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N Deposition as a Site Factor for Forest Stands in Southwest Germany

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N Deposition as a Site Factor for Forest Stands in Southwest Germany

Ernst E. HILDEBRAND (Freiburg)

1. Introduction

In Baden-Württemberg, we monitor the importance of atmospheric N input in forests using three large-scale grids:

- Input of ions through open air precipitation and crown through fall on 17 sampling sites, grouped into three west-east transects.
- Needle analyses and current growth rates in a 4 × 4 km grid in 5 year-intervals.
- Soil chemical analyses in a 8 × 8 km grid. Special attention we give to the pool of water soluble and effectively exchangeable ions.

2. Results and Discussion

2.1 Bulk N Deposition

In Figure 1 the N flux in open air precipitation and in the canopy drip of red spruce stands is plotted as nitrate and ammonium in the hydrological year 1992 (HEPP and HILDEBRAND 1993). The bulk airborne N input ranges from 5 to 36 kg/ha · a. We must consider, that N input by crown through fall is only a very conservative estimation, because hidden deposition by direct canopy uptake can not be directly measured. Experiments with $^{15}$N-labelled ammonium quantified this »missing link« at 9 kg N/ha · a in a mature spruce stand in the Solling highlands (EILERS et al. 1992). The rate of canopy N uptake seems to depend on the N saturation of the individual ecosystem. Forests stands, heavily depleted by historical practices such as litter raking, may have still insufficient N pools, and are able to assimilate the airborne nitrogen (ZÖTTL 1990). In such cases the N flux through canopy drip can be less than through open air precipitation.

Even if we disregard the budget problem by »occult N deposition«, the N input via crown through fall exceeds critical loads in most of our sampling plots. In this case »critical load« is defined as N input higher than the long lasting N export by timber harvest. Consequently, we have a general increase of N saturation in the forested area. In regions with intensive agriculture, such as the glacial moraine landscape of the »Alpenvorland«, ammonium is the dominating airborne N species.

The deposition history of two measuring plots with agricultural environment reveals a tendency of increasing ammonium deposition over time (Fig. 2). The reduced input of free protons is partially compensated by increased proton input via ammonium. The total acid load therefore remains nearly unchanged.

2.2 N Nutrition of Forest Stands

Applying conventionally recognized criteria of N nutrition, the N levels of conifer needles rarely indicate luxury consumption, in spite of considerable and widespread N input. At the integration level of the total forested area of Baden-Württemberg we find, nevertheless, no correlation between the N content of needles and the current radial
Fig. 1 Bulk N deposition in open air precipitation (left column) and in the canopy drip of red spruce (right column) in the hydrological year 1992. In the case of the sampling site »Heidelberg«, the third column records the N input in a fertilized spruce stand (HEPP and HILDEBRAND 1993).

Tree growth (Tab. 1, HILDEBRAND and SCHÖPFER 1993). These results are unexpected, as N should still have considerable growth stimulating potential on the actual N nutrition level, which was monitored via needle analysis. Such growth reactions were proved by various N-fertilizing experiments. In contrast to the minor importance of N contents in needles, we find highly significant influences of K and Mg contents on current radial growth. From an ecosystematical point of view, the atmospheric N input
Tab. 1 Levels of significance in a multiple regression model relating nutrient contents of 3 year old needles to the current radial growth within 3 years (HILDEBRAND and SCHÖPFER 1993)

<table>
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<th>element</th>
<th>significance level (p)</th>
<th>n = 1302</th>
</tr>
</thead>
<tbody>
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<td>N</td>
<td>0.13</td>
<td>n = 1302</td>
</tr>
<tr>
<td>P</td>
<td>0.27</td>
<td>n = 1302</td>
</tr>
<tr>
<td>K</td>
<td>0.01</td>
<td>n = 1302</td>
</tr>
<tr>
<td>Mg</td>
<td>0.04</td>
<td>n = 1302</td>
</tr>
</tbody>
</table>

Fig. 2 History of N deposition in the sampling sites »Grubenhau« and »Welzheim« (HEPP and HILDEBRAND 1993).

apparently represents »lost capital«, which is not completely converted into a biomass increase. We must therefore recognize that a »bottleneck« situation characterizes the nutritional status of the forests in Baden-Württemberg: Mg and K are growth limiting factors. Airborne N input, which is not assimilated, causes additional loss of acid neutralization capacity (ANC) in the soil, rendering K and Mg deficiency even more severe.

2.3 Soil Chemical N Status

In Figure 3 we plotted the C/N ratios in forest stands of Baden-Württemberg in a 8 × 8 km grid. It is unexpected, that even in highlands with slow litter breakdown (e.g. Black Forest) C/N ratios > 25 are rather seldom. C/N ratios in the organic layers are
generally closer than conventionally attributed to the humus types (Fig. 4). A clear ranking of C/N distributions, as for example published by von Zezschwitz (1980) can not be obtained. Especially in acid organic layers we find frequently »disharmonic« humus types such as »N-rich raw humus«.

We can also demonstrate the change in N turnover by comparing the actual abundance of molar C/N ratios with representative values measured by Evers et al. (1968) 25 years ago. Figure 5 shows the drastic changes of the C/N ratios. Whereas Evers et al. did not find C/N ratios < 15, recent values do not exceed 30.

In deeper mineral soil horizons (90–140 cm) nitrate is frequently the dominating water soluble anion in soil equilibrium solutions (Fig. 6). In approximately \( \frac{1}{4} \) of the Baden-Württemberg forest stands, nitrate therefore becomes the major driving force for cation exportation from the rhizosphere. There is a clear gradient of increasing nitrate dominance with increasing soil depth. In contrast to the behaviour of sulfate there is apparently no effective chemical or biological sink for nitrate beyond the rhizosphere.
3. Conclusions and Summary

The bulk N input in forest stands of south-west Germany actually ranges from 9-39 kg N/ha·a. During years with higher precipitations, deposition rates of up to 50 kg N/ha·a were measured (Hochstein and Hildebrand 1992). Input rates that are lower than the export rates by timber harvest (<10–15 kg N/ha·a) are only recorded in lee-situations in the Black Forest highlands. In regions where agriculture dominates, ammonium is the major airborne N species.

Despite considerable and widespread N input, the N levels of conifer needles rarely indicate luxury consumption. On the integration level of the total forested area of Baden-Württemberg we find, however, no correlation between the N content of needles and the current radial tree growth for the period, represented by the respective needle age. This contradicts results expected from N-fertilizing experiments. An explanation could be that airborne N input is linked with »unphysiological sets« of cations or anions. In contrast to the insignificance of N contents in needles we find highly significant influences of K and Mg contents on current radial growth. As the
Fig. 5 Actual and historical distribution of C/N ratios in forest soils of Southwest Germany.

Fig. 6 Abundance of nitrate as the dominating anion in the equilibrium soil solution, plotted against soil depth.
atmospheric N input is in great part not converted into biomass increase, risks may arise for the hydrosphere as well as for drinking water gained from forested catchments.

Results gained from the Institute’s soil chemical monitoring network show, that C/N ratios in the organic layers are often closer than conventionally attributed to the respective humus types. A comparison of historical C/N ratios with recently measured values reveals a drastic change towards closer ratios during the last decades. This drift is caused by N enrichment through deposition rather than by increased mineralization, as there is no evidence of marked changes of humus types and C/P ratios. In deeper mineral soil horizons (90–140 cm), nitrate is the dominating water soluble anion in the soil equilibrium solution in \( \frac{1}{4} \) of the investigated samples and, therefore, acts as an important driving force for cation export.

It is important to keep in mind that these statements only apply to the integration level of the total forested area of Baden-Württemberg. Such large-scale monitoring results can neither be proved nor be falsified by results gained from the local level of individual stands.

**Literature**


**The Impact of Increased Nitrogen Levels on the Temperate Zone Biosphere in Europe**

Wolfgang HABER (Munich/Freising)

In order to understand and evaluate the effects of increased nitrogen impacts on natural ecosystems, which are often overlooked, a short recourse to the landscape history of Central Europe is useful.

For natural ecosystems or biotic communities in the temperate zone forest biome, nitrogen has always been limited supply, but the ecosystems have well adapted to this situation. By turnover and storage of bound nitrogen in different time-scales, a small but continuous gain in nitrogen was achieved during the post-glacial vegetation