Forest Condition in Europe

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(CLRTAP)

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5 ATMOSPHERIC DEPOSITION IN EUROPEAN FORESTS IN 2016

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5.1 Summary

Studying the effects of atmospheric pollution to forest ecosystems requires an evaluation of air quality and of the amount of pollutants carried to the forests by atmospheric deposition. Pollutant flux towards ecosystems through deposition mainly follows two pathways: wet deposition of compounds dissolved in rain and snow and dry deposition of particulate matter through gravity or filtration, for example by forest canopy.

Pollutant deposition shows a relatively high local variability, related to the distribution of pollutant sources and the local topography, and in-situ measurement is needed to obtain accurate evaluations and to validate model estimates.

In 2016, the chemical composition of atmospheric deposition was measured in 276 Level II permanent plots. In this report, we focus on acidifying, buffering, and eutrophying compounds.

High throughfall deposition of nitrate was mainly found in central Europe (Germany, Switzerland), Denmark, and Belgium, while for ammonium high deposition was also found in northern Italy. The area of high deposition is smaller for sulphate, including some plots in Germany and Poland. High values were also measured in Belgium, but they are partially due to deposition of marine aerosol, and they are less evident after sea-salt correction. High deposition in southern Italy may be related to local anthropogenic sources and to volcanic contribution.

Calcium, potassium, and magnesium deposition can buffer the acidifying effect of atmospheric deposition. High values of calcium throughfall deposition were reported for southern Europe, where it is often related to the deposition of Saharan dust, and for Eastern Europe. The correction for the marine contribution does not affect its spatial pattern. On the contrary, for magnesium, the number of sites with the highest values is markedly reduced by the sea salt correction.

5.2 Introduction

The atmosphere contains a large number of substances of natural and anthropogenic origin. A large part of them can settle, or be adsorbed to receptor surfaces, or be included in rain and snow and finally reach land surface as wet and dry deposition.

Among these substances, in the last two centuries human activities led to a dramatic increase in the deposition of nitrogen and sulphur compounds.

Sulphur deposition almost completely occurs in the form of sulphate (SO$_4^{2-}$), deriving from marine aerosol and from the interaction in the atmosphere between water and sulphur dioxide (SO$_2$) forming sulphuric acid.

SO$_2$ emission derives from volcanoes, forest fires and the combustion of fossil fuels, mainly sulphur containing coal and oil. Following industrial and economic development, SO$_2$ emission increased since the early 19th century until the 1980s, causing an increase in the deposition of sulphate and in deposition acidity, which can be partly buffered by the deposition of base cations, mainly calcium (Ca$^{2+}$) and magnesium (Mg$^{2+}$).

As a consequence of the application of the CLRTAP protocol and of economic transformation, SO$_2$ emission in the countries participating in ICP Forests markedly decreased in the last decades (EEA 2016) resulting in a downward trend in sulphate deposition and a similar decrease in deposition acidity (Waldner et al. 2014).

Natural sources of reactive nitrogen in the atmosphere are mainly restricted to the decomposition of the nitrogen gas molecule (N$_2$) during lightning. However, human activities cause the emission of a large amount of nitrogen oxides (NO$_x$), released during combustion processes, and of ammonia (NH$_3$) deriving from agriculture and farming. They are found in atmospheric deposition in the form of nitrate (NO$_3^-$) and ammonium (NH$_4^+$).

N compounds have two effects on the ecosystem: They are important plant nutrients with strong effects on plant production and metabolism (e.g., Silva et al. 2015), all forest processes (e.g., Meunier et al. 2016) and biodiversity (e.g., Bobbink et al. 2010), but they can also reinforce soil acidification (Bobbink and Hettelingh 2011).

Emission and deposition of both sulphur and nitrogen are recently decreasing, but the trend for nitrogen is less evident than for SO$_4^{2-}$ (Waldner et al. 2014; EEA 2016).
5.3 Materials and methods

Atmospheric throughfall and bulk deposition is collected in the ICP Forests permanent plots under the tree canopy (throughfall samplers, Figure 5-1) and in a nearby clearance (open field samplers), respectively. The latter samplers are intended to estimate the intensity of wet deposition, i.e. the amount of pollutants carried by rain and snow. The former samplers are intended to estimate total deposition, including dry deposition due to particulate matter collected by the tree canopy.

However, a tree canopy interacts with atmospheric deposition, for example by the uptake of ammonium ions and the release of potassium, magnesium, and calcium ions and organic compounds, affecting the composition of throughfall deposition.

In the case of beech, a significant component of atmospheric deposition captured by tree crown flows along the smooth bark and tree trunks, and is therefore sampled by stemflow collectors installed on beech plots.

Sampling, analysis and quality control procedures are harmonized on the basis of the ICP Forests Manual (Clarke et al. 2016). Quality control and assurance include laboratory ring-tests, use of control chart and performing conductivity and ion balance checks on all samples (König et al. 2016). In calculating ion balance, the charge of organic compounds was considered proportional to the dissolved organic carbon (DOC) content following Mosello et al. (2005, 2008).

In this report, we report on the annual throughfall deposition of the year 2016, collected on 250 permanent plots. Data from 26 further plots, collected following the ICP Forests Manual, were kindly provided by the Swedish Throughfall Monitoring Network (SWETHRO).

5.3.1 Results

The uneven distribution of emission sources and receptors and the complex orography of part of Europe result in a marked spatial variability of the measured throughfall deposition on the ICP Forests Level II plot network. However, on a broader scale, regional patterns in throughfall deposition arose similar to those reported for earlier years. In the case of nitrate, high throughfall deposition was mainly found in central Europe (part of Germany, Denmark, Belgium, and Switzerland), while the lower values, below 1 kg N ha\(^{-1}\) y\(^{-1}\), were found in Sweden, France, Slovakia, and Estonia (Figure 5-2).

The central European area of high ammonium throughfall deposition is larger, including parts of Belgium, Germany, Poland, Switzerland, and Italy (Figure 5-3). Low values, below 1 kg N ha\(^{-1}\) y\(^{-1}\), were found again in Finland and France, but also in parts of Switzerland and Italy.

The area with higher throughfall deposition of sulphate is smaller than for the nitrogen compounds (Figure 5-4), including parts of Germany and Poland. Further plots with high sulphate throughfall deposition were found in Belgium, where the influence of marine aerosol accounted for around one half of sulphate throughfall deposition (Figure 5-5). The highest sulphate throughfall deposition was recorded in southern Italy, related to the influence of anthropogenic emission, volcanic activity and marine aerosol. The lowest sulphate throughfall deposition (below 1 kg S ha\(^{-1}\) y\(^{-1}\)) was measured at specific sites in Sweden, Switzerland, and France.

Calcium and magnesium are also analyzed in the ICP Forests deposition monitoring network, because their deposition can buffer the acidifying effect of other compounds in atmospheric deposition, and can decelerate or prevent soil acidification. High values of calcium throughfall deposition are reported in southern Europe, (Italy, Slovenia, France and Switzerland) mainly related to the deposition of Saharan dust, and in Eastern Europe (Figure 5-6). The correction for the marine contribution...
does not affect their spatial pattern and gives only minor changes in throughfall deposition (data not shown).

On the contrary, in the case of magnesium, the distribution of the highest values, including a large portion of southern and central Europe and parts of Sweden (Figure 5-7), is markedly reduced by the sea salt correction indicating that larger parts are from maritime origin (Figure 5-8).

Figure 5-2: Throughfall deposition of nitrate-nitrogen (kg NO₃⁻N ha⁻¹ yr⁻¹) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network
Figure 5-3: Throughfall deposition of ammonium-nitrogen (kg NH₄⁺-N ha⁻¹ yr⁻¹) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.
Figure 5-4: Throughfall deposition of sulfate-sulfur (kg SO$_4^{2-}$-S ha$^{-1}$ yr$^{-1}$) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.
Figure 5-5: Throughfall deposition of sea-salt corrected sulfate-sulfur (kg SO$_4^{2-}$ S ha$^{-1}$ yr$^{-1}$) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.
Figure 5-6: Throughfall deposition of calcium (kg Ca\(^{2+}\) ha\(^{-1}\) yr\(^{-1}\)) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.
Figure 5-7: Throughfall deposition of magnesium (kg Mg\(^{2+}\) ha\(^{-1}\) yr\(^{-1}\)) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network
Figure 5-8: Throughfall deposition of sea-salt corrected magnesium (kg Mg\(^{2+}\) ha\(^{-1}\) yr\(^{-1}\)) measured in 2016 on the ICP Forests Level II plots and the Swedish Throughfall Monitoring Network.
5.5 References


