Is N and S deposition altering the mineral nutrient composition of Norway spruce and Scots pine needles in Finland?

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Introduction

In Finland, the nutrient status of conifer needles has been monitored almost every year since 1987 on 36 plots of the Finnish Level I network of the Forest Focus/ICP Forests programmes. Based on this material, our study (Luyssaert et al. 2004, 2005) aimed to evaluate the extent to which elevated N and S deposition have affected the mineral nutrient composition of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* L. Karst.) needles during the period 1987-2000.

Material and Methods

Needle samples were collected from 36 (16 Norway spruce, 20 Scots pine) of the Level I plots, located on mineral soil sites in background areas in different parts of the country. The stands were sampled almost each year between 1987 and 2000, resulting in 367 needle samples (Luyssaert at al. 2005). Sampling and chemical needle analyses were carried out according to the ICP Forests Manual. Pre-treatment, elemental analysis and instrumental quality control are discussed in detail in Luyssaert et al. (2004).

Deposition data of the Co-operative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe were used. The monthly precipitation sum and mean temperature at 30 weather stations located in the vicinity of the study plots were obtained from the Finnish Meteorological Institute for the period 1971 to 2000.

Tree nutrition was described by means of nutrient profiles (NPs; Luyssaert et al. 2004, 2005). The NP of tree foliage is defined as the nutrient status that accounts for all element concentrations, contents and interactions between two or more elements. Stands with similar NPs, and thus a similar elemental composition of the foliage, were characterized by a group nutrition profile (GNP). Current-year N, S and P concentrations and needle mass were used in the calculation of NPs. Mg, Ca and Al were added when presenting the profiles. A neural network, in this case a self-organizing map (SOM) (Kohonen 2001) and an agglomerative clustering algorithm with pruning (Vesanto and Sulkava 2002), were used for calculating which NPs were members of a given GNP.

A two-step approach was applied in calculating the relationship between the N deposition and the elemental composition of the needles. (1) The hypothesis was tested that the mean N deposition between already established GNPs could statistically not be considered equal. (2) The conditional probability was calculated that, given the GNP, the total N deposition was higher than 4.0 kg $ha^{-1}year^{-1}$, which was considered to be an increased level (i.e. above the threshold level) of deposition in Finland. The same two-step approach was used to determine the relationships between the NPs and S deposition, using a threshold deposition of 5.0 kg $ha^{-1}year^{-1}$.

A literature study of controlled experiments revealed that acidifying deposition mediates increasing N and S concentrations, and decreasing Mg:N and Ca:Al ratios in the needles. When this fingerprint for N and S elevated deposition on tree foliage was observed simultaneously with increased N and S inputs, it was considered sufficient evidence for assuming that acidifying deposition had altered the elemental composition of tree needles on that plot in the given year. Evidence for deposition-induced changes in the elemental composition of tree foliage was calculated on the basis of a simple frequency model.

Results

The chemical composition of tree needles (NPs) was classified in six distinct groups (GNPs) (Luyssaert et al. 2004, 2005). The relationship between the N and S deposition and the established GNPs shows that high N deposition coincided more often within two groups (1 and 5) than within the other GNPs for spruce. For pine, there was no evidence to show that the mean N deposition values are different for different GNPs. However, there was a significant relationship between the exceedance of the threshold for N or S deposition and the occurrence of GNPs 1 or 5 for both tree species. In addition, GNPs 1 and 5 were best described as profiles that are consistent with the expectations of the needle composition for simultaneously elevated N and S deposition. On average, the elemental composition of <13% of the spruce samples and 6% of the pine samples was associated with elevated N and S deposition during 1987-2000 (Fig. 1). The extent to which elevated deposition affected the elemental status of spruce needles decreased during 1987-2000. The same trend was not apparent in pine. When fitted using Logit models, the relationships between the NPs and selected stand, site and climatic variables were found to be non significant.

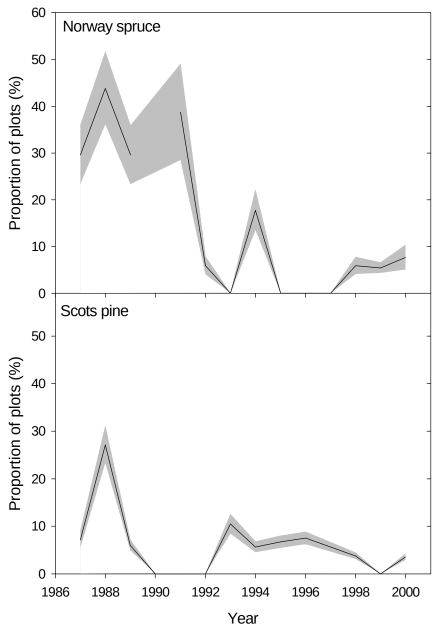

Fig. 1. Proportion of plots on which evidence was found that elevated N and S deposition altered the elemental composition of the needles. The grey area shows the uncertainty caused by the accuracy of the chemical analyses (Luyssaert et al. 2005).

Conclusions and implications

The extent to which acidifying deposition (N and S) has altered the elemental composition of tree needles in Finland since 1995 ranges between 3 and 10% for both Norway spruce and Scots pine. Evaluation of the elemental composition of Norway spruce and Scots pine needles between 1987 and 2000 provided no evidence to support a widespread onset of N saturation or acidification problems in Finnish forests on mineral soils in the near future. In the long term, the loss of nutrient-poor GNPs could result in increased tree growth, altered species composition of the ground vegetation, and perhaps gradual soil acidification and eutrophication.

References

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