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INTERNATIONAL CO-OPERATIVE PROGRAMME ON ASSESSMENT AND MONITORING OF AIR POLLUTION EFFECTS ON FORESTS - ICP FORESTS -

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Abstract: ICP Forests was launched in 1985 under the Working Group on Effects of the Convention on Long-range Transboundary Air Pollution of UN/ECE. As part of the Programme, forest condition is surveyed annually on up to 33,600 sample plots with about 622,000 sample trees in 35 countries, representing about 225 million hectares of forest. Results of the national surveys are reported as country related mean values, split into tree species and age groups. A special transnational survey is performed in cooperation with the European Commission, based on a uniform 16 x 16 km grid of 4,800 plots with 103,000 trees in 27 countries. Results show that large scale forest decline has been less dramatic than was suggested in the early 1980s. Nevertheless, a general worsening of forest condition can be shown in many parts of Europe. In some areas, particularly in Central and Eastern Europe, several thousand hectares of forest have died. Whilst the most important probable causes reported for the observed forest damage are adverse weather conditions, insects and fungi, most countries consider air pollution as a threatening to forest health.

Key words: forest damage, defoliation, discolouration, Europe,

1. Introduction

In view of the growing threat of acid precipitation and other forms of air pollution to the environment, the Convention on Long-range Transboundary Air Pollution (LRTAP Convention) was adopted within the framework of the United Nations Economic Commission for Europe (UN/ECE) in November 1979. Under the LRTAP Convention the Contracting Parties identify the effects of transboundary air pollution and accept their responsibility to undertake appropriate abatement action. The implementation of the LRTAP Convention is supervised by its Executive Body, which in 1985 established the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) in response to growing concern about increasing forest damage observed from the late 1970s on. ICP Forests was established under the Working Group on Effects (WGE), together with other ICPs studying the effects of air pollution on ecosystems and materials.

The present paper has the purpose to inform the reader on the objectives, the methodical approach and the accomplishments of ICP Forests, as well as on its activities planned for the future.

2. Objectives and Approach of ICP Forests

Since its establishment in 1985, the objectives pursued by ICP Forests have been the following:

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1. to gain knowledge of the spatial and temporal variation in forest condition in Europe and of its relationship to stress factors including air pollution on a regional, national and international scale,
2. to contribute to a better understanding of the impact of air pollutants and other damaging factors on forest ecosystems and of the cause-effect relationships involved,
3. to provide deeper insight into cause-effect relationships in the sense of ecosystem analysis.

Corresponding to these three objectives three special monitoring intensity level (levels I, II and III, respectively) were conceived, the first two of which have been implemented.

As regards the first objective, level I was implemented in 1986 as a continuous and harmonized systematic crown condition assessment with defoliation and discolouration as the key parameters. In this assessment, trees with up to 10% defoliation are considered "undamaged", the range >10% to 25% is identified as warning stage and trees with more than 25% defoliation are considered "damaged". This crown condition assessment is carried out annually on up to 622, 000 trees of about 33, 000 sample plots of national grids of different densities in 35 countries, representing about 225 million hectares of forest. Results of these national surveys are reported as country related mean values, split into tree species and age groups. Besides assessment results at the national scale, also results at the European scale are calculated. For this purpose a special transnational survey is performed in cooperation with the European Commission (EC), based on a uniform 16 x 16 km grid of 4,800 plots with 103,000 trees in 29 countries. Results of the national and transnational surveys are documented annually in the Forest Condition Report (EC and UN/ECE, 1994).

With respect to the second objective, the intensive monitoring on level II comprises besides the crown condition assessment

- soil analyses
- foliar analyses
- increment analyses
- deposition measurements

on a number of permanent monitoring plots. Up to now, level II has been implemented in cooperation with EC on about 400 permanent monitoring plots. Moreover, soil and foliar analyses are performed by several countries also on their plots of the transnational grid. The results of the intensive monitoring on both the the permanent monitoring plots and the transnational grid will become available as from 1995 according to a specific time schedule.

The basic methods and criteria for harmonized sampling, assessment, monitoring and analysis of air pollution effects on forests are laid down in the manual of ICP Forests, the first edition of which was published in 1986. This manual is continuously updated and was recently published in its third edition (UN/ECE, 1994).

3. Results

3.1. SPATIAL VARIATION OF FOREST CONDITION

The results of the annual national forest condition surveys of ICP Forests, though not directly comparable because of national peculiarities of site conditions and assessment methods, clearly reveal regional differences. These results indicate that the severest forest damage occurs in Central and Eastern Europe. For instance, in 1993 the following countries rated more than one third of their sample trees as damaged:

Denmark (33.4% of the sample trees classified as damaged), Latvia (35.0%), Slovak Republic (37.6%), Poland (50.0%), Moldavia (50.8%) and Czech Republic (53.0%). In Germany the percentage of damaged trees (24.2%) was also considerable.

In several of these countries, certain highland stands are severely affected and partly dead. In these main damage areas, the most affected tree species are Scots Pine (*Pinus sylvestris L.*), Norway spruce (*Picea abies (L.) Karst.*), European beech (*Fagus sylvatica L.*), Pendunculate oak (*Quercus robur L.*) and Durmast oak (*Quercus petraea (Matt.) Liebl.*).

The smallest percentages of damaged sample trees in 1993 were found in France (8.3%), Austria (8.2%) and Portugal (7.3%).

In the transnational survey of 1993, 22.6% of about 103 000 sample trees were classified as damaged. The transnational survey results shows that on 50% of all sample plots the share of damaged sample trees lies between 0% and 10%. These plots lie mainly in Scandinavia, in Western and Southwestern Europe and in the Alps. On 9% of all plots the share of damaged trees ranges between 51% and 75% and on 7% of all plots this share lies between 76% and 100%. This means that on 16% of all plots more than half of the trees are classified as damaged. The overwhelming part of these plots is situated in central and Eastern Europe with concentrations in the main damage areas along the borders between Germany, Poland and the Czech Republic.

3.2. TEMPORAL VARIATION OF FOREST CONDITION

National forest condition surveys have been performed in most of the 35 countries participating in ICP Forests for the last five to nine years. This permits first calculations of trends, both on the national and on the transnational basis.

According to the national surveys of 1993, a particularly high increase in forest damage is observed in 10 countries (Bulgaria, Ireland, Lithuania, Luxembourg, Poland, Romania, Ukraine, Hungary and the United Kingdom). Forest damage also increased in 9 further countries (Denmark, Germany, Greece, Norway, Portugal, Sweden, Slovenia, Spain and Switzerland). In the remaining countries, no clear trends are found. This could be interpreted as a long-term deterioration of forest condition in the majority of the participating countries. Long-term trends, however, must be derived from the na-

tional survey results with great care only, as they are based on annually changing tree samples.

The transnational survey provides a more reliable basis for the calculation of trends, as its results are submitted treewise to the data centre. In this way those trees which have been assessed for a number of years can be evaluated separately. For all of the twelve most common tree species in Europe, this evaluation reveals a deterioration of crown condition from 1988 to 1993.

A particularly severe deterioration was found in Sitka spruce (*Picea sitchensis (Bong.) Carr.*), Cork oak (*Quercus suber L.*) and Silver fir (*Abies alba Mill.*) In Sitka spruce, the percentage of damaged trees increased from 4.6% in 1988 to 33.8% in 1993. In Cork oak, the respective percentage increased from 0.7% in 1988 to 44.0% in 1991, but decreased again to 9.5% in 1988. The percentage of damaged Silver fir trees increased from 25.3% in 1988 to 30.5% in 1993.

Also the most frequent trees in central Europe show a clear increase in the percentage of damaged trees. In Norway spruce (*Picea abies (L.) Karst.*) the percentage of damaged trees increased from 14.5% in 1988 to 21.9% in 1993. In Scots pine (*Pinus sylvestris L.*) the percentage of damaged trees increased in the same period from 8.4% to 16.9%. The respective increase was from 10.0% to 17.3% for Common beech (*Fagus sylvatica L.*) and from 12.9% to 26.8% for Pendunculate oak (*Quercus robur L.*). Figure 1 shows the relative increases in the numbers of damaged trees since 1988. The highest relative increase in the number of damaged trees is found for Pendunculate oak, namely 107.7% since 1988. The respective relative increases are 101.2% for Scots pine, 73.0% for Common beech and 51.0% for Norway spruce.

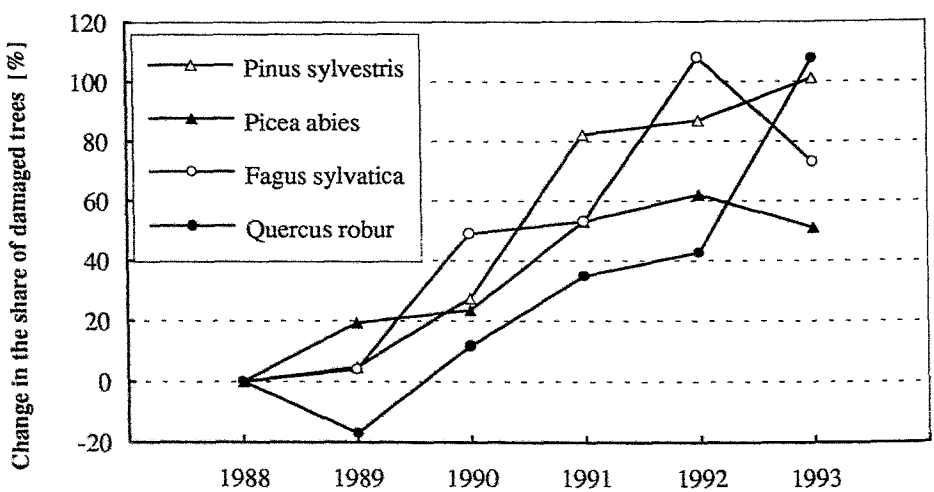

Figure 1: Increase in the number of damaged trees between 1988 and 1993

4. Interpretation

In both the national and the transnational surveys the most important probable causes for the observed defoliation and discolouration were reported to be adverse weather conditions, insects, fungi, forest fires and air pollution. The degree to which air pollution among the other factors has contributed to defoliation and discolouration, cannot be quantified as a consequence of the lacking specifity of these two symptoms. However, the continuous trend towards the worsening of forest cannot be readily explained by site conditions and damaging agents. Although there is no direct evidence of this being an effect of air pollution, this phenomenon deserves attention because a continuous and large scale weakening of forest health by long-range transboundary air pollution is likely to manifest itself in effects like the ones observed.

Whilst forest damage has developed less dramatically at the large scale, it is severe in certain regions and may be catastrophical locally. In some areas, particularly in the main damage areas of central Europe, several thousand hectares of forest have died. Particularly in these main damage areas, but also in several other regions, air pollution is considered as of major concern, because the atmospheric concentrations and the depositions of several air pollutants are thought to exceed the critical levels and loads for forest ecosystems. It is evident that the regions of highest damage coincide approximately with those areas of high immissions of sulphur and nitrogen oxides. The countries situated in these areas regard air pollution as the most important factor causing forest damage. The majority of the remaining countries consider air pollution as a predisposing factor leading to the weakening of forest ecosystems, while indirect influences on plant nutrition, soil acidification, eutrophication by nitrogen and leaching of base elements can be considerable.

5. Conclusions and Future Activities

Today's knowledge of the spatial and temporal variation of forest condition in Europe can not be imagined without the large-scale crown condition assessment on level I. Corresponding to the objectives of the level I approach, the large-scale assessment has

- provided a comprehensive knowledge of the extent, dynamics and spatial distribution of forest damage in terms of defoliation in Europe.
- created a comprehensive database suitable for future time series analyses of defoliation and complex studies in combination with further ecological parameters
- given impetus to forest damage research and environmental policies.

The crown condition assessment on level I will be continued in order to complete long-term time series and in order to perform synoptical analyses of the wealth of large-scale data collected over the years. Time series of many consecutive years will be helpful both for the identification of the potential impact of transboundary air on forests and for the identification of potential effects of air pollution abatement strategies. Moreover, the crown condition, soil and foliar data of level I will be analyzed in connection with the datasets of other ICPs running under the Working Group on Effects of UN/ECE. As

part of this work, critical loads for forest ecosystems and their exceedances are planned to be calculated and mapped.

ICP Forests and EC are striving for a common level II data bank, which will be the basis for the evaluations of the data received from the permanent monitoring plots. For the special forest ecosystem analysis aimed at a deeper insight into cause-effect relationships on a smaller number of sample plots (level III), close cooperation with the ICP on Integrated Monitoring is being planned.

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