The present report presents the results of the activities undertaken since the previous report by the Programme Coordinating Centre for the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests. The activities and the report on them are in accordance with the request of the Executive Body to the Convention on Long-range Transboundary Air Pollution in its 2012–2013 workplan for the implementation of the Convention (ECE/EB.AIR/109/Add.2, items 3.1 (c) and 3.4). The report details, in particular, work on monitoring and modelling in 2012.
I. Introduction

1. The present report presents the results of the activities undertaken since the previous report by the Programme Coordinating Centre for the International Cooperative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). The activities and the report on them are in accordance with the request of the Executive Body to the Convention on Long-range Transboundary Air Pollution in its 2012–2013 workplan for the implementation of the Convention (ECE/EB.AIR/109/Add.2, items 3.1 (c) and 3.4).

II. 2012 results of monitoring/modelling

A. Epiphytic lichen diversity in relation to atmospheric deposition

1. Introduction

2. Lichens have been considered to be among the most sensitive groups of organisms at the ecosystem level for several types of pollutants. They have been recently used for revising the critical levels for ammonia in sensitive ecosystems, and they have also been used for defining critical loads (e.g., for forest habitats) under the European Union Air Quality Directive and the Convention.

3. In the present chapter, epiphytic lichen diversity and possible relations to nitrogen deposition are studied based on 70 ICP Forests Level II plots, which were monitored with the support of the European Commission. A total of 292 epiphytic lichen species were determined on 1,155 trees. Deposition information was available from the programme’s database. For the correlation with lichen data, measured mean deposition values (1996–2007) were used.

4. The methodology for the calculation of mean deposition follows the one given in the 2010 ICP Forests report. Each lichen species observed was classified as oligotrophic, mesotrophic or nitrophitic. The functional group “oligotrophic lichens” has been used in the present study as an early warning indicator. Oligotrophic species are adapted to nutrient poor conditions, i.e., low or even absent eutrophication; they are thus the first species group to react to changes in nitrogen deposition. One hundred and forty-two species, corresponding to a share of 49% from all determined species, were classified as oligotrophic. A shift towards nitrogen tolerant species has already been observed in existing studies from several countries in Europe, due to the intensification of livestock and other agriculture practices.

---


4 See www.forestbiota.org.

2. Results

5. The total epiphytic lichen species richness on the observed plots was related to the average yearly total throughfall deposition, and significantly decreased for nitrogen deposition above 10 kilograms per hectare per year (kg ha\(^{-1}\) yr\(^{-1}\)). The study shows close links between lichen species composition and deposition. In particular, the percentage of oligotrophic lichen species showed relations between nitrogen compounds (ammonium and nitrate) at plot level. A value of 40% of all lichens species on a plot being oligotrophs has been considered a critical threshold for nitrogen deposition.\(^6\)

6. The present study also shows that a share of over 40% of oligotrophic species only occurs at rather low deposition levels (figure 1). Throughfall nitrogen deposition of 3.8 kg ha\(^{-1}\) yr\(^{-1}\) was related to the threshold of 40% oligotrophs. The effects of ammonium (NH\(_4^+\)) and nitrate (NO\(_3^-\)) on the percentage of oligotrophs seem to be quite similar. As expected, the effects of nitrogen compounds were closely related to the quantity of throughfall precipitation. On drier plots, a nitrogen deposition of > 9 kg ha\(^{-1}\) yr\(^{-1}\) led to a complete disappearance of oligotrophic species, whereas, given the same amount of nitrogen deposition, a modelled percentage of 20% oligotrophic species still occurred on plots with higher annual precipitation. Moreover, significant differences between coniferous and broadleaved forests were observed. The effects of nitrogen deposition are by far less evident in coniferous than in broadleaved forest types. The underlying ecological phenomenon has still to be explored in more detail.

7. Higher percentages of oligotrophic species have been observed in Finland and in some Mediterranean plots in Italy and Spain, whereas most of the plots in Central Europe (especially Germany) were characterized by very low percentages of oligotrophic lichen species (figure 2). Plots in Central Europe and the Netherlands are affected by relatively

---

\(^6\) L. H. Geiser et al., 2010.
high nitrogen deposition values. Interestingly, in some plots of the Italian Eastern Alps and Spain, a mean annual nitrogen (N) deposition over the critical value did not correspond to a decrease of oligotrophs.

Figure 2

Percentage of oligotrophic macrolichens on the total number of species on selected ICP Forests Level II plots

3. Conclusions

8. The study supports the threshold of 40% of all lichens species being oligotrophs as an operational limit for determining nitrogen effects. For the Level II plots studied, a percentage of 40% oligotrophs seemed to be related to throughfall nitrogen deposition of approximately 3.8 kg ha⁻¹ yr⁻¹. The effects of $\text{NH}_4^+$ and $\text{NO}_3^-$ deposition on the percentage of oligotrophs are supposed to be similar.

9. Based on the relative share of oligotrophic macrolichen species at plot level, it was shown that approximately 80% of the investigated Level II plots are affected by an unsustainable throughfall nitrogen deposition, which can be suspected to cause a significant change of the expected composition of epiphytic lichen vegetation, together with a significant decrease in total lichen diversity, as well. About 58% of the plots, mainly

---

located in Germany and other central European countries, showed a very low occurrence or even a complete lack of oligotrophic lichen species.

10. Nevertheless, a contribution of other influencing factors (e.g., other pollutants or climate) cannot yet be excluded and more studies are still needed at the European level for a better understanding of the underlying cause-effect relationships.

B. Exceedance of critical limits and their impact on tree nutrition and vitality

1. Introduction

11. On ICP Forests plots various ecosystem parameters are monitored offering the possibility to investigate tree response to critical loads exceedances. Specifically, present nitrogen saturation and acidification status of plots with exceedances of critical loads are in the focus of this study, as well as the tree response to exceedances of critical limits in soil solution. The investigation was carried out on up to 251 plots depending on the survey, located in 25 countries.

12. Data used for the analysis include bulk and throughfall deposition continuously collected with weekly to monthly sampling intervals. Annual deposition was calculated as described in the ICP Forests Technical Report. The volume of bulk deposition was used to derive precipitation quantity.

13. Soil solution was sampled using lysimeters in the same time intervals as deposition, and analysed chemically in the laboratory. Annual mean concentration of the samples, as well as the ratio of samples exceeding critical limits, were calculated for each depth and depth classes were aggregated as described in ICP Forests reports. For the comparison of critical loads exceedance and soil solution a generic critical base cation to aluminium ratio of 0.8 was used, while for comparison of soil solution and foliar nutrition the species-specific values from Stefan et al. (1997) were applied. Damage cause assessments followed the ICP Forests Manual, which offers a detailed list of biotic and abiotic damage causes. The proportion of trees showing the symptom “light green to yellow discolouration” as well as “insect occurrence” has been computed for each year.

14. Critical loads for nitrogen as nutrient $N_{\text{nut}}$ (CLN$_{\text{nut}}$) and for acidification (CLA$_{\text{SMB}}$) have been calculated as described in Nagel et al. (2011), based on the measurements described above as well as on soil analyses, using the methods recommended in the Modelling and Mapping Manual of the International Cooperative Programme on Modelling and Mapping of Critical Loads and Levels and Air Pollution Effects, Risks and Trends.

---


12 Manual on Methodologies and Criteria for Modelling and Mapping Critical Loads and Levels; and
2. Results

15. On plots with higher N throughfall (>20 kg N ha\(^{-1}\) a\(^{-1}\)) critical limits for N saturation in the soil solution are more often exceeded (figure 3).

Figure 3
Percentage of plots with exceedances of critical limits for N saturation in soil solution of the lowest lysimeter (>0% of samples) for plots with throughfall N deposition less than 10, between 10 and 20 and exceeding 20 kg N ha\(^{-1}\) a\(^{-1}\)

16. Nutrient imbalances related to high nitrate concentrations could be substantiated. Magnesium (Mg) deficiencies occurred more frequently for coniferous plots with exceedance of critical limits for NO\(_3^-\) in soil solution. Also, for beech trees the percentage of plots with low Mg values is higher for plots with critical limits exceeded. For spruce, pines, beech and oak there is a tendency towards less optimal Mg/N ratios with increasing exceedances of critical limits for N in soil solution.

17. The symptoms “light green to yellow discolouration” and the cause “nutrient deficiency” have not been assessed on all plots. But results show that the reported ratio of trees with the symptom is higher on plots where soil solution critical limits for nutrient imbalances is exceeded (figure 4).
Figure 4
Percentage of trees with symptom “light green to yellow discolouration” for plots with critical limits for N in soil solution for nutrient imbalances exceeded in >0%, between 0% and 50%, and >50% of the samples from the mineral topsoil

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure4}
\caption{Percentage of trees with symptom “light green to yellow discolouration” for plots with critical limits for N in soil solution for nutrient imbalances exceeded in >0%, between 0% and 50%, and >50% of the samples from the mineral topsoil.}
\end{figure}

Notes: The relation is shown for the species groups “Spruce” (top left), “Pines” (top right), “Beech” (bottom left) and “Silver Fir” (bottom right). N = number of plots.

18. Similar relations have been found between exceedance of base cations to aluminium (BC/Al) ratio and ratio of trees with reporting of cause “insects”, but not for cause “fungal disease” on foliage, with the current set of assessment based on the assumptions mentioned in the method sections.

3. Conclusions

19. Most relations found in this investigation of the recent data of the ICP Forests Level II plots from 2006 to 2009 support the hypothesis of ongoing nitrogen saturation and acidification effects due to atmospheric nitrogen deposition:

(a) There is a clear relation between N deposition and the occurrence of high nitrate concentrations below the rooting zone indicating plots being in the phase of N saturation. Around half of the plots with exceedance of critical loads for nutrient nitrogen are still in the phase of accumulation and may show increasing effects in the future;
(b) The relation between nitrate in soil solution and foliar nutrition status confirmed the tendency towards less optimal Mg/N ratios with increasing exceedance of critical limits of nitrate in soil solution for all major tree species groups;

(c) Exceedances of critical limits for nitrate in soil solution were related to both less favourable foliar nutrition and higher frequency of light to green discolouration, which is a typical symptom of nutrient deficiencies.

20. These findings support the critical loads concept. It has to be mentioned that relation between variables do not necessarily prove cause-effect relationships. There might be confounding factors. In this study the influence of, e.g., soil condition, tree age, tree density, management and drought stress has not been considered.