ECN-C--05-083

THROUGHFALL MONITORING AT 5 SITES IN THE NETHERLANDS IN 2004

A. Bleeker

M. Geusebroek

W.C.M. van den Bulk

P.B. Fonteijn

Revisions		
Made by: A. Bleeker	Approved by: G.J. de Groot	ECN Clean Fossil Fuels
Checked by: A. Hensen	Issued by: J.W. Erisman	Air quality and climate change

OCTOBER 2005

Preface

This project is the result of the ECN-project 7.2818 that was funded by the EU and by the Dutch ministry VROM with contract number 200107331

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 2004 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.

Contents

List of tables

List of figures

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 and Leende site. For the other three 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 2004 and the results of the quality checks performed on the data. The total nitrogen deposition in 2004 varied between 800 and 2600 $mol.ha^{-1}.y^{-1}$. 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 5 Level II plots in the Netherlands between January 2004 and December 2004, 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 2004. The results for 2003 are described in Bleeker et al. (2004). 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 (2), the Utrechtse Heuvelrug (4), the Veluwe (3), Drenthe (1) and Brabant (5).

Table 2.1 *Sites, stand characteristics and their co-ordinates*

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

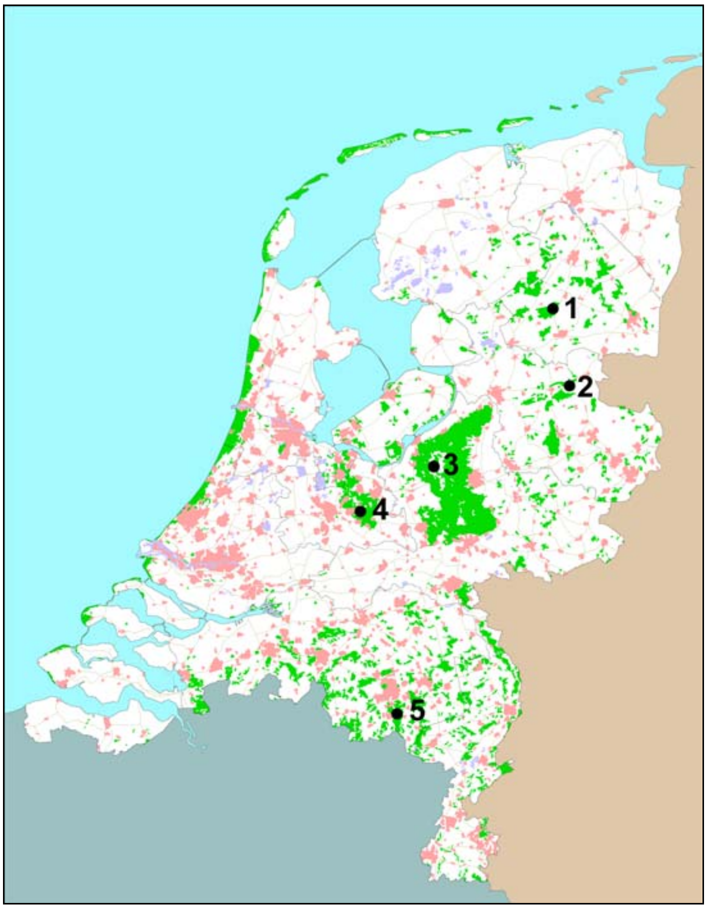

Figure 2.1 *Location of the throughfall monitoring sites*

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 the plots Hardenberg (106) and Leende (175). 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. These gutters are placed in two parallel lines of 5 gutters, each at distances of 1-2 m. The gutters are 5 m long and have a collecting area of about 400 cm^2. They are placed with an angle of 15^o, with a maximum height of about 1.5 m above the surface. Sample bottles are placed below the surface. Sample bottles were collected two-weekly and the gutters were rinsed with demi-water. After sampling the samples were kept in the dark at a temperature of 4 ^oC. Five individual samples per sampling period were pooled into one sample, resulting in two pooled samples per sampling period. The two-weekly pooled samples were then 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 2004 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).

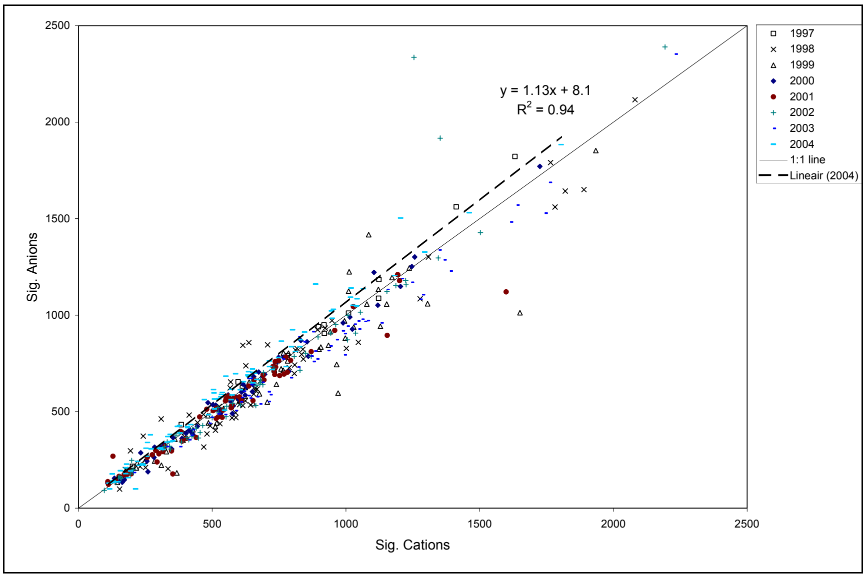

Figure 3.1 *Cations versus the anions for monthly samples for 2004 (meq.m^{-3})*

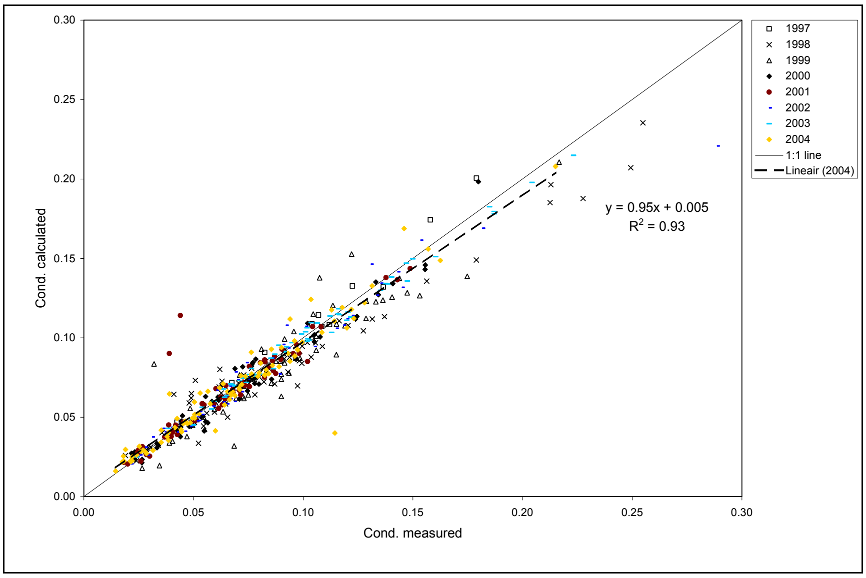

Figure 3.2 *Calculated conductivity versus the measured conductivity (mS.cm^{-1})*

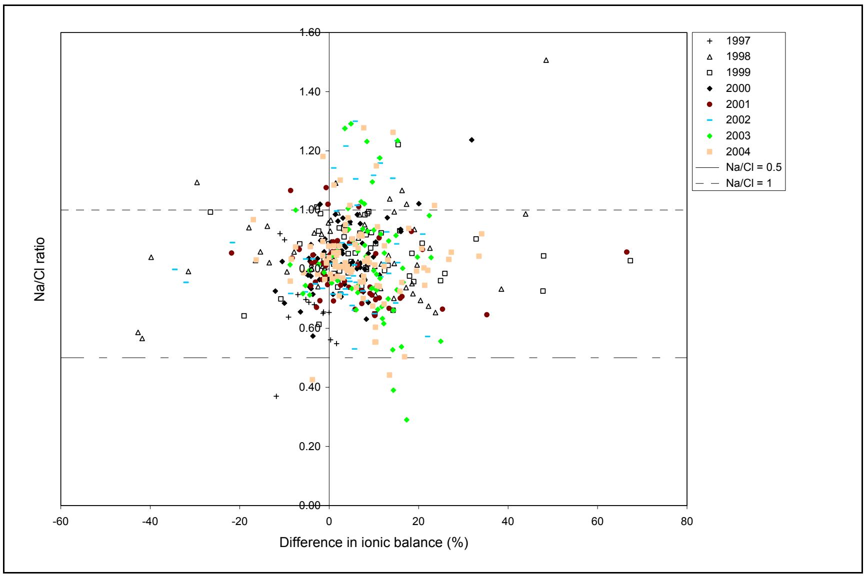

Figure 3.3 *Molar Na-Cl concentration ratio versus the deviation of the ion balance (%)*

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 then 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.

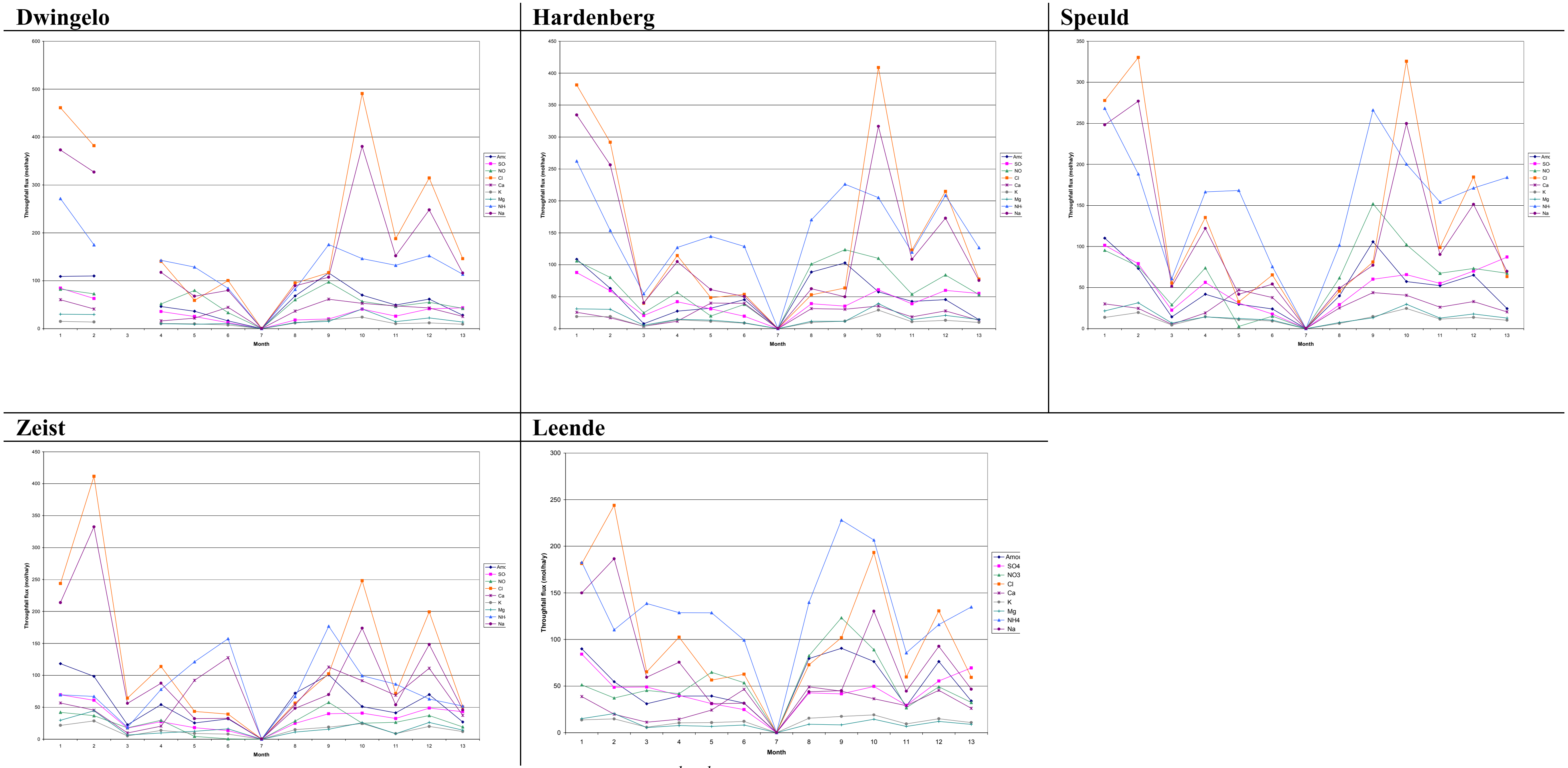

Figure 3.4 *Temporal variations in throughfall fluxes (mol.ha^{-1}.y^{-1}) and amount of throughfall (mm) in 2004*

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 five sites. Generally, the throughfall fluxes display the same pattern for all components, except for sodium and chloride. The temporal variation is primarily determined by the amount of precipitation for each month, while for chloride and sodium the occurrence of storm events largely determines the variation. Fluxes are low when the amount of precipitation is low. All sites show distinct peaks during the autumn and winter period for sodium and chloride. July was very dry, resulting in very low fluxes for that month.

3.3 Annual average throughfall fluxes in 2004

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 2004. Annual average fluxes were calculated as the sum of monthly fluxes. The open field bulk measurements were corrected for the dry deposition contribution to the bulk precipitation. For this correction average factors (ratio between wet-only deposition and bulk precipitation fluxes) were taken from Van Leeuwen *et al*. (1995). The total nitrogen flux is calculated as the sum of nitrate and ammonium fluxes, whereas the potential acid flux is estimated according to:

$$Potential\ acid = NH_4^+ + NO_3^- + 2\ SO_4^{2-} \qquad [9]$$

Table 3.1 *Annual throughfall fluxes measured at the five sites and open field (of) precipitation measured at Hardenberg and Leende in 2004 in mol.ha^{-1}.y^{-1}*

site:	NH_4	Na	Mg	K	Ca	Cl	NO_3	SO_4	Tot N	Pot. Acid
Dwingelo	1675	2125	215	475	140	2570	700	430	2375	3240
Hardenberg	1930	1635	215	300	155	1870	850	550	2780	3875
Speuld	2005	1480	190	360	150	1695	815	675	2820	4175
Zeist	1055	1295	220	850	180	1645	325	435	1380	2250
Leende	1700	935	120	395	150	1330	695	565	2395	3525
of-Hardenberg	220	320	55	85	55	395	385	95	605	795
of-Leende	425	225	30	35	35	265	270	140	695	970

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 Speuld (4170 $mol.ha^{-1}.y^{-1}$) and lowest in Zeist (2250 $mol.ha^{-1}.y^{-1}$).

4. Deposition estimates

Deposition estimates can be made by using a canopy exchange model. Such a model is described in the Erisman *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 2004 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 2600 $mol.ha^{-1}.y^{-1}$.

Table 4.1 *Deposition estimates per plot in 2004 in* $mol.ha^{-1}.y^{-1}$.

Location	Dry deposition			Wet deposition			Total deposition			Total Nitrogen	Potential Acid
	NH_4	SO_4	NO_3	NH_4	SO_4	NO_3	NH_4	SO_4	NO_3		
Dwingelo	840	300	480	410	130	220	1250	430	700	1950	2810
Hardenberg	360	450	470	220	100	380	580	550	850	1430	2530
Speuld	1240	460	500	580	220	320	1820	680	820	2640	3990
Zeist	100	200	-20	380	230	350	480	440	330	800	1670
Leende	1110	430	430	420	140	270	1540	570	700	2230	3370

4.2 Trends in deposition

Throughfall and open field precipitation has been measured at the four sites in 1995-1996, 1998, 1999, 2000, 2002-2004. 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 two years of measurements are available, therefore no temporal variation can be given here yet. The other four sites show a further decrease in deposition, after a small increase in 2003.

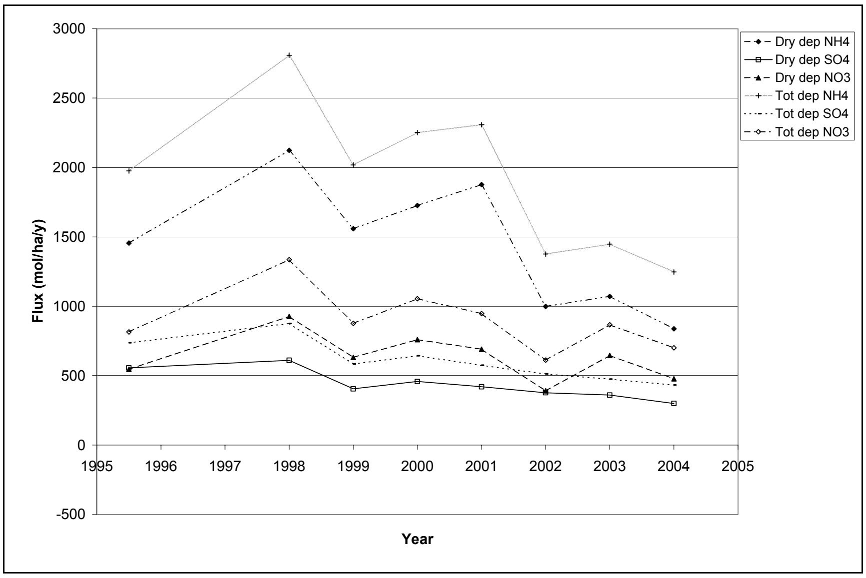

Figure 4.1 *Temporal variation in deposition measured at Dwingelo*

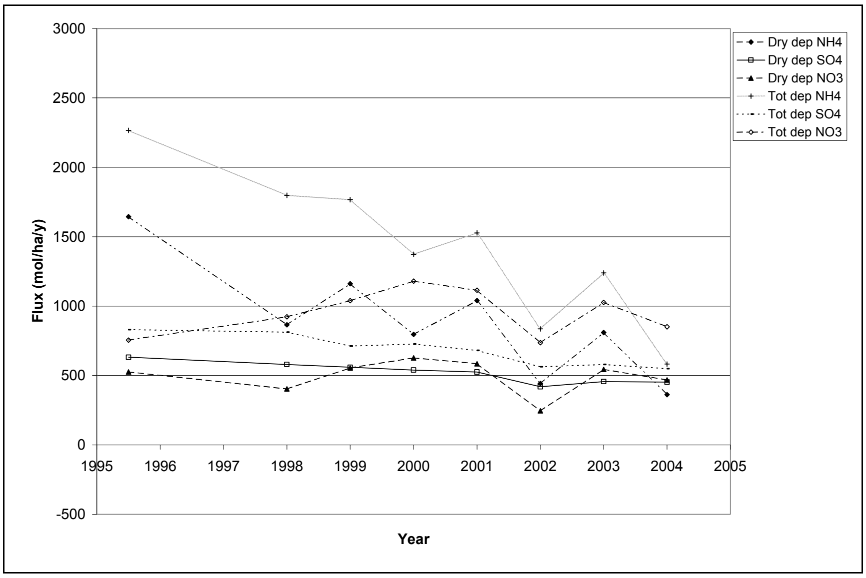

Figure 4.2 *Temporal variation in deposition measured at Hardenberg*

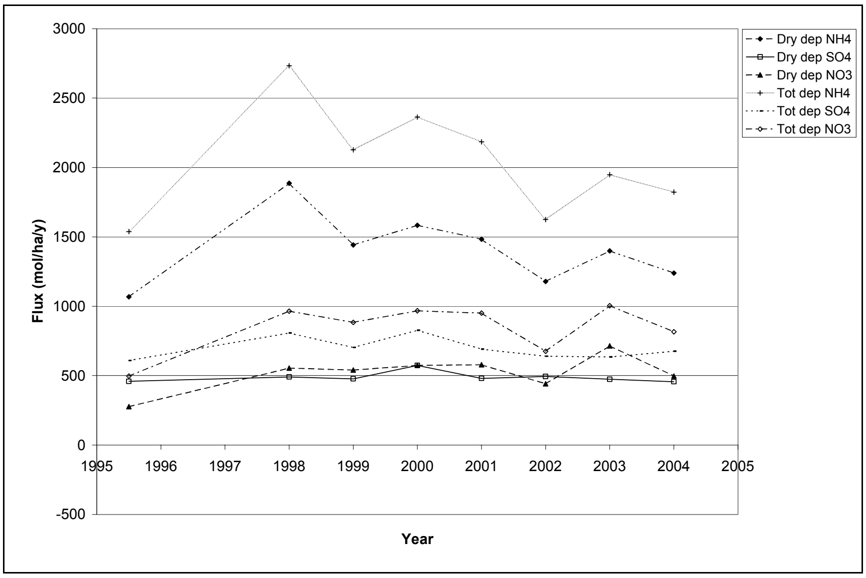

Figure 4.3 *Temporal variation in deposition measured at Speuld*

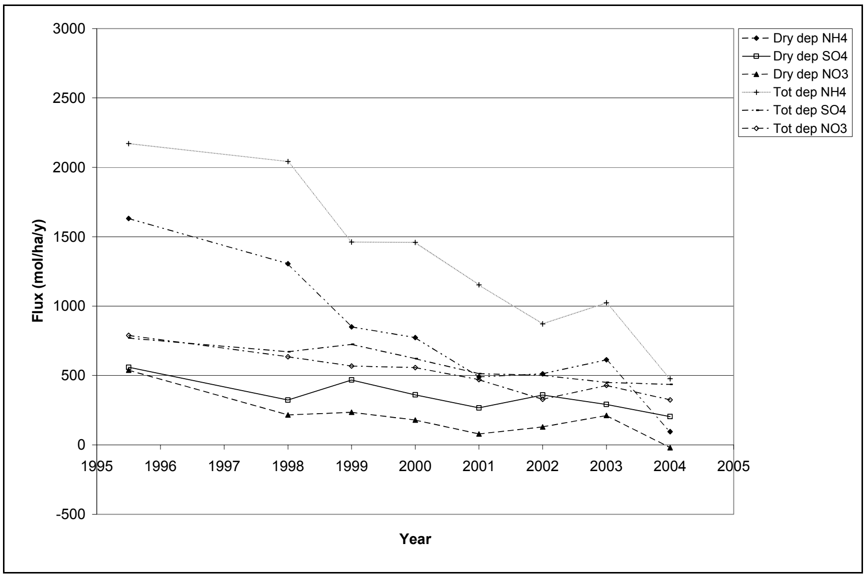

Figure 4.4 *Temporal variation in deposition measured at Zeist*

5. Conclusions

During one year (between January and December 2004), 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 2004 somewhat lower deposition fluxes were found compared with the previous year.

References

Bleeker, A., G.J. de Groot, J.J. Möls, P.B. Fonteijn and F.P. Bakker (2004): *Throughfall monitoring at 5 sites in the Netherlands in 2003*. ECN-C--05-006, ECN Petten, The Netherlands.

Draaijers, G.P.J. and J.W. Erisman (1996): *A canopy budget model to assess atmospheric deposition from throughfall measurements*. Water, Air and Soil Pollut., 85, 2253-2258.

Draaijers, G.P.J., J.W. Erisman, T. Spranger and G.P. Wyers (1996): *The application of throughfall measurements for atmospheric deposition monitoring*. Atmospheric Environment, 30, 3349-3361.

Erisman, J.W. and G.P.J. Draaijers (1995): *Atmospheric deposition in relation to acidification and eutrophication*. Studies in Environmental Research 63, Elsevier, the Netherlands.

Erisman, J.W., J.J. Möls, G.P. Wyers and G.P.J. Draaijers (1997): *Throughfall monitoring during one year at 14 ICP Forest Level II sites in the Netherlands*. ECN--C-97-090, ECN Petten, the Netherlands.

Erisman, J.W., J.J. Möls, P.B. Fonteijn and F.P. Bakker (2001): *Throughfall monitoring at 4 sites in the Netherlands between 1995 and 2000*. ECN-C--01-041, ECN Petten, the Netherlands.

ICP Forests (2004): *Manual on Methods and Criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forest; Part VI – Sampling and Analysis of deposition*.

RIVM (1999): *Meetactiviteiten in 1999 in het Landelijk Meetnet Luchtkwaliteit. RIVM report 723101032*. RIVM, Bilthoven, the Netherlands.

RIVM (2000): *Monitoring activities in the Dutch National Air Quality Monitoring Network in 2000*. RIVM Rapport 723101055, RIVM, Bilthoven, the Netherlands.

Leeuwen, E.P. van, C. Potma, G.P.J. Draaijers, J.W. Erisman and W.A.J. van Pul (1995): *European wet deposition maps based on measurements*. RIVM Report no. 722108006, RIVM, Bilthoven, the Netherlands.

Vries, W. de and E.E.J.M. Leeters (1996): *Effects of acid deposition on 150 forest stands in the Netherlands. 1. Chemical composition of the humus layer, mineral soil and soil solution*. Wageningen, the Netherlands, Alterra, Report 69.1.

Vries, W. de, G.J. Reinds, H.D. Deelstra, J.M. Klap and E.M. Vel (1999): *Intensive Monitoring of Forest Ecosystems in Europe.* Technical report 1999. UN/ECE, EC, Forest Intensive Monitoring Coordinating Institute, 173 pp.