ICP Forests

LRTAP
Long-range Transboundary Air Pollution

The Condition of Forests in Europe

2012 Executive Report

2012

Institute for World Forestry

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The Condition of Forests in Europe

2012 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)

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Contents and Summary

The ICP Forests monitoring programme was established in 1985 under the auspices of the Convention on Long-range Transboundary Air Pollution. Results reported are based on more than 7000 Level I and 500 Level II plots. Today, 42 countries participate in the programme. ICP Forests monitors the status and development of European forest health and vitality and assesses the effects of various stress factors on forest ecosystems.

Around a fifth of all trees assessed in 2011 were rated as damaged. Coniferous forests are the most frequently occurring forests in Europe. They show lower levels of defoliation than deciduous forests. European and sessile oak had the highest proportion of damaged trees. Time series show continuously low defoliation in northern Europe. Worsening trends and peaks in defoliation in central and southern Europe are mostly related to drought.

Sulphur deposition to forests has substantially decreased in Europe over the past decades. Nitrogen deposition shows only small decreasing trends. More than half of the forests with high nitrogen deposition are nitrogen-saturated. Nitrate is leached from these sites. Nutrient imbalances are specifically occurring on plots with high nitrogen deposition loads. Imbalanced nutrition makes forests more sensitive to additional stress factors.

Climate scenarios project that forest growth will increase across Europe. This is mostly based on the assumption that the effects of CO_2 concentrations on productivity will continue to increase. With CO_2-concentrations fixed at current levels there would, however, be decreased growth in the south and increased growth in the north of Europe. Growth information is needed to project future timber supply and to support the development and adaptation of management regimes.

Preface

I am very proud to be able to introduce to you *The Condition of Forests in Europe: 2012 Executive Report* of the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). Poland hosted the Programme's Task Force Meeting in 2012 and has operated the forest monitoring programme since 1989.

This report is the result of a collective undertaking by 42 countries that acknowledge forests as a necessary and desirable part of the landscape, and forest sustainability as the key feature in protecting biological diversity, mitigating climate change effects and providing the source of renewable goods and services. All this underlines the great importance of the ICP Forests monitoring programme; the only programme in Europe devoted entirely to forest condition evaluation and complex analyses of ecosystem functioning at the level of the continent.

The ICP Forests monitoring programme was initiated over 25 years ago in a response to the growing fears of large-scale forest dieback related to air pollution. Since then, the programme has undergone considerable development enabling the system not only to detect changes in forest condition over space and time but also to address questions related to the cause-effect relationship between environmental drivers such as climate, pollution and atmospheric deposition, and forest growth, biological diversity, and the stability and health status of forests. The following report is an excellent example of the type of information we now have about the European forests. Today, the ICP Forests monitoring programme involves over 7000 extensive Level I plots, several hundred Level II and intensive monitoring plots, a team of around 300 scientists and forestry experts, supported by tens of analytical laboratories, and a network of collaborating institutions in all European countries. Harmonized methodology for data collection and the use of quality assurance procedures are another feature of the programme, that provides policy-relevant forest information at the regional, national and international levels.

Europe and the European Union in particular need reliable, sound and policy-relevant forest information now and in the future. To ensure the continued delivery of this vital information, a firm and stable financial framework is required with a long-term perspective. Poland supports the efforts undertaken in this matter by the European Commission and Member States.

I would like to thank everyone involved in the ICP Forests monitoring programme for their efforts to keep this programme running and wish you all continued success in the future.

Nina Dobrzyńska
Director of the Department of Forestry and Nature Conservation
Ministry of the Environment of Poland

Open field monitoring station, Germany

Intensive monitoring on a 'Level II' plot.

1. Harmonized pan-European forest monitoring

Data for forest management, nature conservation and policy making

Forests cover one third of Europe's land surface and 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 being used for recreational purposes. The forests have major value in terms of nature conservation and environmental protection, and are important in the context of climate change by acting as significant carbon sinks. 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.

Monitoring for the long term

The International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985. The programme operates under the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP) and provides regular updates on the condition of forests in Europe as a basis for the development of air pollution abatement strategies.

Over many years, ICP Forests has been closely cooperating with the European Union. The 'LIFE+' Regulation (EC No. 614/2007) is the most recent legal basis for co-financing the future development of forest monitoring in the EU, operating through the so-called 'FutMon' project during 2009 to 2011.

The monitoring activities provide information on a number of criteria and indicators of sustainable forest management as defined by the Forest Europe Ministerial Conference on the Protection of Forests in Europe. Data are also needed within the context of the Framework Convention on Climate Change (FCCC) and the Convention on Biological Diversity (CBD). The programme also maintains close contacts with the Acid Deposition Monitoring Network in East Asia (EANET).

Challenging objectives and a unique monitoring system

One aim of the monitoring under the ICP Forests programme is to assess the status and development of European forest health and vitality at the large scale. Another is to assess the effects of different stress factors on forest ecosystems. Air pollution effects were the original focus of the programme but other stress factors such as changes in climate and land use have been considered in recent years.

ICP Forests provides an important platform for information exchange, education and method harmonisation across Europe.

Data are collected by participating countries on up to 7000 permanent and representative observation plots, known as 'Level I' plots. In many countries the Level I plots are a subset of national forest inventory systems. In addition to the annual crown condition surveys, a demonstration project was carried out in 2006 on Level I plots and provided soil, growth and ground vegetation data for many of these plots.

Intensive monitoring is carried out on around 500 so-called 'Level II' plots (Table 1-1). These provide detailed data on trees, soil, water and meteorology and related stress factors and are located in forests that represent the most important forest ecosystems in Europe. Monitoring methodology has been documented from the start of the programme in a harmonized monitoring manual and has been further developed over time. Regular control analyses, laboratory intercomparisons and intercalibration courses ensure high data quality.

Survey	Number of plots		Frequency
	In data base[1)]	With data submission 2010	
Crown condition and damage	763	565	Annual
Tree growth	365	100	Every five years
Ground vegetation	316	254	Every five years
Phenology	228	131	Several times per year
Foliar chemistry	568	112	Every two years
Litterfall	294	172	Continuous
Ozone induced injury	147	124	Annual
Ambient air quality	301	164	Continuous
Atmospheric deposition	487	311	Continuous
Soil solution chemistry	293	206	Continuous
Solid soil chemistry	270	62	Every ten years
Meteorology	314	233	Continuous
Ground vegetation biomass[2)]	165	92	Once
Leaf area index[2)]	156	145	Continuous
Soil moisture/water[2)]	93	47	Once/Continuous

Table1-1: Level II data surveys, monitoring plots and assessment frequencies.
1) Plots with at least one year of data submission in the period 2006 to 2010.
2) New survey – only covers years 2009/10.

Lebanon cedars, Turkey

2. Deciduous trees show higher levels of damage than conifers

Summary

- *Coniferous forests are comparatively healthy with less than 15 % of trees classified as damaged in northern and southern Europe and less than 20 % as damaged in central Europe.*
- *Central and southern European oak, beech and mixed deciduous forests show higher levels of damage. The greatest defoliation, with over 30 % of trees damaged, was observed in Alpine coniferous forests.*
- *Time series show continuously low mean defoliation rates for forests in northern Europe. In central Europe trends are characterised by a peak in defoliation in 2004 triggered by extreme drought the previous year. A progressive increase in defoliation was observed in southern European forests until 2006/07 since when there has been little change. Studies have confirmed the negative impact of drought on forests in southern Europe.*

A fifth of all trees rated as damaged

Defoliation represents a valuable early warning system for the response of forest ecosystems to different stress factors. In 2011, 20 % of all trees assessed had a defoliation of more than 25 % and so were classified as either damaged or dead. European and sessile oak had the highest levels of damaged and dead trees, at 34.2 %. Scots pine (15.7 %) and Mediterranean lowland pines (16.2 %) had the lowest proportion of damaged and dead trees. The percentage was lower for conifers (18.2 %) than broadleaves (22.1 %).

Deciduous and alpine forests more affected than conifers

Around 24 % of all Level I plots in Europe represent northern (boreal) forests. On average, these forests are considered healthy, with only 10.8 % of trees classified as damaged. North-central European coniferous and mixed

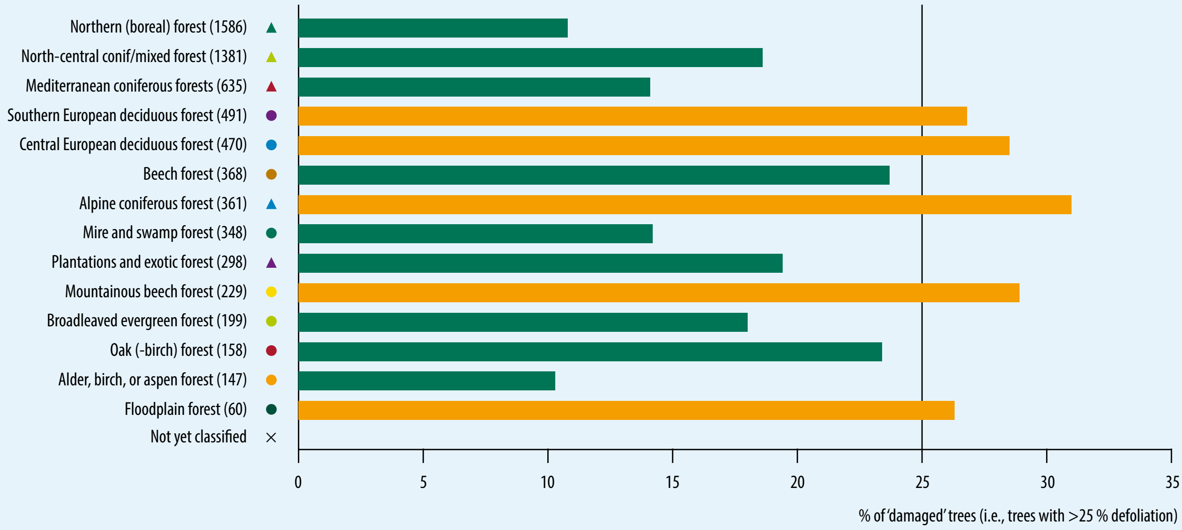
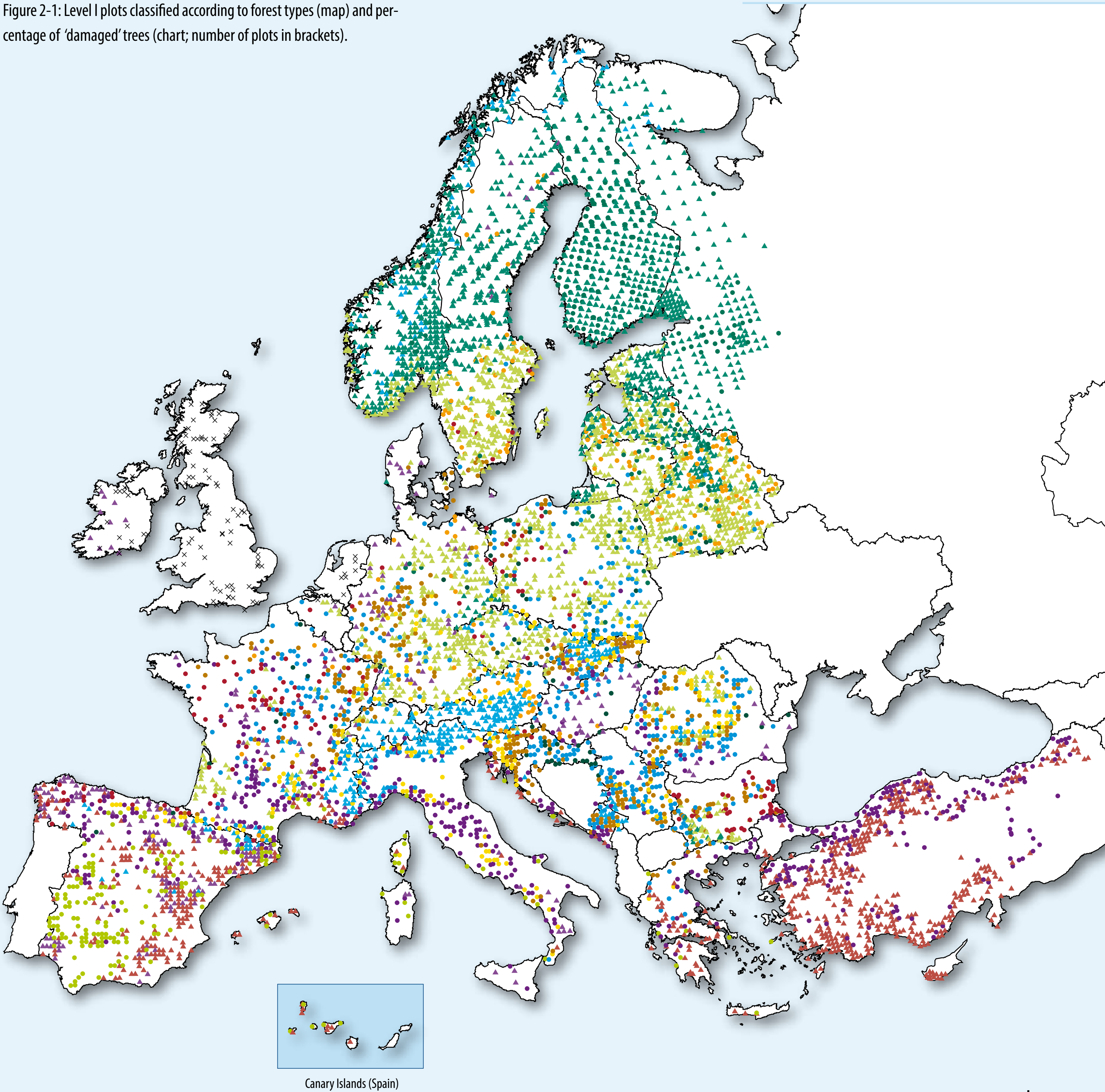


Figure 2-1: Level I plots classified according to forest types (map) and percentage of 'damaged' trees (chart; number of plots in brackets).



Monitoring methods

The health status of forest trees is monitored by surveys of tree crown condition. Fully foliated trees are considered healthy and are rated as having 0 % defoliation whereas dead trees are rated as having 100 % defoliation. Trees with over 25 % defoliation are rated as moderately damaged. The 'Forest Europe' Ministerial Conference uses defoliation as one of four indicators of forest health and vitality.

In 2011, defoliation data were submitted for 6807 plots in 28 countries. In total, 135 388 trees were assessed. Forest-type information following an updated classification system by the 'Forest Europe' Conference was submitted for the first time along with regular forest health data, allowing forest health to be evaluated by forest type (Figure 2-1). Causes of damage were assessed in parallel with defoliation and identified on 43 588 trees. Temporal trend analyses of tree crown condition were only undertaken for countries with continuous assessments and data submission.

Forest patches with bark beetle attack in the High Tatra Mountains, Slovak Republic.

forests represent the second largest group. These forests are characterised by 18.6 % of trees rated as damaged and so are also relatively healthy. Mediterranean coniferous forests are mostly rated as healthy. Central and southern European deciduous forests show a higher degree of damage. These forest types mostly comprise different oak species (including European and sessile, pubescent and Turkey oak), as well as common and oriental beech and mixed broadleaved stands. Alpine coniferous forests showed the highest level of defoliation (Figure 2-1).

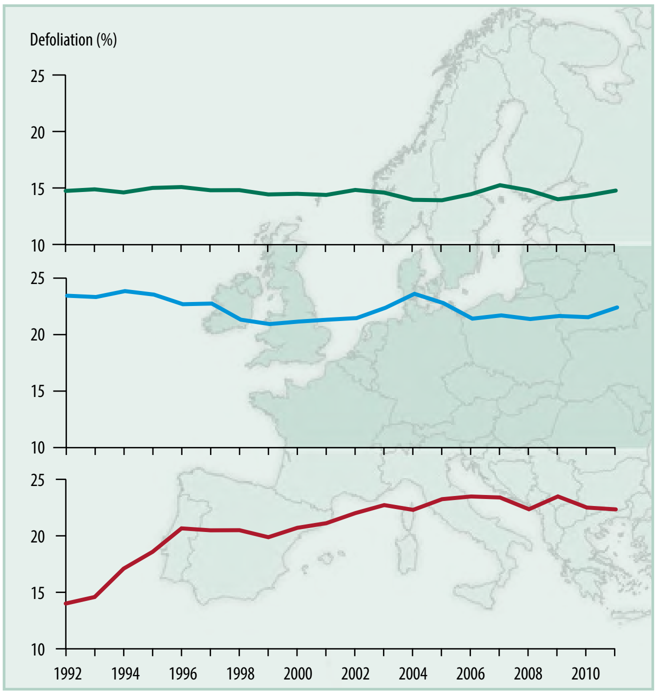


Figure 2-2: Time series of mean percentage defoliation for all tree species in northern , central and southern Europe over the past two decades. The data represent 14 countries with continuous data submission since 1991. (top: all plots north of 58°N; middle: all plots between 46° and 58°N; bottom: all plots south of 46°N).

Trends differ from north to south across Europe

Defoliation in all tree species has been consistently low across northern Europe over the past two decades, and thus the northern forests are in general considered healthy (Figure 2-2). There was some improvement in the health status of the central European forests throughout the 1990s but this was followed by increasing defoliation in 2003/04. This was due to the extreme drought of 2003. Levels of defoliation in southern Europe increased until 2005, since when there has been little change. A number of dry years triggered this increase and also partly led to oak dieback. On the Iberian Peninsula, a long period of drought from 1990 to 1995 was significantly associated with the observed increase in crown defoliation in all tree species and provides a good and well evaluated example of drought effects. Regional developments and trends for single species often differ from the European average.

Insects the most frequent cause of damage

The ICP Forests monitoring programme is the only system in Europe providing transnational and harmonized data on damage agents on an annual basis.

Signs of insects, fungi and other factors that can damage trees were visible on 32.6 % of all trees. A third of all occurrences of visible damage was caused by insects. Many insect species naturally live and depend on forest trees. Thus, data on insects influencing tree condition also reflects aspects of biodiversity and the observed symptoms

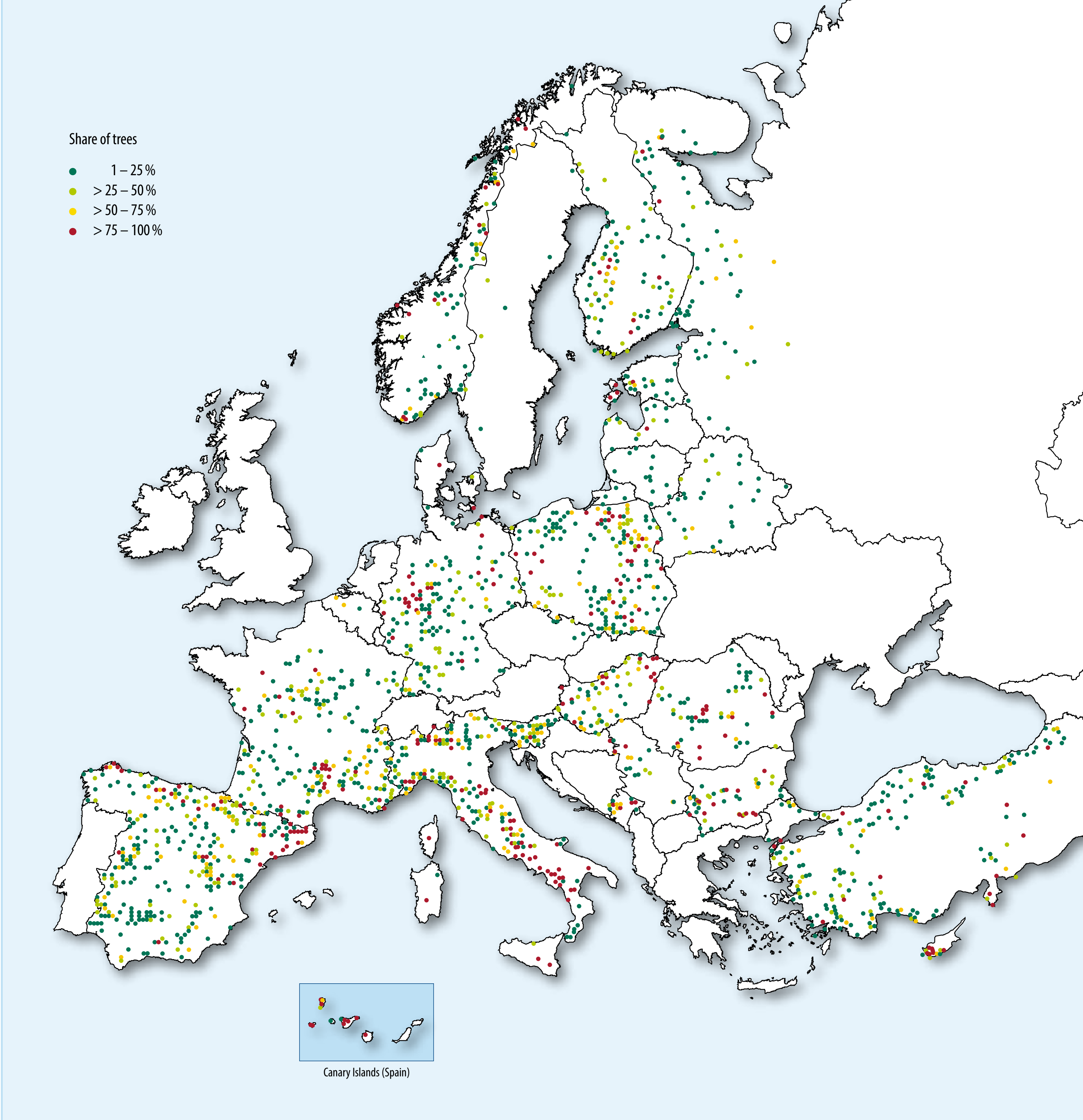


Figure 2-3: Share of trees per plot with recorded agent group 'insects', 2011.

are not exclusively interpreted as damage. However, when forests have already been damaged by storms, drought or other stress factors, insect populations often increase and cause severe economic damage. Hot spots with high insect occurrence in 2010 were at the eastern edge of the Pyrenees, the Apennine Mountains, in Cyprus and in eastern Poland (Figure 2-3).

Other causes of observed damage include fungi, abiotic agents (such as drought, storms, frost), game and grazing, and human activities (such as felling operations). Damage due to 'air pollution' referring to the direct impacts of smoke on trees is also assessed but this has little impact on trees. The indirect impacts of air pollution were not assessed in the context of the large-scale survey. The damage caused by insects and fungi may be exacerbated by changing environmental conditions and so their continued annual assessment is of great importance.

Level II plot with litterfall traps (green) and throughfall deposition samplers (orange), Finland.

3. Air pollution affects the stability and nutrition of forests

Summary

- *Sulphur deposition to forests has substantially decreased across Europe over the past decades. Nitrogen deposition shows only a small decrease. Model results suggest that by 2020, critical loads for nutrient nitrogen will still be exceeded on up to 50 % of the land surface of the EU depending on the deposition scenario applied.*
- *More than half of the analyzed forests with high nitrogen deposition are nitrogen-saturated. Nitrate can no longer be retained by these forests and is leached out.*
- *Nutrient imbalances are specifically occurring on plots with high nitrogen saturation leading to an increased sensitivity of trees to additional stress factors such as frost, storms and insect damage.*

Sulphur and nitrogen deposition greatest in central and eastern Europe

Forests with the highest nitrogen inputs are located in central Europe. Inputs to forests above 20 kg nitrogen per hectare are common in this region. On average, sulphur inputs are lower. However, the spatial patterns of both are similar with the highest loads in central and eastern Europe (Figure 3-2). Means of annual sulphate sulphur and inorganic nitrogen compounds have been calculated for plots with at least 330 days of deposition measurements per year.

Clear decrease in sulphur inputs but small reductions for nitrogen

A general decrease in mean sulphate and nitrogen deposition could be detected for the mean of all investigated forests with continuous measurements over 14 years.

The decrease is greater for sulphate (5.5 % per year) than inorganic nitrogen (about 2 % per year). For both, measurements in rain in the open field near the forests and below the forest canopy (throughfall) were averaged to generate an overall trend for the total of all investigated sites. Throughfall sulphate deposition is always greater than open field measurements because sulphur deposition is filtered from the air by the tree crowns before being washed to the forest floor (Figure 3-1).

The progressive decrease in sulphate and inorganic nitrogen inputs reflects the success of clean air policies and measures. However, there is considerable variation in the

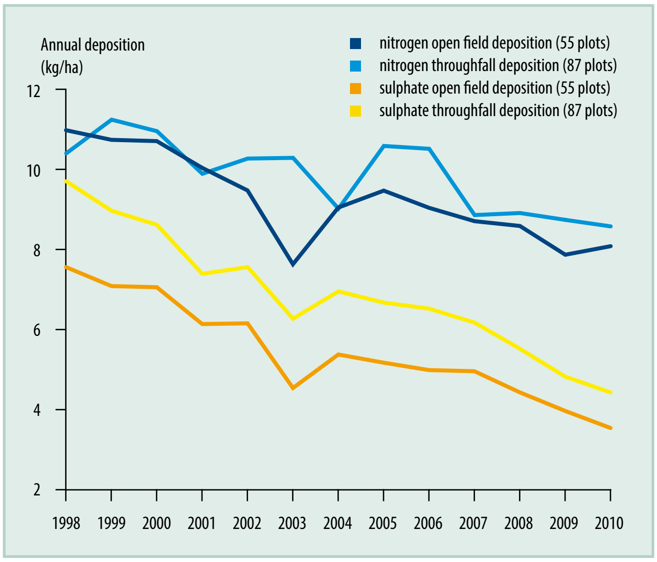


Figure 3-1: Mean sulphate (SO_4-S) and inorganic nitrogen (NO_3-N and NH_4-N) deposition in open field and below the forest canopy (throughfall) on plots with continuous measurements from 1998 to 2010.

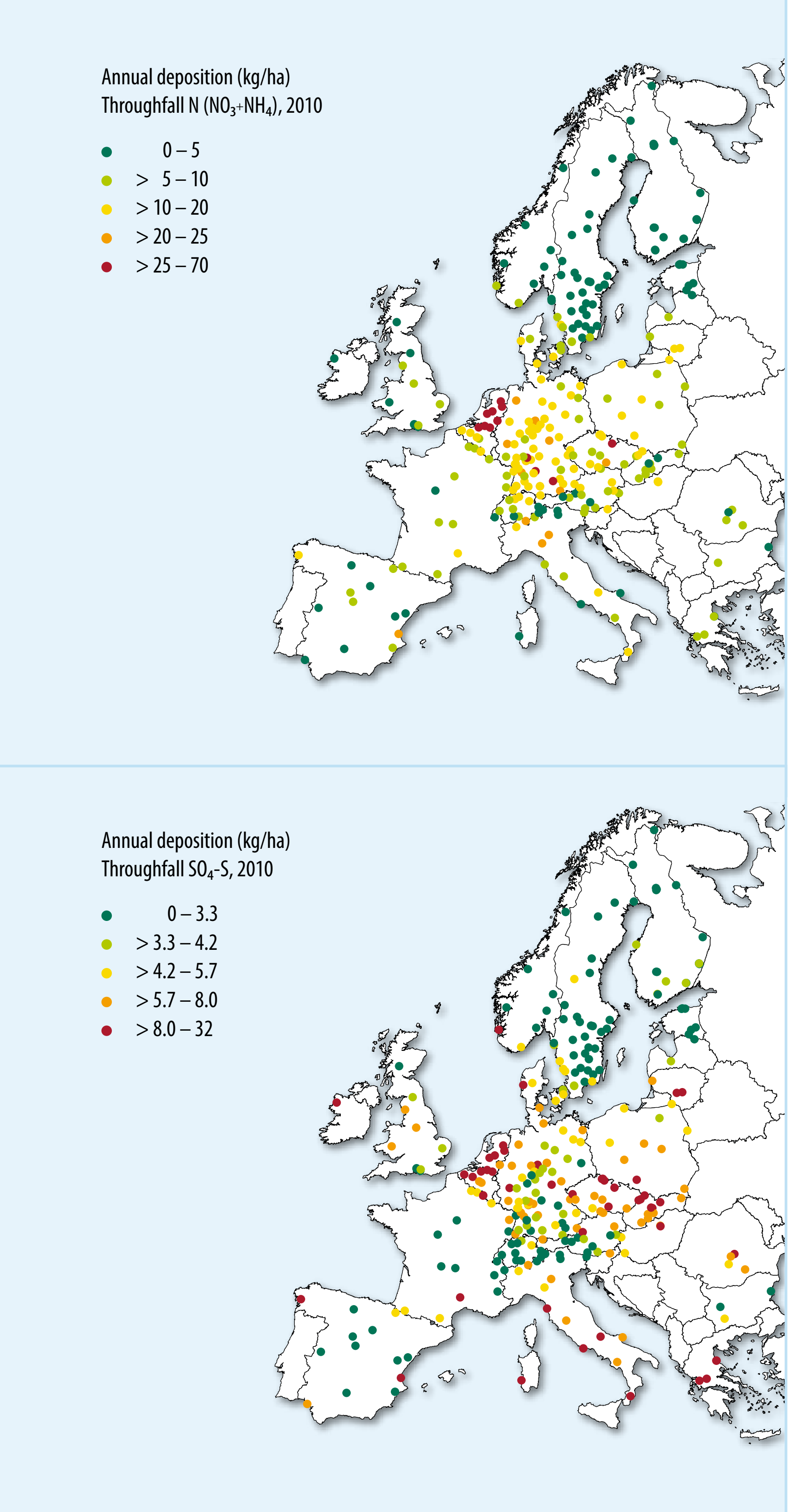


Figure 3-2: Throughfall deposition of nitrogen (top) and sulphate (bottom) in European forests in 2010.

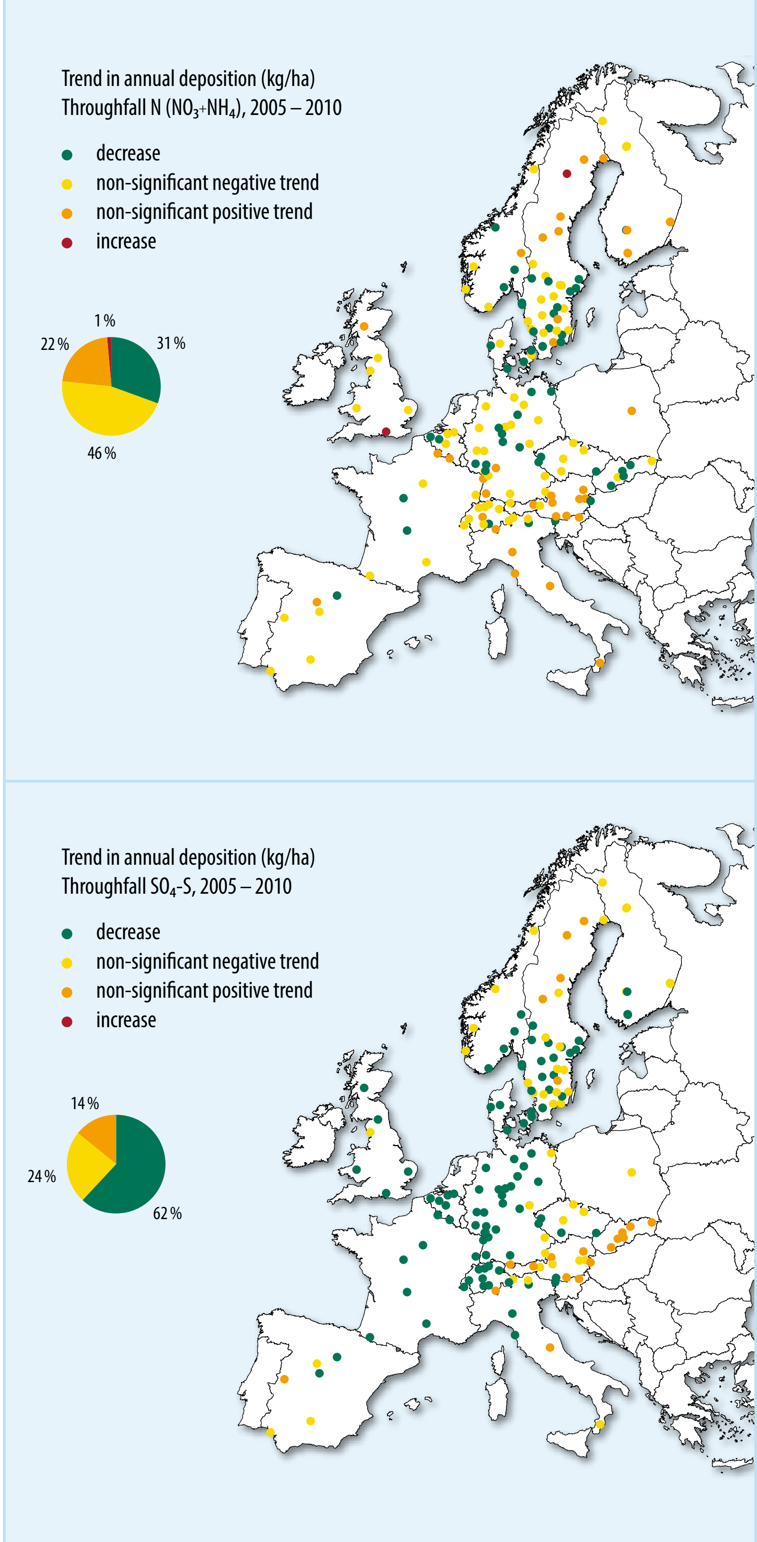


Figure 3-3: Trends in inorganic nitrogen (top) and sulphate (bottom) throughfall deposition in forests with continuous deposition measurements between 2005 and 2010 (160 plots).

volume and concentrations in precipitation. Continuous long-term data series remain key to determining temporal changes in atmospheric deposition to forests.

Deposition has decreased over the past few years in many forests. This is especially true for sulphate in the western part of Europe, but much less so for nitrate and for some regions in the eastern and southern parts of Europe (Figure 3-3). For nitrogen, statistically significant trends in deposition could not be detected for a six-year period in a majority of forests, despite many of these forests having indications of decreasing trends. Plots with continuous high nitrogen inputs are susceptible to damaging effects (see next paragraph). These forests are mostly located in central Europe. For sulphate deposition, plots with high inputs mostly show statistically significant reduction trends.

The results indicate that deposition from human activities is still a substantial issue for forest ecosystems. Model results (not depicted) suggest that by 2020, critical loads for nutrient nitrogen will still be exceeded on up to 50 % of the EU area depending on the deposition scenario applied.

More than 50 % of plots with high deposition are already nitrogen saturated

Lysimeters are installed in the soil at different depths and continuously extract soil solution from the soil pores on intensive forest monitoring (Level II) plots. Measured nitrate concentrations are then compared to critical limits obtained from the literature. Measurements of soil water chemistry from the lower soil horizons are important for determining the amount of nitrogen being lost from the forest and for establishing the nitrogen status of the forest ecosystem as a whole. When plots are nitrogen-saturated, forests can no longer accumulate and store additional inputs. About a quarter of the plots with nitrogen deposition below 20 kg per hectare can be rated as nitrogen saturated because they showed frequent exceedances of the critical nitrogen limit of 1 mg nitrate per litre in soil solution. The situation is aggravated in forests with higher levels of nitrogen deposition. Of these, more than half are nitrogen-saturated (Figure 3-4). Among other effects, nitrogen deposition thus leads to nutrient imbalances and destabilisation (see next paragraph) or to leaching of nitrate from forest soils. In forests with low nitrogen status, deposition may on the other hand accelerate growth of forest trees due to a fertilizing effect. Critical limits in soil solution were most frequently exceeded in forests with high nitrogen deposition in central Europe (Figure 3-5).

Nutrient imbalances are not widespread but are related to nitrogen deposition

Nutrients are analysed in living leaves and needles of the main tree species to provide information on nutrient status and possible deficiencies. Data from Level II plots indicate balanced nutrition of forest trees on the majority of plots. In forests with no exceedance of critical nitrogen limits there were hardly any occurrences of magnesium deficiency. In contrast, nutrient deficiency becomes more frequent and occurs on 10 % of plots in nitrogen-saturated forests (Figure 3-6). In cases where nitrogen deposition stimulates tree growth this can lead to a deficiency of nutrients like magnesium. With few exceptions, low magnesium availability is limited to central European forests (Figure 3-7). Nutrient deficiencies can be visually detected by observing yellowing and discolouration of needles and leaves. For pine and spruce trees such discolouration was more frequently observed in forests with higher exceedances of critical limits (not depicted). Nutrient imbalances are therefore not widespread in the monitored forests, but are specifically occurring where high nitrogen deposition leads to high nitrogen concentrations in the soil solution. With continuing high nitrogen deposition loads and increasing nitrogen saturation the importance of nutrient deficiencies will increase, particularly in forests that are naturally nutrient poor. Unbalanced tree nutrition leads to an increased sensitivity to additional stress factors such as frost, storms and insect damage.

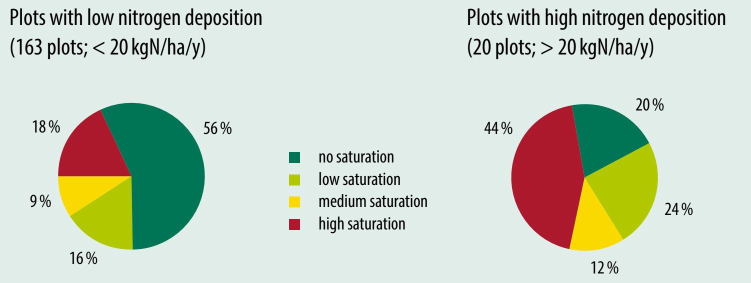


Figure 3-4: Shares of plots with different nitrogen status. Plots with high nitrogen deposition are more frequently nitrogen saturated. Classification follows class limits as defined in Figure 3-5.

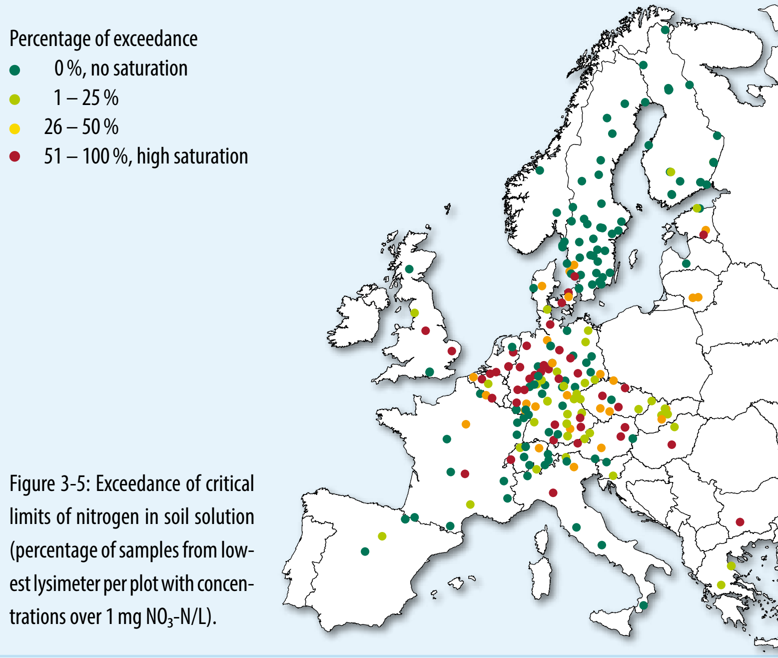


Figure 3-5: Exceedance of critical limits of nitrogen in soil solution (percentage of samples from lowest lysimeter per plot with concentrations over 1 mg NO_3-N/L).

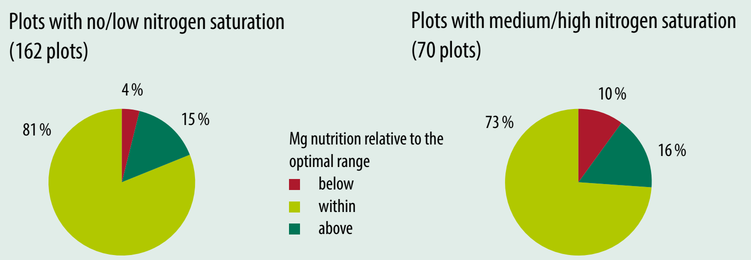


Figure 3-6: Foliar magnesium status. On nitrogen saturated plots magnesium nutrition is more frequently below optimal range. Plots with both soil solution and foliar data were analysed.

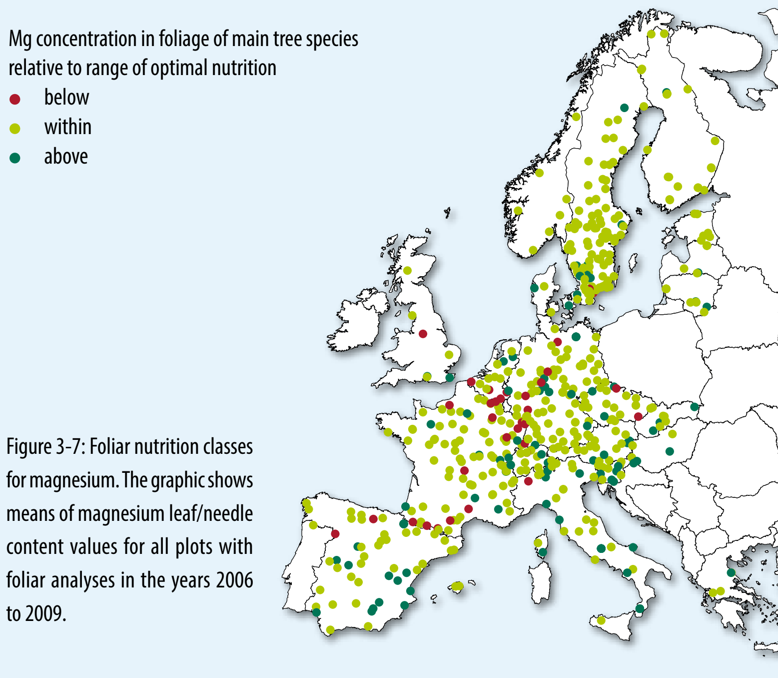


Figure 3-7: Foliar nutrition classes for magnesium. The graphic shows means of magnesium leaf/needle content values for all plots with foliar analyses in the years 2006 to 2009.

Continuous stem growth measurements on a Level II plot, as well as deposition measurement equipment for stemflow (black bin) and throughfall (orange samplers), Poland.

4. Forest growth is affected by climate change

Summary

- *A changing climate will affect forest tree growth. Increasing CO_2 concentrations represent a persistent fertilization and are likely to lead to increased growth in most regions.*
- *With CO_2-concentrations fixed at current levels there would, however, be decreased growth in southern Europe and increased growth in northern Europe. Rising temperature and changing rainfall distribution would drive the regional dynamics of changing growth.*
- *Results from Level II forest plots reflect natural growth conditions, with higher wood volumes and growth rates in the forests of central Europe and the Alps.*

Harmonized tree growth data reflect natural growing conditions

Present monitoring data show higher stocking stem volumes per hectare for plots in central Europe and the Alps and lower volumes per hectare in the northern and southern regions (Figure 4-1).

Many forests have between 300 and 600 m³ per hectare. This mainly reflects natural growing conditions. Whereas the climate is often too hot and dry in the south, low temperatures prevent more growth in the north. The high standing volume in central Europe can be partially attributed to higher precipitation and partially to higher age classes. In some stands it may reflect increasing stock-

ing volumes due to reduced management intensity and a shift in tree age distribution. High volumes in the Alps occurred at lower, montane altitudes where good water supply coincides with moderate temperatures, lower harvest intensities and higher stand age, rather than under alpine conditions.

Stem volume increments show similar spatial patterns (Figure 4-2). The high increment in western Europe can be attributed to the moderate Atlantic climate (high precipitation and temperature) and the faster-growing conifer species in many of these forests. Differences for single tree species are not depicted in the summary graphics.

Models project increased growth in the future

Forest net primary productivity (NPP) describes how much biomass forests can produce. It is an important ecological variable and a key indicator of forest condition and growth. Net primary productivity under climate change across Europe strongly depends on the effect of atmospheric carbon dioxide (CO_2). Rising atmospheric CO_2 levels have positive effects on photosynthesis and water-use efficiency and thus on forest growth but it is unclear how persistent this 'CO_2-effect' will be in the long-term. The applied model projects that with increasing CO_2, growth across Europe and across different tree species will increase (Figure 4-3). Under constant CO_2-levels the chang-

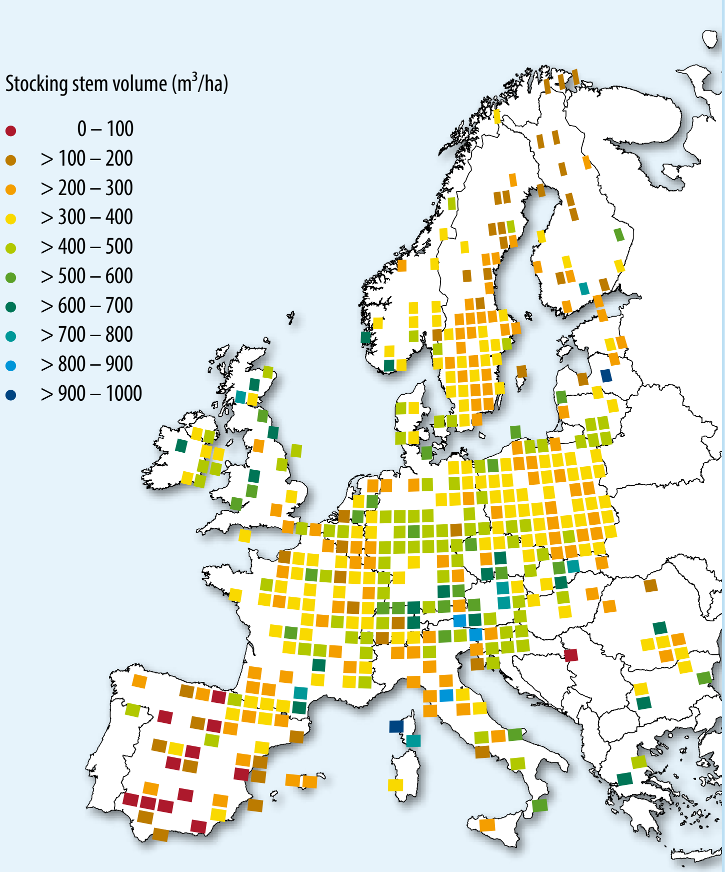


Figure 4-1: Stocking stem volume (m^3/ha). Data from 822 plots averaged to means per grid cell. Average for years between 1992 and 2010.

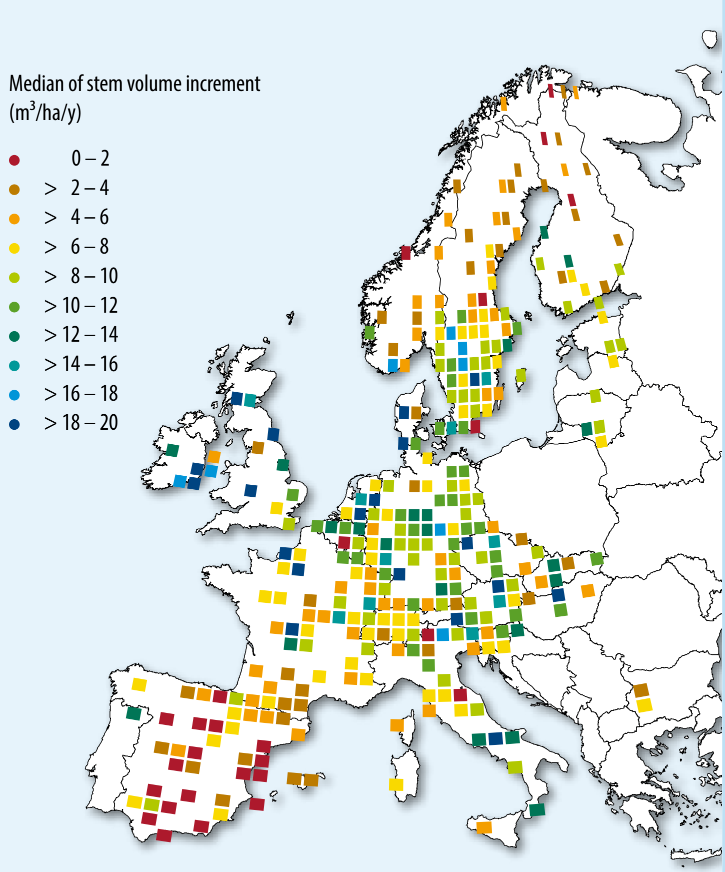
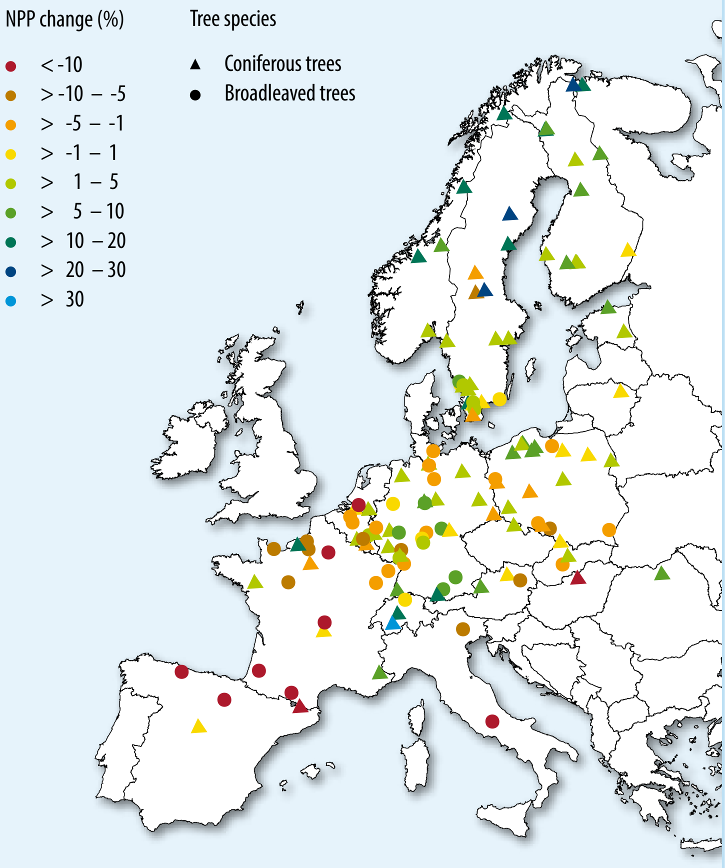


Figure 4-2: Median of stem volume increment (m^3/ha/y). Average for years between 1992 and 2010 for 539 plots with at least two measurements.



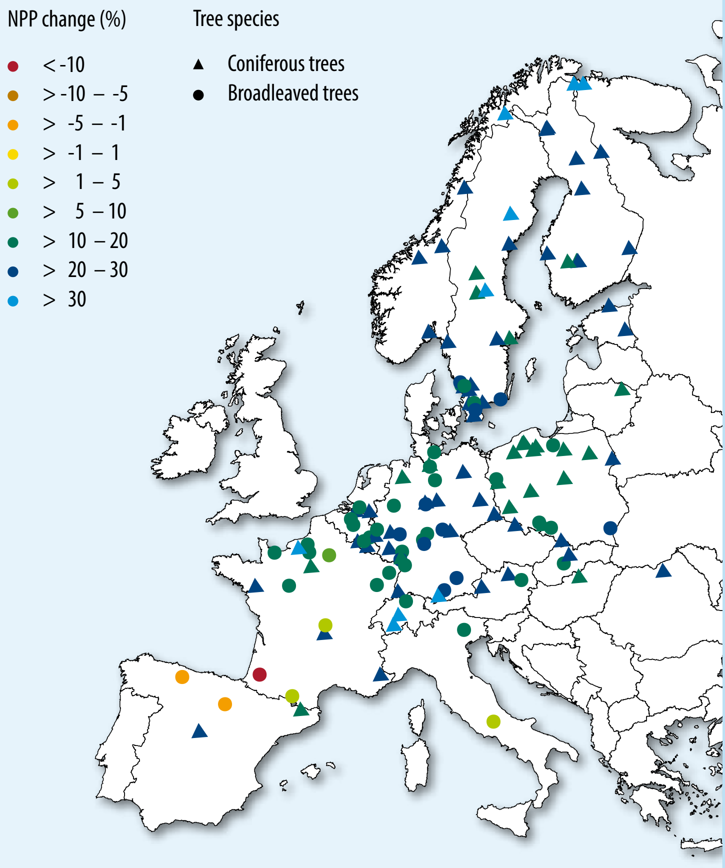


Figure 4-3: Projected mean change in net primary productivity (NPP) for the period 2061–2090 relative to 1971–2000 assuming constant (left) and increasing (right) CO_2 concentrations at 132 Level-II plots. Means of six modelled climate change scenarios are depicted.

Weather station, stem growth measurements and boxes for soil solution measurement equipment, Austria.

es are much smaller and become negative particularly for plots in the south and some regions of central Europe. Coniferous stands mostly show increasing productivity. This effect is, however, because coniferous stands dominate in northern regions and at higher altitudes where climate change is assumed to have more growth-stimulating effects. In contrast, net primary productivity of broadleaved tree species is projected to decrease under constant CO_2 on a majority of the studied forests, particularly in the south (Figure 4-4).

Effects of extreme weather events and disturbances still difficult to predict

The model results demonstrate how sensitive Europe's forests are to changing climatic and atmospheric conditions. It is crucial to note that these simulations represent the response of forest trees to higher temperatures, changing precipitation, radiation and CO_2 and do not include the effects of disturbances such as fires, storms or insect outbreaks that may change under a warmer climate and to which coniferous trees may be more susceptible. Such changes as well as forest management effects and nitrogen deposition may amplify or reverse the projected changes shown here. These results have implications for increasing or decreasing regional timber supply and can support the adaptation of management regimes needed to cope with altered growth conditions. They also support an understanding of the carbon balance of Europe's forests which in turn is crucial to establish the possible role of forests within the context of climate change mitigation.

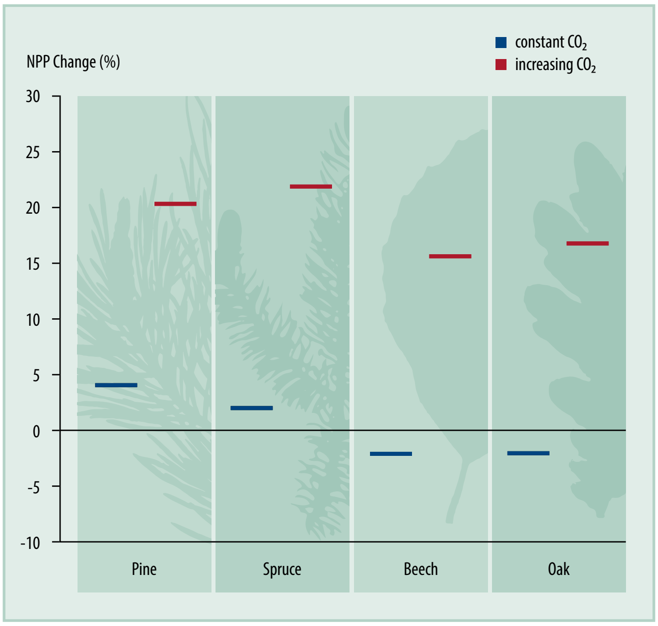


Figure 4-4: Projected change in net primary productivity (NPP) for four main tree species in the period 2061–2090 relative to 1971–2000 under constant and increasing CO_2 concentrations. Means of six modelled climate change scenarios are depicted.

Methods and data

Within the MOTIVE project (http://www.motive-project.net), Level II data were used to initialise the process-based forest model 4C (FORESEE – Forest Ecosystems in a Changing Environment, http://www.pik-potsdam.de/~lasch/4c.htm). The model 4C was applied at 132 Level II plots with five European main tree species (Scots pine, Norway spruce, European beech and sessile and pedunculate oak) to simulate the impact of climate change and increasing atmospheric CO_2 concentrations on net primary productivity. This was done using climate change projections from three different climate models (CCLM, HadRM3, HIRHAM3) two greenhouse gas emissions scenarios (A1B: all climate models; B1: CCLM only) and two realisations of each emissions scenario (CCLM only) leading to six climate change scenarios. Average changes in net primary productivity were projected for the period 2061–2090 relative to the baseline period 1971–2000.

5. Conclusions

A unique and transnationally harmonized long-term monitoring system

For more than 25 years forest condition in Europe has been monitored by ICP Forests. The programme is the only harmonized terrestrial forest monitoring network in Europe, with around 500 intensive forest sites and 7000 large-scale forest sites. Assessments and data are based on comparable methodologies and standardized data quality checks. ICP Forests continuously reports on the status and development of European forest health and vitality and describes the effects of different stress factors on forest ecosystems. The programme provides scientific information as a basis for clean air policies and international conventions and processes related to air pollution, climate change, the carbon cycle, sustainable forest management, timber and biomass production, and biodiversity. This annual report provides the latest findings and offers an update on overall forest health based on numerous policy reports and scientific results published over many years.

Broadleaved trees and forests in the south show more damage

At the large-scale, forest condition has deteriorated far less severely than was feared three decades ago when increasing defoliation was observed in many places in Europe. Little change has been observed at the European scale over the past ten years. Today, a fifth of the assessed trees show moderate or severe damage, but on the other hand defoliation varies greatly among tree species and regions. Broadleaved tree species have higher proportions of damaged trees. The most severely damaged of the main tree species are Mediterranean and central European oaks. In general, northern forests are in better health than forests in central and southern Europe. The direct effects of air pollution are mostly masked by the stronger effects of stand and site characteristics including the age of the trees, and by insect and fungal damage. Drought and weather extremes are dominant stress factors.

Nitrogen excess continues to affect nutrient cycles

Atmospheric deposition has been the specific focus of the programme since its inception. Current evaluations show mean sulphur inputs to be half those measured at the end of the 1990s. This is a result of clean air policies under the Convention on Long-range Transboundary Air Pollution and EU legislation. Based on model results, critical loads for acid deposition were exceeded on nearly 60 % of forest sites by 1980. Future scenarios project that by 2020 there will be hardly any exceedances. In contrast to decreasing sulphur deposition, mean nitrogen inputs have shown only a minor decrease over the past ten years. There is clearly a need for more emissions reductions in this field. Critical loads for nitrogen deposition are likely to be exceeded on 30 % of the forest sites by 2020. This year's results show that more than half of the sites with high nitrogen inputs are nitrogen-saturated. These forests can no longer retain additional nitrogen which is then leached into ground and surface waters. The evaluations reveal nutrient imbalances specifically in areas with high nitrogen deposition loads.

Further development of growth and climate change models needed

The data of the programme provide an excellent basis for studying the effects of a changing climate on forests across Europe. Most climate change scenarios project continuously rising CO_2 concentrations and a growth model that uses these scenarios shows effects on forest trees leading to more growth. This may compensate for drought stress in forest trees. Without the fertilizing effect of increasing CO_2 concentrations, only forests in northern Europe and at higher altitudes are assumed to show growth increases due to the stimulating effects of rising temperatures. Forest growth has a direct economic importance and forest management needs to rely on sound scientific data. Yet, there remains uncertainty about the future for European forests because the models do not include the effects of possibly increasing disturbances such as fires, storms or insect outbreaks. Species shifts under climate change and adaptation by forest management must also be taken into account.

Forest monitoring in Europe at risk

After 25 years of close cooperation between the European Commission and ICP Forests there is at present no co-financing mechanism in place and monitoring is relying exclusively on national funding and priorities. Experience to date shows that harmonized and continued activities require the will and motivation of involved institutions as well as budgetary incentives. Large-scale and intensive forest ecosystem monitoring are essentially long-term endeavours and must rely on long-term funding. The present situation calls for dialogue between scientists, resource managers and policy makers. Resource managers and policy makers need to formulate their information needs more precisely, and scientists need to adapt to changing information needs while preserving and continuing data time series. These data are essential for documenting past and present ecosystem conditions and for providing baselines and standards against which future developments can be assessed.

Annex

Photo references

Page	Name
3, 4	Bayerische Landesanstalt für Wald und Forstwirtschaft
5	B. Ehrensperger
6, 18	A. Semerci
8	Z. Sitková
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35