LRTAP
Long-range Transboundary Air Pollution

Life

The Condition of Forests in Europe

2010 Executive Report

Institute for
World
Forestry

Contents and Summary

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The ICP Forests monitoring programme was established in 1985 under the auspices of the Convention on Long-range Transboundary Air Pollution. Building on a close collaboration with the European Commission since 1986, the FutMon project co-financed by the European Commission is aiming at the further development of the programme. Results reported here are based on more than 7000 Level I and 400 Level II plots. Today, 41 countries participate in the programme.

2. Forest condition shows little change ....p. 6

Nearly two-thirds of the plots showed no significant change in tree crown condition over the past ten years. Forest condition deteriorated on 24% of the continuously assessed plots, with only 15% of the plots showing any improvement. Trends differ between the main tree species. European and sessile oak were the most frequently damaged species. Defoliation reacts to many different stress factors. The transnational survey based on more than 7000 plots is a valuable early warning system for environmental change.

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Mean annual sulphur inputs decreased by 30% between 1998 and 2007. Significant reductions were measured on half of the plots. These findings result from measurements conducted under the forest canopy on around 150 plots. Mean nitrogen inputs showed only a minor decrease. There are still a number of plots showing an increase in nitrogen deposition. Deposition is highest on plots in central Europe. For nitrogen, considerable emission reductions are still needed.

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Critical limits for soil acidification were substantially exceeded in a quarter of the samples taken from 160 intensive monitoring plots. On these plots there is an enhanced risk of damage to vegetation. Soil acidification can result in unbalanced nutrient uptake and other stress reactions and can destabilize forest ecosystems. Between 2000 and 2006 there was little change in soil acidification on the plots studied.

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Biological diversity on the monitoring plots is affected by nitrogen deposition. In the past seven or more years, ground vegetation composition has changed towards more nitrogen tolerant species. Nitrogen deposition was statistically linked to the present species composition and is a driver for ongoing change. In addition, soil, climate and the main tree species present are determining the forest floor vegetation.

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THE CONDITION OF FORESTS IN EUROPE

2010 Executive Report

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

European Commission
Environment Directorate General
LIFE Unit

ISSN 1020-587X
Printed in Germany

http://www.icp-forests.org
http://www.futmon.org
http://ec.europa.eu/life

Acknowledgements

The European Commission and ICP Forests wish to express their appreciation to all persons and institutions that have contributed to the preparation of this report, in particular the

- Johann Heinrich von Thünen-Institute (vTI),
  Federal Research Institute
  for Rural Areas, Forestry and Fisheries,
  Institute for World Forestry,
- its partners under the LIFE+ project 'FutMon', *
- the National Focal Centres of ICP Forests *

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Co-financing

The production of this report was co-financed under the LIFE+ Regulation (EC) No 614/2007 of the European Parliament and of the Council

Citation

Fischer R, Lorenz M, Köhl M, Mues V, Granke O, Iost S, van Dobben H, Reinds GJ, de Vries W, 2010: The Condition of Forests in Europe. 2010 Executive Report. ICP Forests and European Commission, Hamburg and Brussels, 21 pp [http://www.icp-forests.org/RepEx.htm]

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25 Years Succesful Provision of Information

Forests are important and diverse habitats which make an indispensable contribution to protecting the climate and preserving our natural resources. Forests cover 44% of the land area of Europe (~33% of the EU) and the same area often performs several functions simultaneously. The production of wood as a renewable resource is managed such that the forests can continue to perform their protective functions in relation to the water cycle, the soil and biodiversity. Protective functions are even the main priority in more than 20% of European forests, particularly in mountainous areas. Forests also play a major role in the earth's carbon cycle, storing a massive 53 gigatonnes of carbon and are also important economically. 600 to 700 million m^3 of wood are harvested each year and Europe is a net exporter of wood products. Last but not least forests are highly complex ecosystems that represent our natural and cultural heritage, as well as providing important recreational areas.

But forests can only fulfil these roles if they remain stable and healthy over the long term. Large-scale forest damage observed across Europe in the 1980s was attributed to air pollution and led to the formation of ICP Forests within the framework of the UNECE Convention on Long-range Transboundary Air Pollution. For 25 years ICP Forests has collected data on the state of the forests using Europe-wide harmonised methods. These data make it possible to measure and provide evidence for the success of air pollution control measures.

However, pollution inputs are still too high at many forest sites, especially in Central Europe. Critical loads are still being exceeded and models predict that it will be decades before forest soils recover from earlier pollution inputs even if the 'clean air' policies continue to be applied.

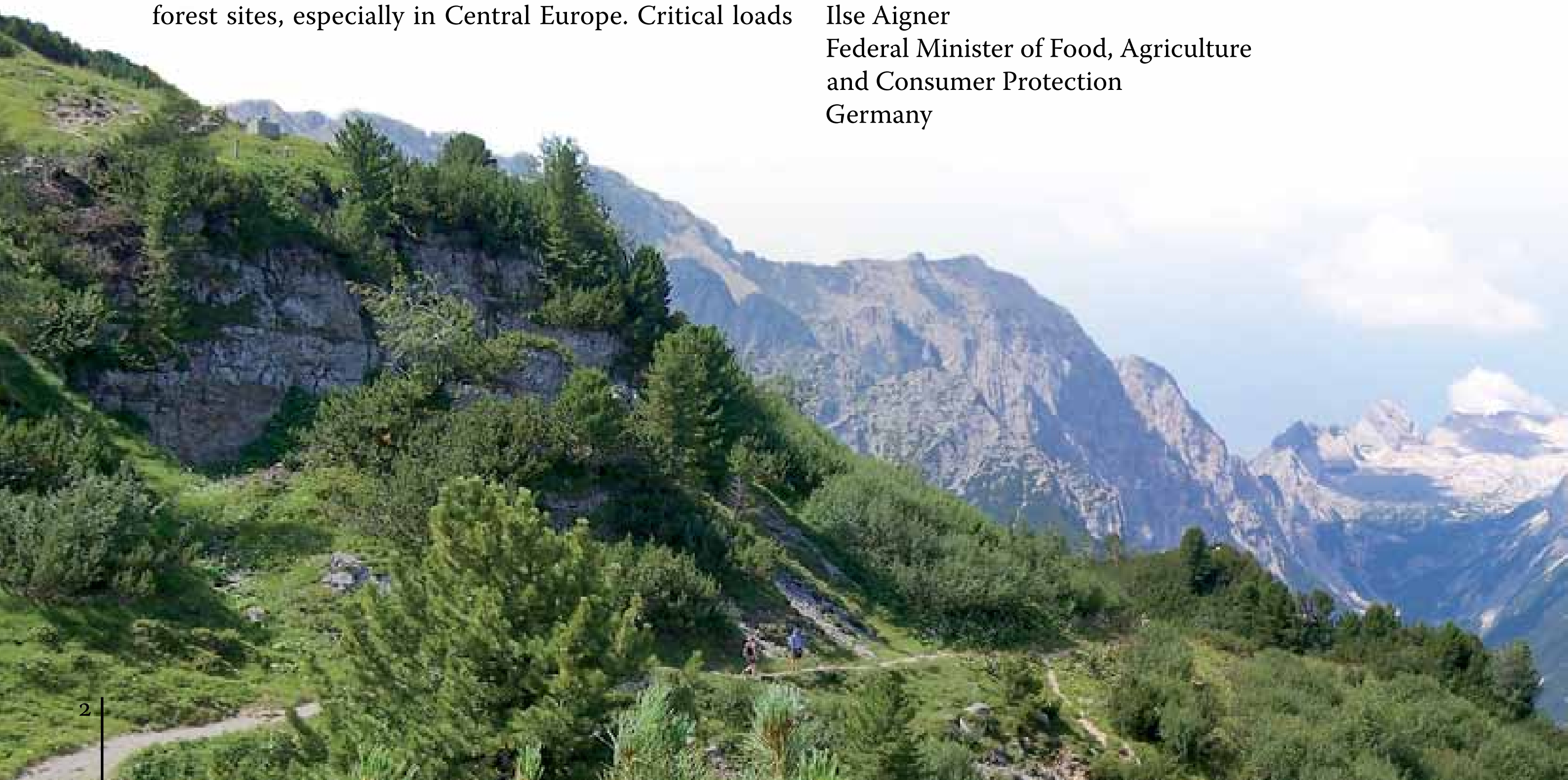
Meanwhile new questions are occupying policymakers, the public and forest managers: What does climate change mean for our forests? How will the forests respond to higher temperatures and changes in the water regime? How well prepared are they for the far-reaching changes expected? How can we support the forestry sector in adapting to climate change?

A switch from fossil fuels to renewable energy sources as part of ongoing adaptations to climate change is increasing the demand for wood. This raises several questions: What kind of timber use is sustainable, and at what intensity? On what scale can nutrients and micronutrients be removed from the forests, in particular via the use of biomass, without impairing the productivity and functioning of the soils? The forest monitoring datasets will help to answer these questions and so remain an indispensable addition to the national forest inventories which provide periodic large-scale surveys of forest status and production potential.

I would like to thank all those involved for their valuable work and wish continued success in the future.

Ilse Aigner

Ilse Aigner
Federal Minister of Food, Agriculture
and Consumer Protection
Germany



Forest Monitoring in Europe Endangered

I have great pleasure in introducing the report on the Condition of Forests in Europe 2010 on behalf of the Spanish Presidency of the European Union.

Twenty-five years ago, in 1985, the ICP-Forests Programme was created under the Convention on Long-range Transboundary Air Pollution (CLRTAP) of the United Nations Economic Commission for Europe (UNECE). The result was the establishment of one of the largest harmonised biomonitoring networks in the world which has become an important data source for studying the European forests. The programme is also a major international data provider for the Ministerial Conference on the Protection of Forests in Europe (MCPFE) and for the development of forest-related policy by the European Commission. Through its long history, forest monitoring data generated through the programme have constituted the base for many projects and studies both at national and international level, as well as for various public information needs.

Throughout this 25-year period, the European Union and ICP-Forests have actively collaborated in a range of ways. The ICP-Forests Experts have worked together to develop and adapt the methodologies and objectives of the programme in order to provide the policy relevant information required at the European level, while the European Commission has co-financed the forest monitoring since 1986. Funding is currently available through the project 'Further Development and Implementation of an EU-level Forest Monitoring System (FutMon)' under LIFE +, ending in December 2010.

After that deadline, the EC co-financing of forest monitoring will stop. For that reason, forest monitoring in Europe is under threat and urgently requires a new means of support as it provides the basis for forest policy information in Europe. The programme has recently contributed data regarding highly topical issues such as the combined effects of climate change and air pollution on forest vegetation and on the diversity of the plant species in the European forests. Furthermore, the long-term datasets are likely to become extremely useful for assessing the vulnerability and adaptation of the European forests under a changing climate; the effects of changes in soil moisture, water availability, atmospheric deposition and temperature on forest development, species composition and distribution; biomass and carbon stocks and their changes over time.

Within the framework of the Spanish Presidency of the European Union, a Conference on the Protection of Forests in Europe was held on 6th and 7th of April 2010 in La Granja de San Ildefonso (Segovia, Spain). The issue of support for forest monitoring in Europe and the continuation of the programme was raised at the meeting. As a consequence, the forest condition monitoring system is mentioned in the Green Paper on Forest Protection and Information in the EU, specifically in point "4.4. Forest Information" as one of the main contributors and forest data providers in Europe.

Within this context, let us hope that the long and fruitful collaboration between the European Commission and ICP-Forests can still continue in the future and that the importance of forest monitoring in Europe is acknowledged by all Europeans.

José Jiménez García-Herrera
General Director
General Directorate for Nature and Forest Policy
Ministry of Environment and Rural and Marine Affairs
Spain

Science-policy interface: Representatives of the ministries and scientists visiting an intensive monitoring plot in Germany.

1. A PAN-EUROPEAN FOREST MONITORING PROGRAMME

Data for forest management, nature conservation and policy

The European forests have many important functions. They are a basis for economic activity and play a significant role in the development of rural areas, as well as for recreational purposes. The forests have major value in terms of nature conservation and environmental protection, and by acting as significant carbon sinks are very important in the context of climate change. Sustainable forest management and good environmental policy rely on the sound scientific resource provided by long-term, large-scale and intensive monitoring of forest condition.

In 1985, the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established under the UNECE Convention on Long-range Transboundary Air Pollution (LRTAP). In 1986, the EU adopted Council Regulation (EEC) No. 3528/86 on the protection of forests against atmospheric pollution, and thus the legal basis for co-financing forest assessments was established. In 2003, this was superseded by the Forest Focus Regulation (EC No. 2152/2003), which was in turn superseded on 1 January 2007 by the Financial Instrument for the Environment (LIFE+) Regulation (EC) No. 614/2007. LIFE+ co-finances the further development and implementation of an EU-level forest monitoring system, known as the 'FutMon' project. Both FutMon and ICP Forests are coordinated by the Institute for World Forestry, hosted at the Johann Heinrich von Thünen-Institut (vTI) in Hamburg, Germany.

Embedded in a network of co-operation

ICP Forests aims to provide periodic overviews on the spatial and temporal variation of forest condition in relation to man-made and natural stress factors (particularly air pollution); to contribute to a better understanding of the cause-effect relationships between the condition of forest ecosystems and man-made and natural stress factors (particularly air pollution); and to study the development of important forest ecosystems in Europe.

FutMon aims at the creation of a pan-European forest monitoring system which can serve as a basis for the provision of policy relevant information on forests in the EU. More specifically, to support harmonised forest monitoring (by linking existing and new monitoring mechanisms at the national, regional and EU level); to collect quantitative and qualitative forest data related to climate change, air pollution, biodiversity, and forest condition; and to contribute information on sustainable forest management to the Ministerial Conference on the Protection of Forests in Europe.

Survey	Number of plots		Assessment frequency
	Installed	Data submitted for 2007	
Crown condition	836	462	Annually
Foliar chemistry	904	200	Every two years
Soil condition	615	0	Every ten years
Soil solution chemistry	302	169	Continuously
Tree growth	811	70	Every five years
Deposition	657	353	Continuously
Ambient air quality (active)	84	27	Continuously
Ambient air quality (passive)	254	167	Continuously
Ozone induced injury	114	43	Annually
Meteorology	265	191	Continuously
Phenology	186	58	Several times per year
Ground vegetation	777	67	Every five years
Litterfall	262	105	Continuously
Remote sensing	national data		Preferably at plot installation

Table 1-1: Surveys and number of plots for Level II monitoring. The variation in assessment frequency results in different numbers of plots with data submission for the different surveys.

ICP Forests and FutMon monitor the same plots, with the data collected by participating countries. Data were submitted for more than 7000 permanent observation plots in 2009. These 'Level I' plots are representative of forests within the countries concerned and occur at a density of one per 256 km². In many countries the Level I plots are linked to the national forest inventory systems. As well as annual crown condition surveys, soil chemistry was assessed in the mid-1990s and again about ten years later. Biodiversity has been assessed on ~ 4000 plots and foliar chemistry on a much smaller number of plots.

The effects of stress factors on forest ecosystems are investigated through intensive monitoring on so-called 'Level II' plots. These plots are located in forests representative of the most important European forest ecosystems. Data collection is under national responsibility. It follows harmonized procedures documented in regularly updated manuals. Owing to new data submission and validation routines, this report includes data up to and including 2007 only. Variation in the number of plots monitored each year reflects variation in sampling frequencies. Data were submitted for 462 plots in 2007. Under FutMon, Level II monitoring has been restructured such that a larger number of surveys are carried out on a smaller number of plots.

Table 1-2: Surveys and number of plots for Level I monitoring

	Frequency	Number of plots with data
Crown condition	Annually	8388[1] / 6791[2]
Foliar chemistry	Once	1497
Soil chemistry	1994-1996	5289
	2005/06	4027[3]
Biodiversity (tree growth, ground vegetation, deadwood)	2006/07	3379[3]

[1] all plots in the data base

[2] plots with data submitted for 2009

[3] data assessed under the BioSoil project

Further information:

http://www.icp-forests.org

http://www.futmon.org

http://ec.europa.eu/life

Harmonized methods enable monitoring across different forest types: Pine stand in Turkey.

2. FOREST CONDITION SHOWS LITTLE CHANGE

Summary

- *There were no significant changes in crown condition over the past ten years on two-thirds of the plots, but deterioration prevailed on the remaining third.*
- *In 2009, a fifth of the 136 778 trees studied were considered damaged or dead.*
- *Trends vary between species, with European and sessile oak the most frequently damaged species. However, both have shown some recovery over the past five years. The health of Norway spruce and Scots pine has improved over the past 18 years. Defoliation in common beech, holm oak and maritime pine has increased.*

Defoliation indicates tree health across large areas

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

In 2009, crown condition data were submitted for 7193 plots in 30 countries. In total, 136 778 trees were assessed. This constitutes the programme's largest number of plots for which annual data were submitted. This particularly large number of plots is mainly due to the ongoing installation of monitoring plots in Turkey and Russia, and to the re-approved co-financing of monitoring activities within the EU in 2009 which led to assessments on a larger number of plots than in previous years.

A fifth of all trees assessed were damaged

In 2009, 20.2 % of all trees assessed had a needle or leaf loss of more than 25 % and were thus classified as either damaged or dead (Fig. 2-1). This represents no change relative to 2008. Of the main tree species, European and sessile oak had the highest levels of damaged and dead trees, at 31.8 %.

Changes in forest health vary across regions and species

There has been no significant change in tree health on most plots monitored over the past ten years. Defoliation increased on 24.4 % of plots monitored and decreased, indicating an improvement in crown condition, on only 14.9 % (Fig. 2-3). Over the past 18 years there has been a clear improvement in crown condition for Scots pine and a slight improvement for Norway spruce. European and sessile oak have shown the highest mean defoliation over the past decade. Defoliation peaked after the extremely dry and warm summer in 2003 and has been slowly re-

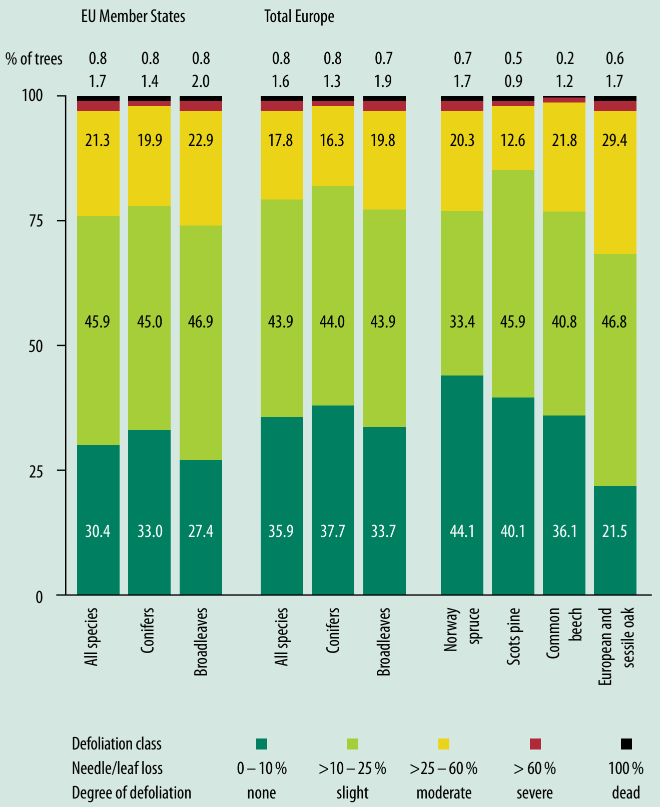


Figure 2-1: Extent of defoliation for the main European tree species. Total Europe and EU, 2009.

Figure 2-2: Mean percentage defoliation for the most frequent tree species in European forests. Samples only include countries with continuous data submission.

covering since 2007. Defoliation of common beech peaked in 2004, while holm oak showed a sharp deterioration in crown condition in the mid-1990s and again in 2005. Unfavourable weather conditions are thought to be responsible for these trends. There was a reasonably consistent increase in defoliation of maritime pine up to 2005, followed by a short period of recovery after which crown condition again deteriorated in 2009.

Defoliation is an indicator of tree health and vitality that can be easily monitored over large areas and which reacts to many different factors, including climatic conditions and weather extremes as well as insect and fungal infestations. Deposition of pollutants from the air can affect soil and site conditions and thus the condition of forest trees. The status and trends in forest condition vary regionally and for different species. Local conditions may differ from the European average. Defoliation represents a valuable early warning system for the response of the forest ecosystems to change – this is particularly relevant as climatic extremes are predicted to occur more frequently in the relatively near future.

Quality assurance and control: Leaders of different national teams regularly assess the same forest stands.

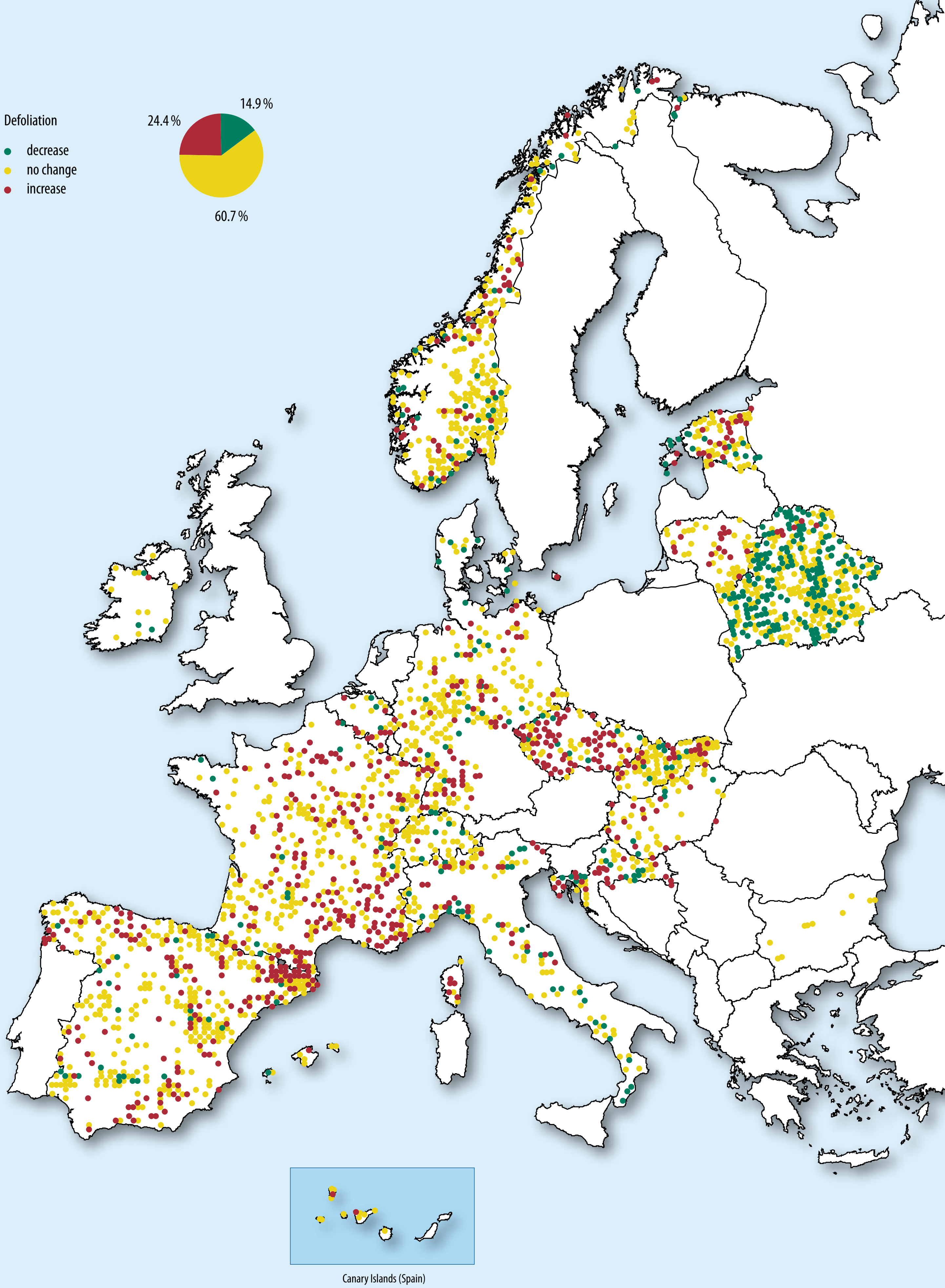


Figure 2-3: Change in defoliation for all tree species over the period 1998 to 2009. For some countries and regions changes in plot location prevent this assessment.

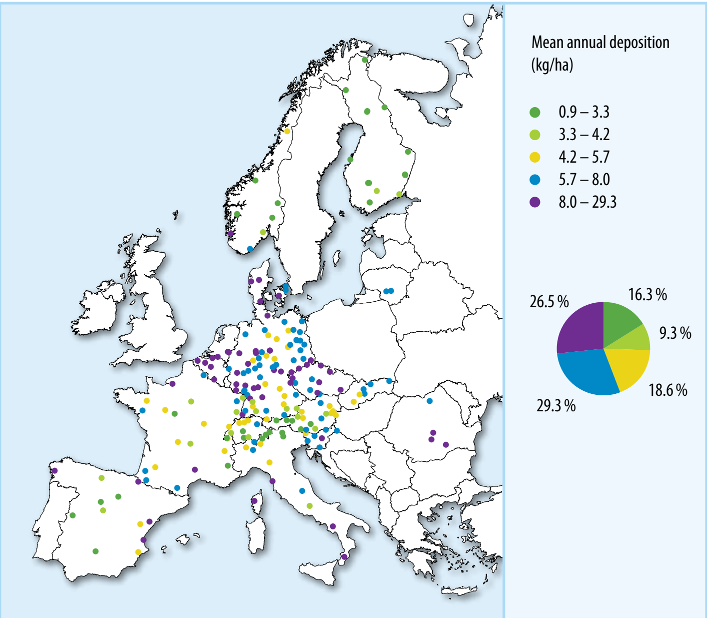


Figure 3-1: Mean annual sulphate sulphur (S-SO$_4^{2-}$) throughfall deposition for 2005 to 2007. Highest inputs were measured in central Europe.

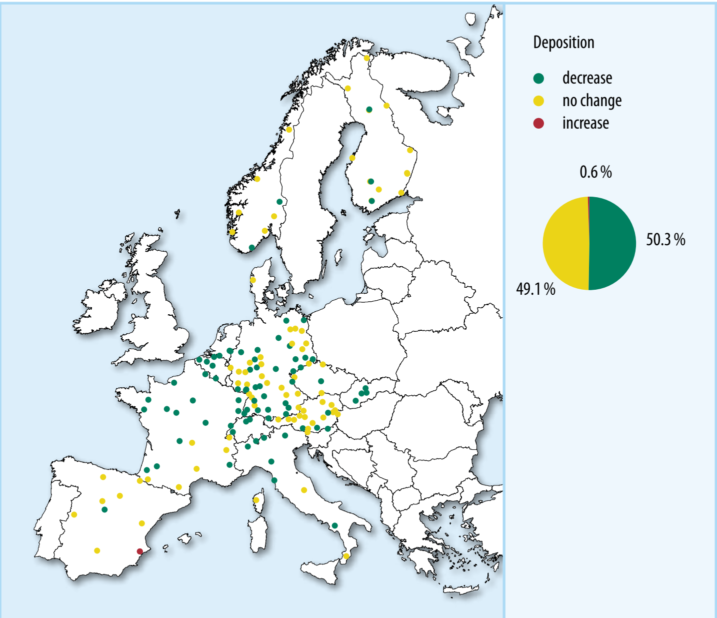


Figure 3-2: Trends in sulphate sulphur (S-SO$_4^{2-}$) in throughfall deposition from 1998 to 2007. Sulphate inputs decreased on nearly half of the plots.

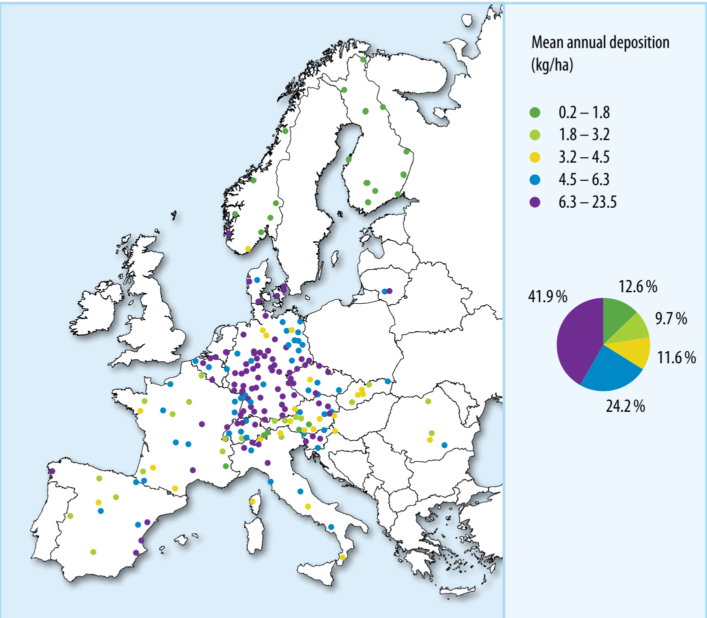


Figure 3-3: Mean annual nitrate nitrogen (N-NO$_3^-$) throughfall deposition for 2005 to 2007. Industry and traffic exhaust cause most of these emissions.

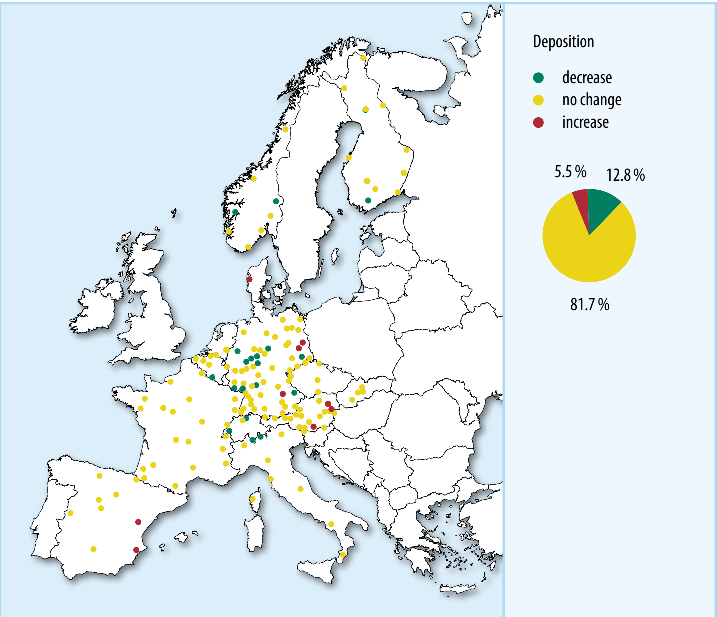


Figure 3-4: Trends in nitrate nitrogen (N-NO$_3^-$) throughfall deposition from 1998 to 2007 show an unchanged situation on around 80% of the plots.

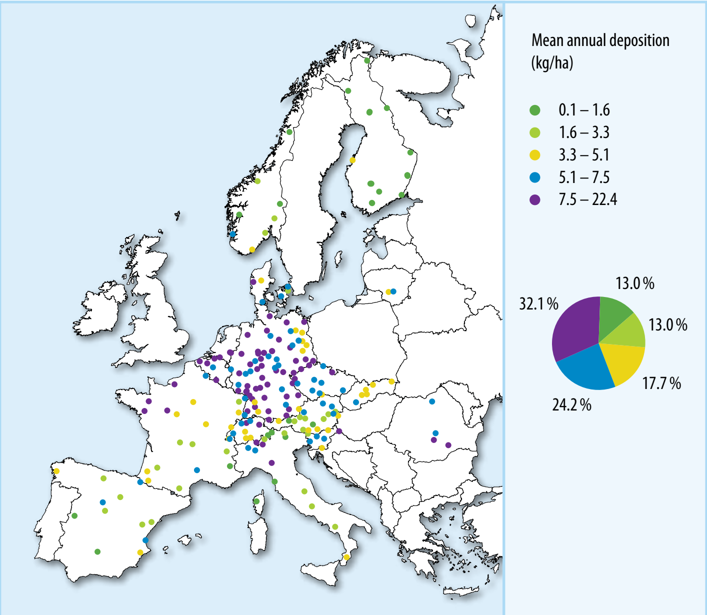


Figure 3-5: Mean annual ammonium nitrogen (N-NH$_4^+$) throughfall deposition for 2005 to 2007. Animal husbandry is a major source for these emissions.

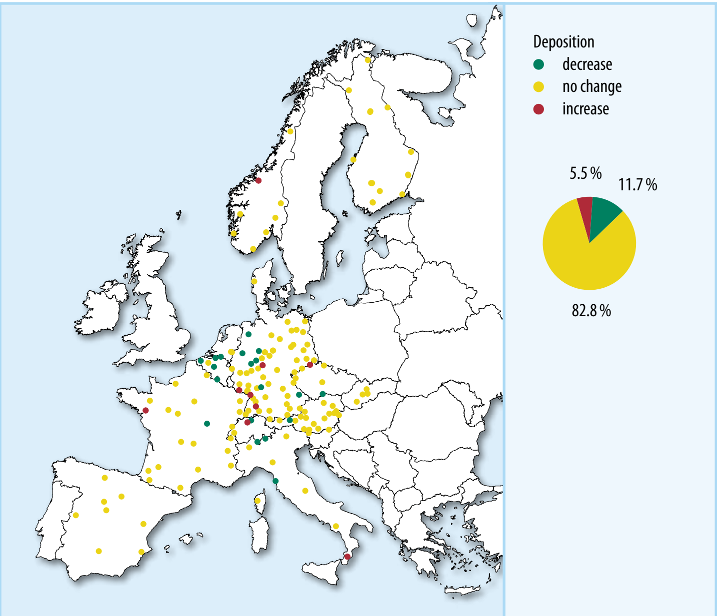


Figure 3-6: Trends in ammonium nitrogen (N-NH$_4^+$) throughfall deposition from 1998 to 2007 reveal some plots with increasing deposition.


Nutrient cycles in the forest: Different types of deposition samplers are being tested in Slovenia.

3. FURTHER NITROGEN EMISSION REDUCTIONS ARE CLEARLY REQUIRED

Summary

- *Mean annual sulphur inputs decreased by 30 % between 1998 and 2007, with significant reductions measured on half of the plots. These findings are based on deposition measurements made under the forest canopy on 157 plots located mostly in central Europe. Mean nitrogen inputs showed little change or only a very small decrease.*
- *The downward trend in sulphur deposition reflects the success of the clean air policies under the UNECE and the EU for sulphur emissions. In contrast, the nitrogen deposition data indicate a clear need for further reductions in nitrogen emissions.*
- *Deposition is generally higher on central European plots than on plots in northern and southern Europe.*

Forests more affected than open field sites

On average, throughfall deposition in forests is higher than deposition on open field sites because trees filter dust and other dry deposition from the air which is then washed from the foliage to the forest floor by rain. Between 1998 and 2007, sulphate deposition on the open field sites fell by 26 %; from 6.1 to 4.5 kg per hectare per year. The decrease in sulphate throughfall deposition (measured below the forest canopy) was higher at 34 %; from 10.0 to 6.6 kg per hectare per year (Fig. 3-7). Collectively, about half the plots showed a significant reduction in sulphur inputs over the 10-year study period. The data are mean values from around 150 measurement stations located mainly in central Europe.

Mean nitrogen deposition within the forest stands fluctuated (for nitrogen measured as nitrate and ammonium) and few plots showed significant changes in throughfall deposition. There was a slight decrease in mean nitrogen deposition at the open field plots (Fig. 3-8).

The deposition data show the success of the clean air policies under the UNECE and the EU for sulphur emissions, and show the need for further reductions in nitrogen emissions.

Levels and trends in deposition vary across Europe

Most plots with high nitrate and ammonium deposition are located in central Europe from the north of Italy to Denmark. The highest sulphate inputs were to sites in central Europe and on parts of the investigated plots in the Mediterranean region. Sulphate inputs to plots near the coasts can be of natural maritime origin as seawater contains sulphate which is transported to the land surfaces in spray. Studies have shown this to be the case for plots in Denmark and partly for plots in the Mediterranean re-

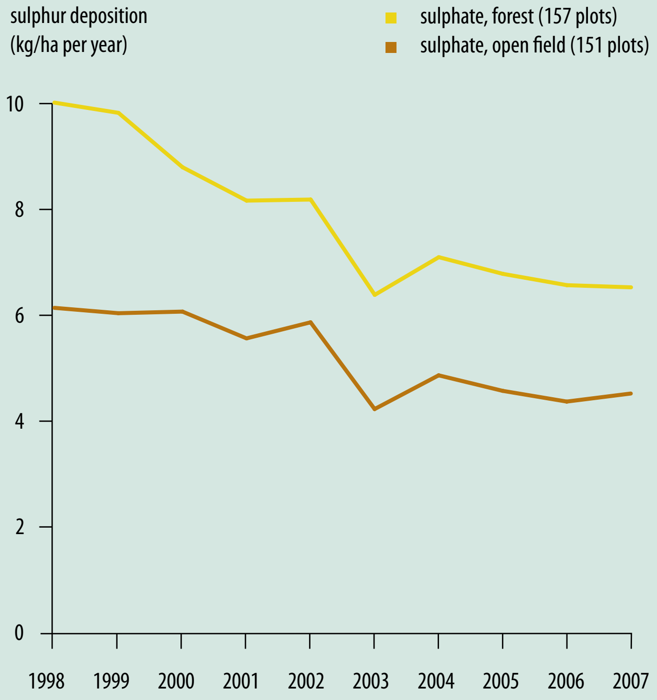


Figure 3-7: Development of mean deposition of sulphate from 1998 to 2007. The forest canopy filters pollutants from the air. Inputs within the forest stands are higher than in the open field. In 2003 there was less precipitation and thus less deposition.

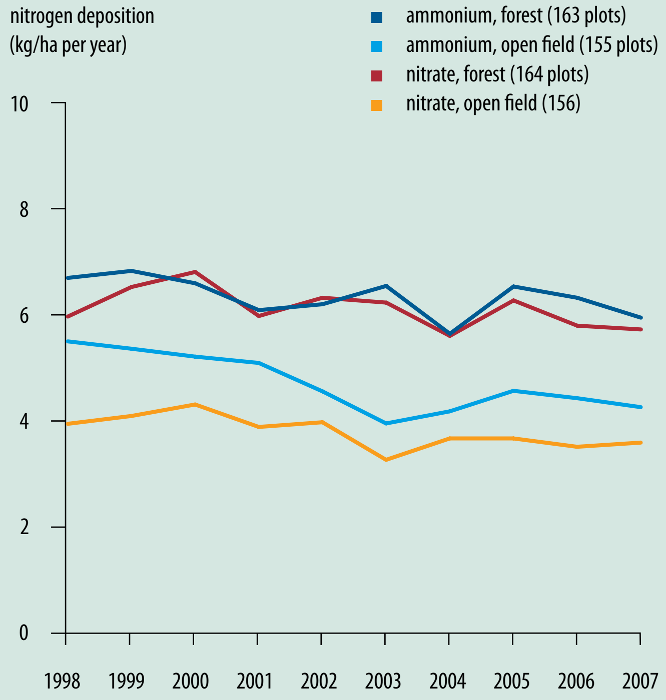


Figure 3-8: Development of mean plot deposition of nitrogen compounds (number of plots) from 1998 to 2007. Some reductions are visible in open field measurements. There was little change in deposition for the forest stands over the 10 years of observation.

gion. However, across all plots in Europe, 80 % of the sulphate inputs are of human origin (Figs. 3-1 to 3-6).

The amounts of sulphur and nitrogen deposited on forest ecosystems are not directly correlated to the impacts. The impacts depend on the specific site and stand conditions on the monitoring plots. So-called 'critical limits' and 'critical loads' are calculated by ICP Forests to determine the effects of soil status and soil acidification as well as of the atmospheric deposition on the European forests (see Section 4).

Deposition fluxes and their assessment

ICP Forests began deposition measurements on intensive (Level II) monitoring plots in the latter half of the 1990s. Measurements are carried out within the forest stands (throughfall deposition) and in nearby open fields (bulk deposition). In the forest canopy, some elements can be leached from the foliage and increase the measured deposition load, whereas others are taken up by leaves and needles and are so not detected in throughfall. Bulk deposition is mostly lower than throughfall deposition because of the additional deposition loads filtered from the air by the forest canopy. Thus, neither throughfall deposition nor bulk deposition are equal to the total deposition received by the forest stands. However, throughfall deposition is presented here as this reflects the inputs reaching the forest floor and so these measurements are of greater ecological relevance to forest ecosystems than open field measurements. On the plots, samples are collected weekly, fortnightly or monthly and are analysed by national experts. After intensive quality checks, annual mean deposition for the years 1998 to 2007 was calculated for plots with complete data sets. Slopes of plotwise linear regressions of deposition over time were tested for significance. Plot-specific means were calculated for the period 2005 to 2007.

4. Soil acidification remains a threat to forest vegetation

Summary

- *Critical limits for threats to forest vegetation caused by soil acidification were exceeded at around half of the samplers. At a quarter of the samplers, critical limits were substantially exceeded.*
- *There was little change in soil acidification on 111 plots evaluated between 2000 and 2006. Soil water was analysed for nutritional status (base cation to aluminium ratio) and pH.*
- *Atmospheric deposition contributes to changes in soil chemistry and soil water chemistry. Soil acidification and nutrient imbalances result in stress reactions and can destabilize forest ecosystems.*

Atmospheric deposition affects forest soils and vegetation

Atmospheric deposition of sulphur and nitrogen affects soils and the nutrient cycles within the forest ecosystems. Nutrient imbalances and deficiencies can result in reduced growth, fine root dieback and general stress reactions in the vegetation such as excessive flowering and increased susceptibility to weather extremes.

Chemical analyses indicate soil status

Regular analyses of the soil water chemistry on intensive forest monitoring plots makes it possible to estimate the risk of forest damage. pH values indicate the extent of soil acidification and the base cation to aluminium (BC/

Measurement equipment for soil water analyses

Soil water is continuously extracted from different soil depths on the monitoring plots using so-called 'lysimeters', mostly tension lysimeters. These consist of a suction cup which is dug into the soil and at which a permanent vacuum is applied, thus sucking out the water from the pores in the soil. The water is collected for regular analysis in the laboratory. PH was calculated for all samplers that provided data continuously from 2000 to 2006 with at least four different analyses per monitoring year. Trends in the BC/Al ratio were calculated for all samplers that provided data continuously from 2000 to 2006 and at least six single analyses per monitoring year. Using these criteria, linear trends for BC/Al were calculated for 111 samplers on 58 plots, and for pH for 166 samplers at 66 plots.

Al) ratio is used to estimate the risk of damage to the vegetation from acidified soil. Risk is estimated by reference to thresholds below which harmful effects to the forest vegetation are not expected to occur. These thresholds are termed 'critical limits'. Data from 160 plots with continuous measurements for periods of at least four years up to 2006 were used for comparing BC/Al ratios to critical limits. Time trends for critical limits and for pH were only calculated for plots with continuous data submission over seven years.

Critical limits are exceeded

At around one quarter of the samplers the critical BC/Al ratio was substantially exceeded. Critical limits were not exceeded at 46.2 % of the samplers, but were permanently exceeded at 3.8 % of the samplers (see Fig. 4-1). Critical limit exceedances were analysed for single plots (see Fig 4-3). The greatest exceedances occurred on central European and Danish plots. Soil water was analysed for different depths. Spatial patterns were the same for all soil depths analysed.

Little change in soil water chemistry

Trends for critical limit exceedance and pH showed little change between 2000 and 2006. The BC/Al ratio was below 1 on around one quarter of the plots and soil water pH was below 5 on 40 % to 50 % of the plots for the entire period (Fig. 4-2). The monitoring data show the need for further emission reductions. The lack of change in the level of soil acidification on many plots constitutes a risk for forest ecosystem stability. The rooting system of the forest trees and thus their nutrition is impaired by acidified soil water. Higher storm damage on acidified plots has already been reported from the monitoring sites.

Left: Forest soils are analyzed using lysimeters (top) and soil profiles (bottom), Belgium.

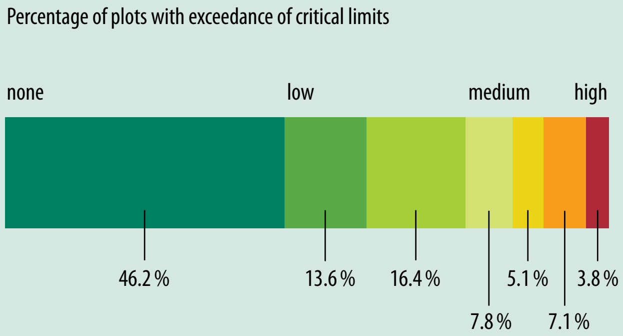


Figure 4-1: Critical BC/Al limit exceedance from 396 samplers on 160 intensive monitoring plots. The critical limits are a chemical indicator for estimating risks to vegetation resulting from soil acidification (all soil depths).

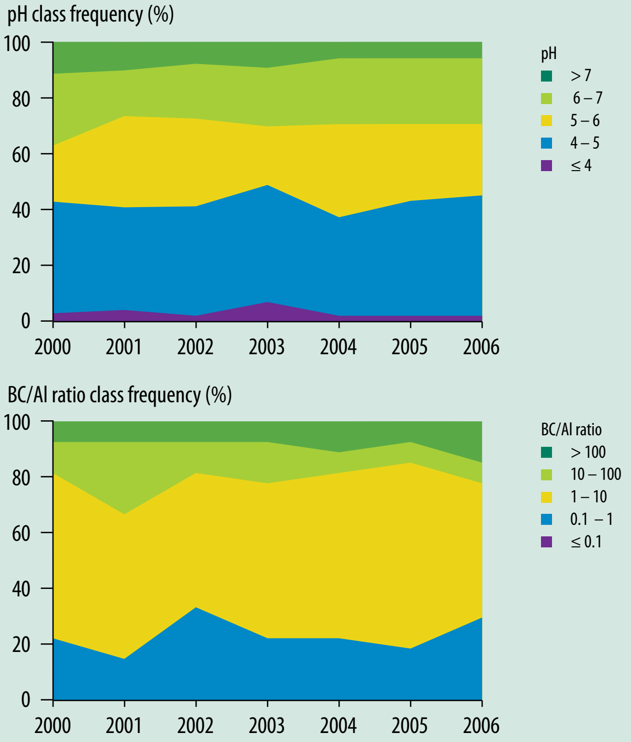


Figure 4-2: pH classes (51 plots, top) and BC/Al ratio (27 plots, bottom) in soil water. There is no trend apparent. However, on many plots measurements only began after acidic inputs had already been reduced.

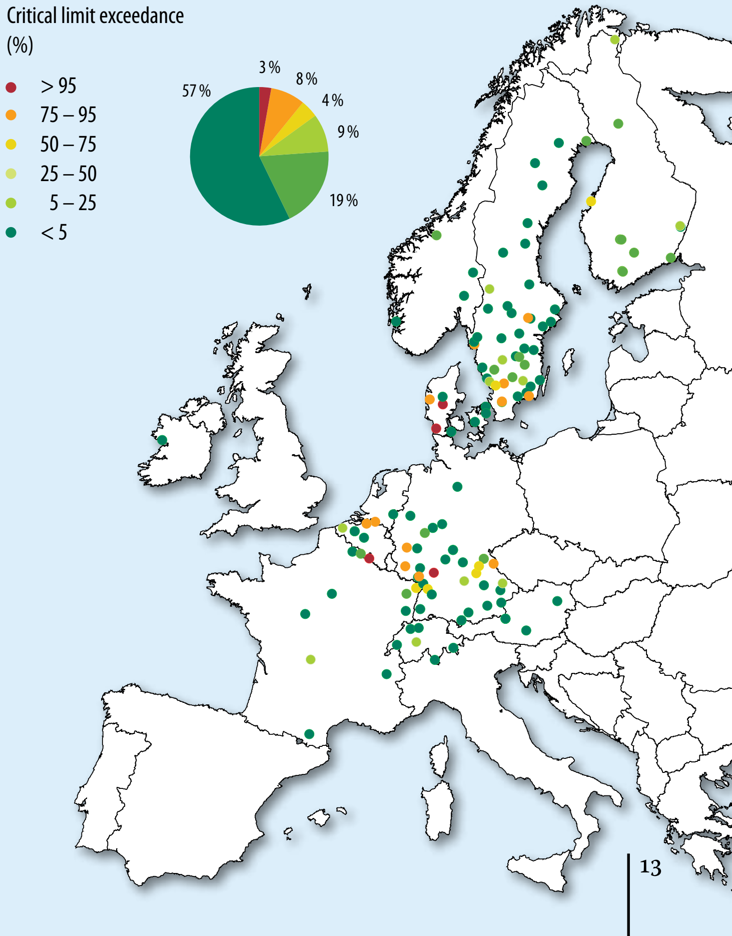


Figure 4-3: Plotwise critical BC/Al limit exceedance. There is no distinct pattern of exceedance across the plots in Europe (40-80 cm soil depth).

5. NITROGEN DEPOSITION ALTERS PLANT SPECIES COMPOSITION

Summary

- *Nitrogen deposition is clearly affecting the species composition of ground vegetation on the monitoring plots. Results are consistent for different data sets based on between 181 and 477 plots.*
- *Plant species composition on the plots changed due to nitrogen deposition. Species that can tolerate a lower nutrient status were less dominant after an evaluation period of six years.*
- *In view of the unchanged nitrogen inputs this calls for a reduction in nitrogen emissions. A change in nitrogen status is not only linked to alterations in vegetation composition but can also affect forest ecosystem stability, forest growth and water filtering functions.*

Ground vegetation is a good bioindicator for environmental change

Ground vegetation is an important component of the biological diversity in forest ecosystems. It plays a major role in the nutrient and water cycles and many animal and fungal species depend on it. The data provide an excellent basis for examining shifts in species composition and for exploring links with atmospheric nitrogen deposition.

Comprehensive data sets enable advanced statistical evaluations

Ground vegetation data were available for 776 plots. Complete data sets with information on ground vegetation species, the main tree species present, soil chemistry, climate (including altitude and geographical location) and modelled atmospheric deposition were available for 477 intensive monitoring plots for the years to 2006 (Fig. 5-1). Measured deposition was available for 181 plots. Using statistical tools, up to 19 % of the variance in the ground vegetation could be explained by change in different environmental factors. However, forest ecosystems host many species and are too complex to be fully explained by statistical methods.

Changes in species composition were examined using 'Ellenberg indicators'. These quantify ecological requirements for single plant species. Only plots with an interval of more than six years between the first and last assessment were included. Multiple regression analysis was used to find the correlation between environmental variables and change in those indicators.

Present vegetation composition related to deposition

The data indicate that the composition of the ground vegetation is strongly related to well known site and stand factors. The main tree species growing on the plots most strongly determined the plant species composition on the forest floor. The influence of climatic factors and soil properties was also confirmed. But in contrast to earlier evaluations based on shorter time series and smaller data sets there are now clearly significant effects of nitrogen deposition on the ground vegetation (Fig. 5-2). Additional calculations using vegetation data from 477 intensive monitoring plots in combination with modelled rather than measured deposition data confirm the deposition effect.

Nitrogen deposition: a driver for change in plant species composition

Species that indicate a higher nitrogen status are clearly increasing on the monitoring plots. There was a significant change in the respective indicators. The shift in ground vegetation species composition is linked to many environmental influences, but nitrogen deposition is clearly a major factor. Nitrogen inputs are driving change towards more nitrogen tolerant plant species. In fact, nitrogen deposition is of greater importance as an explanation of change in composition than it is as an explanation of the present composition (Fig 5-3). National evaluations confirm these results. French and Swiss data also suggest that the opening of the forest canopy by storms results in changes in light and temperature regimes that induce change in ground vegetation composition. Browsing by game should also be considered.

At present, the ground vegetation does not indicate change in temperature or soil moisture. The time interval examined, however, is very short and as the time series become longer more ecological trends may become apparent. For many plots, vegetation assessments only began at a time when ecological conditions had already changed.

Left: Ground vegetation aspect in Norway.

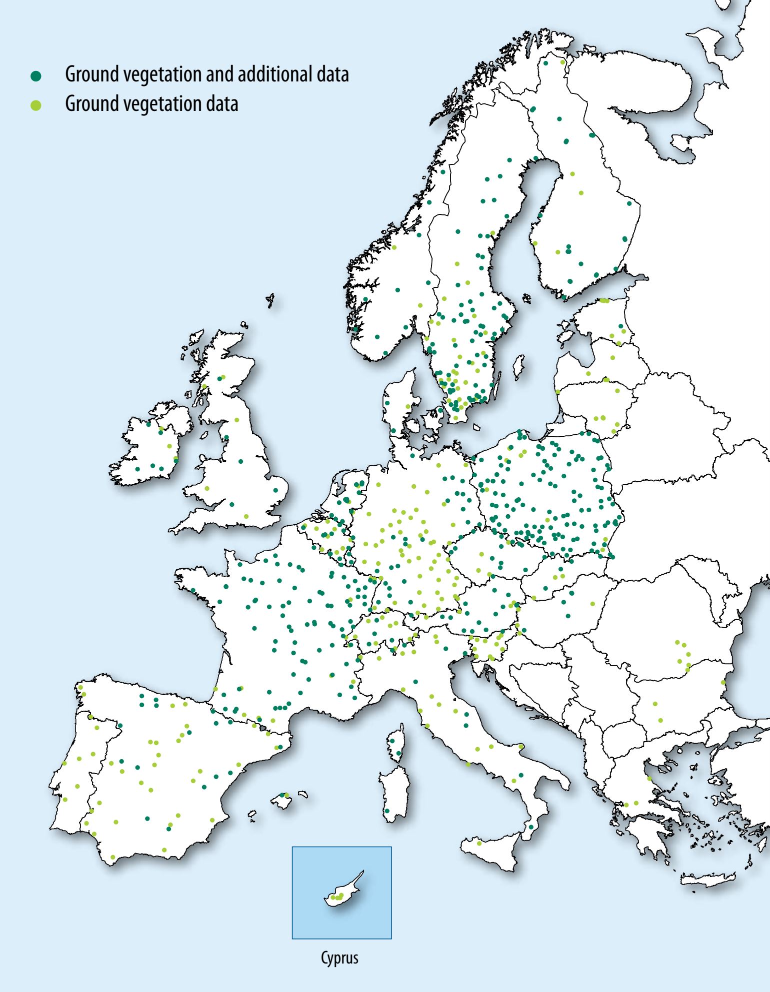


Figure 5-1: Data sets used for the ground vegetation study.

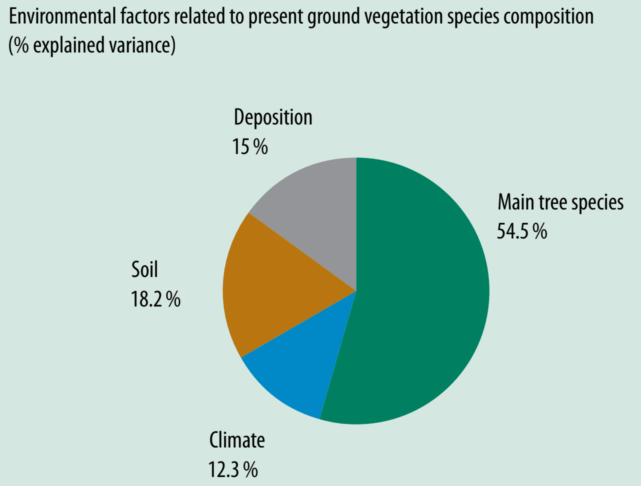

Environmental factors related to present ground vegetation species composition (% explained variance)

Figure 5-2: Environmental factors related to present ground vegetation species composition on 181 intensive monitoring plots. 'Traditional' factors including tree species, climate and soil had the strongest influence on species composition, but deposition was also important. Overall 19 % of the variance in ground vegetation could be explained .

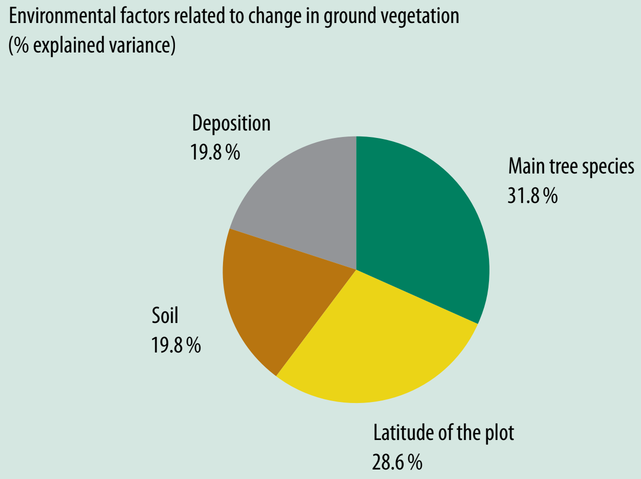

Environmental factors related to change in ground vegetation (% explained variance)

Figure 5-3: Factors linked to change in ground vegetation species composition towards higher nitrogen status on 42 intensive monitoring plots. Overall 38 % of the variation in change in ground vegetation could be explained.

CONCLUSIONS

An expanding forest monitoring system celebrates 25 years

For 25 years, forest condition has been monitored by ICP Forests in close cooperation with the European Commission. Today the joint programme is the largest terrestrial forest monitoring network in the world. In 2010, the number of Level I plots was the largest in the history of the programme. The ongoing installation of an ICP Forests monitoring system in Russia and Turkey contributed to this increase. At the intensive monitoring level the collaboration with the US Department of Agriculture Forest Service has been intensified, aiming at the further installation of Level II plots and the calculation of critical loads following the UNECE standards for the United States. The system combines an inventory approach with intensive monitoring. It provides reliable and representative data on forest ecosystem health and vitality and helps to detect responses of forest ecosystems to the changing environment. The data collected so far provide a major input for several international programmes and initiatives, such as the Convention on Long-range Transboundary Air Pollution (CLTRAP) and the Ministerial Conference for the Protection of Forests in Europe (MCPFE).

The programme provides an early warning system for stresses such as air pollution and climate change

In the early 1980s, a dramatic deterioration in forest condition was observed in Europe and this initiated the implementation of forest condition monitoring under CLRTAP. Today, the monitoring results indicate that, at the large-scale, forest condition has deteriorated far less severely than was feared at that time. Stress factors like insects, fungi and weather effects have been shown to affect tree health. The drought in the Mediterranean region in the mid-1990s and the extremely warm and dry summer across large parts of Europe in 2003 led to increased levels of defoliation as a natural reaction of trees to this type of stress. The programme has also reported on acidifying deposition which is regionally correlated with defoliation and on atmospheric inputs that are accentuating other stress factors. In the past three years there has been little change in the mean levels of defoliation for the main European tree species. However, long-term trends show more deterioration than improvement. It is very likely that Europe may have to face the effects of climate change in the near future, including the alteration of natural ecosystems, changing agricultural, forestry and fisheries productivity, and increased risk of floods, erosion, and wetland loss. Although (forest) species have responded to environmental change throughout their evolutionary history,

a primary concern for forest ecosystems is the rapid rate of human-induced change.

Nitrogen inputs remain a driving force for change in biodiversity and forest condition

Atmospheric deposition has been the specific focus of the programme since its inception. Current evaluations show decreasing sulphur inputs on about 50% of around 150 intensive monitoring plots since 1998, which is a result of clean air policies under the LRTAP Convention and EU legislation. However, critical limits in the soil water are still substantially exceeded on a quarter of the plots and indicate a potential threat to forest vegetation. Earlier studies conducted under the programme have shown that the risk of storm damage is higher on acidic soils. Nitrogen inputs have hardly changed over the past ten years and the data sets now show shifts in the composition of forest ground vegetation towards more nitrogen tolerant species. Atmospheric deposition is a driver for these changes in biodiversity. Another effect of nitrogen deposition is increased tree growth which was found on intensive monitoring plots across Europe.

Cooperation and further development remain important

Today, most countries of the pan-European region participate in the programme, which became one of the main data providers for the Ministerial Conference for the Protection of Forests in Europe. Contributions have also been made to the Forest Resource Assessment, the Convention on Biological Diversity, and other international initiatives and programmes. The continued cooperation with the Acid Deposition Monitoring Network in East Asia (EANET) aims at mutual benefits from scientific cooperation and at the harmonization of methods. Under the FutMon project links between the Level I large-scale network and national forest inventories have been further developed in order to provide synergies for both systems at national level and to streamline European reporting. At Level II, an intensification of the assessments along with a reduction in the number of sites will make it possible to run complex ecological models requiring more comprehensive data sets.

Future cooperation with the European Commission depends on the outcome of political decisions which could mean a risk for the full implementation of the restructured monitoring system. The strong national commitments under ICP Forests and the active involvement of national experts will help to meet new challenges arising from air pollution, biodiversity loss and climate change effects on forests, as well as the increasing importance of forests as a source of renewable resources. This constitutes the basis for a programme, adapted to future information needs.

Annex I: Forest surveys and defoliation classes for all tree species in European countries (2009)

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

Participating countries	Forest area (× 1000 ha)	% of forest area	Grid size (km × km)	No. of sample plots	No. of sample trees	Defoliation of all species by class (aggregates), national surveys		
						0	1	2-4
Albania	1063	37.0			no survey in 2009			
Andorra	18		16 × 16	3	73	60.3	32.9	6.8
Austria	3878	46.2			no survey in 2009			
Belarus	7921	38.2	16 × 16	409	9620	27.7	63.9	8.4
Belgium	700	23.1	4^2 / 8^2	122	2858	30.7	49.1	20.2
Bulgaria	3699	33.3	4^2 / 8^2 / 16^2	159	5560	29.6	49.3	21.1
Croatia	2061	36.5	16 × 16	83	1991	37.2	36.5	26.3
Cyprus	298	32.2	16 × 16	15	362	3.0	60.8	36.2
Czech Republic	2647	33.6	8^2 / 16^2	133	5284	11.7	31.5	56.8
Denmark	527	12.2	7^2 / 16^2	16	384	69.0	25.5	5.5
Estonia	2213	49.1	16 × 16	92	2202	44.3	48.5	7.2
Finland	20150	66.3	16^2 / 24 × 32	886	7182	58.2	32.7	9.1
France	15840	28.9	16 × 16	500	9949	28.7	37.8	33.5
Germany	11076	31.0	16^2 / 4^2	424	10376	36.4	37.1	26.5
Greece	2034	19.5		89	2098	42.2	33.5	24.3
Hungary	1904	22.5	16 × 16	78	1872	54.8	26.8	18.4
Ireland	680	6.3	16 × 16	30	599	69.9	17.5	12.5
Italy	8675	28.8	16 × 16	257	6966	24.5	39.7	35.8
Latvia	3162	49.0	8 × 8	340	8036	17.0	69.2	13.8
Liechtenstein	8	50.0			no survey in 2009			
Lithuania	2150	32.9	8 × 8 / 16 × 16	983	5961	18.6	63.7	17.7
Luxembourg	89	34.4			no survey in 2009			
FYR of Macedonia					no survey in 2009			
Rep. of Moldova	318	9.4	2 × 2	622	13676	43.1	31.7	25.2
The Netherlands	334	9.6			no survey in 2009			
Norway	12000	37.1	3^2 / 9^2	1622	9332	43.1	35.8	21.0
Poland	9200	29.4	16 × 16	1923	38460	24.1	58.2	17.7
Portugal	3234	36.4			no survey in 2009			
Romania	6233	26.1	16 × 16	227	5448	44.1	37.0	18.9
Russian Fed.	809090	73.2		365	11016	80.0	13.8	6.2
Serbia	2360		16 × 16 / 4 × 4	130	2765	68.1	21.6	10.3
Slovak Republic	1961	40.0	16 × 16	108	4049	9.3	58.6	32.1
Slovenia	1099	54.2	16 × 16	44	1056	18.2	46.4	35.5
Spain	11588	30.9	16 × 16	620	14880	17.8	64.4	17.7
Sweden	28300	69.0	varying	3217	7097	59.9	25.1	15.0
Switzerland	1186	28.7	16 × 16	48	1040	32.3	49.4	18.3
Turkey	21389	27.5	16 × 16	563	12290	25.1	56.2	18.7
Ukraine	9400	15.4	16 × 16	1483	34498	66.4	26.8	6.8
United Kingdom	2837	11.7			no survey in 2009			
Total	1011322		varying	15591	236980			

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 (1998-2009)

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

Participating countries	All species Defoliation classes 2–4												Change % points
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2008/2009
Albania	9.8	9.9	10.1	10.2	13.1		12.2		11.1				
Andorra							36.1		23.0	47.2	15.3	6.8	-8.5
Austria	6.7	6.8	8.9	9.7	10.2	11.1	13.1	14.8	15.0				
Belarus	30.5	26.0	24.0	20.7	9.5	11.3	10.0	9.0	7.9	8.1	8.0	8.4	0.4
Belgium	17.0	17.7	19.0	17.9	17.8	17.3	19.4	19.9	17.9	16.4	14.5	20.2	5.7
Bulgaria	60.2	44.2	46.3	33.8	37.1	33.7	39.7	35.0	37.4	29.7	31.9	21.1	-10.8
Croatia	25.6	23.1	23.4	25.0	20.6	22.0	25.2	27.1	24.9	25.1	23.9	26.3	2.4
Cyprus				8.9	2.8	18.4	12.2	10.8	20.8	16.7	47.0	36.2	-10.8
Czech Rep.	48.8	50.4	51.7	52.1	53.4	54.4	57.3	57.1	56.2	57.1	56.7	56.8	0.1
Denmark	22.0	13.2	11.0	7.4	8.7	10.2	11.8	9.4	7.6	6.1	9.1	5.5	-3.6
Estonia	8.7	8.7	7.4	8.5	7.6	7.6	5.3	5.4	6.2	6.8	9.0	7.2	-1.8
Finland	11.8	11.4	11.6	11.0	11.5	10.7	9.8	8.8	9.7	10.5	10.2	9.1	-1.1
France	23.3	19.7	18.3	20.3	21.9	28.4	31.7	34.2	35.6	35.4	32.4	33.5	1.1
Germany	21.0	21.7	23.0	21.9	21.4	22.5	31.4	28.5	27.9	24.8	25.1	26.5	1.4
Greece	21.7	16.6	18.2	21.7	20.9			16.3					
Hungary	19.0	18.2	20.8	21.2	21.2	22.5	21.5	21.0	19.2	20.7		18.4	
Ireland	16.1	13.0	14.6	17.4	20.7	13.9	17.4	16.2	7.4	6.0	10.0	12.5	2.5
Italy	35.9	35.3	34.4	38.4	37.3	37.6	35.9	32.9	30.5	35.7	32.8	35.8	3.0
Latvia	16.6	18.9	20.7	15.6	13.8	12.5	12.5	13.1	13.4	15.0	15.3	13.8	-1.5
Liechtenstein													
Lithuania	15.7	11.6	13.9	11.7	12.8	14.7	13.9	11.0	12.0	12.3	19.6	17.7	-1.9
Luxembourg	25.3	19.2	23.4										
FYR of Macedonia													
Rep. of Moldova			29.1	36.9	42.5	42.4	34.0	26.5	27.6	32.5	33.6	25.2	-8.4
The Netherlands	31.0	12.9	21.8	19.9	21.7	18.0	27.5	30.2	19.5				
Norway	30.6	28.6	24.3	27.2	25.5	22.9	20.7	21.6	23.3	26.2	22.7	21.0	-1.7
Poland	34.6	30.6	32.0	30.6	32.7	34.7	34.6	30.7	20.1	20.2	18.0	17.7	-0.3
Portugal	10.2	11.1	10.3	10.1	9.6	13.0	16.6	24.3					
Romania	12.3	12.7	14.3	13.3	13.5	12.6	11.7	8.1	8.6	23.2		18.9	
Russian Fed.				9.8	10.9								
Serbia	8.4	11.2	8.4	14.0	3.9	22.8	14.3	16.4	11.3	15.4	11.5	10.3	-1.2
Slovak Rep.	32.5	27.8	23.5	31.7	24.8	31.4	26.7	22.9	28.1	25.6	29.3	32.1	2.8
Slovenia	27.6	29.1	24.8	28.9	28.1	27.5	29.3	30.6	29.4	35.8	36.9	35.5	-1.4
Spain	13.6	12.9	13.8	13.0	16.4	16.6	15.0	21.3	21.5	17.6	15.6	17.7	2.1
Sweden	14.2	13.2	13.7	17.5	16.8	19.2	16.5	18.4	19.4	17.9	17.3	15.0	-2.3
Switzerland	19.1	19.0	29.4	18.2	18.6	14.9	29.1	28.1	22.6	22.4	19.0	18.3	-0.7
Turkey										8.1	24.6	18.7	-5.9
Ukraine	51.5	56.2	60.7	39.6	27.7	27.0	29.9	8.7	6.6	7.1	8.2	6.8	-1.4
United Kingdom	21.1	21.4	21.6	21.1	27.3	24.7	26.5	24.8	25.9	26.0			

Andorra: Observe the small sample size. *Austria:* From 2003 onwards results are based on the 16 × 16 km transnational grid net and must not be compared with previous years. *Cyprus:* Only conifers assessed. *Moldova:* Only broadleaved species assessed. *Poland:* Change of grid net since 2006. *Russian Federation:* North-western and Central European parts only. *Ukraine:* Change of grid net in 2005. *Hungary, Romania:* comparisons not possible due to changing survey designs.

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

ANNEX III

Photo references

Name	Page
Dan Aamlid	14
Adamus © www.fotolia.com	landscape 2/3
Nathalie Cools	12 (top)
Bruno De Vos	12 (bottom)
Federal Ministry for Food, Agriculture and Consumer Protection, Germany	3
Richard Fischer	4, 5, 6, landscape 16/17
General Directorate for Nature and Forest Policy, Spain	2
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