# Forest Condition Monitoring in Finland – National report



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## Foliar chemistry on the intensive monitoring plots

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### Summary

The elemental composition of foliage has been monitored bi-annually on all the plots belonging to the Finnish Level II intensive monitoring network since 1995. In this article the results are presented for Level II plots with the longest time series (n = 2,7 and 8 for Silver birch, Scots pine and Norway spruce plots, respectively) amended with the results of two new Level II plots established in Luumäki in 2009. Nitrogen concentrations of needles showed a slight increasing trend on a part of the monitoring plots. This trend was the clearest in the current needles of the Scots pine plots. Other foliar element concentrations showed no clear trends or drastic changes.

### Background

The elemental composition of foliage represents an important tool when diagnosing nutrient deficiencies, excesses and imbalances in forest trees. When carefully applied, the chemical composition of leaves serves as a competent indicator of health status at the ecosystem level. Changes in the nutrient status of trees may result from several factors affecting nutrient availability and needle mass, such as the occurrence of abiotic and biotic damage, fluctuation in weather conditions, changes in anthropogenic deposition or, in general, changes in the nutrient pools in the ecosystem.

### Results and discussion

In Finland, the nutritional status of the trees on the ICP Forests Level II plots has been monitored biannually since 1995 (Merilä 2007).

On many of the coniferous monitoring plots, N concentrations of the needles showed an increasing trend. This trend was the clearest in the current needles on the pine plots: their N concentration showed a significant positive regression with time in Miehikkälä (plot nr. 18), Punkaharju (nr. 16), Juupajoki (nr. 10), Lieksa (nr. 20) and

Kivalo (nr. 6). This is an interesting result considering that N is the most limiting nutrient for growth in the boreal forest ecosystems (Tamm 1991). Needle N concentration was also found to be well explained by the N concentration of the organic layer (Merilä & Derome 2008). Thus, the further development of the N nutrition of the monitoring plots requires a special attention.

In the beginning of the monitoring period, there probably was a slight decreasing trend in S concentrations of the needles, consistently with the respective decrease in the sulphur deposition (see also Luyssaert et al. 2005). However, a decreasing trend in S concentrations was no longer detected, the only exception being the spruce plot in Oulanka (nr. 21). The other elements showed no drastic changes during the monitoring period. The overall averages for the monitored elements are presented in Table 1 (pdf).

The Cu concentrations in Sevettijärvi (nr. 1) clearly stood out from the concentrations on the other plots. The elevated Cu concentrations may be due to Cu deposition originating from the copper-nickel smelter in Nikel, which is located on the Kola Peninsula in the Russia at a distance of ca. 70 km from the Sevettijärvi plot.

In general, the plots located near the coast show higher B concentrations than those in Finland.This difference is especially distinct in northern Finland; foliar B concentrations in Sevettijärvi (nr. 1) are clearly higher than on the other pine plots in northern Finland (plots nr. 3, 5, 6), and indicates the significance of sea spray as a source of B deposition.

## Material and methods

In Finland, the nutritional status of the trees on the ICP Forests Level II plots has been monitored biannually since 1995 (Merilä 2007). Here we present the results for the Level II plots with the longest time series amended with the results of the two Level II plots established in 2009 in Luumäki (nrs. 34 and 35; Table 2). The Scots pine stand in Luumäki was established to replace the Scots pine plot in Miehikkälä (nr. 18), terminated in 2008. The two Silver birch plots (nrs. 32 and 33) were sampled for leaf analysis in 2005, 2007, and 2009.

Two sets of 10 predominant or dominant sample trees have been selected for foliar chemistry analyses on each Level II plot. Sample branches are taken from 10 of these trees every second year. The two tree sets are sampled in rotation, i.e. each set is sampled every 4 years. Needle samples are collected from the bottom part of the uppermost third of the living crown (between the 7th and 15th whorls) with a pruning device during October and November. Leaf samples on the birch plots were collected similarly in August in 2005, 2007 and 2009.

| Year | Silver birch | Scots pine | Norway spruce | Total |
|---|---|---|---|---|
| 1995–2003 | 0 | 7 | 8 | 15 |
| 2005–2007 | 2 | 7 | 8 | 17 |
| 2009 | 2 | 7 | 9 | 18 |

Table 2. The number of Level II plots by dominating tree species included in this report on the biannual monitoring of foliar chemistry.

The branches were stored in a freezer (-18°C) during the period between sampling and pretreatment. In the pretreatment procedure, the coniferous branches were cut into separate shoot sections bearing different needle-year classes. Shoots with the same needle-year class of each tree were pooled and subsequently treated as a separate sample. The shoots were dried at 60°C for 10 days and the needles then removed from the shoots. The dry needles were milled using an ultracentrifugal mill (mesh size 1 mm).

In 1995-2005, unwashed leaves or current (c) and previous year (c+1) needles on each tree (n = 10) and on each plot were analysed separately for total nitrogen (N), sulphur (S), phosphorus (P), calcium (Ca), potassium (K), magnesium (Mg), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), and boron (B). For samples of 2007 and onwards, composite samples were formed for each plot and needle age class by weighing an equal amount (generally 5 g) of dried needles from each tree.

The N concentration of the foliage was determined without any further pre-treatment on a CHN analyser (1995-1999) samples: LECO CHN-600 Analyser, 2001- samples: LECO CHN 2000 Analyser). The S, P, Ca, K, Mg, Zn, Mn, Fe, Cu, concentrations were determined, following wet digestion in $HNO_3/H_2O_2$, by inductively coupled plasma emission spectrometry (ICP/AES). For the 1995 and 1997 samples, digestion was performed by the open wet digestion method (Thermolyne 2200 Hot Plate), followed by determination on an ARL 3580 ICP emission spectrometer.

Since 1999, the foliar samples were digested by the closed wet digestion method in a microwave oven (CEM MDS 2000) and analysed on a TJA Iris Advantage ICP -emission spectrometer. For the samples of 1995 and 1997, boron was determined by azomethin H-reagent on a UV-VIS spectrophotometer, and for samples of 1999 and onwards, boron was determined by ICP/AES after CEM digestion. The results were calculated as mean concentrations per plot per 105°C dry weight (Rautio et al. 2010).

## References

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Table 1. Overall average ±S.D. for nitrogen (N), sulphur (S), phosphorus (P), calcium (Ca), potassium (K), magnesium (Mg), zinc (Zn), manganese (Mn), iron (Fe) copper (Cu) and boron (B) concentrations in Silver birch leaves and in current (C) and previous year (C+1) Scots pine and Norway spruce needles during monitoring period 1995–2009.

| | Scots pine n = 7 | | Norway spruce n = 8–9 | | Silver birch n = 2 |
|---|---|---|---|---|---|
| Element | C needles | C+1 needles | C needles | C+1 needles | Leaves |
| N, mg $g^{-1}$ | 12.7 ± 1.7 | 12.6 ± 1.7 | 11.8 ± 1.9 | 10.8 ± 1.5 | 23.7 ± 1.7 |
| S, mg $g^{-1}$ | 0.88 ± 0.09 | 0.90 ± 0.10 | 0.86 ± 0.10 | 0.83 ± 0.09 | 1.53 ± 0.20 |
| P, mg $g^{-1}$ | 1.48 ± 0.15 | 1.35 ± 0.13 | 1.66 ± 0.21 | 1.36 ± 0.25 | 2.06 ± 0.10 |
| Ca, mg $g^{-1}$ | 1.97 ± 0.38 | 3.22 ± 0.55 | 3.64 ± 0.64 | 5.93 ± 1.09 | 8.24 ± 2.32 |
| Mg, mg $g^{-1}$ | 1.05 ± 0.14 | 0.89 ± 0.17 | 1.17 ± 0.17 | 1.09 ± 0.18 | 2.86 ± 0.25 |
| K, mg $g^{-1}$ | 5.41 ± 0.39 | 4.79 ± 0.43 | 6.66 ± 0.81 | 5.01 ± 0.71 | 8.59 ± 1.11 |
| Zn, µg $g^{-1}$ | 40.7 ± 5.0 | 50. 4 ± 7.4 | 33.4 ± 7.3 | 36.6 ± 15.9 | 121.4 ± 23.6 |
| Mn, µg $g^{-1}$ | 412 ± 112 | 664 ± 179 | 686 ± 235 | 991 ± 338 | 1156 ± 167 |
| Fe, µg $g^{-1}$ | 30.0 ± 7.1 | 41.9 ± 10.2 | 25.2 ± 5.9 | 29.4 ± 7.5 | 51.4 ± 5.4 |
| Cu, µg $g^{-1}$ | 2.8 ± 0.5 | 2.4 ± 0.6 | 2.0 ± 0.4 | 1.7 ± 0.4 | 4.2 ± 1.2 |
| B, µg $g^{-1}$ | 13.0 ± 3.8 | 11.8 ± 4.2 | 11.7 ± 4.3 | 12.0 ± 6.2 | 11.2 ± 5.5 |
| C, % | 53.2 ± 0.8 | 54.0 ± 0.5 | 51.5 ± 0.6 | 51.7 ± 0.7 | 52.1 ± 0.5 |