THROUGHFALL MONITORING AT 5 SITES IN THE NETHERLANDS IN 2003

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<table>
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ECN-Clean Fossils
Air Quality & Climate Change
Preface
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Abstract
During one year, throughfall was measured in five Level II forest sites in the Netherlands as part of the PAN European monitoring programme for the Intensive Monitoring of Forest Ecosystems. The data for the monitoring year 2003 are reported and a canopy exchange model was applied to estimate the atmospheric deposition to these sites. Further evaluation of the results including comparison with previous years will be reported with the results of the project concerning throughfall measurements 2003-2005.
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SUMMARY

The Pan-European Programme for the Intensive Monitoring of Forest Ecosystems is the so-called Level II Programme of the International Co-operative Programme on Assessments and Monitoring of Air Pollution Effects on Forests (ICP Forests of UN/ECE). It provides the framework in which analysis of the effects of atmospheric loads and its temporal variation is investigated. The current monitoring programme of ICP Forest at the so-called ‘Intensive Monitoring’ (Level II) plots in the Netherlands includes deposition measurements at four sites. Throughfall is measured by the Energy research Centre of the Netherlands at Dwingelo, Hardenberg, Speuld and Zeist. In 2003, throughfall measurements were started at a fifth site at Leende. Bulk deposition is measured close to the Hardenberg site. For the other four sites bulk deposition data are obtained from the National Air Quality Monitoring Network by the National Institute of Public Health and Environment.

This report describes the measurements performed in 2003 and the results of the quality checks performed on the data. The total nitrogen deposition in 2003 varied between 800 and 2800 mol.ha\(^{-1}\).y\(^{-1}\). Lowest nitrogen deposition is measured at Zeist, the other sites showing about the same inputs. Potential acid deposition is highest at Speuld and amounts to 4000 mol.ha\(^{-1}\).y\(^{-1}\). The other sites show inputs of about 3000 mol.ha\(^{-1}\).y\(^{-1}\), except Zeist receiving about 1700 mol.ha\(^{-1}\).y\(^{-1}\).

Further evaluation of the results will be reported with the results of the throughfall measurements 2003-2005.
1. INTRODUCTION

The Pan-European Programme for the Intensive Monitoring of Forest Ecosystems is the so-called Level II Programme of the International Co-operative Programme on Assessments and Monitoring of Air Pollution Effects on Forests (ICP Forests of UN/ECE). It provides the framework in which analysis of the effects of atmospheric loads and its temporal variation is investigated. The current monitoring programme of ICP Forest at the so-called ‘Intensive Monitoring’ (Level II) plots in the Netherlands includes the yearly assessment of the forest condition, foliar composition and the soil solution since 1992 at 14 sites (12 before 1995) and the five-yearly assessment of a large number of more slowly changing parameters. The chemical composition of the groundwater has been measured three-monthly at the initial 12 sites during all years. In 1990 a national survey of the chemical composition of needles, litter, soil and soil solution was also conducted for 150 stands (De Vries and Leeters, 1996), which has been repeated in 1995 for 200 stands, including the 14 intensive monitoring plots. A new assessment is foreseen in the year 2005. Up until now throughfall (or atmospheric deposition) was not measured at the 14 plots.

EC-LNV co-ordinates the Dutch contribution to ICP Forest. ECN performed throughfall measurements at the 4 Level II plots in the Netherlands between January 2003 and December 2003 and at a fifth plot between March 2003 and December 2003, using the method recommended by Draaijers et al., (1996). The research was financed by the EC through EC-LNV and by the Ministry of Housing, Physical Planning and the Environment (VROM).

This report is an intermediate publication of the results for the 5 plots in 2003. This report first gives a description of the sites and the measurement methods. The results of the measurements are described in Chapter 3. The report ends with short conclusions. Further evaluation of the results will be reported with the results of the throughfall measurements 2003-2005.
2. EXPERIMENTAL

The current monitoring programme of ICP Forest at the Level II plots in the Netherlands includes the yearly assessment of the forest condition, foliar composition and the soil solution since 1992 at 14 sites. At these sites, throughfall gutters were installed in 1995 and for one year data were collected (Erisman et al., 1997). In October 1997 the measurements were continued at four of the 14 sites. Since March 2003 throughfall measurements were also started at a fifth site. The sites, stand characteristics, the co-ordinates and the dominant tree species are given in Table 2.1. Figure 2.1 shows the location of the sites in a map of the Netherlands. The plots are located in the main forested areas in the country: in Overijssel (1), the Utrechtse Heuvelrug (2), the Veluwe (3), Drenthe (4) and Brabant (5).

Table 2.1 Sites, stand characteristics and their co-ordinates

<table>
<thead>
<tr>
<th>No.</th>
<th>Plot</th>
<th>Locatie</th>
<th>Lon</th>
<th>Lat</th>
<th>Species</th>
<th>Distance to forest edge (m)</th>
<th>Tree height (m)</th>
<th>Crown coverage (%)</th>
<th>Bulk deposition site</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2085 Dwingleo</td>
<td>06°26'45&quot;</td>
<td>52°50'20&quot;</td>
<td>Scots pine</td>
<td>&gt;100</td>
<td>15-20</td>
<td>&gt;75</td>
<td>928 Witteveen</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>106 Hardenberg-DG</td>
<td>06°33'00&quot;</td>
<td>52°32'42&quot;</td>
<td>Douglas fir</td>
<td>&gt;100</td>
<td>&gt;20</td>
<td>50-75</td>
<td>Rheezerveen</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2084 Speulder-DG</td>
<td>05°44'17&quot;</td>
<td>52°16'03&quot;</td>
<td>Douglas fir</td>
<td>&gt;100</td>
<td>10-15</td>
<td>&gt;75</td>
<td>732 Speulder Veld</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1040 Zeist-EI</td>
<td>05°13'50&quot;</td>
<td>52°06'32&quot;</td>
<td>Oak</td>
<td>20-40</td>
<td>15-20</td>
<td>50-75</td>
<td>628 Bilthoven</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>175 Leende</td>
<td>05°31'04&quot;</td>
<td>51°19'19&quot;</td>
<td>Scots pine</td>
<td>20-40</td>
<td>15-20</td>
<td>50-75</td>
<td>131 Vredepeel</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2.1 Location of the throughfall monitoring sites
2.1 Sampling and analysis

The sampling was performed according to the descriptions in the Submanual on deposition on ICP Forests Level 2 plots (ICP Forest Expert Panel on Deposition, 1994, updated 06/1999) and data was handled according to the Basic documents for the implementation of the intensive monitoring programme of forest ecosystems in Europe (EC, VI/3908/95-EN). An extensive description of the methods is given in Part VI of the ICP-Forests Manual (ICP, 2004). Bulk deposition (open field) measurements were only performed at plot Hardenberg (106). For all other locations, bulk precipitation was obtained from wet-only measurements performed by RIVM at the sites indicated in Table 2.1. The data from the Air Quality Monitoring Network were kindly being made available by RIVM (RIVM, 1999; 2000). Open field precipitation is measured as two-weekly averages, which were combined in the lab to obtain monthly samples.

At each plot, 10 gutters are used in two parallel lines with 5 collectors, each at distances of 1-2 m. The gutters are 4 m long and have a collecting area of about 400 cm$^2$. They are placed with an angle of 150°, about 1.5 m above the surface. Sample bottles are placed below the surface and CHCl$_3$ was added as a preservative. The samples were kept in the dark at temperatures between 4 and 8 °C. Sample bottles were collected two-weekly and the gutters were rinsed with demi-water. Five samples were combined into one sample. Weekly samples were combined in the lab to obtain monthly samples.

In the lab, the monthly sample was split; one half was acidified with HNO$_3$ to pH 1 for analyses of metals. These were determined by atomic absorption spectroscopy (ICP-AES). Ions determined were: K, Ca, Mg, Na, Al, Mn and Fe. The other sample was used to determine conductivity, pH (potentiometric), Cl, NO$_3$, SO$_4$ by ionic chromatography, N$_{total}$ by Kjeldahl analysis and NH$_4$ by Flow Injection Analysis, FIA/conductivity. Before delivering the data, data checks were performed, as described in de Vries et al., (1999) and outlined in the next paragraph.

2.2 Quality checks

Several criteria were met to safeguard the quality and to estimate the uncertainty. First of all the measurement set-up, conservation and handling of samples was done according to the recommendations in Draaijers et al., (1996) and the ICP-Forests Manual (ICP-Forests, 2004). Gutters were used instead of open samplers. The number of gutters was 10. Secondly, sample analysis was performed according to and with methods certified by STERLAB. Finally, samples were collected and stored in light-tight bottles at low temperatures. CHCl$_3$ was added as a preservative to prevent biological conversion. Additional quality checks can be done after sampling and are described in Erisman et al. (2001).
3. RESULTS

In this chapter, the results of the monitoring of throughfall and bulk precipitation at the five sites are given. First, the results of the quality checks are discussed after which the results of the year 2003 are given.

3.1 Quality checks

The quality checks were done as previously reported by Erisman et al. (2001). About 10% of the data show discrepancies from the acceptable ranges in ionic balances, conductivity and/or Na-Cl ratio. Errors could be identified based on the interpretation of the three criteria and in few cases they were corrected for. Examples of errors that were encountered were dilution factor not taken into account and missing values. Samples were reanalysed or, if no explanation could be found, only one of the duplo samples was taken into account. The corrected data are shown in Figure 3.1 to Figure 3.3. These figures show the comparison of the cations versus the anions (Figure 3.1), the measured versus the calculated conductivity (Figure 3.2) and the Na-Cl ratio versus the deviation of the ionic balance (Figure 3.3).

![Figure 3.1 Cations versus the anions for monthly samples for 2003 (meq.m⁻³)](image_url)
As can be seen from the figures, most of the data fall within the acceptable ranges (Erisman et al., 2001). However, several data are rejected when using the FIMCI software to evaluate the data using the above described data checks, especially related to the conductivity test. It is suspected that the FIMCI software uses more stringent criteria for rejecting data than listed in de Vries et al. (1999). Organic compounds might also cause the data to be outside the limits.

Annual fluxes were calculated by averaging the concentrations for those periods, which fulfilled either the ion-balance or conductivity criteria, or both. These concentrations were multiplied by the total amount of throughfall or precipitation over the whole year, including also the rejected periods.
3.2 Temporal variations in throughfall fluxes

The temporal variation as monthly averages in throughfall fluxes of $K^+$, $Ca^{2+}$, $Mg^{2+}$, $Na^+$, $NH_4^+$, $Cl^-$, $NO_3^-$ and $SO_4^{2-}$ is plotted in Figure 3.4 for the four sites. Generally, the throughfall fluxes display the same pattern for all components. The temporal variation is primarily determined by the amount of precipitation for each month. Fluxes are low when the amount of precipitation is low. All sites show a distinct peak in the eleventh period of the year.
3.3 Annual average throughfall fluxes in 2003

The fluxes of throughfall and open field precipitation were calculated by multiplying the concentration with the amount of water and make the necessary conversions to express the flux in mol.ha\(^{-1}\).y\(^{-1}\). Table 3.1 gives the fluxes for the year 2003. Annual average fluxes were calculated as the sum of monthly fluxes. The total nitrogen flux is calculated as the sum of nitrate and ammonium fluxes, whereas the potential acid flux is estimated according to:

\[
\text{Potential acid} = NH_4^+ + NO_3^- + 2SO_4^{2-}
\]

Table 3.1  
Annual throughfall fluxes measured at the five sites and open field precipitation measured at Hardenberg in 2003 in mol.ha\(^{-1}\).y\(^{-1}\). 

<table>
<thead>
<tr>
<th>site</th>
<th>NH₄</th>
<th>Na</th>
<th>Mg</th>
<th>K</th>
<th>Ca</th>
<th>Cl</th>
<th>NO₃</th>
<th>SO₄</th>
<th>Tot N</th>
<th>Pot. Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dwingelo</td>
<td>1983</td>
<td>1568</td>
<td>174</td>
<td>132</td>
<td>544</td>
<td>1900</td>
<td>867</td>
<td>475</td>
<td>2850</td>
<td>3801</td>
</tr>
<tr>
<td>Hardenberg</td>
<td>2245</td>
<td>1162</td>
<td>197</td>
<td>164</td>
<td>297</td>
<td>1377</td>
<td>1025</td>
<td>1025</td>
<td>580</td>
<td>3271</td>
</tr>
<tr>
<td>Speuld</td>
<td>1895</td>
<td>1118</td>
<td>187</td>
<td>176</td>
<td>341</td>
<td>1306</td>
<td>1002</td>
<td>633</td>
<td>2897</td>
<td>4163</td>
</tr>
<tr>
<td>Zeist</td>
<td>1303</td>
<td>990</td>
<td>212</td>
<td>200</td>
<td>848</td>
<td>1285</td>
<td>426</td>
<td>449</td>
<td>1730</td>
<td>2628</td>
</tr>
<tr>
<td>Leende</td>
<td>1518</td>
<td>545</td>
<td>87</td>
<td>147</td>
<td>415</td>
<td>874</td>
<td>630</td>
<td>400</td>
<td>2148</td>
<td>2949</td>
</tr>
<tr>
<td>bulk-Hardenberg</td>
<td>429</td>
<td>302</td>
<td>46</td>
<td>53</td>
<td>53</td>
<td>361</td>
<td>481</td>
<td>123</td>
<td>1083</td>
<td>1366</td>
</tr>
</tbody>
</table>

Throughfall fluxes of total nitrogen are lowest at Zeist, a plot relatively far away from livestock breeding areas. The northern sites and Speuld show approximately the same nitrogen loading of 40–45 kg N.ha\(^{-1}\). The potential acid fluxes are highest in Hardenberg (4400 mol.ha\(^{-1}\).y\(^{-1}\)) and lowest in Zeist (2600 mol.ha\(^{-1}\).y\(^{-1}\)).
4. DEPOSITION ESTIMATES

Deposition estimates can be made by using a canopy exchange model. Such a model is described in the Erismann et al. (2001). The sections below describe the results of the model followed by a description of deposition trends at the different plots.

4.1 Dry, wet and total deposition estimates

Dry deposition fluxes in 2003 calculated with this model, together with the wet deposition data measured by RIVM (RIVM, 1999) and the total deposition, are given in Table 4.1. Dry deposition is generally an order of magnitude higher than wet deposition and determines about 70% of the total deposition flux for NH$_4$ , SO$_4$ and NO$_3$. The total nitrogen deposition varies between 800 and 2800 mol.ha$^{-1}$.y$^{-1}$.

<table>
<thead>
<tr>
<th>Location</th>
<th>Dry deposition (mol.ha$^{-1}$.y$^{-1}$)</th>
<th>Wet deposition (mol.ha$^{-1}$.y$^{-1}$)</th>
<th>Total deposition (mol.ha$^{-1}$.y$^{-1}$)</th>
<th>Total Nitrogen</th>
<th>Potential Acid</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NH$_4$</td>
<td>SO$_4$</td>
<td>NO$_3$</td>
<td>NH$_4$</td>
<td>SO$_4$</td>
</tr>
<tr>
<td>Dwingelo</td>
<td>660</td>
<td>360</td>
<td>650</td>
<td>380</td>
<td>110</td>
</tr>
<tr>
<td>Hardenberg</td>
<td>690</td>
<td>460</td>
<td>540</td>
<td>430</td>
<td>120</td>
</tr>
<tr>
<td>Speuld</td>
<td>1230</td>
<td>470</td>
<td>710</td>
<td>550</td>
<td>160</td>
</tr>
<tr>
<td>Zeist</td>
<td>-20</td>
<td>290</td>
<td>210</td>
<td>410</td>
<td>160</td>
</tr>
<tr>
<td>Leende</td>
<td>890</td>
<td>270</td>
<td>410</td>
<td>560</td>
<td>140</td>
</tr>
</tbody>
</table>

4.2 Trends in deposition

Throughfall and open field precipitation has been measured at the four sites in 1995-1996, 1998, 1999, 2000, 2002 and 2003. From these data, the temporal variation can be determined. Figure 4.1 to Figure 4.4 show the temporal variation in deposition estimates for four of the sites as derived from throughfall measurements and bulk deposition data after application of the canopy exchange model. For Leende, only one year of measurements is available, therefore no temporal variation can be given here. Dwingelo, Hardenberg and Speuld show a small increase of deposition, after a decrease in 2002. For Zeist no clear trend can be seen in the last few years.
Figure 4.1 Temporal variation in deposition measured at Dwingelo

Figure 4.2 Temporal variation in deposition measured at Hardenberg
Figure 4.3  Temporal variation in deposition measured at Speuld

Figure 4.4  Temporal variation in deposition measured at Zeist
5. CONCLUSIONS

During one year (between January and December 2003), throughfall measurements were performed at 5 ICP Level-II plots in the Netherlands. The measurements were performed with 10 gutters per plot, sample bottles were stored in light protected bottles at low temperatures, all to assure high quality results. Most of the fluxes could be used to estimate atmospheric deposition after the application of several quality checks. For the estimation of atmospheric deposition, a canopy exchange model was applied and dry and wet deposition fluxes were calculated. In general in 2003 somewhat higher deposition fluxes were found compared with the previous year. At Zeist, the fluxes are rather constant over the last 6 years.
REFERENCES


UN/ECE (1996).
