, except the eastern parts of Europe (see Fig. 2-4). Deterioration was less obvious for European and sessile oak because of the higher defoliation in earlier years (not depicted). For Norway spruce (see Fig. 2-5) the deviation from the medium term mean defoliation shows a high spatial variation. Defoliation was higher than average in eastern Austria and central Sweden, but lower than average in large regions of central, eastern and northern Europe.

The increase in defoliation in 2004 was already predicted in last year's report in view of the heat and drought stress that occurred in summer 2003. Depending on tree species, there are several reasons for continuing or even increasing defoliation after the actual drought year, all involving a weakening of the trees lasting over several years. Beech constitutes a classical example for the explanation of increasing defoliation by drought stress (see Chapt. 3-1). The improvement of crown condition of Scots pine in central and eastern Europe has been known for nearly a decade and has been attributed to improved weather conditions and decreased air pollution.

Crowns of Scots pine trees with no (left), slight (center), and moderate (right) defoliation.

Closed evergreen holm oak forest at the Level II plot at Cala Violina, on the coast in Tuscany, Italy.

MEDITERRANEAN EVERGREEN OAK FOREST: CONDITION, DYNAMICS AND THREATS

Mediterranean evergreen oak forests are the most characteristic natural vegetation of southern Europe, where they are today estimated to cover an area of around 5 million hectares, 2 million of which are located in Spain.

The dominant tree species is holm oak (*Quercus ilex*). Due to a very high ecological and conservation value these forests are listed by the EU Habitat Directive no. 9¾3, and there is a need to protect an ecosystem so rich in biodiversity and characteristic for the Mediterranean landscape.

The broad-leaved evergreen forests seem to be very resistant to air pollution. However, in the past a strong decline in biodiversity has been reported. This was mainly due to overexploitation resulting in land use change and habitat fragmentation. However, the higher the forests' ecological integrity is, the higher is their capacity to prevent forest fires and slow desertification processes. Only well-functioning forests can contribute to achieving the objectives of both the UN Framework Convention on Climate Change and the Convention to Combat Desertification.

Under the monitoring framework of ICP Forests, hundreds of Level I plots and several Level II Intensive Monitoring Plots are located in Mediterranean evergreen oak forests, one of which is the Lugar Nuevo plot in Spain, which is presented in more detail in other chapters of this report.

Ecological niche and conditions

The natural range of evergreen oak forests covers the whole of southern Europe from Portugal to Turkey, mainly from sea level to 500 m a.s.l. In some areas, however, they reach up to 1 200 m. These forests require mild average temperatures (15-20°C) and low to medium annual precipitation (300-1 000 mm) and do rarely occur in areas with more than ten frost days per year.

Two main communities occur naturally in the central Mediterranean, both dominated by holm oak: (1) a drought adapted type in the coastal areas (*Viburno-Quercetum ilicis*) and (2) a mountainous type (*Orno-Quercetum ilicis*). Recent research suggests that in historic times the latter naturally also comprised deciduous oaks like pubescent oak. Very sporadic, native communities dominated by cork oak also occur in the western Mediterranean area.

Dynamics

For more than 2 500 years, the evergreen oak forests have been closely linked to the cultural development in the region and to human influence. Today's remaining natural and semi-natural dense forests constitute only a small part of a forested area that was originally much larger. The natural forests are well structured with four vegetation layers and only 20-25 vascular species per 100 m2. These remnants are mostly managed for protective functions. A larger area has been transformed into low density anthropogenic woodlands, forming a mosaic together with bushes and dry grasslands called dehesa in Spain

A larger area of formerly closed holm oak forests has been transformed to open holm oak formations (dehesa). Spanish monitoring plot at Lugar Nuevo.

Repeated fires and grazing in large areas of the Mediterranean lead to a degradation of evergreen oak forests. Garique stage in Croatia.

and montado in Portugal. These are managed for multi-purpose functions including pasture. Most of the natural range, however, is presently covered by more simplified shrub communities (maquis), which substitute for the forest as a result of recurrent fire and grazing. The maquis vegetation type is three layered but does not show significant changes in species composition. A still further increased pressure through fire, grazing and wood exploitation has led to single-layered communities (garigue or phrigana) with a very significant increase in species numbers of up to 50 vascular species per 100 m2.

Threats

- In the last ten years, decreasing forest fires have been reported in Italy. According to the data from 2000 to 2003, only 10% of burned forest area is covered by evergreen oak forest; 21% are covered by maquis. In total, only an area of 12 000 ha per year, corresponding to 3% of the evergreen forests and maquis, is really affected by fire; the fires occur mostly in the same areas year after year.
- Ozone levels are high (40-50 ppb*h) and largely exceed the AOT40 threshold (5 000 ppb*h). However, visible symptoms have not yet been detected and the correlation with crown condition is not significant. The Mediterranean forest types seem to be adapted to these high ozone levels.
- Biodiversity is still affected by tourist activities, but recently a number of protected areas have been established to protect the Mediterranean ecosystem. On the other hand, increasing tourism can be a threat to biodiversity richness. Therefore, specific management and information are needed. In addition, land abandonment, a quick decrease in the economic value of timber and an increasing protection by regional, national and EU legislation have helped to stop the degeneration to very fragile and not equilibrated garigue stages. The prevalent tendency today is instead a regeneration process towards the maquis stage.

Percentage of damaged holm oak trees on the transnational Level I gridnet. Sample size is above 3 000 trees. The peak in the mid 1990s was mainly due to excessive drought in Spain.

- The recorded changes in climate in the past 50 years appear on the other hand as an emerging threat. They have led to increased drought symptoms in the Mediterranean ecosystem. Despite an expected negative effect on the forest communities as a whole, climate change might as well be a positive factor for frost-limited species like holm oak and others, which might expand their distribution range. A specific pilot project, carried out by Italy with the financial aid of the EU, will provide new evidence by 2006.

Ongoing monitoring activities

A number of holm oak dominated Level II plots were selected for a first biodiversity assessment test phase under the EU/ICP Forests ForestBIOTA pilot project in Italy, Spain and Greece. First results from Italy point to a high value for biodiversity and conservation. Some of the plots have shown the minimum amount of around 20 vascular species underlying a natural fluctuation process in combination with maximum values of a lichen biodiversity index. They are characterized by high structural complexity and up to 30 m³ deadwood per hectare. The evaluation of the monitoring data revealed a high naturalness and landscape diversity. In addition, three new insect species were described for the first time in a Mediterranean evergreen forest.

Summer heat symptoms on beech leaves.

3. ENVIRONMENTAL INFLUENCES AND ECOSYSTEM REACTIONS

3.1 Forests suffered from climatic extremes in 2003 and 2004

Summary

- *2003 was characterized by extreme heat and drought, especially in central Europe. Intensive monitoring data reveal that soil water reserves were completely exhausted on many plots. These weather conditions are supposed to be a major explanation for the observed increase in defoliation of many main tree species in 2004.*
- *In the Mediterranean region, forests had already suffered from excessive drought at the beginning of the 1990s. Monitoring results since then show that a recovery is not only related to natural factors such as site and weather conditions but depends as well on forest management including tree species selection.*
- *Storm events of historic dimensions hit southern Sweden in January 2005 and the Tatra Mountains in Slovakia in November 2004. Swiss research results focussing on the storm damage in 1999 suggest a relationship between nitrogen supply and storm damage risk.*

Exceptional heat and drought in 2003

In the year 2003, temperatures rose above 40°C for several subsequent days at many locations in Europe and precipitation was below long term averages (see Fig. 3-1). Globally, the World Meteorological Organization (WMO) classifies 2003 as the third warmest year in the instrumental record from 1861 to the present. Particularly in central Europe, the resulting drought stress is considered to be a major explanation for the increased defoliation of broadleaved species (see Chapt. 2). Stands suffering from such extreme weather are more susceptible to additional stress factors like insect outbreaks and air pollution. High ozone concentrations were linked to extreme solar radiation (see Chapt. 3-2).

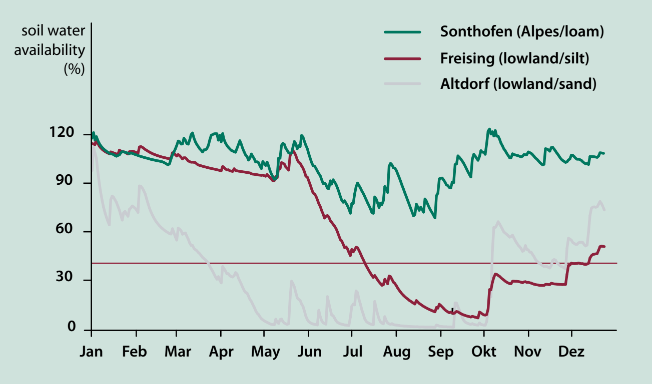


Figure 3-2: Soil water availability at 3 Level II plots with different soil types in Bavaria, Germany, in 2003.
At a water availability of 100 %, all soil pores are filled with water. Values above 100% indicate surface water runoff or seepage. At values below 40%, no more water is available for most tree species and drought reactions of the trees take place. At 28 out of 39 evaluated German plots the relative soil water availability decreased below the 40% margin during summer 2003. Soil water availability is mainly determined by weather and climate, soil type and vegetation type on the plot.

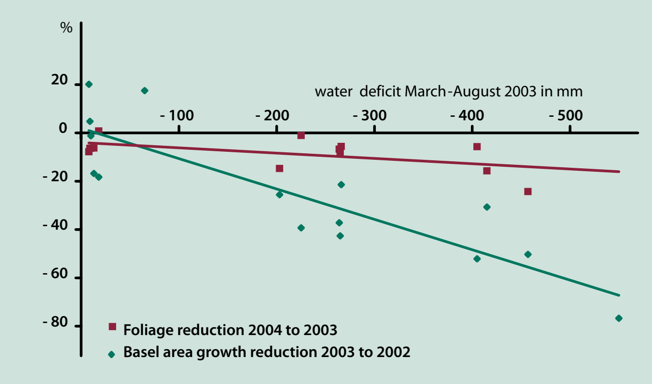


Figure 3-3: Soil water deficit, change in tree growth and in crown condition at Level II plots in Switzerland.
In summer 2004, the tree foliage was reduced compared to 2003. This reduction was related to the amount of water deficit during the growth period in 2003 (March-August). While crown condition did not show any sign of drought damage in 2003, the tree stem growth was reduced in that year. The water deficit was calculated as the difference between the actual and the potential evapotranspiration between March and August 2003.

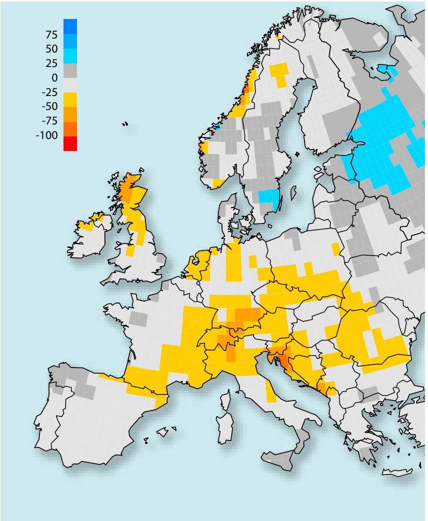


Figure 3-1: Precipitation difference in mm/month in June, July, August 2003 compared to 1960-90 (source: www.dwd.de). The extended and long-lasting precipitation deficit was in many parts of Europe aggravated by high temperatures.

Soil water availability decreased below critical values at many central European plots

Physical models enable the computation of soil water availability curves (see Fig. 3-2). Calculations for plots in central Europe show that the drought stress in 2003 was comparable and in part even worse than in 1976 and 1947.

Many tree reactions only became visible in 2004

In many areas of Europe, high defoliation values in 2004 are to a large degree due to the drought of the previous year. In stands suffering from drought in 2003, water transpiration and transport in the plants was reduced over weeks. Growth and production processes were considerably reduced or stopped. Trees lived on reserve substances, which they lacked for bud formation, shoot elongation and growth in 2004. Weakened by drought, broadleaved trees in particular produced fewer buds in 2003, yielding low foliage in 2004. The foliage of beech, as the species with the sharpest increase in defoliation, was also reduced because of high seed production, which is a typical reaction of trees after drought stress. For Swiss Level II plots, a significant statistical relationship between reduced plot foliage in 2004 and soil water deficit in 2003 was found (see Fig. 3-3).

Drought in the Mediterranean region

Compared to earlier years, the drought in 2003 was not so extreme in the Mediterranean region. However, between 1991 and 1995 an extreme water shortage affected most of Spain, with heat waves in 1994 in particular. During that period, specific drought monitoring was implemented in the country based on almost half of the Level I plots in Spain, which have become centres of visual assessment areas of about 100 hectares. In addition, historical defoliation scores were analysed, showing that the main Spanish forest species, holm oak, developed from 17% to 33% mean defoliation between 1991 and 1994. Results of the monitoring system show that drought damage, as well as recovery, was influenced by soil type, topography, stand history and age. Stands with reduced density and biomass showed a higher drought resistance. Overall, two key factors turned out to be of major importance: changes in tree species composition and human management.

In Slovakia, a storm on 19 November 2004 destroyed 24 000 ha of forest stands, which is 1.2 % of the total forest area of the country. 5.5 million m³ of timber were broken or felled. The Tatra National Park was the area most affected.

The storm that hit southern Sweden in the night of 8 January 2005 caused the worst storm damage to Swedish forests ever known. Approximately 75 million m³ were wind thrown or damaged.

Again storms of historic dimensions

Over the past decades, storm events and damage severity have increased in Europe. With an extreme storm in Slovakia and another one across Sweden, Latvia and Denmark, the series of storm events in the last decades continued. In both cases a wood volume was felled or broken corresponding to the total annual cut of the whole of Sweden and Slovakia, respectively. The highest storm damage ever reported for Europe occurred only five years earlier in December 1999, when 200 million m^3 of damaged timber were recorded, mainly in France, Switzerland and Germany.

Stem breakage risk of Norway spruce was linked with growth and nitrogen supply

In Switzerland 1 600 Norway spruce trees in 104 stands damaged by the storm in 1999 were analyzed in order to find out whether CO_2 or nitrogen availability influences the risk of damage. Broken trees showed wider tree rings in the decade 1990-99 compared to non-broken trees. Also, higher nitrogen concentrations were measured in the wood of broken trees. This most likely reflects a higher nitrogen supply for broken trees. The study suspects that increased tree growth and nitrogen supply reduced mechanical resistance in the Switzerland-wide sample.

Outlook

According to most climatic models, extreme weather events like storms, high temperatures, and long lasting drought will occur more often in the future. The multifunctional monitoring programme of ICP Forests offers a unique tool to record the extent and intensity of these events and to follow the reactions of the forest ecosystems.

Further information:
Indermühle M., Raetz P., Volz R. 2005:
LOTHAR Ursächliche Zusammenhänge und Risikoentwicklung. Synthese des Teilprogramms 6. Umwelt-Materialien Nr. 184. Bundesamt für Umwelt, Wald und Landschaft, Bern. 45 pp.

3.2 Successful ozone monitoring implemented

Summary

- *Ozone concentrations in 2003 were distinctly higher than in 2002. This is mainly due to the extremely hot and dry summer in 2003. Ozone formation in the atmosphere is increased by intensive solar radiation and high temperatures. Climate change towards hotter and drier summers is expected to result in higher ozone concentrations in the future.*
- *Ozone concentrations are higher in the south of Europe and at higher altitudes.*
- *A system for the identification of visible ozone injuries has been successfully implemented across Europe. Risk assessment is very complex, as high ozone concentrations do not always result in higher damage to the plants.*

A successful monitoring test phase

Ground level ozone is today regarded as one of the most important greenhouse gases. Its formation in the atmosphere is aggravated by air pollutants such as nitrogen dioxide and non-methane volatile organic compounds (VOCs). As ozone data from remote and forested areas were until recently hardly available, ICP Forests started a test phase for so-called passive samplers on its Level II plots in 2001. This has produced information on monthly, fortnightly or weekly mean concentrations on more than 100 plots and supported the determination of visible ozone injuries on plant leaves and needles.

Heat fostered an increase in ozone concentrations in 2003

At most of the surveyed plots, ozone concentrations were higher in 2003 compared to 2002 (see Fig. 3-4). This is particularly evident in Germany, Greece, and Italy, where many plots reached ozone mean concentrations above the critical limit of 45 ppb (Directive 2002/3/EC). The increase reflects different weather conditions in the two years. 2002 was a rainy and stormy year, with exceptional flood episodes in central Europe, whereas 2003 was characterized by exceptionally high temperatures and drought problems in large parts of Europe. The long and intensive sunshine periods in 2003 resulted in the high ozone concentrations as solar radiation is a prerequisite for ozone formation in the atmosphere.

Plots with higher ozone concentrations were located in southern Europe and at higher altitudes

Ozone passive sampler installed at the beech Level II plot in central – eastern Greece.

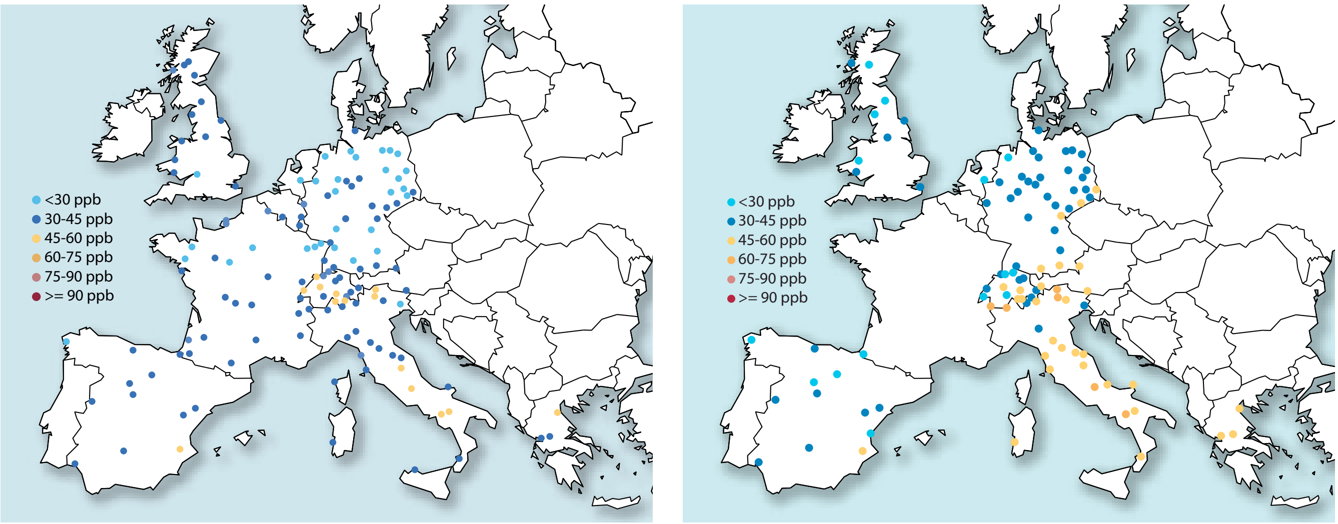


Figure 3-4: Mean ozone concentrations from April to September in 2002 and 2003; only for plots with measured values for more than 50% of the days between April and September.

Figure 3-5: Regression analysis for ozone concentrations and altitude for the years 2002 and 2003.

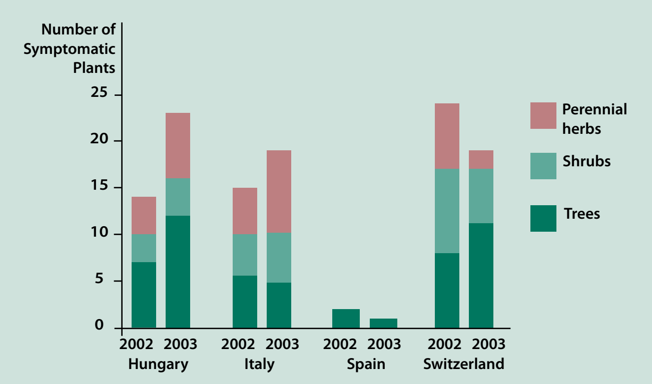


Figure 3-6: Number of species showing symptoms for common plots surveyed in 2002 and 2003.

(see Fig. 3-5). Highest concentrations were measured in southern Switzerland and northern Italy. During spring and summer, ozone-rich layers are regularly formed and re-circulated in the Mediterranean basin for several days. This explains the high ozone concentrations observed in southern Europe.

Visible ozone injuries show reactions of the plants

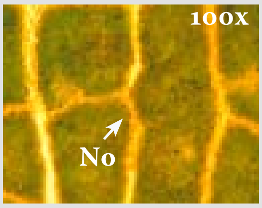
For the overall test phase, 2001-2003, six countries submitted data on visible injuries. Across Europe, 108 different plant species have been reported as showing symptoms by the different countries. Visible ozone injury was reported for beech for up to 13 plots, while for ash the annual maximum number of plots was 8 during the test phase. In Spain and Switzerland, the number of species showing symptoms decreased from 2002 to 2003, whereas it increased in Italy. In Hungary too, more species showing symptoms were detected in 2003 than in 2002, but here ozone concentration measurements were not carried out (see Fig. 3-6). A clear link between hot summers and more injuries can not be demonstrated. Decreased water availability for the plants reduces gas exchange through leaves and needles and thus also ozone uptake. Thus, high ozone concentrations in dry summers are not necessarily linked to more damage.

Conclusions and outlook

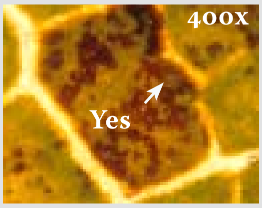
The ozone monitoring test phase of ICP Forests has contributed urgently needed concentration data from remote areas. Longer series of ozone measurements and ozone injury assessments will help to draw more definite conclusions on the effects of ozone in European forests. This is in particular necessary under changing climatic and environmental conditions with a predicted increase in summer temperatures and a higher frequency of drought episodes. The comparison of the years 2002 and 2003 shows that under such climate scenarios higher ozone levels are to be expected.

Determination of ozone injury to beech leaves

Ozone damage can develop as bronzing between the veins on the upper surface of the leaf, especially at sun-exposed parts (see big photo). This can normally be recognized in the field without using much technical equipment. When symptoms are not clear, they can be verified by the use of a microscope method. In cases where only epidermal cells are affected, damage is not caused by ozone (Type A, brown structures at the yellow lines). The brown and dark coloured palisade cells however are symptoms of ozone damage (Type B).



Type A



Type B

Throughfall deposition sampler in Cyprus and open field sampler in Norway.

3.3 Decreasing sulphur and fluctuating nitrogen deposition

Summary

- *Mean annual sulphur inputs under the canopy decreased by 40%. These results are based on 169 plots located mostly in central Europe.*
- *Forest trees filter large quantities of sulphate and other pollutants from the air. Thus, sulphur inputs under the canopy are mostly higher compared to nearby open field measurements.*
- *High nitrate deposition is common on plots in central Europe from the north of Italy to southern Scandinavia. Plots with high sulphate deposition can still be found in almost all of the evaluated countries.*

Forests in particular are affected by reduced air pollution

Between 1996 and 2001, sulphate deposition decreased from 7.4 to 5.9 kg S $ha^{-1}y^{-1}$. Throughfall deposition measured below the forest canopy decreased from 16 to 9.5 kg S $ha^{-1}y^{-1}$. These are mean values from 169 measurement stations mainly located in central Europe (see Fig. 3-7). Forest trees clean the air by filtering pollutants from it. This is the reason why deposition in nearby forest stands was on average twice as high compared to the open fields. The pronounced 40% decrease in the sulphate throughfall deposition curve impressively illustrates that emission reductions specifically relieve forest ecosystems. Mean throughfall deposition of ammonium and nitrate has decreased as well. In open field measurements, nitrate inputs fluctuated rather than decreased. Despite the improvements achieved, last years' reports have shown that deposition is still above critical loads on many plots. Also, pollutants have been deposited in the forest soils for years and decades. Dynamic models show that even a partial recovery will take further decades (see Chapt. 3-5).

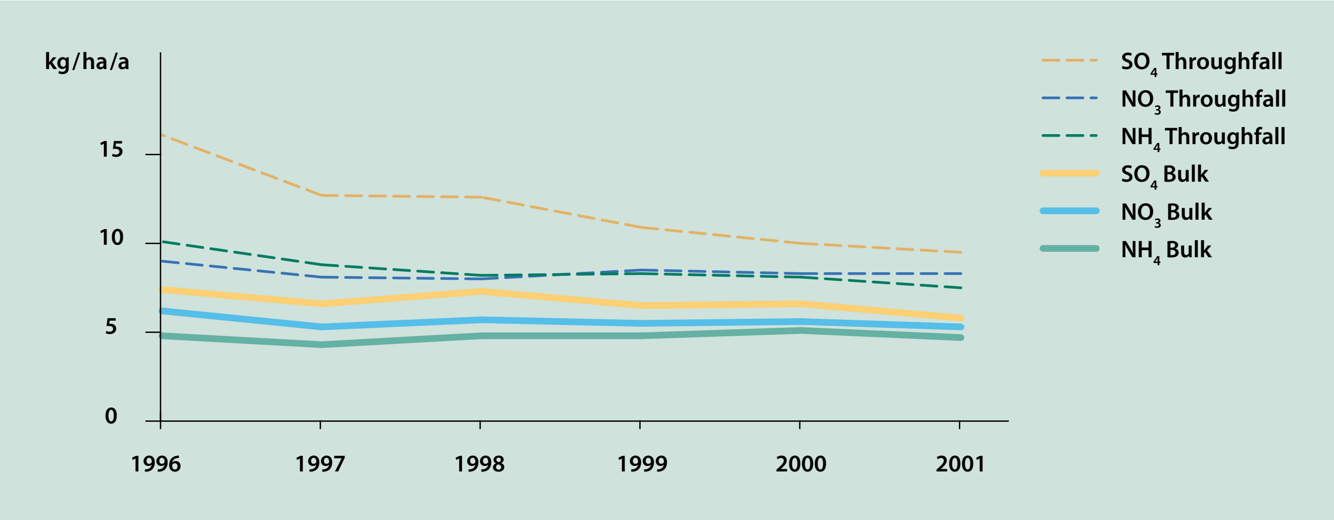


Figure 3-7: Development of mean plot deposition of sulphate (SO_4-S,) nitrate (NO_3-N), and ammonium (NH_4-N) on 169 plots.

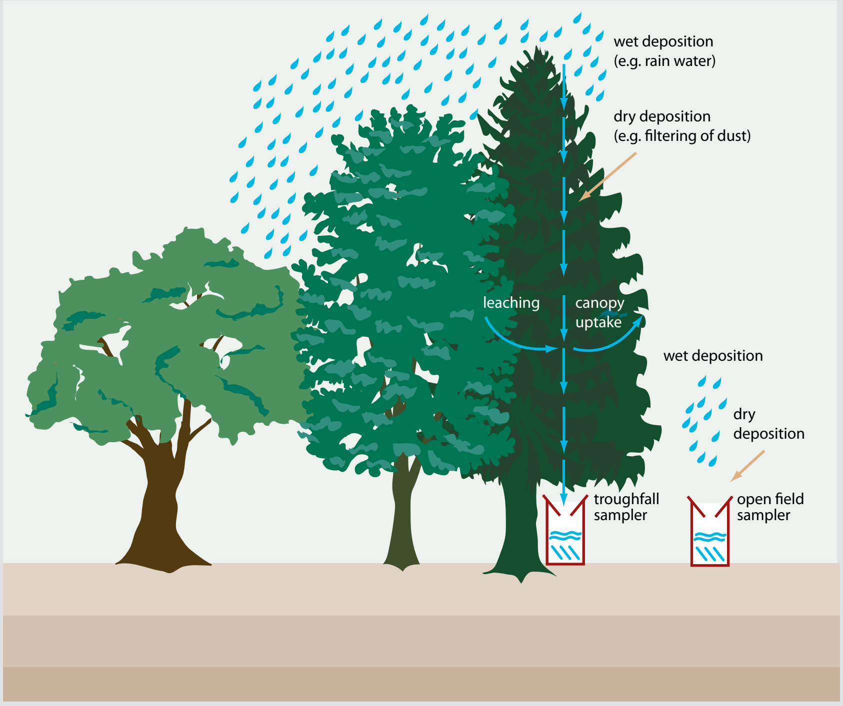
Levels and trends of deposition vary across Europe

High nitrate deposition is common on plots in central Europe from the north of Italy to southern Scandinavia. Plots with no change in open field inputs are in general prevalent. Sulphate bulk deposition decreased at 21.8% of the plots. This reflects largely the success of clean air policies (see Figs. 3-8 – 3-11). With regard to the still high nitrate and ammonium inputs, the implementation of the UNECE Protocol to Abate Acidification, Eutrophication and Ground-level Ozone that entered into force on 17 May 2005 remains high on the political agenda. Annual fluctuations of atmospheric depositions are often due to variations in precipitation. However, the decreases in sulphur deposition are stronger than could be expected from the observed trends in precipitation in the same period. High sulphate inputs on plots near the coasts can be of natural maritime origin. The high variability of plot situations and forest types across Europe underlines the necessity of a broad monitoring approach. Three specific examples presented on the following page illustrate this.

Deposition fluxes, plot selection and data evaluation

Following its mandate, ICP Forests started to implement deposition measurements on Intensive Monitoring Plots in the second half of the 1990s. Deposition is measured in the open field (bulk deposition) as well as in the forest stands (throughfall). Stemflow measurements are of particular importance in beech stands where considerable amounts of rain water reach the forest floor running along the smooth bark of the trees. In open field samples, wet and an unknown part of dry deposition can be directly quantified. Deposition in forest stands is usually higher compared to open fields due to the filtering effects of tree canopies. However, the measurements have to be interpreted with care, as rain water washes certain elements (e.g. potassium, K) from the trees' foliage when percolating through the canopies (leaching). Other compounds (e.g. nitrogen, N) are taken up by leaves and needles (canopy uptake). In comparison to nitrogen compounds, leaching or canopy uptake of sulphate is low.

After intensive quality checks, complete data sets for throughfall and bulk deposition of nitrate (NO_3-N), ammonium (NH_4-N), and sulphate (SO_4-S) were available for 169 plots over the years 1996 to 2001. For these plots annual mean depositions were calculated. For the same period, slopes of plotwise linear regressions were tested for significance. Plot specific means were calculated for the period 1999 to 2001. On the maps all plots are included that have complete data sets of the depicted compound. Plot numbers are thus higher.



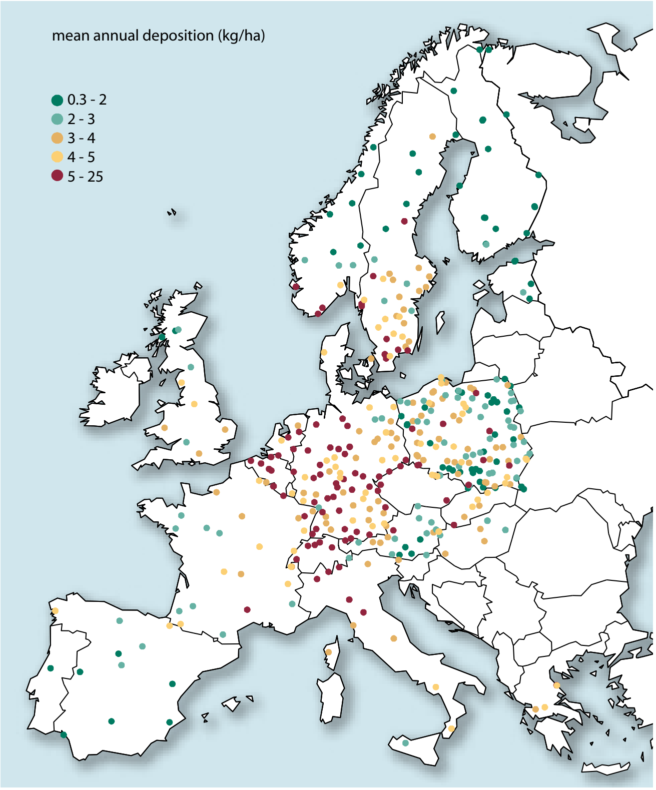


Fig 3-8: Mean nitrate (NO_3-N) in bulk deposition. 1999 – 2001 on 409 plots.

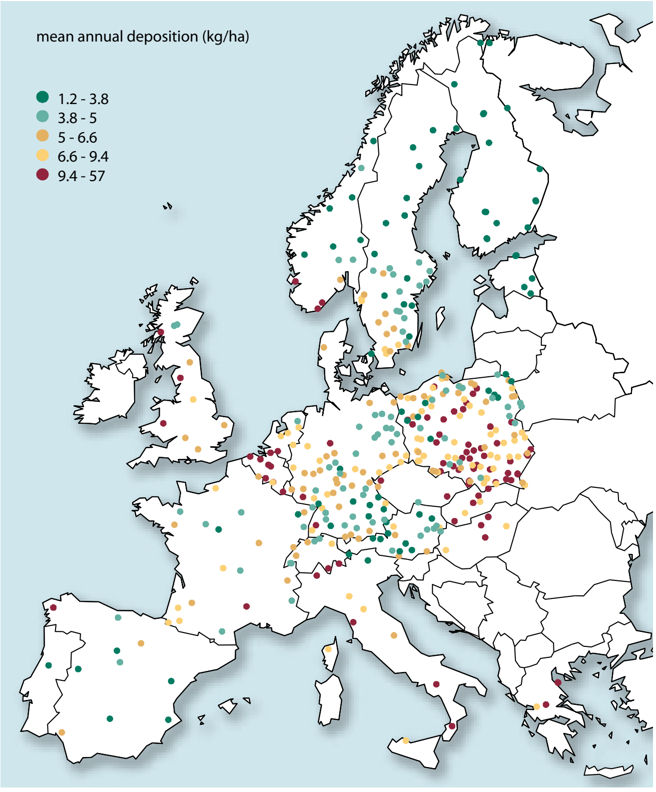


Figure 3-9: Mean sulphate (SO_4-S) in bulk deposition. 1999 – 2001 on 401 plots.

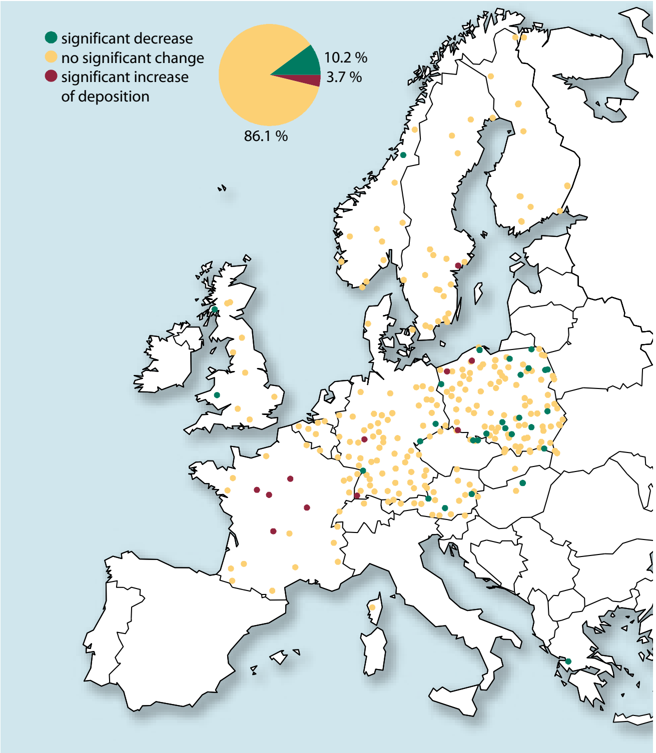


Figure 3-10: Trend of nitrate (NO_3-N) in bulk deposition. 1996 – 2001 on 294 plots. Only plots with complete data sets in the respective time period are included.

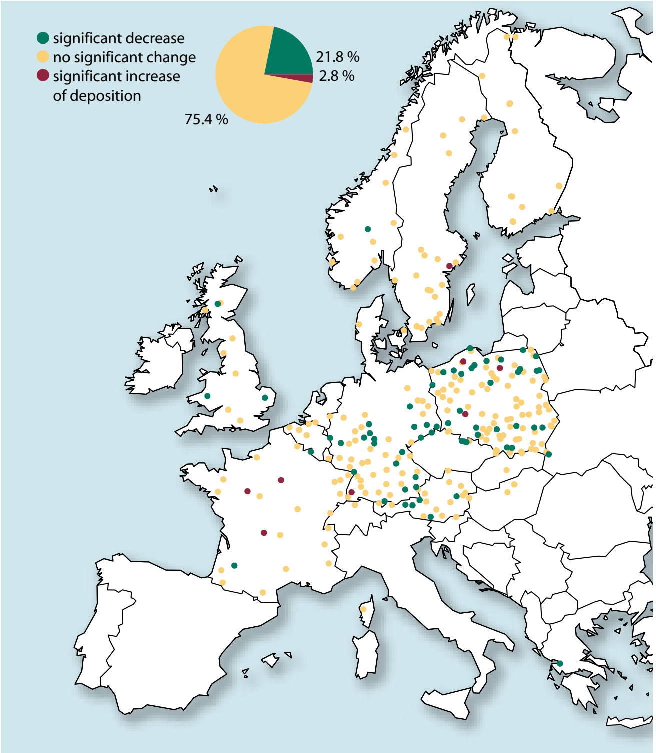
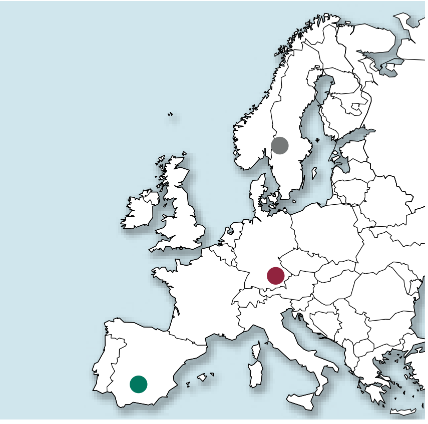


Figure 3-11: Trend of sulphate (SO_4-S) in bulk deposition. 1996 – 2001 on 285 plots. Only plots with complete data sets in the respective time period are included.

Lugar Nuevo, Freising, Blåbärskullen:

DIFFERING DEPOSITION TRENDS ACROSS EUROPE



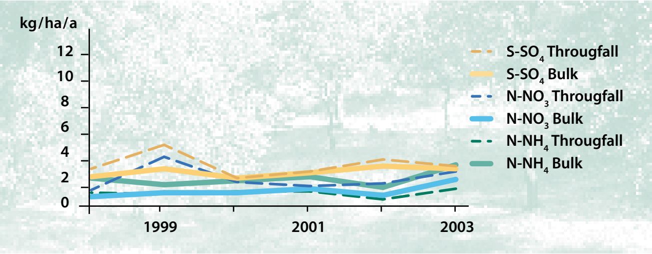


Figure 3-12: Trend for mean deposition of sulphate (SO_4-S), nitrate (NO_3-N), and ammonium (NH_4-N) at Lugar Nuevo in Spain.

● Full deposition monitoring at the Spanish plot in the Sierra Morena started in 1998. Its low deposition is typical for remote sites in the Mediterranean region (see Fig. 3-12). Nitrate and sulphate throughfall deposition is equal to or a little above the open field measurements, showing that (i) there is not much dry deposition to be filtered and (ii) the rather open holm oak stands are probably not so effective air filters. Ammonium throughfall below open field inputs indicates canopy uptake. With this uptake, trees obtain additional nitrogen, which seems to be a growth limiting nutrient on the plot.

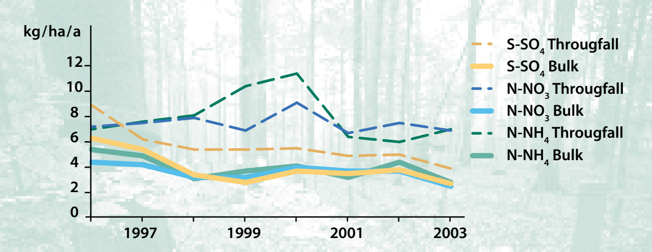


Figure 3-13: Trend for mean deposition of sulphate (SO_4-S), nitrate (NO_3-N), and ammonium (NH_4-N) at Freising in Germany.

● The Level II plot in Freising receives sulphate inputs below that of other sites in central Europe. An overall decrease can be observed (see Fig. 3-13). As in many other central European forests, however, nitrogen inputs in the forest stands are the prevailing problem. The stand continues to filter considerable quantities of pollutants from the air. This is demonstrated by throughfall inputs that are sometimes twice those of the open field samples, which is very remarkable for a deciduous beech stand. Up to now nitrogen loss from the soil is very low.

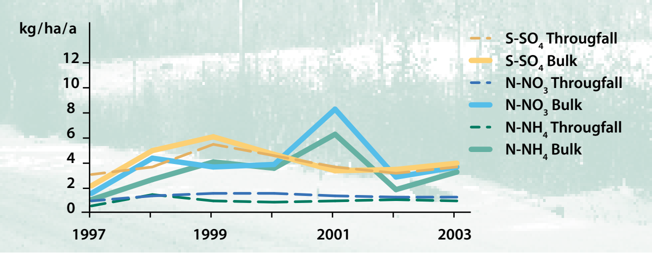


Figure 3-14: Trend for mean deposition of sulphate (SO_4-S), nitrate (NO_3-N), and ammonium (NH_4-N) at Blåbärskullen in Sweden.

● At Blåbärskullen in central Sweden, sulphate deposition fluctuates below European mean values (see Fig. 3-14). Nitrogen inputs have increased in the open field measurements over the evaluated five-year period. The low nitrogen throughfall deposition indicates that only very small quantities reach the forest floor. Instead, the trees consume most of the incoming nitrogen via canopy uptake. The low open field nitrogen deposition in 1997 and the high values in 2001 are strongly correlated with the amount of annual precipitation.

3.4 Leaching of nitrogen deposition into the ground water

Summary

- *Nitrogen leaching into the ground water is strongly related to atmospheric nitrogen inputs. This is particularly true for sites that are already nitrogen enriched.*
- *For sites with a lower nitrogen status, mean annual temperature plays an additional important role. The model shows the highest leaching at a mean annual temperature of around 7.5 °C. At lower and higher mean annual temperatures, lower leaching rates are observed.*

Introduction

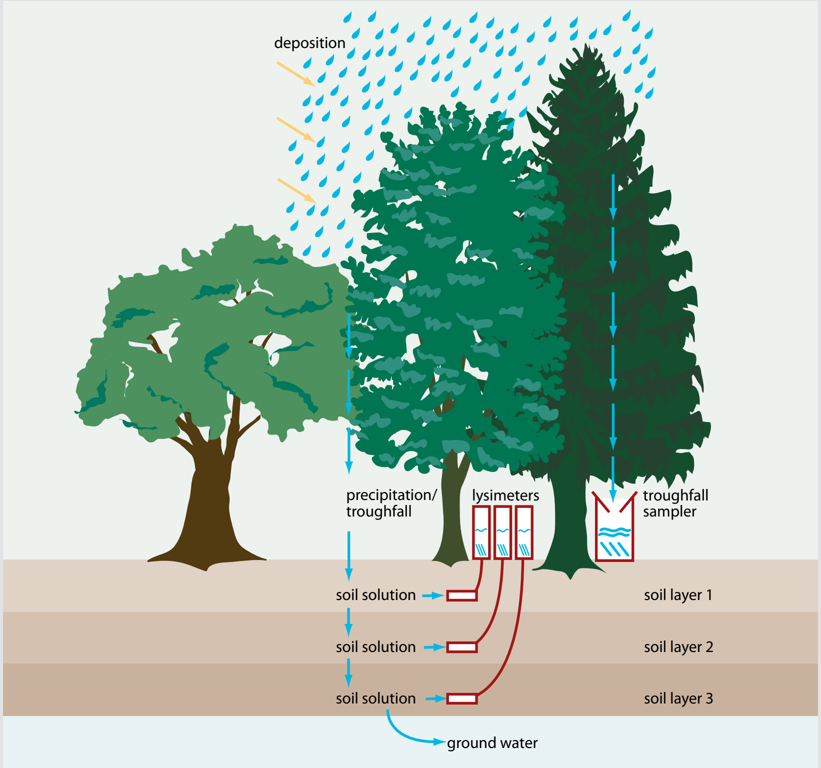
Nitrogen emissions from agriculture and fossil fuel combustion are still a major problem in central Europe. As shown in Chapter 3.3, nitrogen deposition at the forest plots has on average decreased only slowly or remained on the same level. Over the last decades this deposition has led to increased storage of nitrogen in the organic matter and soil, and ultimately to enhanced concentrations of nitrogen in surface water runoff and groundwater. Data from 121 Intensive Monitoring Plots together with additional large-scale data from the Indicators of Forest Ecosystem Functioning database were the basis for assessing the impact of high nitrogen deposition on forest soils in central and northern Europe. This research was sponsored by the EU projects DYNAMIC and CNTER.

Nitrogen input and nitrogen status of the soils determine leaching fluxes

As reported earlier, high leaching of nitrogen was largely related to high nitrogen throughfall deposition. In other words, when rain water contains large quantities of nitrogen, there is a higher probability of nitrogen leaching into the ground water. This general relationship is specifically true for sites with a forest floor that is already nitrogen-enriched ('high-N status') (see Fig. 3-15). Here,

Lysimeters extracting soil solution in France.

For the determination of relationships between nitrogen inputs and nitrogen leaching into the ground water, throughfall measurements as well as lysimeters are required.



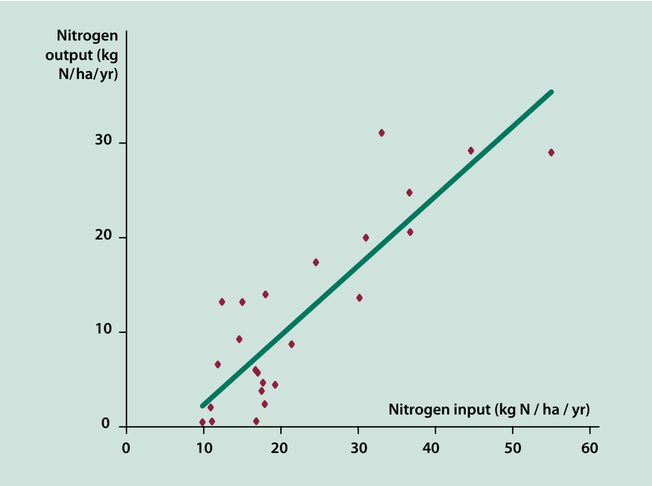


Figure 3-15: Nitrogen leaching (kg N ha^{-1} y^{-1}) against input in throughfall at nitrogen enriched sites.

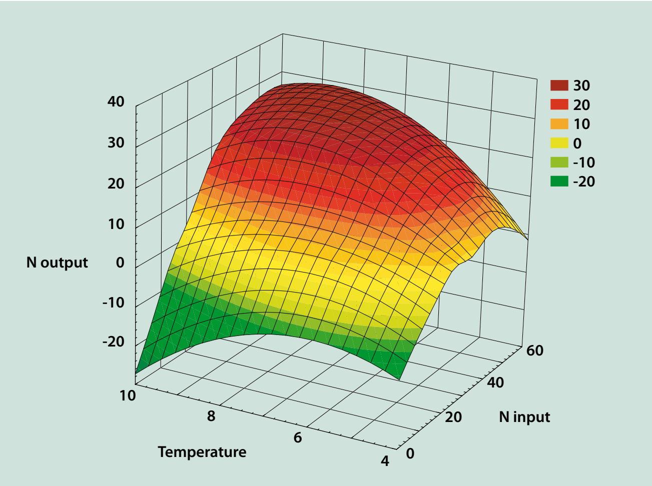
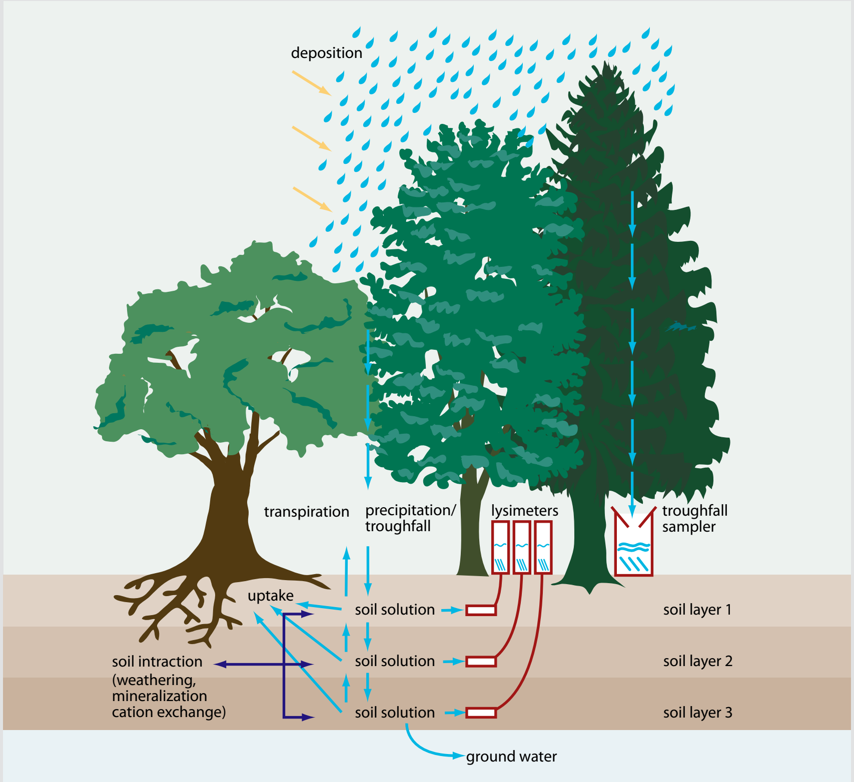


Figure 3-16: Nitrogen leaching (kg N ha^{-1} y^{-1}) in relation to deposition (throughfall) and mean annual temperature for forests with low nitrogen status.

neither the soil nor the plants are capable of retaining much additional nitrogen and let it pass through rather quickly.

At sites that are rather nitrogen-poor ('low-N status'), mean annual temperature was shown to play an additional role determining nitrogen leaching. For any given nitrogen input, the model shows that nitrogen output is highest at mean annual temperatures of around 7.5° C. At higher temperatures there is lower nitrogen leaching (see Fig. 3-16). A possible explanation for this is that warmer temperatures are linked to enhanced vegetation productivity and thus more nitrogen uptake. Lower leaching rates also occur at lower temperatures, probably due to microbial domination of nitrogen cycling at lower temperatures.

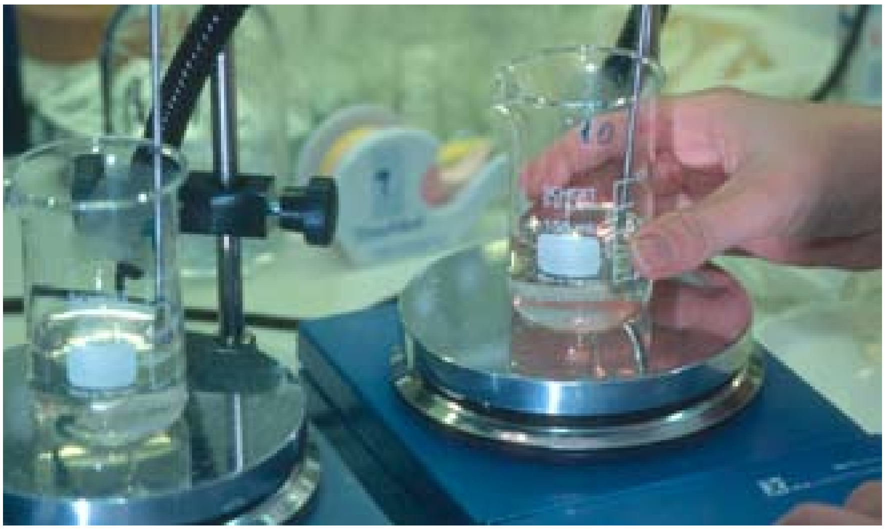
Further information:
www.flec.kvl.dk/CNTER



Dynamic soil chemistry models

Dynamic soil chemistry models such as SAFE (Soil Acidification in Forest Ecosystems) and VSD (Very Simple Dynamic Model) show the effects over time of acid deposition and forestry measures like harvesting and liming on soils and soil solution. The key processes included in dynamic models are soil solution equilibrium reactions including CO_2, organic acids and aluminium, cation exchange, element movement with horizontal water flow in multi-layer models, and nitrification. Element fluxes in deposition, nutrient uptake and nutrient cycling including mineralization, weathering processes for base cations and aluminium, and leaching of elements to groundwater are as well taken into account.

3.5 Forest ecosystem recovery from acidification can take decades - the application of dynamic models



Analysis of soil solution in the laboratory.

Summary

- *For many plots, a slow recovery of soil solution chemistry is predicted after emission reductions following the UNECE Gothenburg protocol. However, the chemistry of the soil solid phase reacts even more slowly, as dynamic soil models show.*
- *Recovery processes are mainly determined by the plot specific acid and base cation deposition, mineral weathering and the nutrient uptake of the trees.*
- *Results of dynamic models indicate that further emission reductions based on the already negotiated ceilings are necessary in order to reach critical limits.*

Monitoring results show that sulphur deposition has clearly decreased on many plots, whereas nitrogen inputs are in general either fluctuating or decreasing (see Chapt. 3.3). But what are the medium- and long-term effects of decades with high air pollution? Can we again proceed as if nothing had happened once the inputs are below critical loads? Dynamic models offer a process-oriented tool to estimate the recovery time for forest ecosystems (see box on opposite page). Level II data give an excellent basis for these calculations. In previous reports, results of the so-called SMART model have been presented. Now, first results of the VSD and the more complex SAFE model are presented.

Dynamic models have successfully been applied to national monitoring data by countries like Bulgaria, Germany, Norway, Sweden, Switzerland and the United Kingdom. Results show that:

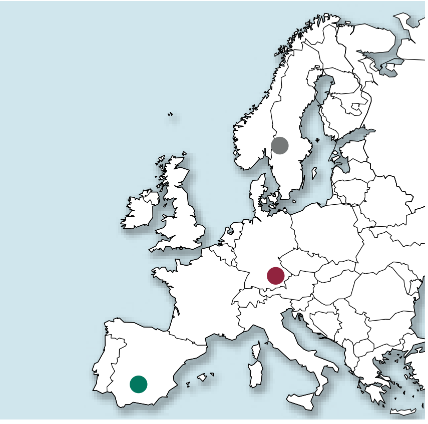
- The application of SAFE at 84 Level II plots in Germany predicts that at more than 90% of the investigated plots the critical limits will still be exceeded in 2010 and recovery processes will be very slow.
- A slow recovery of soil chemistry for 16 forest sites in Sweden has also been predicted by the models, assuming full implementation of the Gothenburg Protocol. In 2100, 44% of the modelled sites might still have soil layers with a base cation/aluminium ratio below the presumed critical value of 1.
- Critical loads for sulphur and nitrogen were not exceeded at any of the three evaluated Level II plots in Bulgaria.
- For Norway a dynamic model application predicts that, even with a maximum feasible reduction scenario, base saturation levels in soils will not reach pre-industrial levels in the next 50 years at any of the sites modelled.
- In general, the recovery of acidified and depleted soils is largely dependent on mineral weathering, acid and base cation deposition and nutrient uptakes of the trees.
- Emission reductions based on the UNECE Gothenburg protocol, the EU CAFE programme and further international agreements result in some soil recovery at most plots.
- Further emission reductions are necessary in order to ensure a soil status that ensures long-term ecosystem stability. In contrast to the comparatively fast reacting soil solution, the chemistry of the soil solid phase, and even more the fauna and flora, react much more slowly. Here, recovery processes can take many decades.

Future efforts will be directed towards the application of SAFE to a larger number of Level II plots and towards still more sophisticated models which are able to simulate reactions of plant communities and forest growth to changing environmental parameters.

Further information:
www.icpmapping.org

Lugar Nuevo, Freising, Blåbärskullen:

DYNAMIC MODELS REVEAL SUSTAINED DEPLETION OF SOILS EVEN AFTER EMISSION REDUCTIONS



Dynamic models were applied for the three example plots. The calculations rely on Level II data and historic deposition rates available from the literature. Future deposition scenarios based on the Gothenburg protocol were applied as calculated by the International Institute for Applied Systems Analysis (IIASA). In order to define critical limits it was required that the pH of the soil body below 10 cm soil depth in pre-industrial times should not be changed significantly. For the plots in Freising and Blåbärskullen, the availability of optional measurement data enabled the application of the multilayer model SAFE.

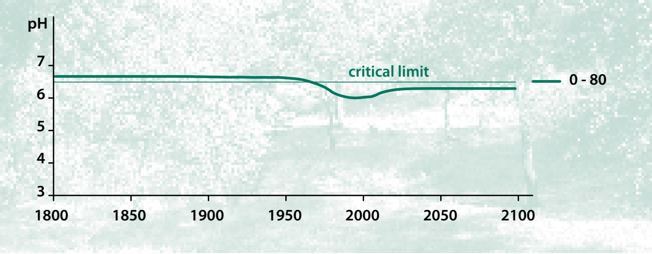


Figure 3-17: Modelled soil solution pH at Lugar Nuevo in Spain.

● The plot Lugar Nuevo receives relatively high base cation deposition (see Fig. 3-17). This is the reason for a (modelled) pH of 6.7 in 1800. Due to atmospheric nitrogen and sulphur deposition between 1950 and 1998 the pH decreased to 6.0. In the case of emission reductions that follow the Gothenburg protocol, pH might again increase to 6.3 after 2030, which is however still below a critical limit that was calculated with a pH of 6.5. This shows the necessity of further emission reductions.

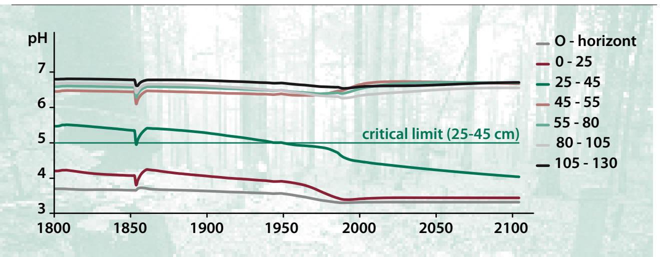


Figure 3-18: Modelled soil solution pH at Freising in Germany.

● At the Intensive Monitoring Plot in Freising, a clear cut documented in the stand history has led to a collapse of soil solution pH over several years in the mid 19th century (see Fig. 3-18). Increasing air pollution contributes to a continuous decrease of pH since then. At the end of the 20th century this decline was rather extreme across the mineral soil layers above 45 cm depth. The emission reduction scenario results in a recovery of the deeper soil layers supported by cations from the weathering of rather nutrient rich parent materials. For the upper soil layers, the cation supply from the deeper soil is not sufficient in relation to acid deposition, and the pH is predicted to stay below the critical limit as indicated for the layer from 25 – 45 cm.

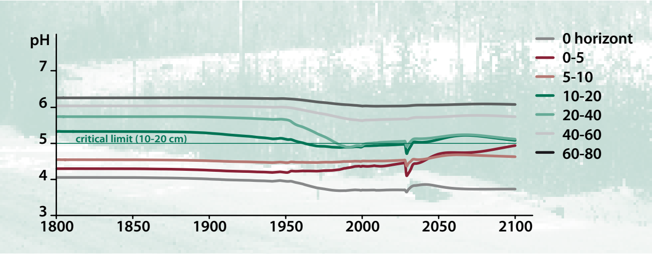


Figure 3-19: Modelled soil solution pH at Blåbärskullen in Sweden.

● At the Blåbärskullen plot, soil solution pH decreases in the deeper soil layers in particular after the plantation of a spruce stand on former agricultural land in 1950 and due to increased deposition (see Fig. 3-19). Only the top mineral layers profited from base cation inputs through litterfall. A recovery after emission reductions can be observed at most layers after the year 2000 and the critical limit is no longer exceeded after 2050. If traditional management operations are carried out, a clear-cut in 2030 will clearly influence the pH.

3.6 Litterfall – an important part of the ecological cycle

Summary

- *Litterfall assessments have been carried out for years by many countries. A harmonized methodology for the survey is available since 2004.*
- *The surveys give important information on the tree crown condition of the ecosystem, on nutrient cycles and on phenological events like fruiting, flowering and leaf and needle fall.*

Litterfall traps installed at a fir Level II plot in central Greece.

The collection of needles, leaves, fruits, and flowers shed by the trees to the forest floor is called a litterfall survey. Litterfall forms an important part of the chemical and biological cycle in the forest ecosystems. The importance of these measurements has been recognized by many countries and litterfall was monitored under national initiatives on around 45% of the Intensive Monitoring Plots already in 2001. Since 2004, this survey is officially included in the transnational monitoring programme and a manual for harmonized methods has been adopted recently. Only few countries have evaluated these data. These national results demonstrate the importance of this survey already.

Litterfall and weather conditions

A Norwegian study in Norway spruce stands investigated the relations between needle-fall and warm and dry weather conditions over 15 years. The needle-fall was separated in brown and green needle-fall and correlated to weather conditions. Unusually dry summers were followed by increased brown needle fall in autumn and winter and unusually high temperatures were accompanied by increased amounts of green needle fall. These results may explain increased crown defoliation in the South East of Norway, because of their temporal correspondence to the surplus needle-fall. Together this indicates that climate is a dominating factor for needle-fall and likely also for defoliation.

Litter transports nutrients for recycling

The chemical composition of the litter gives information on the nutrient situation. Evaluations from eleven Level II sites in the United Kingdom showed that nitrogen input to the soils through broadleaf litterfall was up to 93 kg per hectare in a mast year (2002) and thus, much higher than nitrogen input in deposition. However, it must be noted that the nitrogen content in litterfall results from both internal nitrogen cycling and deposition as an additional input.

Seed production is important ecological and management information

Natural regeneration is increasingly used instead of forest planting in many areas in Europe. Information on the amount of fruits produced per hectare, and the trends in this production over the years, can help foresters tremendously in the planning of forest areas to be regenerated naturally or seeds to be harvested for artificial regeneration. The fruiting of trees is also related to weather conditions as well as to stress factors and a closer understanding of these influences is essential to describe forest dynamics. First results from France confirm the well-known variation between years and sites (see Fig. 3-20). The data offer a unique opportunity to evaluate the factors related to seed production.

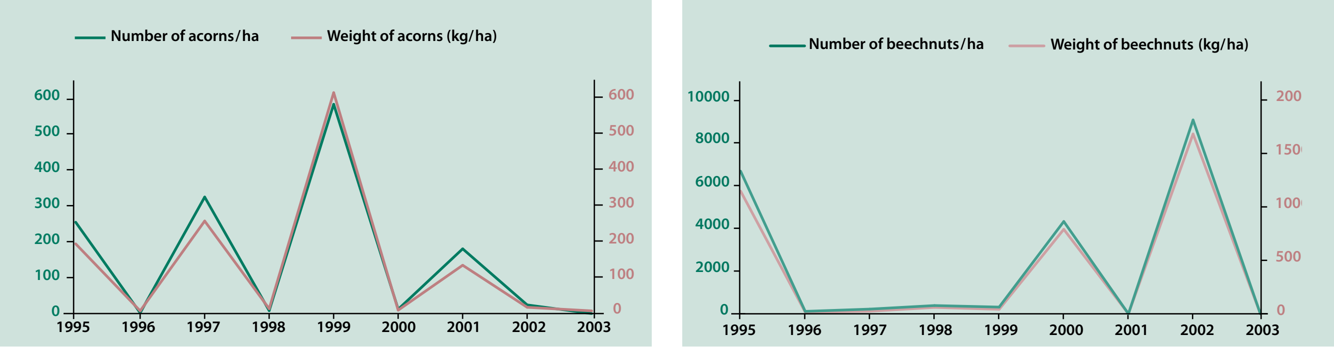


Figure 3-20: Trends in the number and weight of acorns (*Quercus petraea*, left) and beechnuts (*Fagus sylvatica*, right) per hectare from 1995 to 2003 in stands in northern France.

Beech forest, Germany.

4. CONCLUSIONS

More than two decades ago Europe was alarmed by scenarios of air pollution effects causing catastrophic forest damage. The headlines have changed in the meantime. Measures in the field of clean air policies have been taken since then. Forest condition has deteriorated far less dramatically at the European scale than was feared in the early 1980s.

The provision of a more detailed picture of forest condition in space and time and the establishment of an early warning system for European forests are among the main results of the joint monitoring under the International Cooperative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) and the European Union scheme "Forest Focus".

However, in many regions various stress factors, including air pollution, affect forest condition considerably. Extreme drought and heat during the summer of 2003 contributed to the pronounced worsening of the condition of many of the main tree species in 2004, notably for beech and especially in central Europe. Only the defoliation of Scots pine is now clearly lower than in the mid 1990s. Crown condition has proved to be a valuable indicator to estimate the condition of trees in a relatively short time and with low costs. The inclusion of a new litterfall survey into the monitoring system is an additional opportunity to evaluate the link between defoliation and environmental stress factors.

There are various causes for the different trends in forest ecosystem condition across Europe. The Intensive Monitoring Programme (so-called Level II plots) of ICP Forests offers a unique chance for more in-depth insights into ecosystem reactions related to different stress factors. The mean annual nitrogen deposition under the canopy of 169 Level II plots located mostly in central European regions was reduced from around 19 to 16 kg per hectare per year between 1996 and 2001. At nearly all plots, observed nitrogen inputs were considerably higher than the sulphur deposition. Mean sulphur inputs were 10 kg per year and hectare in the year 2001. The high nitrogen deposition increases the risk of nitrate leaching into the groundwater. This is particularly true for sites that are already nitrogen enriched.

International protocols under the UNECE Convention were set into force in order to reduce air pollution effects on ecosystems. Dynamic soil chemistry models predict a certain recovery of soil solution chemistry as a consequence of the abatement strategies. However, the full recovery of many plots will take decades and will depend on further emission reductions.

The monitoring test phase for ambient air quality that started in 2001 on around 100 Intensive Monitoring Plots has led to reliable ozone data from remote forested sites. The threat of higher ozone concentrations in repeated warm summer episodes has been substantiated. The assessment of ozone effects on plants has just begun. The very first results show that there is no clear link between ozone concentrations and visible ozone injury, as gas exchange, and thus ozone uptake, is limited in dry weather conditions.

The results published by ICP Forests within the past two decades constitute a part of the scientific basis of the protocols under the Geneva Convention on Long-range Transboundary Air Pollution. In the future too, the provision of relevant scientific information to the Convention will remain of highest priority for ICP Forests. Nevertheless, the programme will also use its multidisciplinary monitoring approach and its comprehensive database to contribute to other international environmental policies. It will provide information on species diversity in European forests and on causes of its changes over time. In addition, harmonized data on carbon sequestration will be contributed by ICP Forests. The close cooperation with the scientific community will assure further mutual benefits and, finally, the close contact with programmes on other continents like in East Asia and North America will help to complete the global picture regarding forest condition.

ANNEX I: FORESTS, SURVEYS AND DEFOLIATION CLASSES IN EUROPEAN COUNTRIES (2004)

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

Participating countries	Forest area (x 1000 ha)	% of forest area	Grid size (kmxkm)	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	10 x 10	299	8970	42.7	45.1	12.2
Andorra	17		16 x 16	3	72	16.7	47.2	36.1
Austria	3878	46.2	16 x 16	136	3582	51.4	35.4	13.2
Belarus	7845	37.8	16 x 16	406	9603	40.0	50.0	10.0
Belgium	691	22.8	4^2 / 8^2	125	2966	38.2	42.4	19.4
Bulgaria	3314	29.9	$4^2/8^2/16^2$	124	4356	19.8	40.5	39.7
Croatia	2061	36.5	16 x 16	87	2082	35.3	39.5	25.2
Cyprus	298	32.2	16x16	15	360	22.5	65.3	12.2
Czech Republic	2630	33.4	$8^2/16^2$	140	6585	11.7	31.0	57.3
Denmark	468	10.9	$7^2/16^2$	24	576	64.9	23.3	11.8
Estonia	2267	49.9	16 x 16	93	2201	49.4	45.3	5.3
Finland	20302	65.8	16^2 /	594	11210	57.1	33.1	9.8
France	14591	26.6	16 x 16	511	10219	32.0	36.3	31.7
Germany	11076	28.9	16^2 / 4^2	451	13741	27.6	41.0	31.4
Greece	2512	19.5	16 x 16					No survey in 2004
Hungary	1836	19.4	4 x 4	1204	28313	39.9	38.6	21.5
Ireland	650	6.3	16 x 16	19	403	56.8	25.8	17.4
Italy	8675	28.8	16 x 16	255	7111	20.5	43.6	35.9
Latvia	2923	44.9	8 x 8	352	8384	20.9	66.6	12.5
Liechtenstein	8	50.0						No survey in 2004
Lithuania	2069	31.3	8x8/16x16	261	6243	10.7	75.4	13.9
Luxembourg	89	34.4						No survey in 2004
Rep. of Moldova	318	9.4	2 x 2	680	11895	30.1	35.9	34.0
The Netherlands	334	9.6	16 x 16	11	232	52.2	20.3	27.5
Norway	12000	37.1	$3^2/9^2$	1566	8191	43.3	36.0	20.7
Poland	8894	28.0	Varying	1276	25520	8.3	57.1	34.6
Portugal	3234	36.4	16 x 16	133	3990	44.8	38.6	16.6
Romania	6244	26.3	4 x 4	3827	100041	62.5	25.8	11.7
Russian Fed.	8125	73.2	Varying					No survey in 2004
Serbia Montenegro	2360		16 x 16	130	3031	58.3	27.4	14.3
Slovak Republic	1961	40.0	16 x 16	108	4216	11.3	62.0	26.7
Slovenia	1099	54.2	16 x 16	42	1008	30.5	40.2	29.3
Spain	11588	30.9	16 x 16	620	14880	24.0	61.0	15.0
Sweden	23400	57.1	Varying	2819	14805	48.8	34.7	16.5
Switzerland	1186	28.7	16 x 16	48	1041	25.6	45.3	29.1
Turkey	20199	25.9						No survey in 2004
Ukraine	9316	15.4	16 x 16	57	1395	18.6	51.5	29.9
United Kingdom	2156	11.6	Random	347	8328	24.2	49.3	26.5
TOTAL	201615		Varying	16763	325550			

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 instandards used. This restriction, however, does not affect the reliability of the trends over time.

ANNEX II: DEFOLIATION OF ALL SPECIES (1993-2004)

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

Participating countries	All species, defoliation classes 2-4												change % points
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2003/ 2004
Albania						9.8	9.9	10.1	10.2	13.1		12.2	
Andorra												36.1	
Austria	8.2	7.8	6.6	7.9	7.1	6.7	6.8	8.9	9.7	10.2	11.1	13.1	2.0
Belarus	29.3	37.4	38.3	39.7	36.3	30.5	26.0	24.0	20.7	9.5	11.3	10.0	-1.3
Belgium	14.8	16.9	24.5	21.2	17.4	17.0	17.7	19.0	17.9	17.8	17.3	19.4	2.1
Bulgaria	23.2	28.9	38.0	39.2	49.6	60.2	44.2	46.3	33.8	37.1	33.7	39.7	6.0
Croatia	19.2	28.8	39.8	30.1	33.1	25.6	23.1	23.4	25.0	20.6	22.0	25.2	3.2
Cyprus									8.9	2.8	18.4	12.2	-6.2
Czech Rep.	51.8	57.7	58.5	71.9	68.6	48.8	50.4	51.7	52.1	53.4	54.4	57.3	2.9
Denmark	33.4	36.5	36.6	28.0	20.7	22.0	13.2	11.0	7.4	8.7	10.2	11.8	1.6
Estonia	20.3	15.7	13.6	14.2	11.2	8.7	8.7	7.4	8.5	7.6	7.6	5.3	-2.3
Finland	15.2	13.0	13.3	13.2	12.2	11.8	11.4	11.6	11.0	11.5	10.7	9.8	-0.9
France	8.3	8.4	12.5	17.8	25.2	23.3	19.7	18.3	20.3	21.9	28.4	31.7	3.3
Germany	24.2	24.4	22.1	20.3	19.8	21.0	21.7	23.0	21.9	21.4	22.5	31.4	8.9
Greece	21.2	23.2	25.1	23.9	23.7	21.7	16.6	18.2	21.7	20.9			
Hungary	21.0	21.7	20.0	19.2	19.4	19.0	18.2	20.8	21.2	21.2	22.5	21.5	-1.0
Ireland	29.6	19.7	26.3	13.0	13.6	16.1	13.0	14.6	17.4	20.7	13.9	17.4	3.5
Italy	17.6	19.5	18.9	29.9	35.8	35.9	35.3	34.4	38.4	37.3	37.6	35.9	-1.7
Latvia	35.0	30.0	20.0	21.2	19.2	16.6	18.9	20.7	15.6	13.8	12.5	12.5	0.0
Liechtenstein													
Lithuania	27.4	25.4	24.9	12.6	14.5	15.7	11.6	13.9	11.7	12.8	14.7	13.9	-0.8
Luxembourg	23.8	34.8	38.3	37.5	29.9	25.3	19.2	23.4					
Rep. of Moldova	50.8		40.4	41.2				29.1	36.9	42.5	42.4	34.0	-8.4
The Netherlands	25.0	19.4	32.0	34.1	34.6	31.0	12.9	21.8	19.9	21.7	18.0	27.5	9.5
Norway	24.9	27.5	28.8	29.4	30.7	30.6	28.6	24.3	27.2	25.5	22.9	20.7	-2.2
Poland	50.0	54.9	52.6	39.7	36.6	34.6	30.6	32.0	30.6	32.7	34.7	34.6	-0.1
Portugal	7.3	5.7	9.1	7.3	8.3	10.2	11.1	10.3	10.1	9.6	13.0	16.6	3.6
Romania	20.5	21.2	21.2	16.9	15.6	12.3	12.7	14.3	13.3	13.5	12.6	11.7	-0.9
Russian Fed.		10.7	12.5						9.8	10.9			
Serbia Monten.				3.6	7.7	8.4	11.2	8.4	14.0	3.9	22.8	14.3	-8.5
Slovak Rep.	37.6	41.8	42.6	34.0	31.0	32.5	27.8	23.5	31.7	24.8	31.4	26.7	-4.7
Slovenia	19.0	16.0	24.7	19.0	25.7	27.6	29.1	24.8	28.9	28.1	27.5	29.3	1.8
Spain	13.0	19.4	23.5	19.4	13.7	13.6	12.9	13.8	13.0	16.4	16.6	15.0	-1.6
Sweden			14.2	17.4	14.9	14.2	13.2	13.7	17.5	16.8	19.2	16.5	-2.7
Switzerland	15.4	18.2	24.6	20.8	16.9	19.1	19.0	29.4	18.2	18.6	14.9	29.1	14.2
Turkey													
Ukraine	21.5	32.4	29.6	46.0	31.4	51.5	56.2	60.7	39.6	27.7	27.0	29.9	2.9
United Kingdom	16.9	13.9	13.6	14.3	19.0	21.1	21.4	21.6	21.1	27.3	24.7	26.5	1.8

Austria: From 2003 on, results are based on the 16x16 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 1997-2004 are consistent, but not comparable to each other. *Italy:* Due to methodological changes, only the time series 1993-96 and 1997-2004 are consistent, but not comparable to each other. *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.

Annex III

ICP Forests data requested by third parties in 2003 and 2004

Project	Institution
ALARM (EU 6FP) Assessing large-scale environmental risks with tested methods	Department of Biology, University of York, United Kingdom
Indicators of the element budget in forest ecosystems	Department of Soil Ecology, University of Bayreuth, Germany
The use of foliar chemistry to indicate vitality in Swedish beech (Fagus sylvatica L.) and oak (Quercus robur L.)	Department of Ecology, Plant Ecology and Systematics, University of Lund, Sweden
European Forest Information System Demonstrator - NEFIS	European Forest Institute (EFI), Finland
Mapping bioavailability and natural background of metals in European soils	European Copper Institute (ECI), Belgium
Methods for mapping European forest types	Nature and Environment Section, Geological Survey of Denmark and Greenland (GEUS), Denmark

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Austria: Bundesforschungs – und Ausbildungszentrum für Wald, Naturgefahren und Landschaft, Mr. Ferdinand Kristöfel, e-mail: ferdinand.kristoefel@bfw.gv.at, Seckendorff-Gudent-Weg 8, A-1131 Wien.

Belarus: Forest Inventory republican unitary company „Belgosles“, Mr. V. Kastsiukevich, e-mail: belgosles@open.minsk.by, 27, Zheleznodorozhnaja St., 220089 Minsk.

Belgium: Wallonia, Ministère de la Région Wallonne, Div. de la Nature et des Forêts, Mr. C. Laurent, e-mail: c.laurent@mrw.wallonie.be, Avenue Prince de Liège, 15, B-5000 Namur.

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Bosnia and Herzegovina: Federalno Ministarstvo Poljop. Vodop. Sum., Mr. Bajram Pescovic, Maršala Tita br. 15, Sarajevo.

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