ICP Forests

LRTAP
Long-range Transboundary Air Pollution

Forest Conditions

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2017 Executive Report

2017

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United Nations Economic Commission for Europe, Convention on Long-range Transboundary Air Pollution, International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests)

For further information, please contact:

Programme Co-ordinating Centre (PCC) of ICP Forests
Dr. Walter Seidling, Alexa Michel
Thünen Institute of Forest Ecosystems
Alfred-Möller-Str. 1, Haus 41/42
16225 Eberswalde, Germany

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Editor
Walter Seidling

Authors
Section 2.1
Stephan Raspe, Hans-Peter Dietrich, Desirée Köhler, Alfred Schubert, Joachim Stiegler
Section 2.2
Rossella Guerrieri, Josep Peñuelas, Maurizio Mencuccini
Section 2.3
Maija Salemaa, Päivi Merilä, Antti-Jussi Lindroos, Raisa Mäkipää, Aino Smolander
Section 3.1
Elena Vanguelova, Nathan Brown, Samantha Broadmeadow, Sandra Denman
Section 3.2
Ionel Popa, Stefan Leca, Ovidiu Badea

Copy editing
Carolyn Symon (carolyn.symon@btinternet.com)

Layout
Simon Duckworth, Burnthebook (simon@burnthebook.co.uk)

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Mertinkat, Eberswalde/Germany

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Contents and summaries

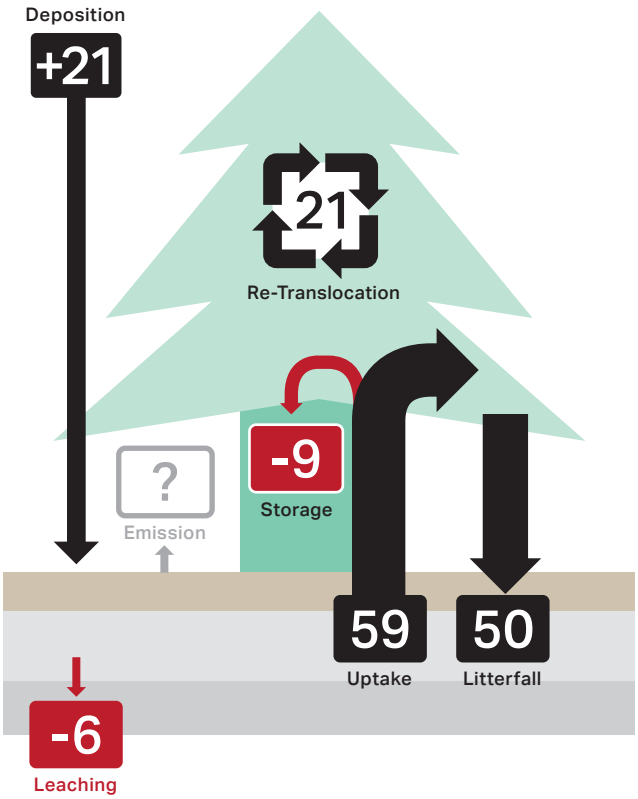

Figure 2-2: Mean annual nitrogen fluxes (kg N ha^{-1}) for the period 1991–2015 based on data from 22 Level II (intensive) forest monitoring sites in Bavaria, Germany. Arrow thickness is proportional to flux value.

Besides calculating nitrogen inputs/outputs to/from forest ecosystems over the past 25 years based on measured data, the study also looked at nitrogen cycling within forest ecosystems. The calculations were based on data from various Level II surveys: including deposition data, meteorological variables, soil chemical and physical values as well as information from soil solution chemistry, forest growth and the nutrient content of foliage and litterfall. Measured data were used to model water budgets and estimate nitrogen fluxes. Results show a total deposition of about 21 kg N ha^{-1} a^{-1} to these central European forest ecosystems. Losses through leaching from the soil (6 kg N ha^{-1} a^{-1}) and net uptake by trees based on the annual increment of woody biomass (9 kg N ha^{-1} a^{-1}) were similar. An ongoing nitrogen accumulation of 6 kg N ha^{-1} a^{-1} was calculated for the forest ecosystems studied.

Nitrogen cycling within forests is very high. The flux through annual litterfall varies widely (average 50 kg N ha^{-1} a^{-1}), and is lowest for pine stands (20 kg N ha^{-1} a^{-1}) and highest for oak stands (70 kg N ha^{-1} a^{-1}). Foliage uptake also varies widely (average 60 kg N ha^{-1} a^{-1}), and is again lowest for pine (30 kg N ha^{-1} a^{-1}) and highest for oak (110 kg N ha^{-1} a^{-1}). These data reveal a mean re-translocation ratio of 21 kg N ha^{-1} a^{-1}. Despite the continued net uptake of nitrogen by forest soils, there was no clear tendency for an increase in internal fluxes over the 25-year study period.

Although the potential for loss of nitrogen by gaseous emission from the forest soils due to denitrification is not yet quantified, this nitrogen budget indicates ongoing nitrogen accumulation within the forest ecosystems in Bavaria. This highlights the problem of ongoing nitrogen saturation found in many central European forests.

2.2 Nitrification in tree canopies

After more than 20 years of continuous monitoring at the ICP Forests Level II (intensive) monitoring plots, it is clear that tree canopies play a significant role in both intercepting rainfall and altering its chemical composition, thus affecting the nutrient input to the soil. Significant differences in terms of nitrogen fluxes have been observed between rainfall in the open field and below forest canopies (so-called throughfall) at many sites. However, the processes responsible for these differences are still unclear.

In an earlier study, nitrogen fluxes (particularly nitrate, NO_3) were examined in combination with stable nitrogen ($\delta^{15}N$) and oxygen isotope compositions ($\delta^{18}O$, $\delta^{17}O$) of NO_3 in rainfall and throughfall. This approach provided the first unequivocal isotopic evidence that biological nitrification, i.e. microbial transformation of ammonia (NH_3) or ammonium (NH_4) to NO_3, occurs

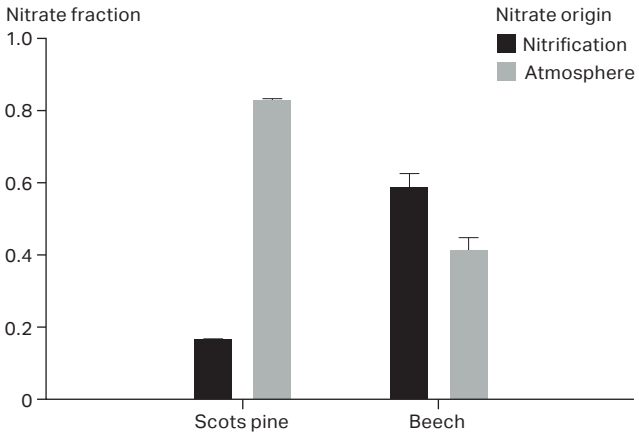

Figure 2-3: Relative fractions of nitrate (NO_3) originating from nitrification and the atmosphere based on the stable oxygen isotope compositions ($\delta^{18}O$ and $\delta^{17}O$) of NO_3 in rainfall and throughfall collected during the 2011 growing season at a Scots pine forest stand and a common beech forest stand in the United Kingdom. Data show mean ± standard error.

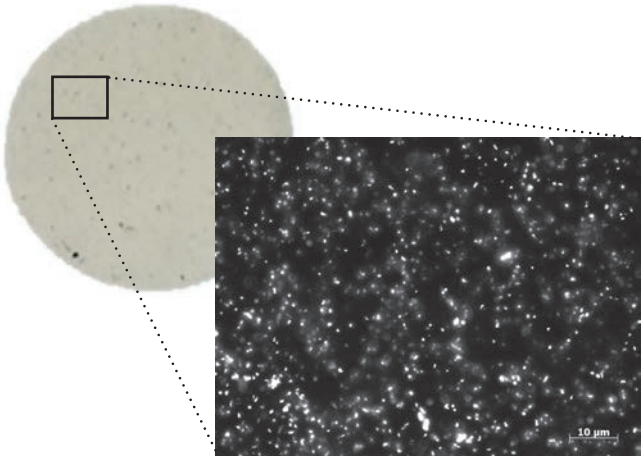

Figure 2-4: One of the 0.2 µm pore size polycarbonate filters used to filter throughfall at a site in Spain, plus an image obtained by epifluorescence microscopy on DAPI-stained cells showing bacteria (white dots) on part of the filter. Observations were made by Joan Cáliz and Mateu Menéndez-Serra (Centre for Advanced Studies of Blanes, Spain).

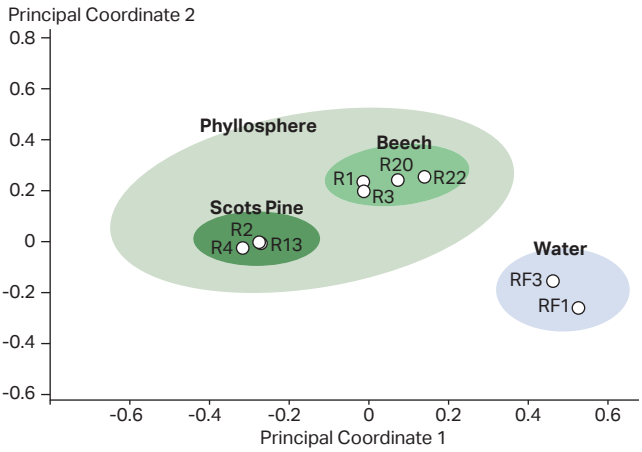

Figure 2-5: Results of a multivariate ordination analysis (NMDS) showing clustering in the bacterial communities of different sample types. Samples with similar community composition form 'clusters', such as phyllosphere (i.e. leaves and needles) versus water (i.e. rainfall or throughfall), and Scots pine needles versus common beech leaves.

on the surfaces and/or inside leaves or needles (the so-called phyllosphere) in tree canopies (Figure 2-3). Biological nitrification was responsible for changes in the amount of NO_3 in throughfall versus rainfall at two UK forest sites receiving high atmospheric nitrogen inputs. This strongly suggests that microbes (bacteria and/or archaea) living in the phyllosphere control important pathways of nitrogen compounds in tree canopies. As microbes are mainly connoted with their role as pathogens it seems that there is still much to be understood about their effects on nitrogen cycling.

The current study has two aims. First, to characterise bacterial communities within tree canopies for common beech (*Fagus sylvatica*) and Scots pine (*Pinus sylvestris*) using meta-genomic techniques and to identify those microbial groups related to nitrogen cycling. Second, to quantify the proportion of NO_3 flux originating from bacterial activity in tree canopies relative to that from atmospheric deposition, by combining nitrogen fluxes with measurements of nitrogen and oxygen isotope ratios in NO_3 from rainfall and throughfall. The study includes six common beech and six Scots pine ICP Forests Level II (intensive) monitoring sites along a climate and nitrogen-deposition gradient from Fennoscandia to the Mediterranean area.

Preliminary results from metagenomic analyses on a subset of sites revealed the presence of bacteria in throughfall (Figure 2-4), with over 300 species identified. Bacterial community composition was clustered for rainfall and throughfall versus phyllosphere, and for

Terminology

Isotopes are atoms of an element, such as nitrogen (N) or oxygen (O), that have the same atomic number (number of protons), but different atomic mass (total number of protons and neutrons). The **stable isotope composition**, i.e. the so-called delta (δ) notation, is the isotopic ratio ($^{15}N/^{14}N$, $^{18}O/^{16}O$, $^{17}O/^{16}O$) of the analysed samples relative to an internationally accepted standard as: $\delta^{XX}E = (R_S/R_{St} -1) \times 1000$, where E is the element of interest (such as N or O), ^{XX} is the atomic mass of the heaviest isotopes (i.e., ^{15}N, ^{18}O, ^{17}O), R is the isotopic ratio (e.g., $^{15}N/^{14}N$) of the sample (S) and the standard (St).

Metagenomics is the study of the metagenome – the collective genome of microorganisms obtained directly from environmental samples, as opposed to the approach of working with traditionally cultured bacteria. A metagenomics workflow classifies organisms based on a specific gene (i.e., 16S rRNA) and its specific region (in this case V5-V6 of the 16S rRNA gene, which does not overlap with plant DNA).

Credits

As editor, Walter Seidling would like to thank all those who have actively contributed to this Executive Report and all those who helped in the planning and realisation of the 6th Scientific Conference at Bucharest, Romania. Thanks are also extended to all those keeping the basic monitoring and research infrastructure of ICP Forests running in the field as well as virtually by feeding and controlling its data infrastructure.

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Participating countries and contacts

Albania: Ministry of the Environment, Forests and Water Administration (*info@moe.gov.al*)

Andorra: Ministeri de Turisme I Medi Ambient, Ms Silvia Ferrer, Ms Anna Moles (*silvia_ferrer_lopez@govern.ad*, *anna_moles@govern.ad*)

Austria: Austrian Research Centre for Forests (BFW), Mr Ferdinand Kristöfel (*ferdinand.kristoefel@bfw.gv.at*)

Belarus: Forest inventory republican unitary company "Belgosles", Mr Valentin Krasouski (*belgosles@open.minsk.by*)

Belgium, Flanders: Research Institute for Nature and Forest (INBO), Mr Peter Roskams (*peter.roskams@inbo.be*)

Belgium, Wallonia: Service public de Wallonie (SPW), Mr Christian Laurent, Mr Etienne Gérard (*christian.laurent@spw.wallonie.be*, *etienne.gerard@spw.wallonie.be*)

Bulgaria: Executive Environment Agency at the Ministry of Environment and Water Monitoring of Lands, Ms Genoveva Popova (*forest@eea.government.bg*)

Canada: Natural Resources Canada, Mr Pal Bhogal (*pal.bhogal@nrcan.gc.ca*), Ministère des Ressources naturelles, Mr Rock Ouimet (*rock.ouimet@mrnf.gouv.qc.ca*)

Croatia: Croatian Forest Research Institute, Mr Nenad Potočić (*nenadp@sumins.hr*)

Cyprus: Ministry of Agriculture, Natural Resources and Environment, Mr Andreas Christou (*achristou@fd.moa.gov.cy*)

Czechia: Forestry and Game Management Research Institute (FGMRI), Mr Bohumír Lomský (*lomsky@vulhm.cz*)

Denmark: University of Copenhagen, Department of Geosciences and Natural Resource Management, Mr Morten Ingerslev (*moi@life.ku.dk*)

Estonia: Estonian Environment Agency (EEIC), Ms Endla Asi (*endla.asi@envir.ee*)

Finland: Natural Resources Institute Finland (LUKE), Ms Päivi Merilä (*paivi.merila@luke.fi*)

France: Level I: Ministère de l'Agriculture, de l'Agroalimentaire et de la Forêt, Mr Frédéric Delport, Mr Fabien Caroulle (*frederic.delport@agriculture.gouv.fr*, *fabien.caroulle@agriculture.gouv.fr*), Level II : Office National des Forêts, Mr Manuel Nicolas (*manuel.nicolas@onf.fr*)

Germany: Bundesministerium für Ernährung und Landwirtschaft (BMEL), Ms Sigrid Strich (*sigrid.strich@bmel.bund.de*)

Greece: Hellenic Agricultural Organization "DEMETER", Mr Panagiotis Michopoulos (*mipa@fria.gr*)

Hungary: National Food Chain Safety Office, Mr László Kolozs (*kolozsl@nebih.gov.hu*)

Ireland: University College Dublin (UCD), Mr Jim Johnson (*jim.johnson@ucd.ie*)

Italy: Ministry for Agriculture and Forestry Policies, Corpo Forestale dello Stato, Ms Angela Farina, Ms Laura Canini (*a.farina@corpoforestale.it*, *l.canini@corpoforestale.it*)

Latvia: Latvian State Forest Research Institute "Silava", Mr Urdis Zvirbulis (*urdis.zvirbulis@silava.lv*)

Liechtenstein: Amt für Umwelt (AU), Mr Olivier Nägele (*olivier.naegele@llv.li*)