UNITED
NATIONS

E

Economic and Social
Council

Distr.
GENERAL

EB.AIR/WG.1/2004/5
7 June 2004

ORIGINAL : ENGLISH

ECONOMIC COMMISSION FOR EUROPE

EXECUTIVE BODY FOR THE CONVENTION ON
LONG-RANGE TRANSBOUNDARY AIR POLLUTION

Working Group on Effects
(Twenty-third session, Geneva, 1-3 September 2004)
Item 4 of the provisional agenda

MONITORING OF FOREST CONDITION IN EUROPE

Summary report by the Coordinating Centre of the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

Introduction

1. Forests have an important multifunctional role in society. Apart from the economic benefit of wood production and their significant role in the development of rural areas, forests are valuable for nature conservation and preserving the environment. They are significant carbon sinks and thus relevant in the context of climate change. Forests also represent a controlling factor for the water cycle. Forest condition in Europe has been monitored over 18 years jointly by ICP Forests and the European Union (EU). This pan-European programme relies on one of the world's largest biomonitoring networks.

GE.04-31377

2. The variation in forest condition over space and time is assessed in relation to natural and anthropogenic factors on 6,000 plots systematically spread across 39 countries in Europe. This large-scale monitoring approach is designated as “level I”. An intensive monitoring approach referred to as “level II” aims at causal relationships and is pursued on another 860 intensive monitoring plots covering the most important forest ecosystems in Europe. Both monitoring intensity levels are complementary to each other.

3. The objectives of the monitoring programme are to:

(a) Provide a periodic overview of the spatial and temporal variation in forest condition in relation to anthropogenic and natural stress factors across a European and national large-scale systematic network (level I);

(b) Contribute to a better understanding of the relationships between the condition of forest ecosystems and stress factors, in particular air pollution, through intensive monitoring of a number of selected permanent observation plots spread over Europe (level II);

(c) Contribute to the calculation of critical levels, critical loads and their exceedances in forests;

(d) Collaborate with other environmental monitoring programmes to provide information on other important issues, such as climate change and biodiversity in forests, and thus contribute to the sustainable management of European forests;

(e) Compile information on forest ecosystem processes and provide policy makers and the public with relevant information.

I. DEPOSITION TRENDS

A. Methods

4. In line with its mandate, ICP Forests pays particular attention to the deposition of air pollution and its effects on forests. Since the late 1990s, atmospheric deposition has been continuously measured on intensive monitoring plots across Europe. Time trends have now been evaluated based on deposition measurements in open fields near the intensive monitoring plots. This bulk deposition is usually lower than the deposition in the forest stands as there are no trees to filter pollutants from the air. On the other hand, bulk deposition is not influenced by interactions between the tree foliage and the incoming deposition, and thus gives a good large-scale overview independent from the specific forest stands on the plots. After intensive data-quality checks, only those plots which had continuous measurements over all the years were evaluated. Means were weighted by the amount of precipitation. For the calculation of the development over time, the significance of the plot-wise linear trends in annual concentration means was tested.

B. Results

5. The mean concentration of sulphate and nitrate in open field measurements on the level II plots decreased during the observation period. The sharpest decrease was recorded for sulphate. Nitrate had the lowest mean concentration throughout all years. The mean ammonium concentration increased in 1997 and decreased slowly in the following years (see fig. I).

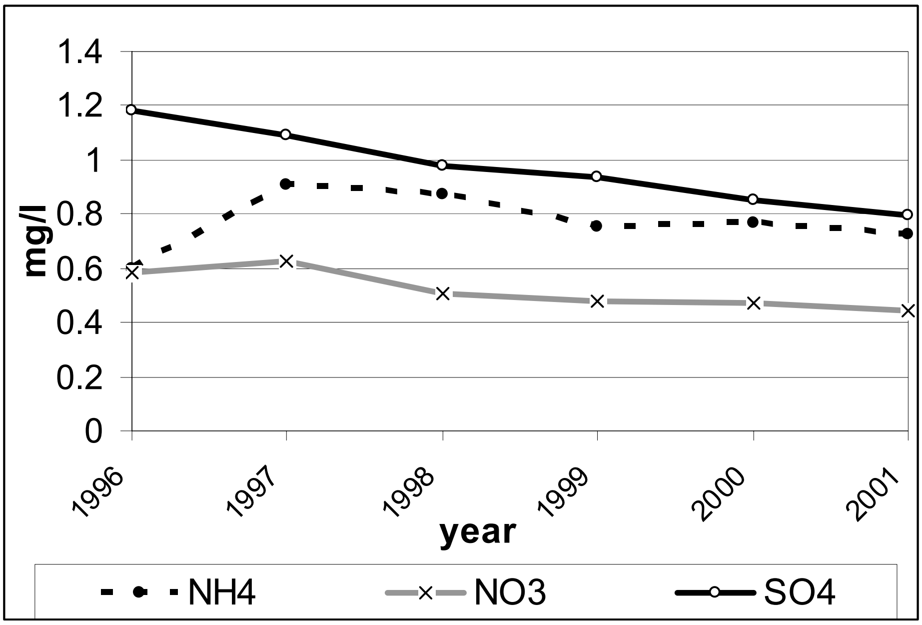

Figure I. Development of mean plot concentration of sulphate (SO_4, 285 plots), nitrate (NO_3, 294 plots) and ammonium (NH_4, 294 plots)

6. Mean nitrate (NO3-N) concentrations were evaluated on 409 level II plots in the years 1999 to 2001. Time trends were evaluated for a longer period (1996 to 2001) on 294 plots. Clusters of plots with the highest concentrations are located in Poland, northern Germany, the Netherlands and Belgium. On most of these plots a decrease was recorded in the years 1996 to 2001; however, it was not significant in most cases. Concentrations in France were among the lowest, however with an increasing tendency in the south of the country. The concentration of nitrate significantly decreased on 15% of the 294 observed plots. A significant increase was registered on only 0.7 % of the plots.

7. Mean ammonium (NH4-N) concentrations were evaluated on 407 level II plots in the years 1999 to 2001. Time trends were evaluated for a longer period (1996 to 2001) on 294 plots. The geographical distribution of ammonium inputs resembled that of nitrate, with high mean concentrations in Belgium, the Netherlands, Poland and other East European countries. The temporal development showed clusters of plots with an increase in Eastern Europe and southern France. However, the increase was significant on only 0.7 % of the evaluated plots, whereas on

12.9 % a decrease in the concentrations proved to be statistically significant. The Mediterranean plots were in most cases excluded from the evaluations as their time series were still not long enough.

8. Mean sulphate (SO4-S) concentrations were evaluated on 401 level II plots in the years 1999 to 2001. Time trends were evaluated for a longer period (1996 to 2001) on 285 plots. Sulphate concentrations were the highest on plots in Eastern Europe and Belgium. On around 45% of all evaluated plots a significant decrease in sulphate concentrations was recorded and there were hardly any plots with a significant increase (0.4%).

II. OZONE CONCENTRATIONS IN FORESTS

A. Introduction

9. Within a study co-financed by the European Commission, AOT40 (accumulated exposure over an ozone concentration threshold of 40 parts per billion) estimates were provided for 57 level II sites in South Western Europe which have been equipped with passive ozone samplers since 2000. Despite several criticisms, AOT40 remains the basis for estimating the potential risk to forests due to ozone and for setting environmental quality objectives within the European Union (EU) and under the Convention.

B. Methods

10. According to its definition, the proper calculation of AOT40 values implies the availability and completeness of hourly concentration measurements through a presumed six-month forest growth period. Such data are rarely available. However, in a pilot project carried out in Italy it was demonstrated that it was possible to obtain AOT40 estimates from passive sampling data with a reasonable level of precision. Concentration data obtained by passive sampling were first validated against measurement stations in the vicinity. Validated data were used to model the expected daily profile of the ozone concentrations in relation to the location of the site, its elevation and the measured concentration level. Then, hourly values were processed to estimate AOT40 values, which were again validated by the co-located automatic measuring devices. Although there are large deviations between measured and modelled hourly concentrations for individual days (see fig. II), their importance is much less on a 6-month basis. The results (see fig. III) confirmed that AOT40 can reliably be predicted by models based on passive sampling data.

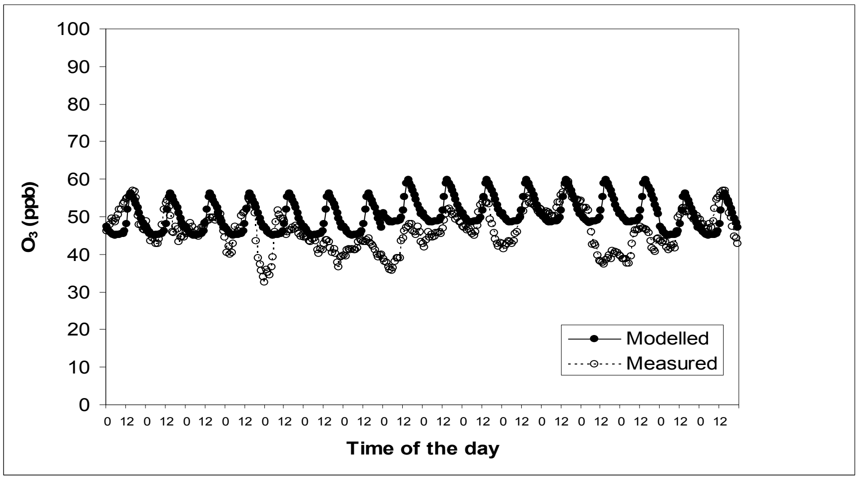

Figure II. Example of modelled hourly ozone concentration plotted together with measured values on a level II plot, La Thuile, north-east Italy, 3-18 April 2001. Deviations between measured and modelled hourly concentrations occur for individual days

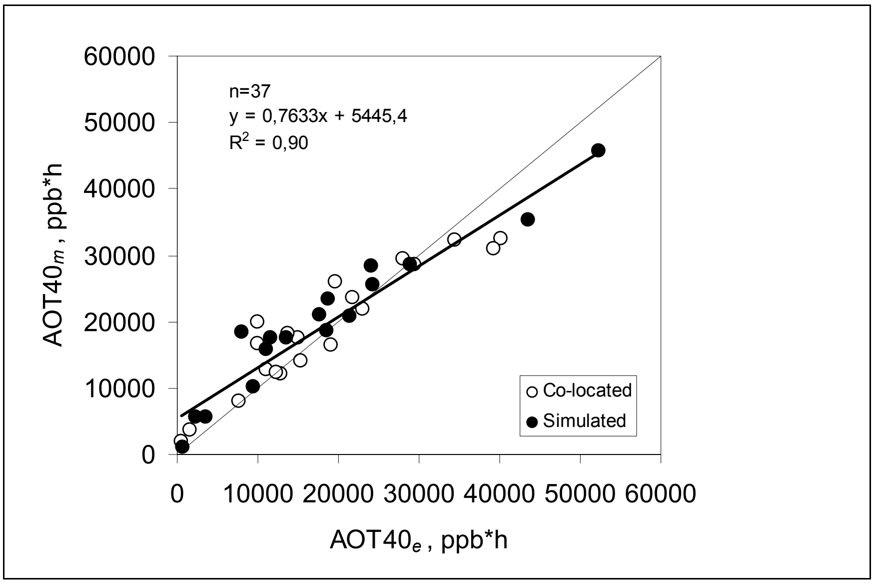

Figure III. Measured AOT40 ($AOT40_m$) in relation to estimated AOT40 ($AOT40_e$) on 37 sites for which measured AOT 40 values were available. AOT40 can reliably be predicted by models based on passive sampling data

C. Results

11. The modelled AOT40 values show a considerable variation throughout the plots in South-Western Europe. However, there is a significant decrease towards northern regions and a slighter, but still significant, increase with elevation, thus confirming in part a known pattern. Sites in northern France almost always have a much lower AOT40 than sites

throughout Italy and Spain. A cluster of sites with very high AOT40 values is also obvious at the border between Switzerland and Italy, a well-known area with high ozone pollution.

12. On the sites considered in the project, critical levels are commonly exceeded. Both critical levels of 10 000 and 5 000, ppb*hour derived at the workshops in Kuopio (Finland) 1996 and Gothenburg (Sweden) 2002, are exceeded at many sites (table 1). The median AOT40 for the respective sites is always higher than the critical levels, with a peak in 2001. However, due to considerable variations in ozone concentrations, an improved calculation of AOT40 is best done on a 5-year basis. Thus, the 3-year AOT40 should be regarded as a preliminary finding.

	2000	**2001**	**2002**	**Mean values 2000-2002**
*Median AOT40, ppb*h*	14397	18306	13589	16263
*% of sites >10000, ppb*h*	68.97	75.86	60.34	68.97
*% of sites >5000, ppb*h*	86.21	98.28	86.21	94.83

Table 1. AOT40 levels on 57 level II plots from April to September 2000. AOT40 values in relation to the relevant thresholds (upper) and percentage of exceedances (lower)

III. FOREST GROWTH

A. Introduction

13. Tree ring analyses and determination of annual height increment make it possible to analyse tree growth retrospectively. They make it possible to compare the present height growth of trees to that of older sample trees at the same site when they were the same age. Such an analysis requires the felling of sample trees, which was carried out in the buffer zone of 46 level II plots. The large data sets of the level II plots also enabled first attempts to investigate the influence of environmental stress factors, including air pollution, on the growth of the trees. The studies were co-financed by the EU.

B. Results

14. Results show that from 1960 to 2000 the height increment of the younger Norway spruce, Scots pine and common beech sample trees was significantly and consistently larger than that of the older trees when they were the same age approximately 50 years ago. Over the observation period the height increment was on average 23% larger for Norway spruce and 25% larger for Scots pine and beech (fig. IV). This also resulted in an increased wood volume increment and confirms earlier findings which also revealed generally accelerated tree growth across Europe.

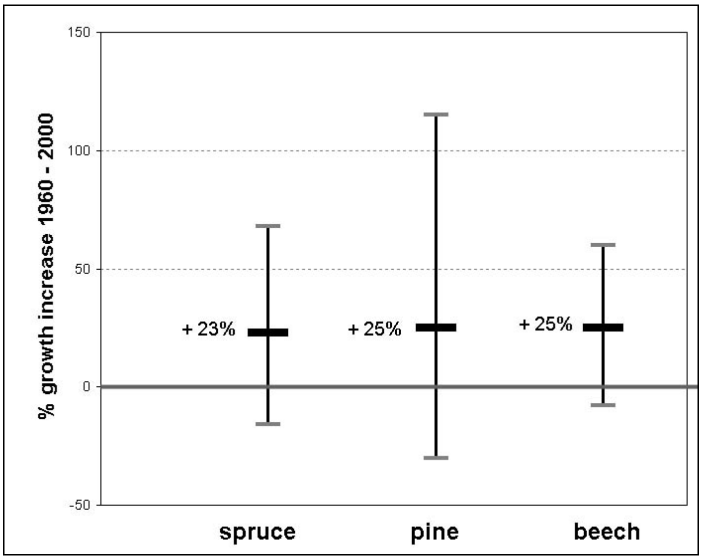

Figure IV. Tree height growth today and in the past (relative changes in annual height increment: observed minimum, median, maximum)

15. It is of great interest to explore the reasons for the significantly increased tree growth. It is well known that, under certain site and stand conditions, deposition can enrich soils with nitrogen (eutrophication). Increases of temperature and of atmospheric CO_2 concentrations can also have stimulating effects. To investigate the influence of environmental factors, level II plots with Norway spruce and beech were selected from seven Central European countries. A regression model was set up to account for internal factors like tree size measurements, site factors, stand density and competition. Results show that actual growth on beech plots with high nitrogen or sulphur deposition was smaller than that estimated by the model, so it can be assumed that high deposition reduces increment. For spruce no clear trend was found between growth and deposition loads. In another approach, changes in tree height growth in relation to nitrogen foliar content and nitrogen deposition were evaluated on level II plots in 14 European countries ranging from Finland to Spain. The calculations show a decreased height increment for Norway spruce with high nitrogen foliar content and a reverse relationship for Scots pine and beech. At the sites where high nitrogen concentrations in the trees' foliage suggest nitrogen saturation of the stands, the height growth is decelerating.

C. Outlook

16. The relationships between environmental factors and tree growth are complex. Further investigations will be carried out after a repetition of the increment assessment in 2004/2005 in order to determine the underlying causes for the increasing tree growth. In this context, special attention will be paid to site and climatic conditions and atmospheric deposition.

IV. UPSCALING OF SOIL SULPHUR RESULTS FROM LEVEL II TO LEVEL I IN CENTRAL AND NORTHERN EUROPE

A. Introduction

17. Within ICP Forests, level I covers 6,000 plots. On 860 intensive monitoring plots (level II), a larger number of parameters are assessed. Key factors are measured at both levels, so that intensive monitoring results can be extrapolated to the representative large scale. An upscaling project dealt with sulphur as one of the most dominant soil acidifying components of deposition.

B. Upscaling methodology

18. Soil sulphur pools in the organic layer were calculated for 111 level II plots. Through complex statistical methods (recursive partitioning), these plots were divided into six groups, each with a characteristic combination of pH, temperature and tree species. These explanatory variables accounted for 73% of the variation in sulphur pool size. At level I, sulphur analyses are not conducted at all. However, information on all of the explanatory variables is available, and through the statistical model established at level II, the sulphur pools in the soils of those level I plots could be estimated, where these plots are located in the areas for which level II data are available.

C. Results

19. The study was confined to Finland and a belt of plots in Central Europe ranging from Belgium and the Netherlands to Slovakia. The level I results show a distinct gradient for sulphur pools in Finland with increasing sulphur pools towards the south, where higher inputs were recorded in the past. In Central Europe there is no distinct gradient, which might be due to more heterogeneous site types, sulphur inputs and forest stands. The higher number of level I plots gives more precise results with regard to area representativity than to the level II data.

V. CROWN CONDITION IN 2003 AND PAST DEVELOPMENTS

A. Introduction

20. Since the early 1980s, when severe deterioration in forest condition was observed in large areas of Europe, the situation and health status of European forests have been under close scrutiny, and with the increasing length of the monitoring time series a differentiated view has become possible. The annual large-scale forest condition assessment of the programme is based on a systematic 16 km x 16 km grid net and gives a good overview of the health status of the forest ecosystems. In 2003, 131,503 trees were assessed in 30 countries. Defoliation is the main parameter in this survey. It is a single-tree estimate for the lack of foliage, responds to many stress factors and is easily assessable over large areas. This makes defoliation a valuable overall indicator of forest condition.

B. Results

21. Of all trees assessed in 2003, 22.7% were classified as moderately or severely defoliated or dead. Crown condition in the 15 EU Member States was slightly better than in Europe as a whole. Of the four most frequent tree species on the plots, European and sessile oak were the most severely defoliated species (fig. V).

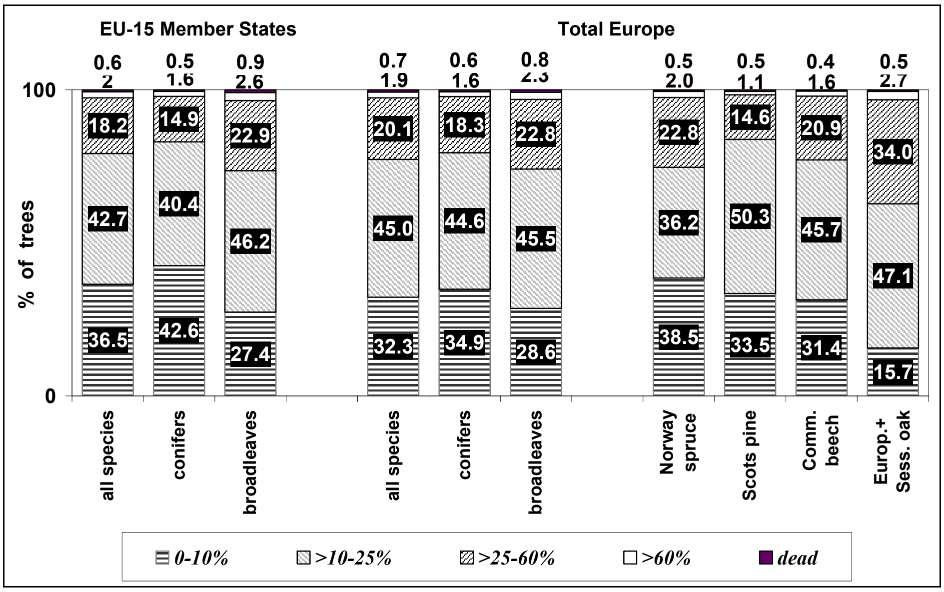

Figure V. Defoliation of major tree species, 2003

22. Mean defoliation has increased during the past year for all major tree species, except Norway spruce, which remained on the same defoliation level (fig. VI). Mean defoliation was still mostly lower than in the mid-1990s, when defoliation peaked for most tree species. Beech reached the level of its previous maximum in 1995. An overall worsening is also documented in the share of plots that show a significant increase in defoliation since 1997 (not depicted). With 15.3%, this proportion is bigger than the percentage of plots showing a decrease (10.7%). The time trends for single plots show a belt with prevailing deterioration along the eastern edge of the Baltic Sea reaching from southern Finland to eastern Germany. Improvements were mainly registered in Belarus and southern Poland. The extreme heat and drought in large parts of Europe during the late summer of 2003 may, however, explain the increased defoliation. The first evaluations reveal examples of related growth reductions. Forests in the Mediterranean region seem to be better adapted to dry conditions. It is expected that these weather extremes will have a sustained effect on the health status of the forests in 2004.

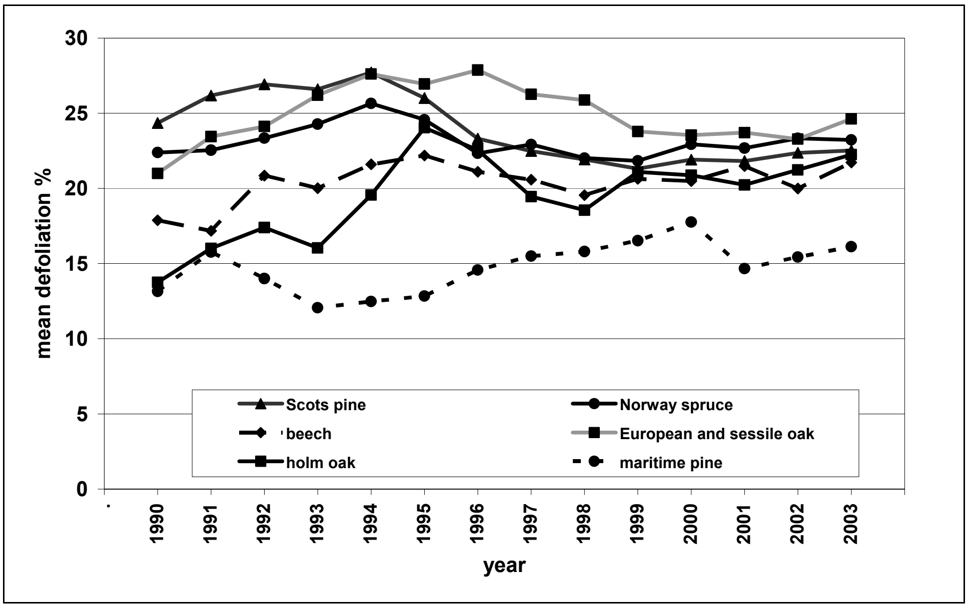

Figure VI. Trends in mean defoliation of Europe's main tree species. Sample sizes vary between 2,600 and 11,924 trees per depicted species. Results are based on data from 21 countries

23. Time trends for the main tree species show that crown condition of common beech fluctuated across large areas of Europe. Distinct worsening was registered in southern Sweden, Romania and Belgium. Here, it was due to the combined influence of adverse weather conditions, bark beetle attacks and fungal infections. In southern Germany the beech trees on the plots recuperated after a worsening at the end of the 1990s. The deciduous oak species deteriorated in this period mainly in southern Sweden, eastern Austria and central France. This last region deserves particular attention as the situation remained unchanged for years. A worsening in Scots pine and Norway spruce in Scandinavia was ascribed to root rot and needle rust fungi. Improving trends for these species have been observed in Belarus in particular.

VI. CONCLUSIONS

A. Main findings

24. After a recuperation of tree crown condition in the mid-1990s, a worsening was recorded in 2003 with nearly 23% of the trees classified as damaged. This is partly ascribed to the extreme drought and heat during last year's summer. The first evaluations reveal examples of related

growth reductions. Forests in the Mediterranean region seem to be better adapted to dry conditions.

25. Defoliation and growth of trees correlate. Forest growth has increased across Europe. This means that today in general both healthy and defoliated trees show larger increments. The absolute growth level of the defoliated trees is, however, lower. Under certain stand and site conditions, nitrogen deposition can contribute to this growth change, but increasing temperature and carbon dioxide concentration also have stimulating effects. It has to be clarified whether this increased forest growth leads to improved forest condition and functioning in the long term.

26. Atmospheric sulphur and nitrate depositions have been decreasing since 1996 and have been stable for ammonium at approximately 300, mostly remote, forest plots. However, as shown in previous reports, the critical thresholds are still exceeded at many sites. The critical level of ozone was, on average, exceeded on 69% to 95% of the investigated plots in South-Western Europe in the years 2000 to 2002. Ozone concentrations are expected to be even higher for 2003, when sun radiation and temperatures were significantly above the long-term average.

B. Forest condition

27. Since the 1980s when severe deterioration was observed in large areas of Europe, growing time series have shown that sharp increases in defoliation were followed by steady-state phases or part recuperation. However, today, defoliation of most tree species is higher than at the beginning of the monitoring programme and it is in response to a multitude of natural and human stress factors. Forest condition monitoring has proven to be an essential instrument for the preservation of one of the most natural ecosystems on the continent.

C. Air pollution and clean air policy

28. Under the Convention, ICP Forests has substantiated positive effects of air pollution abatement policies. However, earlier model calculations indicate that the recovery of forest soils will take decades, even if recent international agreements are fully implemented. Sustained clean air policy at the international level is vital to support this recovery in the future. The reduction in nitrogen deposition and ground-level ozone concentrations will remain the main challenge in this respect. There is a need for further investigations to clarify the influence of nitrogen inputs on increased forest growth and to determine mechanisms of ozone uptake and plant responses. This will also support the further development of ozone threshold values.

D. A multifunctional and cooperating monitoring network

29. With its large and harmonized data sets and the increased knowledge of the experts involved, the monitoring network of ICP Forests has developed into a multifunctional network. Today it tackles questions covering many stress factors. In fields like sustainable forest management, biodiversity, climate change and nature conservation, there is an increasing demand for the programme's data and results. Already the programme is pursuing the objectives of several resolutions of the Ministerial Conference on the Protection of Forests in Europe. Expected results on forest biodiversity will be relevant for the implementation of the Convention on Biological Diversity and assessments of carbon sequestration in forests will contribute to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. The European Commission will remain the main partner of ICP Forests. The new EU Forest Focus regulation is thus a vital basis for the continuity of the programme. It is also essential for the programme to continue its partnerships with monitoring systems in North America and Eastern Asia, as air pollution and changing climatic conditions warrant political actions at the global level.