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2005 RESULTS OF MONITORING FOREST CONDITION IN EUROPE

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

INTRODUCTION

1. In 2005 ICP Forests continued its large-scale (6,093 level I plots) and intensive (860 level II plots) monitoring of forest condition. The parameters monitored included crown condition, foliar chemistry, soil and soil solution chemistry, tree growth, ground vegetation, atmospheric deposition, ambient air quality, meteorology, phenology and litterfall.

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I. SPATIAL AND TEMPORAL VARIATION OF DEPOSITION

A. Methods

2. Bulk deposition and throughfall deposition data are available from approximately 500 level II plots from the second half of the 1990s. The analysis covered sites which had been operational for the whole period 1998–2003, allowing a maximum of one month of missing data per year. Deposition for the missing periods was calculated from the average daily deposition of the remainder of the year. To take into account the variability of deposition, the plotwise mean deposition for a three-year period (2001–2003) instead of a single year was evaluated. The slopes of linear regressions over three years for each plot were calculated and tested for significance to quantify temporal developments.

B. Results

3. Mean nitrogen (N) throughfall deposition ranged from 9.2 to 11.1 kg ha^{-1} year^{-1} measured in 1998–2003 for about 230 plots in Europe. Mean annual values fluctuated. Ammonium deposition ranged from 4.4 to 5.4 kg ha^{-1} year^{-1}. Nitrate deposition ranged from 4.7 to 5.7 kg ha^{-1} year^{-1} (figure 1). The plotwise evaluations showed that about 90% of the plots did not show any significant changes in nitrogen throughfall deposition. Depositions were mostly higher on plots in central Europe than in alpine, northern and southern European regions.

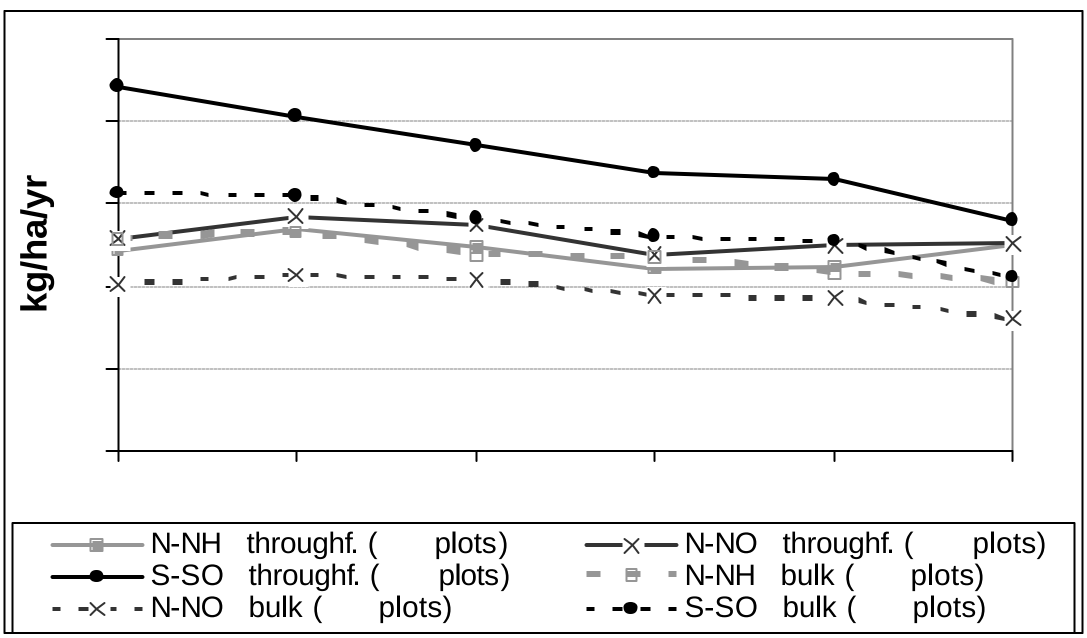

Figure 1. Annual mean bulk and throughfall deposition of sulphate (S-SO_4), nitrate (N-NO_3) and ammonium (N-NH_4) in 1998–2003

4. Mean bulk ammonium deposition for about 200 plots showed a decrease from 5.1 to 4.1 kg N ha^{-1} $year^{-1}$ over the period 1998–2003. The decrease was significant on 10% of the plots, whereas a significant increase was observed on 2% of the plots. Bulk nitrate inputs decreased from 4.0 to 3.2 kg ha^{-1} $year^{-1}$ in the same period. A significant decrease was observed on 12% of the plots. A significant increase was observed on only one plot.

5. Mean throughfall sulphate inputs decreased from 8.8 to 5.6 kg ha^{-1} $year^{-1}$ in 1998–2003. 30.7% of the plots showed significantly decreasing sulphur (S) inputs, whereas only one plot showed an increase (figure 1). Comparatively low sulphate throughfall deposition was measured on plots in the alpine region, Scandinavia and the Iberian peninsula. Mean bulk sulphate deposition decreased continuously from 6.2 to 4.2 kg S ha^{-1} $year^{-1}$ in 1998–2003. The measurements will be compared later with data modelled by EMEP.

II. IMPACT OF NITROGEN DEPOSITION ON GROUND VEGETATION

6. Ground vegetation contributes to the biological diversity of forest ecosystems and supports a considerable number of insects, animals and fungi. Deposition, in addition to natural factors, can influence the species composition of ground vegetation.

A. <u>Methods</u>

7. For the current evaluation, information from vegetation assessments was available for 720 sites for the years 1994–2003. On 477 plots, surveys had been repeated. National experts carried out vegetation assessments. The sampling area was required to be 400 m^2. Species abundance for ground floor vegetation was assessed using different scales such as Braun-Blanquet (1964), Londo (1976) and straight percentage cover. The different scales were transformed into cover percentages following the ICP Forests *Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests*.

8. Within the ground floor layer, a total of 2,003 vascular plant species were identified. Additionally, 91 unidentified taxa were registered. Most assessments had species numbers below 30 species. The highest frequency was recorded for the class of 10–20 species per plot. The maximum was 128 species within one assessment.

9. The floristic composition of the ground vegetation was evaluated using ordination techniques such as detrended correspondence analysis (DCA) (ter Braak 1987).

B. <u>Results</u>

10. The results from the first DCA, applied to 722 plots, explained 10% of the variance in species composition across Europe. This reflected the highly heterogeneous floristic composition

of ground floor vegetation and the multitude of influential environmental factors. 3.1% of the variance was explained by species dominating dry Mediterranean scrublands (maquis), mainly occurring on plots in the Iberian peninsula. In contrast to these plots were sites with shade-tolerating undergrowth species of nemoral and boreal forests. This difference could be accounted for by natural climatic and phytogeographic reasons. Differing management methods could also play a role in this context, as several plots on the Iberian peninsula were located in open forests with low tree layer coverage.

11. The second DCA evaluation focused on 488 plots in central and southern boreal regions of Europe. In this area, air pollution effects on ground vegetation were assumed to be very likely. 10% of the variance could be explained. 4.3% of the variance was explained by species typically occurring on acidic soils, including blueberry (*Vaccinium mult.* spec.). These species contrasted with species such as arum (*Arum maculatum*), dog's mercury (*Mercurialis perennis*) and oxlip (*Primula elatior*) which typically grow on calcareous soils. The results suggested that the acidity status of the plots was an important factor that determined ground floor vegetation composition across the nemoral zone in European forests (cf. Ewald 2003). This acid-base state is mostly determined by soil parent material or forest type, though the influence of acid deposition should be taken into account in the long term.

12. The second DCA evaluation also indicated that additional variation could be explained by the occurrence of species such as climbing corydalis (*Ceratocapnos claviculata*), bifid hemp-nettle (*Galeopsis bifida*) and chickweed (*Stellaria media*). For these species there is considerable evidence from the literature (e.g. Lethmate et al. 2002, De Vries et al. 2003) that they are favoured by high availability of soil nitrogen. Plots with high occurrence of these species were thus characterized by the availability of soil nitrogen. These plots were located in regions of high nitrogen deposition, such as the Netherlands, Flanders, northern Germany and Denmark, southern Poland, Slovakia and Hungary.

13. Analysis also using level II data for soil and deposition showed that plots with acidity-indicating species had more acidic soils characterized by low pH (figure 2). In addition, air pollution effects could explain some of the variation in species composition, as there was a significant relationship between the occurrence of nitrogen-indicating species and nitrogen deposition (figure 3).

14. National evaluations can provide more details. In Italy, the number of plant species increased with soil's nitrogen content, and this occurred mainly in beech forests in the southern part of the country. However, the number of species decreased when nitrogen deposition exceeded critical loads of nutrient nitrogen, mostly in beech forests in northern Italy.

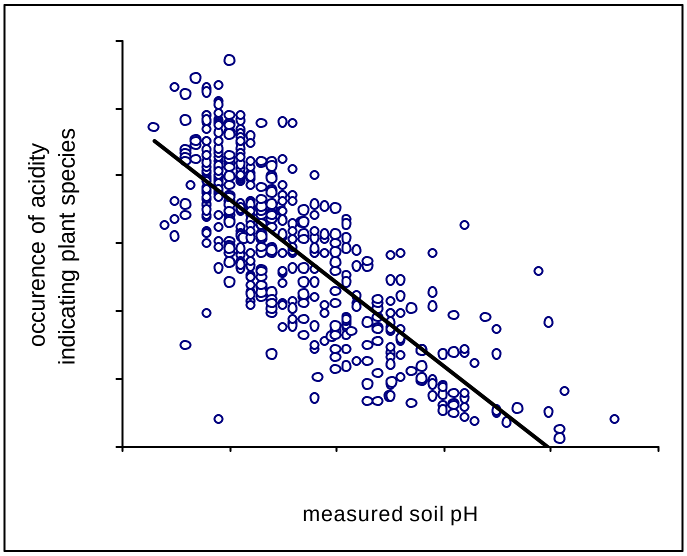

Figure 2. Relationship between the occurrence of acidity-indicating plants and pH in the organic soil layer for 472 plots (the graph shows a large number of plots with very low pH)

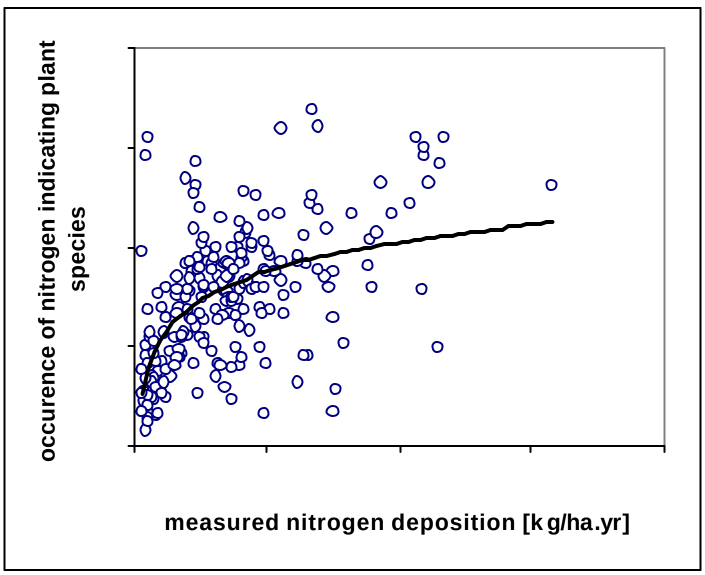

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Figure 3. Relationship between the occurrence of nitrogen-indicating plants and nitrogen deposition for 224 plots

15. Ellenberg indicator values are a common tool for expressing the ecological behaviour of plant species. Species that usually only grow on sites with a poor nitrogen supply are assigned low nitrogen indicator values. Pbts with repeated vegetation assessments thus allow the analysis of possible changes in plant composition over time using mean Ellenberg indicators. Differences were calculated between mean Ellenberg nitrogen indicator values at the most recent and at the first assessments for 475 plots with repeated surveys. Most of the plots did not show any

changes. The time interval between measurements (around five years) may be too short to show a change, or the vegetation may have already been adapted to nitrogen deposition at the time of the first assessments. Longer time intervals will be necessary to evaluate possible changes in ground vegetation composition.

III. DYNAMIC MODELLING OF FOREST SOIL ACIDIFICATION

16. Monitoring results show that sulphur deposition has decreased on many plots, whereas nitrogen inputs have remained stable or decreased (see section II). Dynamic soil chemistry models can demonstrate the effects of acid deposition and forestry measures such as harvesting and liming. They offer a process-oriented tool for estimating the acidification and recovery of forest ecosystems.

17. The Very Simple Dynamic (VSD) model was applied to 35 level II plots located in Spain (7), the United Kingdom (2), Germany (8), Poland (6), Greece (4), Austria (4), Belgium (3) and Hungary (1). The plots were selected based on data availability and were not representative Europe. The calculations used as input the Level II data and historical deposition rates available from the literature. Future deposition scenarios based on the Gothenburg Protocol were provided by the Centre for Integrated Assessment Modelling.

18. When modelled, many of the plots showed an increase in acidification between 1900 and 1990, followed by a slight recovery. The model predicted that recovery would continue until 2030.

19. The partial recovery that has been observed until now is mainly a result of emission reductions. Further emission reductions following implementation of the Gothenburg Protocol were assumed until 2010. The deposition level of 2010 was assumed to remain unchanged until 2050. The model predicted that in 2050 there would be as many plots with pH values below 4 as in 1900 (figure 4). However, only 50% of the sites would have a pH above 5, compared to about 70% in 1900.

20. The ecosystem reaction was not found to be uniform across all sites, due to site-specific conditions. Plots with a constant pH value had mostly calcareous parent material, which is a natural buffer for acidic inputs. Sensitive soils showed a marked decrease in pH and only partial recovery.

21. The chemistry of soil solution in dynamic models is closely linked to certain inputs, such as atmospheric deposition, and reacts quickly to changes in these inputs. The recovery of the solid phase of the soil is much slower and can take many decades.

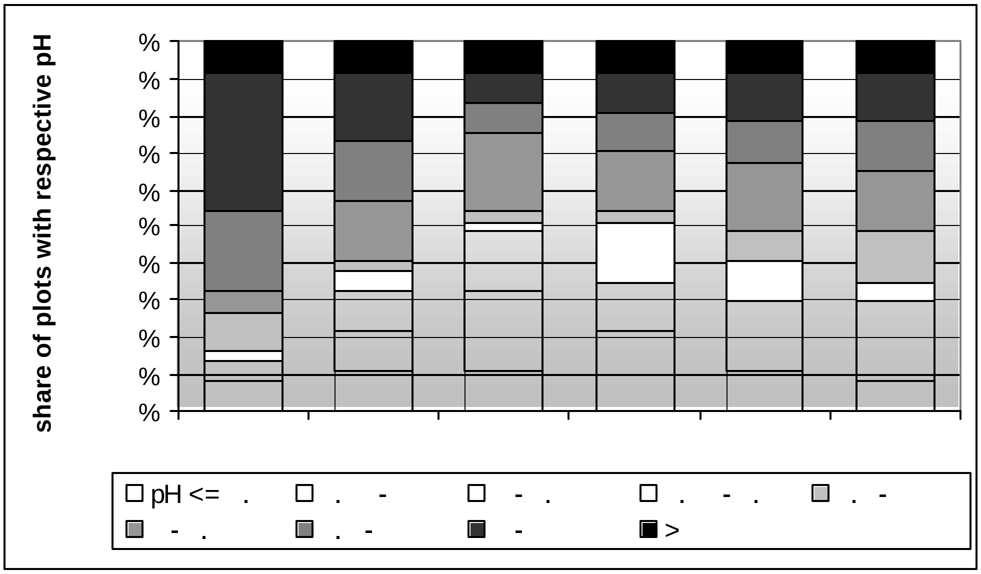

Figure 4. Frequency of modelled pH values at 35 level II plots located in Spain (7 plots), United Kingdom (2), Germany (8), Poland (6), Greece (4), Austria (4), Belgium (3) and Hungary (1)

IV. CROWN CONDITION AND FOREST GROWTH

22. The influence of air pollution on forests in Europe has to be evaluated together with the general health status of forests and additional stress factors, because forests are complex ecosystems and different stressors interact. Forest health is monitored over large areas by a survey of tree crown defoliation. Trees that are fully foliated are classified as undamaged in the defoliation survey.

23. The crown condition survey in 2005 comprised 6,093 plots in 30 countries, with 133,840 trees assessed. 23.2% had needle or leaf loss of more than 25% and were thus classified as damaged or dead. In 2004, the respective share was 23.3%. Of the most frequent tree species, European and sessile oak had the highest share of damaged and dead trees, namely 41.0% in 2005.

24. For the calculation of the long-term development of defoliation, data from countries which had submitted data annually since 1990 without interruption were included. Several of the main species showed an increase in defoliation in 1990–2005 (figure 5). This applied in particular to maritime pine (increase from 13.2% to 18.9% mean defoliation), beech (from 17.9% to 22.2%), holm oak (from 13.8% to 23.8%) and European and sessile oak (from 21.0% to 25.5%). Defoliation of Norway spruce fluctuated around 23%, without a clear trend. Of the main species, Scots pine was the only one experiencing a decrease in defoliation (from 24.3% to 22.6%). Its recovery, particularly in Poland and in parts of the Baltic States, since the mid-1990s resulted in its being in slightly better condition than in 1990. Due to the severe heat and drought

in summer 2003, the crown condition of all main species except Scots pine and holm oak deteriorated rapidly from 2003 to 2004 in southern Finland, southernmost Sweden, central and southern Germany, Bulgaria and some parts of France. From 2004 to 2005 a recovery was visible for beech, Norway spruce, and European and sessile oak.

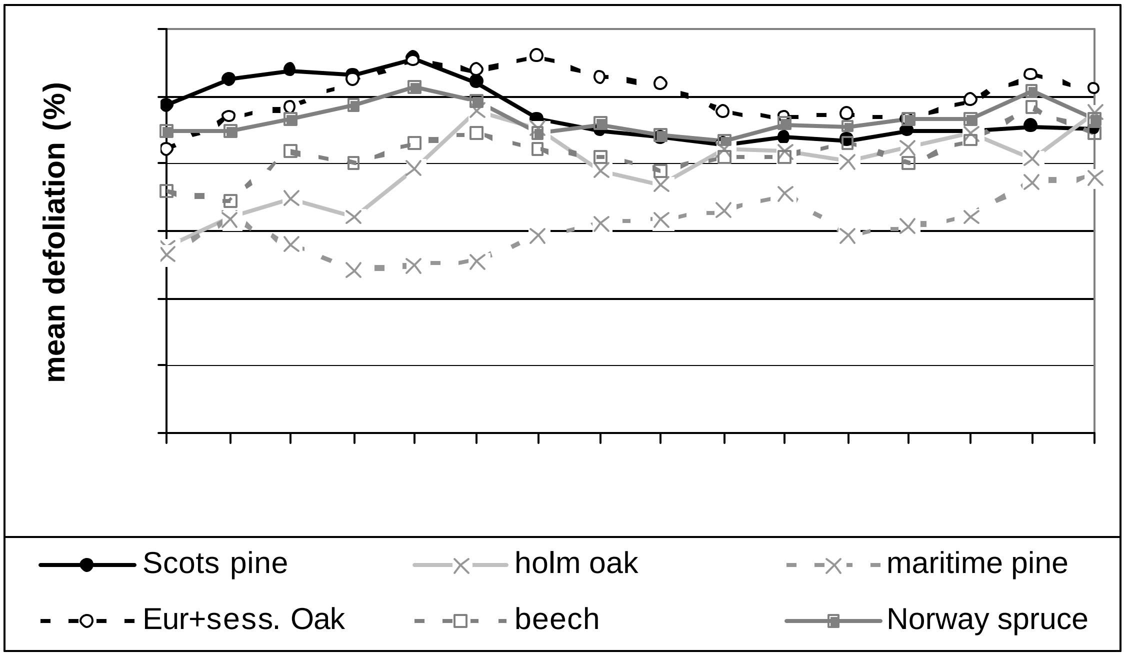

Figure 5. Percentage of damaged trees of all tree species and mean defoliation for the most frequent tree species (data include countries with continuous data submission)

25. Previous studies (e.g. Lorenz et al. 2003) have shown that the variation in defoliation is mainly explained by tree age, weather extremes and biotic factors. Air pollution was found to correlate only partly with defoliation. The crown condition survey is considered a valuable early warning system for many stress factors for forest health.

26. The influence of the extreme drought and heat that occurred in large areas of central Europe in summer 2003 was analysed using annual forest growth data. Such data were available from permanent stem circumference bands and tree cores taken from plots in southern Germany, Switzerland, Austria, Slovenia and northern Italy. The plots covered a large range in altitude and drought stress situations. Data were available only for years before and including 2003. The extent of any recovery in post-drought years can be evaluated only in the future.

27. The comparison of growth data for the years 2002 and 2003 showed that Norway spruce had the strongest growth response to the drought in 2003, common beech had a smaller response, and European and sessile oak showed practically no growth reductions. Below the altitude of

1,000 m, all sites experienced reduced growth in 2003. Growth reductions (in comparison with 2002) of 40–80% for spruce and 60–95% for beech were common. At altitudes higher than 1000 m, drought was not the limiting factor, due to lower temperatures and possibly higher precipitation. Instead, growth was stimulated by high summer temperatures in 2003 that extended the growing period for trees.

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