From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest Condition - Preface and contents

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programme

Results: Crown condition

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Welcome to Metla’s web portal presenting the results of the forest condition monitoring in Finland.

Metla has implemented forest monitoring on two levels. A nationwide extensive monitoring on systematic network (Level I, active during 1986–2012) has provided information on regional and time-based variations in forest condition. Intensive forest monitoring (Level II, 1995–) involves diverse monitoring of forest condition and ecosystem functioning, with the aim of analysing the causes of changes observed. With these acitivities, Finland participates in the international ICP Forests Programme launched in 1985 under the UN-ECE Convention on Long-range Transboundary Air Pollution.

Most chapters of this report present results of the whole active monitoring period in Finland, reaching to mid 1980s’ and mid 1990s’ on the Level I and Level II programmes, respectively. In addition to static table and figure format, we have applied some interactive features in the presentation of data. This report is updated with the latest monitoring data once they are ready for publication.

Päivi Merilä
Chief Editor

Citation: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report].
Available at http://urn.fi/URN:NBN:fi:metla-201305087568. [Cited 2013-05-07].

NEWS

Some results have also been published in the Bulletin.

Tuloksia suomeksi Kansainvälisessä uutiskirjeessä.

ADDITIONAL INFORMATION

Coordinator: Päivi Merilä
Extensive monitoring: Seppo Nevalainen
Intensive monitoring: Liisa Ukonmaanaho

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programme

Pan European programme

Extensive monitoring in Finland

Intensive monitoring in Finland

Results: Crown condition

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Jouni Hyvärinen

Forest condition monitoring under the UN/ECE and EU programmes in Finland

By Päivi Merilä, Liisa Ukonmaanaho, Seppo Nevalainen, Pekka Nöjd & Egbert Beuker

European-wide monitoring system

Forest ecosystems are subjected to a wide range of pressures and disturbances of both natural and anthropogenic origin. Evaluation of the effect of these factors on ecosystem condition and functioning requires scientifically robust, long-term monitoring. Since 1985, Finland has been participating in the pan-European forest condition monitoring programme — the International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) — which was established under the UN/ECE Convention on Long Range Transboundary Air Pollution (CLRTAP).

The monitoring is being carried out on both a systematic plot network (so-called extensive monitoring, Level I) and a limited number of intensive monitoring plots (Level II).

Extensive monitoring of forest condition – Level I in Europe

Extensive forest monitoring (Level I) has been carried out on a network of ca. 6,000 plots arranged on a systematic grid (16 x 16 km) covering the whole of Europe since 1985. By the year 2011, more than a half of the Level I plots in the EU-Member States coincided with the plots of the National Forest Inventories (NFIs), as a result of the revision of large-scale monitoring systems aiming at integration between Level I and NFIs (Fischer & Lorenz 2011).

Level I network provides an annual picture of large-scale trends in crown condition (defoliation, discoloration, abiotic and biotic damage) at the European level. It also offers the possibility to investigate relationships between stress factors and forest condition. In addition to forest condition parameters, more than 5,000 Level I plots have been monitored in two forest soil surveys across Europe. A foliar survey in the 1990s has covered approximately

1,400 plots.

Intensive monitoring of forest condition – Level II in Europe

The intensive monitoring level comprises ca. 500 Level II plots in selected forest ecosystems in Europe and was established in 1994. The aim of Level II programme is to gain better understanding of cause-effect relationships between the condition of forest ecosystems and anthropogenic as well as natural stress factors. Forest decline in response to air pollution still is the driving force behind the Programme, contributing to the development of clean air policies. In addition, monitoring provides information required in decision-making concerning e.g. adaptation to climate change, conserving biodiversity and sustainable utilization of forests. With 41 participating countries, the ICP Forests Programme constitutes one of the world’s largest biomonitoring networks.

The methods applied in ICP Forests Programme are described in detail in the “Manual on methods and criteria for harmonised sampling, assessment, monitoring and analysis of the effects of air pollution on forests”.

Cooperation with the EC and other international processes

During 2009–2011, the Pan-European forest condition monitoring programme was carried out as a part of the FutMon project, co-financed by the Life+ programme of the European Union. The project aimed at the further development of an integrated pan-European forest monitoring system that will serve as a basis for the provision of forest-related information in the European Union. One of the primary aims of the project was to improve current methodology for monitoring the effects of e.g. climate change and air pollution on forest condition and forest ecosystem functioning. In Finland, the Forest Research Institute (Metla) is responsible for forest condition monitoring under the ICP Forests and EU programmes.

For many years before the FutMon project, ICP Forests has collaborated with the European Commission (EC) based on EU-cofinancing under relevant Council and Commission Regulations (3528/86, Forest Focus). The monitoring results are also delivered to processes and bodies of international forest and environmental policies other than CLRTAP, such as Forest Europe (FE), the Convention on Biological Diversity (CBD), the UN-FAO Forest Resources Assessment (FRA), and EUROSTAT of EC.

Database, data evaluation and publication

A database has been set up for handling and archiving the Level I and Level II data, access to which is restricted to persons participating in the programme. The data is forwarded annually to the Programme Co-ordinating Centre of ICP Forests in Johann Heinrich von Thünen-Institute (vTI), Hamburg. The results of the projects are published in national and international reports and scientific journals.

The list of publications:

- 2009-
- 1995-2008

References

Fischer, R. & Lorenz, M. (eds.). 2011: Forest Condition in Europe 2011. Technical Report of ICP Forests and FutMon. Work Report of the Institute for World Forestry 2011/1. ICP Forests, Hamburg, 2011, 212 pp. (pdf)

Lorenz, M. 2010: Objectives, Strategy and Implementation of ICP Forests. Manual Part I, 21 pp. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution

on forests. UNECE, ICP Forests, Hamburg. (htm)

Citation: Merilä, P., Ukonmaanaho, L., Nevalainen, S., Nöjd, P. and Beuker, E. (2013). Forest condition monitoring under the UN/ECE and EU programmes in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087569. [Cited 2013-05-07].

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Results: Crown condition » Summary

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents
Monitoring programmes
Results: crown condition
  Summary
  Extensive monitoring
  Intensive monitoring
  Discussion
Results: Intensive monitoring
Results: Related projects
Publication list of the Programme
About the report

Photo: Metla/Erkki Oksanen

Forest condition in national networks (ICP Forests, Level I and Level II)

By Seppo Nevalainen & Martti Lindgren

Summary

Metla has carried out the large-scale crown condition survey (Level I) since 1986 (until 2012) and the intensive crown condition survey (Level II) since 1995. The main observed variables have been the degree of defoliation and foliage discolouration and the occurrence of abiotic and biotic damage to Scots pine, Norway spruce and broadleaves. The average tree-specific degree of defoliation for the period 1986–2012 on Level I sites was 10.7% in pine, 19.6% in spruce and 12.8% in broadleaves and for the period 1995–2013 on Level II observation plots 11.3% and 18.2% for pine and spruce, respectively.

The proportion of defoliated trees seems to have increased in the southernmost part of the country. In general, the proportion of discoloured spruces was higher and varied annually much more than that in pine or birch.In Level 1, the proportion of trees with symptoms of abiotic or biotic damage decreased during the monitoring period (1986–2012). The mean proportion of symptomatic trees was the same (60%) in all main tree species groups. Pines had less abiotic and unidentified damage, but more insect damage than spruce and broadleaved species. Level I data provides t emporal patterns and coarse spatial distributions of some of the most common causes of damage. The proportion of dead trees on Level I varied from 0.1 to 0.32%. High stand age, weather and climatic factors, as well as abiotic and biotic damage, have a considerable effect on defoliation in background areas of Finland.

Background

Concern about the largescale decline in forest vitality in Central Europe in the late 1970s and early 1980s led Finland to initiate an extensive national survey of forest conditions. The Finnish Forest Research Institute has surveyed crown conditions annually since 1986. The monitoring has been carried out in co-operation with the UN/ECE ICP-Forests-programme and, during 1995-2006, in accordance with EU regulations. Forest condition monitoring is carried out using international harmonized methods (Eichhorn et al. 2010, pdf).

This report presents a review of the results on forest condition monitoring in Finland. The results of extensive (Level I) and intensive level (Level II) surveys, as well as the annual variation in forest conditions and the regional distributions are presented, together with some interpretation of the apparent factors, which may explain the regional pattern and changes in forest conditions.

Results: Extensive monitoring 1986–2012
Results: Intensive monitoring 1995–2013
Discussion

Citation: Nevalainen, S. and Lindgren, M. (2014). Forest condition in national networks (ICP Forests, Level I and Level II). In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201405221017. [Cited 2014-05-22].

The 2013 version available at http://urn.fi/URN:NBN:fi:metla-201305087572

: Updated: 23.05.2014 /SJor | Photo: Erkki Oksanen, Metla, unless otherwise stated | Copyright Metla | Feedback

Forest Condition Monitoring in Finland – National report

Preface and contents
Monitoring programmes
Results: Crown condition
Results: intensive monitoring
- **Foliar chemistry**
- Litterfall
- Understorey vegetation
- Deposition
- Soil percolation water
- Soil
- Phenology
- Girth bands
- Canopy cover
- Quality assurance

Results: Related projects
Publication list of the Programme
About the report

Photo: Metla/Erkki Oksanen

Foliar chemistry on the intensive monitoring plots

By Päivi Merilä

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). Please, click here to view the foliar chemistry data for the Level II plots with the longest time series.

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

Luyssaert, S., Sulkava, M., Raitio, H. & Hollmén, J. 2005. Are N and S deposition altering the chemical composition of Norway spruce and Scots pine needles in Finland? Environmental Pollution 6: 160–167.

Merilä, P. 2007. Needle chemistry on the intensive monitoring 1995-2003. In: Merilä, P., Kilponen, T. & Derome, J. (eds.). Forest Condition Monitoring in Finland - National report 2002–2005. Working Papers of the Finnish Forest Research Institute 45. 166 p.

Merilä, P. & Derome, J. 2008. Relationships between needle nutrient composition in Scots pine and Norway spruce stands and the respective concentrations in the organic layer and in percolation water. Boreal Environment Research 13(suppl. B): 35–47. (pdf)

Rautio, P., Fürst, A., Stefan, K., Raitio, H. & Bartels, U. 2010. Sampling and Analysis of Needles and Leaves. 19 pp. Manual Part XII. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, UNECE, ICP Forests Programme Co-ordinating Centre, Hamburg. ISBN: 978-3-926301-03-1.

Tamm, C.O. 1991. Nitrogen in terrestrial ecosystems: Questions of productivity, vegetational changes, and ecosystem stability. Ecological Studies 81. Springer-Verlag, Berlin. 115 p.

Citation: Merilä, P. (2013). Foliar chemistry on the intensive monitoring plots. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report].
Available at http://urn.fi/URN:NBN:fi:metla-201305087573. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report


Photo: Hannu Nousiainen

Changes of understorey vegetation in Finland in 1985–2006

By Tiina Tonteri, Maija Salemaa & Pasi Rautio

Summary

The understorey vegetation of 443 permanent sample plots on forested mineral-soil sites was surveyed in 1985–86, 1995 and 2006. The main causes of the observed vegetation changes were forest management practices and natural succession of the stands.

In old uncut forests, the largest changes occurred in the ground layer: bryophytes increased as lichens declined. In southern Finland, these changes are most likely due to normal forest succession, but the accumulated nitrogen deposition and long-term lack of forest fires may also have played a role. In northern Finland, reindeer grazing is the main factor in the decline of lichens. As for vascular plants, the total cover and number of species in the dwarf shrub, graminoid, and herb groups remained relatively stable. On the species level, the cover of bilberry (*Vaccinium myrtillus*) remained constant, but that of cowberry (*V. vitis-idaea*) decreased on fertile and increased on less fertile sites.

In forests with regeneration cuttings, the cover and the number of species of herbs and graminoids increased soon after cutting, but the cover of dwarf shrubs declined. Within 20 years after cutting, the cover of herbs and graminoids started to decrease, but the number of species remained high. At that point in time, the cover of cowberry had nearly returned to its pre-cutting level but the cover of bilberry still was only one fourth of that in the previous forest stage. In addition, bryophytes and lichens suffered with the regeneration cuttings; the species adapted to fertile sites suffered more than did those favouring less fertile sites.

After intermediate cuttings, cowberry and bilberry benefited from the increased amount of light. The cover of graminoids decreased, probably because they suffered from competition by dwarf shrubs.

Background

The abundance relationships between the understorey plant species of Finnish forests have changed significantly over the last 60 years (Reinikainen et al. 2000, Mäkipää & Heikkinen 2003). The greatest changes in vegetation took place before the 1980s. Silvicultural practices changed radically after the 1950s, which has greatly modified the environmental conditions of forest plants. As a result, the volume of the growing stock has increased, stands have become denser, and the proportion of young stands has increased (Tomppo 2000, Peltola & Ihalainen 2012). The overstorey stand structure has a considerable influence on the understorey vegetation through shading and via regulation of the moisture and nutrient levels. In addition, deposition of nitrogen, which experienced a peak in the 1970s–1980s, may have had some direct and indirect impacts on understorey vegetation because nitrogen is a growth-limiting factor in boreal forests. The composition of plant communities reflects the species-specific optima and tolerances with respect to nitrogen availability (Heikkinen & Mäkipää 2010), and slightly elevated N deposition may change community structure, stimulating, for example, moss growth (Salemaa et al. 2008a).

In this paper, we report upon and analyse the large-scale changes seen in understorey vegetation at an extensive level. The same 443 permanent sample plots on mineral-soil sites were surveyed in 1985–86, 1995, and 2006 (Fig.1). We present the average values for percentage cover and number of species or species groups in two ways: 1) for different boreal subzones and soil fertility levels (i.e., site types; see Hotanen et al. 2008) and 2) by silvicultural treatment: uncut forests, forests with regeneration cuttings, and forests with intermediate cuttings.

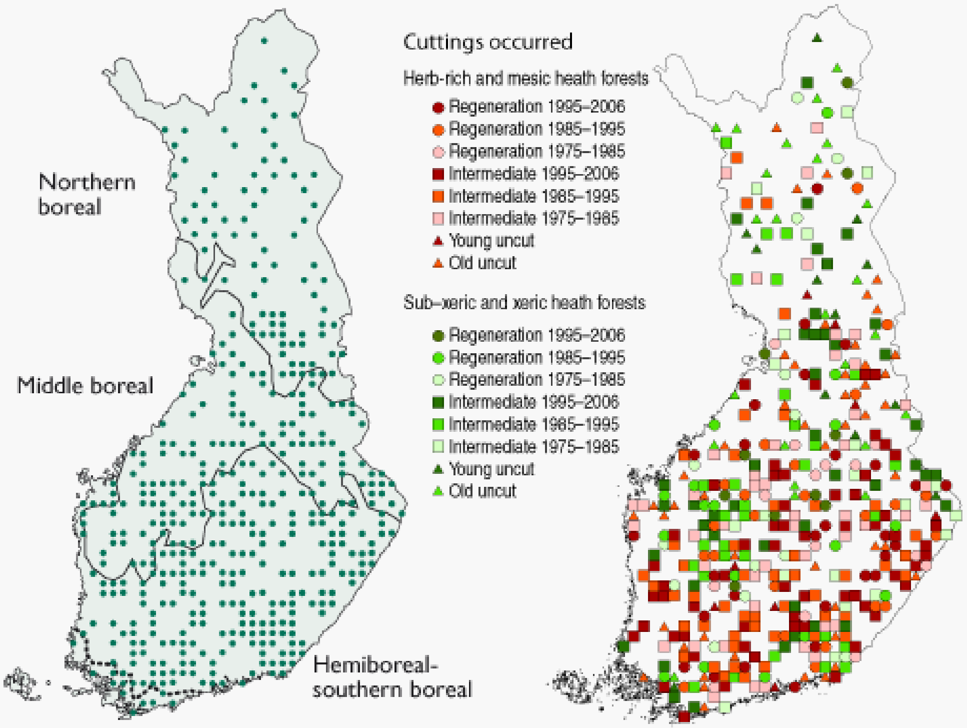


Figure 1. Location of sample plots and subzones of the boreal boreal zone in Finland (left). The point symbols of the plots indicate site types and silvicultural treatments during different time periods (right).

Vegetation changes in 1985–2006, over all silvicultural treatments

The understorey vegetation of 443 permanent sample plots on forested mineral-soil sites was surveyed in 1985–86, 1995, and 2006. Plot-specific sums of percentage cover and number of species were calculated in six plant groups: seedlings and saplings of trees and shrubs (height < 50 cm), dwarf shrubs, graminoids, herbs, bryophytes and lichens. Mean percentage cover and mean number of species or species groups in each plant group were calculated across inventory years and three subzones of the boreal zone in Finland. The number of species was also given for different forest site types (fertility gradient). The results are presented in Fig. 2 (pdf).

The number of herb and graminoid species has increased slightly

Increase of herbs and graminoids has taken place mainly with fertile site types (herb-rich forests and herb-rich heath forests) (Fig. 2, pdf), where these species are most abundant. Further, the cover and the number of tree and shrub species in the field layer (height: < 50 cm), have increased throughout the country in all site types (Fig. 2, pdf).

Lichens have declined throughout the country

Both the cover and the number of lichen species groups have declined nationwide (Fig. 2, pdf). The decrease in the number of species groups has been most prominent in mesic and sub-xeric heath forests. These results are consistent with the findings of Mäkipää & Heikkinen (2003). There were no clear temporal trends in cover or the number of species groups in bryophytes. However, the abundance relationships between bryophyte species have changed.

Vegetation changes in 1985–2006: The effect of silvicultural treatments

Links to Figure 3a-g	
3a	Trees and shrubs (height < 50 cm)
3b	Dwarf shrubs
3c	Graminoids
3d	Herbs
3e	Bryophytes
3f	Lichens
3g	Stand characteristics

Mean percentage cover and mean number of species in each plant group were calculated across inventory years and silvicultural treatments for two soil fertility levels separately. Also mean percentage cover of some selected taxa and means of stand characteristics were included. The results on percentage cover are presented in Figs. 3a–3f (see the table), and stand characteristics in Fig. 3g (pdf). The results on number of species are presented in Fig. 4 (pdf).

Old and young uncut forests

Cowberry and bilberry cover was stable in old but increased in young uncut forests

In old (> 55-year-old) uncut forests, the cover and number of species have remained relatively stable within all plant groups for vascular plants (Figs. 3a-d, see the table, and Fig. 4, pdf). The cover of bilberry (*Vaccinium myrtillus*) has remained constant, but that of cowberry (*V. vitis-idaea*) has slightly decreased on fertile sites (Fig. 3b, pdf) while increasing on less fertile sites. On the other hand, the cover of both *Vaccinium* species has increased in young uncut forests. Cover of heather (*Calluna vulgaris)* shows a clear decrease on less fertile sites and a slight decrease on fertile ones. The cover of graminoids and herbs has decreased, especially in young uncut forests (Figs. 3c and 3d, pdf).

The changes in the cover of dwarf shrubs may be explained by the increase in growing stock, natural succession, low precipitation in the summers of 1995 and 2006, and between-species competition. Norway spruce dominates most fertile sites, whereas the majority of less fertile sites are dominated by Scots pine. The increased cover of tree canopies during stand succession (Fig. 3g, pdf) has decreased the amount of light and affected the species relationships in the understorey vegetation.

Bryophytes increased while lichens declined

In uncut forests, the greatest changes have occurred in the ground layer: the cover of bryophytes has increased as the cover of lichens has decreased (Figs. 3e and 3f pdf). On less fertile sites, *Pleurozium schreberi* and *Dicranum* spp. have increased. On fertile sites, the pattern is quite different: *Hylocomium splendens* has expanded its cover, but the *Dicranum spp.* have decreased. Even the number of lichen species groups has fallen. The decline of lichens in northern Finland is largely caused by reindeer grazing.

In southern Finland, possible causes for the changes include increased shading by tree canopies, greater competition, lack of forest fires, and long-term accumulation of nitrogen originating from deposition. The increased cover of bryophytes and the decline in that of lichens could indicate some eutrophication on less fertile sites. Even in this case, the increment of growing stock and increased shading by closing canopies may have rendered the light and moisture conditions more favourable for bryophytes.

Forests with intermediate cuttings

Cowberry and bilberry benefited from increased light after intermediate cuttings

Intermediate cuttings (i.e., cuttings between regeneration cuttings) have increased the cover of dwarf shrubs (Fig. 3b, pdf). Both *Vaccinium* species have increased, but heather has decreased since the cutting. *Vaccinium* species are likely to benefit from the increased amount of light after thinnings, even though the volume of growing stock increases soon after the treatment. On the other hand, the cover of heather remained low for decades after the cutting. Despite the increased amount of light, graminoids showed a declining trend after cutting (Fig. 3c, pdf). Both rough small-reed (*Calamagrostis arundinacea)* and wavy hair-grass (*Deschampsia flexuosa)* manifested this trend. They probably cannot cope with the competition from the closed mat of dwarf shrubs. No clear trends could be found for herbs after these cuttings (Fig. 3d, pdf). Seedlings and saplings of trees and shrubs < 50 cm increased in the first inventory after the cutting, but their cover fell slightly after that (Fig. 3a, pdf)

Bryophyte species differed in their response to intermediate cuttings

Bryophytes decreased slightly immediately after cuttings but gradually recovered later on. This pattern was typical of *Pleurozium schreberi* (Fig. 3e, pdf). *Hylocomium splendens* did not react so much to intermediate cuttings but showed an overall strong increasing trend as the forests matured. *Dicranum polysetum* increased after cutting on less fertile sites but showed a slight decrease on fertile ones. This species is sensitive to shading by *Pleurozium* and *Hylocomium* (Salemaa et al. 2008b). The total cover of lichens declined during the study period, regardless of the time of cutting, a trend also found in uncut and regenerated forests (Fig. 3f, pdf). The same was true for reindeer lichens (*Cladina spp.*).

Forests with regeneration cuttings

Both early and late successional species persisted 20 years after regeneration cutting

The cover and number of herb and graminoid species increased after regeneration cuttings, whereas the abundance of dwarf shrubs declined (Figs. 3b, 3c, 3d and 4, pdf). Within 20 years after cutting, the cover of graminoids and herbs started to decrease as both shading by growing trees and competition with other species grew. At this stage, the number of species was larger than for mature stands, since early successional graminoids and herbs were still present.

Regeneration cutting and soil preparation dramatically changed the environmental conditions (Fig. 3g, pdf). The amount of light increased, and temperature and moisture conditions changed. Nutrients were released from both the humus layer and the logging residues. Furthermore, as trees were not competing for resources, there were more nutrient resources available for rapidly growing graminoids and herbs.

Bilberry suffered more than cowberry from drought and increased light

Twenty years after regeneration cutting, the abundance of bilberry was only one fourth of the original cover in mature stands (Fig. 3b, pdf). In the same time, the abundance of cowberry grew to reach nearly its original, pre-cuttings level. Thick-leafed cowberry is more resistant to a larger amount of light and drought after cuttings than is the shade-tolerant, thin-leafed bilberry, and it can utilise these resources effectively in its growth. However, cuttings and soil preparation damage the rhizomes of both species, and their below-ground biomass needs decades to recover and reach the level found in mature forests.

Bryophytes and lichens' recovery after cutting took a long time

The cover of bryophytes and lichens declined after regeneration cuttings (Figs. 3e and 3f, pdf). Bryophyte species favouring fertile sites suffered on account of cuttings more than did those adapted to less fertile conditions. The shade-thriving *Hylocomium splendens* recovered more slowly than *Pleurozium schreberi* and *Dicranum polysetum*, which are more resistant to direct sunlight. Lichens are usually severely damaged by cuttings, and recovery from mechanical destruction and soil exposure can take decades.

Future trends in forest vegetation

Future development of forest vegetation will depend on silvicultural practices, stand age and structure, and the proportions of tree species in the forests. Greater use of wood for bioenergy, including uprooting of stumps, and removal of logging residues are likely to cause even more vegetation changes than do the traditional regeneration cuttings. Atmospheric deposition of pollution, reindeer grazing, and control of forest fires will continue creating pressure especially for species that thrive on less fertile sites.

Climate change can affect the understorey vegetation directly by altering temperature conditions and precipitation, but indirect influences through changes in tree stands and soil properties may be even more important.

Methods

Sampling and fieldwork

Understorey vegetation on 443 mineral-soil sites was surveyed in 1985–86, 1995 and 2006 (Fig. 1). These sample plots are a subset of ICP Level 1 plots as well as of a network of 3,000 permanent sample plots established in 1985–86 in association with the 8th National Forest Inventory (Reinikainen et al. 2000, Tonteri et al. 2005).

The data include both unmanaged and managed stands. On 92 of the plots, there were no cuttings in 1975–2006. In all, 72 of the plots were in old uncut forests, aged 55 years or older, and 20 plots were in uncut forests younger than 55 years. Regeneration cuttings were performed on 105 sample plots and intermediate cuttings on 246 sample plots in 1975–2006. All cuttings that took place between regeneration cuttings (usually thinnings) were included in intermediate cuttings.

Plant species were identified, and their percentage cover was estimated, for four sampling units (quadrats of size 2 m^2, for 8 m^2 in total on each plot), positioned in exactly the same locations on each of the three sampling occasions.

Calculations

We calculated the plot-specific sums of percentage cover and number of species in six plant groups:

- seedlings and saplings of trees and shrubs (height < 50 cm)
- dwarf shrubs
- graminoids
- herbs
- bryophytes
- lichens

For the full dataset, temporal changes in percentage cover and number of species or species groups (mean ± SE) in each plant group were analysed across three subzones of the boreal zone in Finland. The number of species was also given for different forest site types (fertility gradient). In the case of bryophytes and lichens, species groups including some or all species from the same genus were used for some taxa instead of species. For instance, in genus *Cladina* the species were treated separately, except that *C. arbuscula* and *C. mitis* were combined to form a species group.

Furthermore, temporal vegetation changes in young and old uncut forests, forests with intermediate cuttings, and forests with regeneration cuttings on different occasions were compared. In this case, the site types were classed into two groups. The group ‘fertile sites’ contained site types ranging from herb-rich forests to mesic heath forests, whereas ‘less fertile sites’ contained sub-xeric and xeric heath forests. Temporal changes in percentage cover were calculated for plant groups as well as for some species and genera. The number of bryophyte species (not species groups) was calculated.

References

Heikkinen, J. & Mäkipää, R. 2010. Testing hypotheses on shape and distribution of ecological response curves. Ecological Modelling 221(3): 388–399.

Hotanen, J.-P., Nousiainen, H., Mäkipää, R., Reinikainen, A. & Tonteri, T. 2008. Metsätyypit – opas kasvupaikkojen luokitteluun. Metsäkustannus, Hämeenlinna. 190 p.

Mäkipää, R. & Heikkinen, J. 2003. Large-scale changes in abundance of terricolous bryophytes and macrolichens in Finland. Journal of Vegetation Science 14: 497–508.

Peltola, A. & Ihalainen, A. 2012. Forest resources. In: Ylitalo, E. (ed.). Finnish Statistical yearbook of Forestry 2012. Metsäntutkimuslaitos, Sastamala. p. 39–78.

Reinikainen, A., Mäkipää, R., Vanha-Majamaa, I., & Hotanen, J-P. (eds.) 2000. Kasvit muuttuvassa metsäluonnossa. [Summary in English: Changes in the frequency and abundance of forest and mire plants in Finland since 1950]. Tammi, Jyväskylä. 384 p.

Salemaa, M., Derome, J. & Nöjd, P. 2008a. Response of boreal forest vegetation to the fertility status of the organic layer along a climatic gradient. Boreal Environment Research 13(supp.B): 48–66.

Salemaa, M., Mäkipää, R. & Oksanen, J. 2008b. Differences in the growth response of three bryophyte species to nitrogen. Environmental Pollution 152: 82–91

Tomppo, E. 2000. Kasvupaikat ja puusto. In: Reinikainen, A., Mäkipää, R., Vanha-Majamaa, I., & Hotanen, J-P. (eds.) 2000. Kasvit muuttuvassa metsäluonnossa. [Summary in English: Changes in the frequency and abundance of forest and mire plants in Finland since 1950]. Tammi, Jyväskylä. p. 61–83.

Tonteri, T., Hotanen, J.-P., Mäkipää, R., Nousiainen, H., Reinikainen, A. & Tamminen, M. 2005. Metsäkasvit kasvupaikoillaan – kasvupaikkatyypin, kasvillisuusvyöhykkeen, puuston kehitysluokan ja puulajin yhteys kasvilajien runsaussuhteisiin. Metsäntutkimuslaitoksen tiedonantoja 946. 52 + 53 p.

Ylitalo, E. (ed.) 2012. Finnish Statistical Yearbook of Forestry 2012. Metsäntutkimuslaitos, Sastamala. 454 p.

Citation: Tonteri, T., Salemaa, M. and Rautio, P. (2013). Changes of understorey vegetation in Finland in 1985–2006. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087583. [Cited 2013-05-07].

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Publications

Sitemap | Search

Forest Condition Monitoring in Finland – National report

- Preface and contents
- Monitoring programmes
- Results: Crown condition
- Results: Intensive monitoring
- Results: related projects
- **Publication list of the Programme**
- About the report

Photo: Hannu Nousiainen

Publication list of the Programme

- 2009-
- 1995-2008

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Report

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programme

Results: Crown condition

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Maija Salemaa

Forest Condition Monitoring in Finland – National Report

Editors

Päivi Merilä (chief editor)
Sinikka Jortikka

Graphics

Irene Murtovaara

Photos

Hannu Nousiainen; Metla/Erkki Oksanen; Jouni Hyvärinen; Maija Salemaa and Liisa Ukonmaanaho

Interactive presentations

Jouni Karhu and Jukka Pöntinen

Website

Sinikka Jortikka, Karipekka Byman and Jussi Voipio

Publisher

The Finnish Forest Research Institute (Metla)

The majority of the monitoring activities presented in this publication have received funding from the EU/FutMon LIFE+ or the EU/Forest Focus (Regulation (EC) No 2152/2003) Programmes

Citation

Merilä, P. & Jortikka, S. (eds.) 2013. Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087568 [Cited 2013-05-07].

Articles, for example

Merilä, P. (2013). Foliar chemistry on the intensive monitoring plots. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087573. [Cited 2013-05-07].

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Monitoring programme» Extensive monitoring

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programme

- Pan European programme
- **Extensive monitoring in Finland**
- Intensive monitoring in Finland

Results: Crown condition

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Jouni Hyvärinen

Extensive monitoring of forest condition – Level I in Finland

By Seppo Nevalainen & Päivi Merilä

Finland has been participating since 1985 in the Level I monitoring of forest condition. Metla annually inventories forest condition, using internationally standardised methods (Eichhorn et al. 2010), on a representative sample of tree stands.

The systematic network used in the annual crown condition survey has been designed to provide information at the national level about crown condition and its variation in background areas. A number of parameters are measured on the trees. The most important variables used to describe crown condition in Finland are relative leaf- and needle-loss (i.e. defoliation), discoloration and abiotic and biotic damage of the crown.

Extensive monitoring network (2009–2012)

The integration between ICP Forests Level I and NFI was accomplished in 2009 in Finland. The sampling design of the current NFI is a systematic cluster sampling, and thus differs from the standard plot design in Europe (Fig. 1a, below). Annually, a new set of ca. 900 permanent plots, established during the ninth NFI in 1996–2003, was assessed in the forest condition survey. The same permanent plots were to be assessed in five-year intervals. Level I survey was ceased in Finland in 2012.

Earlier extensive monitoring networks (1985–2008)

In 1985-2008, the inventory was carried out on about 500 mineral soil and 100 peatland plots selected from the permanent sample plot network of the eighth National Forest Inventory, established in 1985 (Fig. 1b, below).

In addition, soil surveys have been carried out on 338 plots in 1986/87, on an additional 104 plots in 1995, and on 508 plots in 2006–2007. Needle samples were collected for elemental analysis on 160 plots (98 pine plots, 62 spruce plots) during 1987–1989 (Raitio 1994), and on ca. 30 plots (16–18 pine, 12–14 spruce) annually during 1992–2007 (Luyssaert et al. 2005).

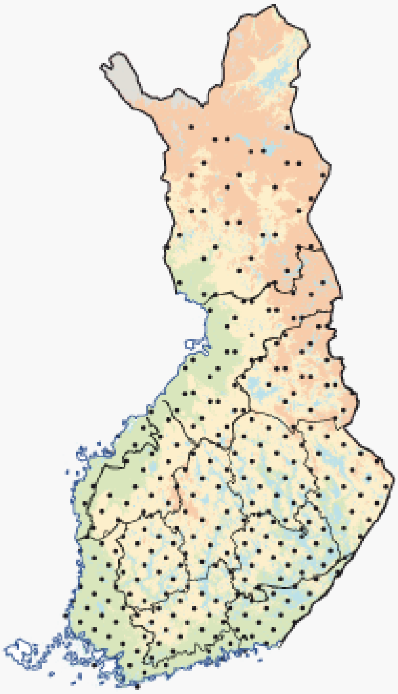


Figure 1a. The extensive forest condition (ICP Forests Level I) monitoring is being carried out on ca. 900 permanent National Forest Inventory (NFI) plots.

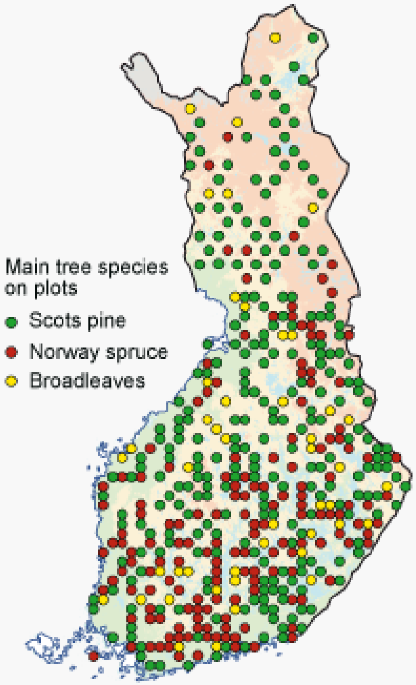


Figure 1b. The network of the annual, large-scale crown condition survey (ICP Forests Level I) in Finland applied in 1985–2008).

References

Eichhorn, J., Roskams, P., Ferretti, M., Mues, V., Szepesi, A. & Durrant, D. 2010. Visual Assessment of Crown Condition and Damaging Agents Manual. Part IV In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE ICP Forests Programme Co-ordinating Centre, Hamburg, 46 pp. (pdf)

Luyssaert, S., Sulkava, M., Raitio, H. & Hollmén, J. 2005. Are N and S deposition altering the mineral composition of Norway spruce and Scots pine needles in Finland? Environmental Pollution 138: 5–17. (pdf)

Raitio H. 1994. Kangasmetsien ravinnetila neulasanalyysin valossa. In: Mälkönen, E. & Sivula, H. (eds.). Suomen metsien kunto. Metsäntutkimuslaitoksen tiedonantoja 527: 25–34. In Finnish.

Citation: Nevalainen, S. and Merilä, P. (2013). Extensive monitoring of forest condition – Level I in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087570. [Cited 2013-05-07].

Citation: Nevalainen, S. and Merilä, P. (2013). Extensive monitoring of forest condition – Level I in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087570. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programme

- Pan European programme
- Extensive monitoring in Finland
- **Intensive monitoring in Finland**

Results: Crown condition

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Jouni Hyvärinen

Intensive and continuous monitoring of forest ecosystems – Level II in Finland

By Päivi Merilä, Liisa Ukonmaanaho, Pekka Nöjd & Egbert Beuker

Current intensive monitoring plot network (2011–)

Since 2011, the number of intensive monitoring plots has been 14. The plots are located in Norway spruce (n = 7) and Scots pine (n = 7) forests in various parts of Finland (Fig. 2a, Table 1, pdf). Most observation plots are located in stands under conventional forest management. Two of the plots (Evo nr. 19, Lieksa nr. 20) also belong to the ICP Integrated Monitoring Programme, representing natural stands in catchment areas. A number of the plots are located close to background, air quality monitoring stations run by the Finnish Meteorological Institute.

Forest ecosystems are diversely monitored on these plots, with the aim of cause-effect analysis. Deposition of air pollutants, the cycles and leaching flux of nutrients, defoliation, abiotic and biotic damage, growth, nutrient status and understorey vegetation are among the attributes monitored (Table 2, pdf). Meteorological measurements are conducted in cooperation with the Finnish Meteorological Institute (Table 3, pdf).

The basic stand characteristics of ICP Level II plots are presented in Table 4, pdf.

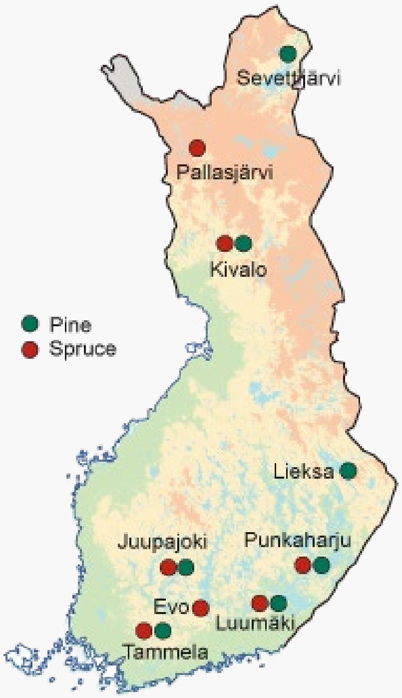


Figure 2a.The intensive forest monitoring plot network of forest ecosystems (ICP Forests Level II) in Finland in 2011–.

Earlier intensive monitoring plot networks (1997–2010)

Finland joined the intensive monitoring of forest ecosystems in 1995. By 1997, 31 intensive monitoring plots had been established in different parts of the country (Fig. 2b, Table 1, pdf): 27 of the plots on mineral soil sites and 4 on peatlands. Seventeen of the plots were located in Scots pine stands and 14 in Norway spruce stands. All the plots, except for the four Integrated Monitoring (ICP-IM) plots, were located in stands under conventional forest management. The IM plots represent natural stands in catchment areas. In 2005, two Norway spruce plots (nrs. 24 and 28) were replaced by two Silver birch plots (nrs. 32 and 33).

In the period 1995–1997, meteorological stations were installed at 12 Level II plots. The parameters measured were:

- Air temperature and humidity (within and above the canopy)
- Precipitation
- Wind speed and direction
- Total radiation and PAR radiation
- Soil temperature and moisture

At the locations Kivalo, Punkaharju, Tammela and Pallasjärvi two or three Level II plots for different tree species were situated close to each other. For these locations, the data from the meteorological stations at one of the plots were used for all plots at that particular location. After the Närpiö plot was closed, the meteorological station was moved to the birch plot in Kivalo. In 2010 and 2011, the meteorological stations were run down and meteorological data for all remaining Level II plots will be obtained from nearby stations of the Finnish Meteorological Institute.

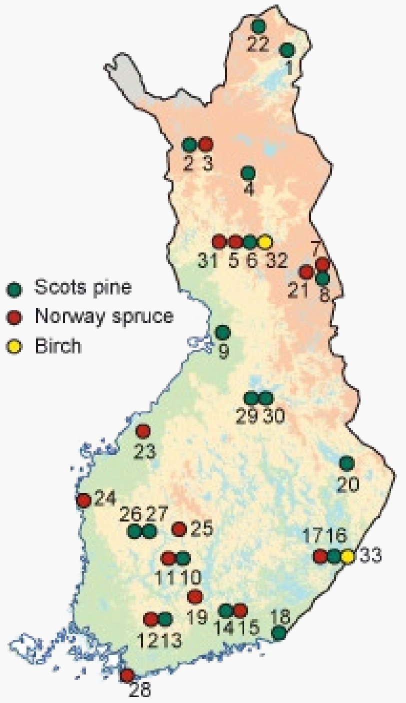


Figure 2b. Intensive forest monitoring network 1997–2008. For information on plotwise active periods see Table 1, pdf.

Four of the intensive monitoring plots were established on drained peatland (nrs. 26, 27, 29, 30; active in 1997–2007). The sites were originally wet, sparsely stocked pine mires that represented the most typical drained peatland site types in Finland. The peat in these site types has a low mineral nutrient status, but usually relatively high nitrogen reserves. As this may result in an unbalanced nutrient status in the tree stand, two of the four plots have been fertilized. The four plots were located at two locations in Finland, with a pair of unfertilized and fertilized plots at each location. Three of the plots were established in long-term spruce provenience trials (nrs. 25, 28, 31).

In 2009, in the beginning of EU Life+ funded FutMon project the number of intensive monitoring plots was reduced to 18 plots in order to carry out a similar intensity of monitoring on all the plots (Fig. 2c, Table 1, pdf). Since 2011 the number of intensive monitoring plots has been 14 (Fig. 2a, Table 1, pdf).

The design of the observation plot and location of the sub-plots

The observation plots proper consist of three sub-plots and a surrounding mantle (sub-plot 4) (Fig. 3, below). The sub-plots are square in shape (30 x 30 m). A 5–10 m wide strip has been left between the sub-plots for possible future use in special studies and for additional sampling. Sampling methods that may have a detrimental, long-term effect on the soil or stand, e.g. soil sampling, deposition and soil water collection, needle and litter sampling etc., are concentrated on one sub-plot. One of the other two sub-plots is reserved for vegetation studies, and the other for tree growth measurements.

The centre point of the observation plot, the corners of the sub-plots and

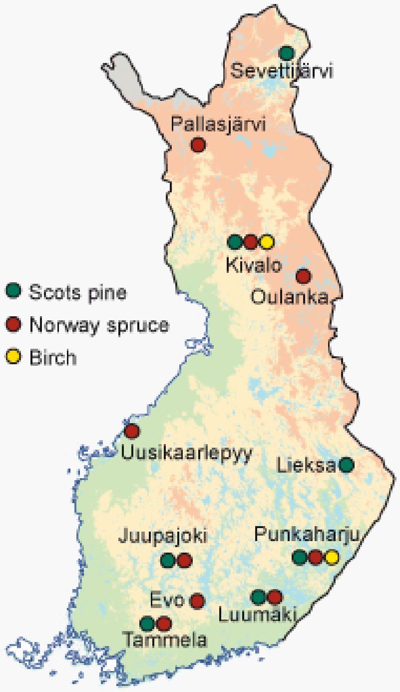


Figure 2c. The intensive forest monitoring network of forest ecosystems in Finland in 2009–2010 (ICP Forests/EU Life+ FutMon).

the outer edge of the mantle area have been marked with wooden posts. The mantle is surrounded by a buffer zone. The width of the mantle and buffer zones varies from 10–30 m.

Basic stand measurements and mapping

All the trees on the observation plot have been numbered at a height of 1.3 m on the side of the tree facing the centre point.

The following parameters have been recorded or measured on each tree: tree species, canopy layer, diameter at 1.3 m, tree height, and length of the living crown. The measurements have been performed on the trees on sub-plots 1–3 and those located in the mantle area (sub-plot 4). Twenty additional trees representing different diameter classes have been selected and numbered on the buffer zone (sub-plot 5). In addition to the above measurements, bark thickness has been measured and increment cores taken at 1.3 m height for determining earlier growth and tree age. The forest site type has also been determined.

The location and elevation of all the trees on the observation plots have been mapped using a tachymeter. The exposition and gradient of each sub-plot have also been determined. Care has been taken during the fieldwork to avoid causing unnecessary trampling of the ground vegetation or other forms of damage. Wooden walkways have been laid on the sub-plot used for collecting deposition and soil water.

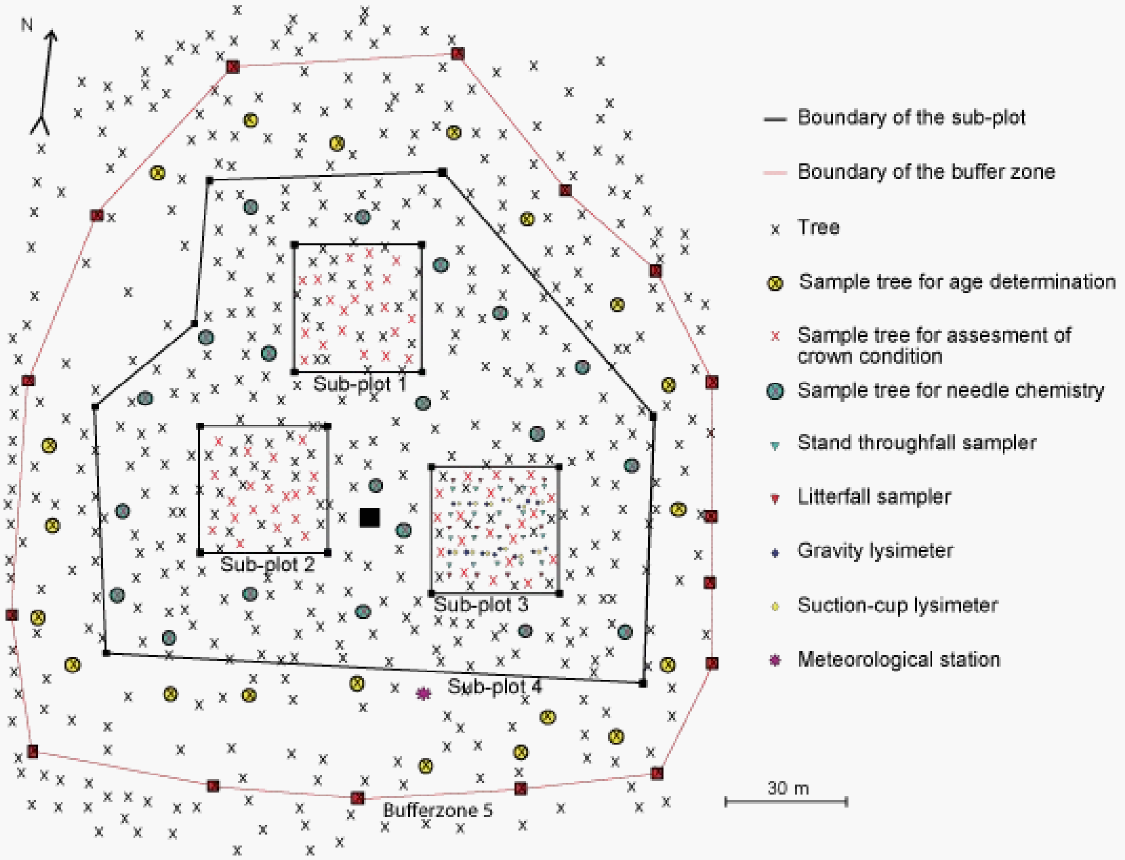


Figure 3. The Finnish design of the intensive monitoring plots (ICP Forests Level II) and location of the sub-plots.

References

Cajander, A.K. 1949. Forest types and their significance. Acta Forestalia Fennica 56:1–71.

Venäläinen, A., Tuomenvirta, H., Pirinen, P. & Drebs A. 2005. A basic Finnish climate data set 1961–2000 – description and illustrations. Finnish Meteorological Institute Report no. 2005: 5. 27 pp.

Citation: Merilä, P., Ukonmaanaho, L., Nöjd, P. and Beuker, E. (2013). Intensive and continuous monitoring of forest ecosystems – Level II in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087571. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programmes

Results: crown condition

- Summary
- **Extensive monitoring**
- Intensive monitoring
- Discussion

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Jouni Hyvärinen

[Return to the beginning of the article]

Results: Extensive monitoring 1986–2012

Defoliation

The average tree-specific degree of defoliation for the period 1986–2012 on Level I sites was 10.7 in pine, 19.6 in spruce and 12,8 % in broadleaves. Across the whole country, the average tree-specific defoliation was at its highest during 1988–1989. Especially the defoliation degree of Norway spruce was at a particularly high level at this time. The defoliation of Scots pine slightly increased during the final years of the period 1986- 2008. The defoliation of both Scots pine and broadleaves (*Betula* sp.) showed a peak in 2007 (Fig. 1). The defoliation seemed to have increased during 2011 and 2012. However, the results from 2009-2012 are separate samples each year, and the results come from a different data network. Therefore the results are not directly comparable. In addition, peatland plots were only included in the 2004–2007 and 2009–2012 data.

Of all the trees assessed, 96% of the pines, 76% of the spruces and 92% of the broadleaves (*Betula* spp.) were not defoliated or were only slightly defoliated (leaf or needle loss was less than 25 % (see Fig. 2, pdf). The proportion of severely defoliated trees (defoliation more than 60%) has remained relatively constant. For pine this proportion was 0.5% and for spruce 2.4 % and for broadleaves 1%, respectively, during 1986–2012.

Despite the relatively small changes in defoliation in the whole data, marked spatial and temporal variations in defoliation existed during the study period. The defoliation of pine in 2012 was highest in northeastern part of the country (Fig. 3b). In contrast, the highest defoliation values in 2008 were found in south-eastern Finland (Fig. 3a). The defoliation of spruce trees in 2012 was highest in Lapland and south-western Finland (Fig. 3d). In the 2008 data, the highest defoliation values in spruce were more scattered across the country (Fig. 3c). The highest values were found in the southernmost and the north-eastern parts of Finland. The defoliation of the assessed birch trees seems to have intensified in the very west-north (Figs. 3e and 3f).

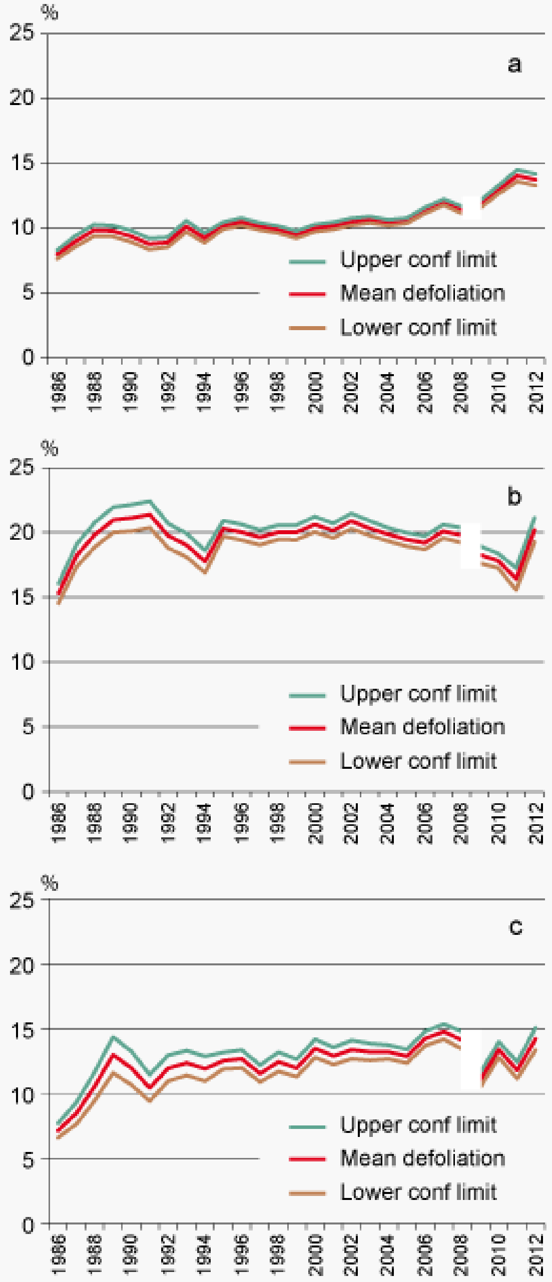


Figure 1 (a–c). Average degree of defoliation of Scots pine (a), Norway spruce (b) and birches (c), with 95% confidence intervals, in 1986–2012. Due to differences in sampling, the results for 2009 and 2010 are not directly comparable with each other or with the results from the previous years.

The temporal pattern of defoliation seems to be different in relation to latitude. The proportion of defoliated (defoliation more than 10%) pines seems to increase in the southernmost zone (below 64 °N'), but has decreased clearly in the northernmost zone. The proportion of defoliated spruces showed a slight increase in the southernmost zone, and decreased in the two northernmost zones. The figures concerning the birches showed big variations in the north, and a slight increase in the southernmost zone (Fig. 4, pdf).

The result is confirmed in a trend analysis. In the 1986–2008 data, clearly more pine forests in the southern part of Finland showed an increasing defoliation trend than the pine forests in the northern part. However, the variation between adjacent sample plots was large. In spruce forests, the number of sample plots showing an increasing defoliation trend was also higher in the south than in the north. However, the difference between southern and northern areas was smaller for spruce than for pine (Figs. 5a and 5b).

The results from the latitude zones in 2009–2012 are not directly comparable with the 1986–2008 data, as mentioned earlier. There was an increase in pine and spruce defoliation in the northernmost zone, and in pine also an increase in the southernmost zone. The defoliation of birches continued to show large variation between the years 2009–2012.

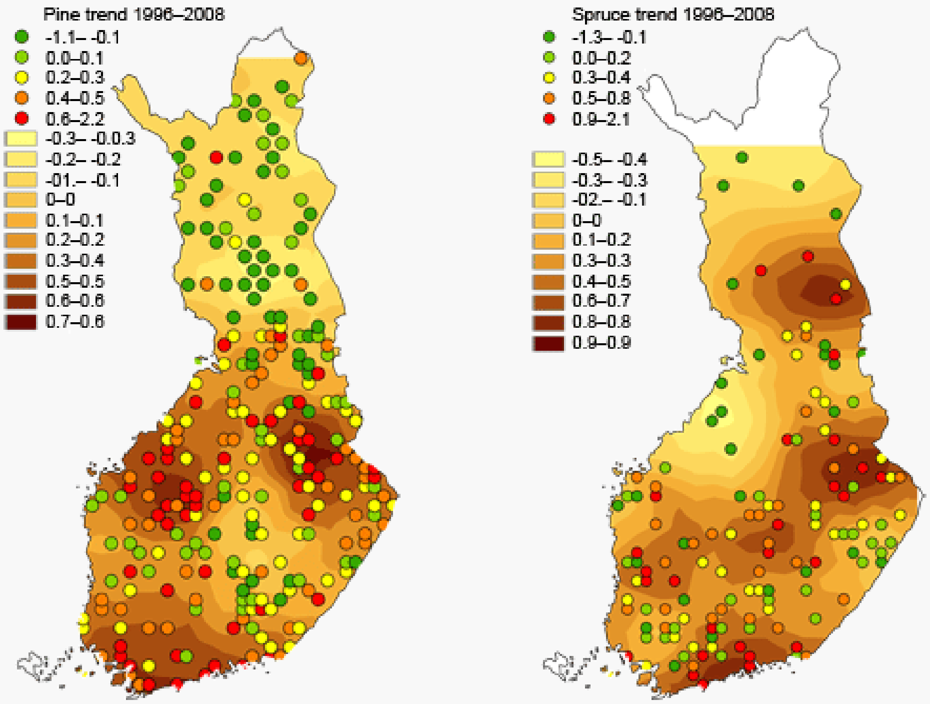


Figure 5 (a–b). The slope of the median (Theil-Sen) trend in the defoliation of Scots pine (a) and Norway spruce (b) in the common plots during 1995-2008. The trend analysis was done with the Earth Trend Modeler in Idrisi 16.05 (Taiga edition). The raster is produced with the kriging function in ArcMap 9.2, using a 30 km grid size, and the dots represent the slope values classified using a class width of ½ standard deviation in ArcMap.

Discolouration

In general, the proportion of discoloured spruces (the proportion of discoloured leaf or needle mass greater than 10%) was higher (8.3%) and varied annually much more than that in pine (1.4%) or birches (2.1%). The proportion of discoloured spruces was high at the beginning of the study period, the highest peak occurring in 1991 (20.4%). In 1989, the proportion of discoloured spruce trees was high in the western parts of Finland (Fig. 6, pdf). Later on, peaks in this proportion were recorded in 2005 and 2008. In pine, the proportion of discoloured trees remained at a low level in most years during the survey period, but it increased significantly in 2006, when the proportion was 6.8% At that time, discoloured trees were most frequently found in eastern Finland and along the south coast (Fig. 7, pdf). However, most of these discoloured conifers belonged to the 11% to 25% discolouration class, and the incidence of moderate or severe discolouration (discolouration over 25%) was rare (0.7% in all trees, 1.5% in the spruces). The most frequent discolouration symptoms in spruce were needle tip yellowing and needle yellowing, and in pine also needle browning. The colour symptoms were mainly concentrated on needles older than two years in spruce, and older than current-year needles in pine. Discolouration was also recorded as a damage symptom. Biotic and abiotic factors causing discolouration were recorded during the peak years, as reported later.

Biotic and abiotic damage

The proportion of trees with symptoms of abiotic or biotic damage decreased rather than increased during the monitoring period (1986–2012). The mean proportion of symptomatic trees was the same (60%) in all main tree species groups. Pines had less abiotic and unidentified damage, but more insect damage than spruce and broadleaved species (Table 1, pdf).

However, there were considerable changes in the occurrence of the agent groups and specified agents over the years (Fig. 8, pdf). Temporal patterns and coarse spatial distributions of some of the most common causes of damage were obtained on the basis of the annual Level I data.

In Scots pine, peaks in the occurrence of abiotic damage occurred in 1989 and 2006 (Figs. 7 and 8a, pdf). The latter peak was especially attributed to drought.

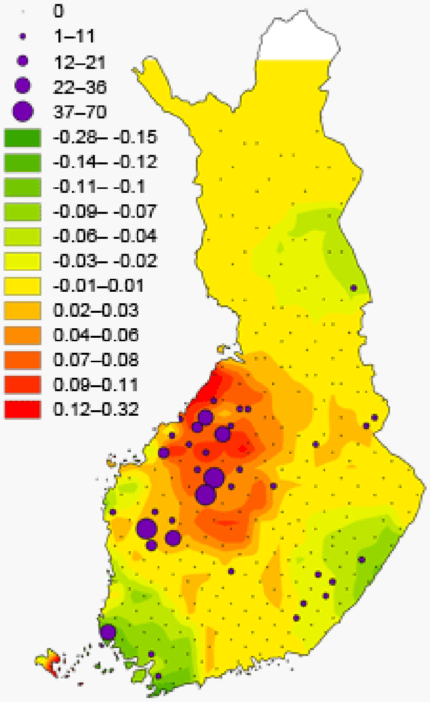


Figure 9. The occurrence of pine sawflies in 2010. The dots show the number of damaged trees per assessment tract. The raster shows the change in the occurrence between 2010 and 2009. Positive values (red) indicate an increase in the damage.

The proportion of Scots pine trees with symptoms was the highest (60%) in 1989. Higher-than-normal occurrence of damage by *Gremmeniella abietina* (Lagerb) Morelet (in the central and central-western parts of Finland), damage of the pine shoot beetles (*Tomicus sp.*) and edaphic factors were characteristic for 1989. Other high peak years in the new infections caused by *Gremmeniella* occurred in 1997 and 2001. During the highest peak of damage by pine sawflies in 2000 (here mostly *Diprion pini* L.), infection was reported in 7.3% of the assessed pines. Another massive epidemic of pine sawflies (this time mostly *Neodiprion sertifer* Geoffr.) became evident in 2008. A shift in the mass outbreak of pine sawflies from south-eastern parts of the country to the central- western parts was evident in the extensive level data in 2009–2010 (Fig 9). In 2012, the proportion of affected pines was again at low level, about 1 %. It should be noted that the results from 2009–2010 come from another monitoring network (permanent plots of the NFI 9), and are thus not comparable to the results from the older network (NFI 8) used between 1986 and 2008. Other examples of the epidemics in Scots pines include frost damage in 1989 in Lapland, the *Lophodermella sulgicena* Rostr. v. Höhn epidemics in central and central-eastern Finland and in Lapland.

The proportion of Norway spruces with damage symptoms was the highest (60%) in 1988–89 (Fig. 8b, pdf), which was also reflected in the discolouration results (see above). In Norway spruces the peaks in fungal damage mostly reflect the infections caused by spruce needle rust (*Chrysomyxa ledi* (Alb. & Schw.) deBary). *Chrysomyxa* (18.4% of spruces) and frost damage (7.4%) were common in 1988. *Chrysomyxa* was also frequent in 1989, 2001 2005 and 2009, and also 2012 in northern Finland.

In birch trees, the most evident damage peaks occurred in 1993 (attributed to abiotic damage) and 2004, caused by birch rust, *Melampsoridium betulinum* (Pers.) Kleb., and by unidentified leaf-spot fungi (Fig. 8c, pdf).

It should be remembered, however, that most of the observed damage was slight. The proportion of moderate and severe damage was 5.1% for pine, 11.3% for spruce and 11.4% for broadleaves. The proportion of severe damage was 0.5% for pines, 0.8% for spruces and 0.9% for broadleaves. The yearly variation in this proportion was small. The moderate or severe damage in Scots pine was frequently caused by *Gremmeniella*, *Cronartium* sp., pine sawflies, especially *Neodiprion sertifer* and competition. In spruce the list of the most serious causes of damage consists of decay fungi, particularly *Heterobasidion* sp., unknown causes and competition. Unknown causes, snow, decay fungi and competition were the most important in birches.

Some spatial patterns were evident when the defoliation and biotic damage data were examined together. For instance, defoliation in pines increased slightly in 2000 in central Finland, which was also the area where pine sawflies (in this case mostly *Diprion pini*) were common.

Annual mortality

The mean annual mortality rate between 1986 and 2008 (i.e. the proportion of trees that had died after the previous year's inventory) were 0.16% for pine and 0.18% for spruce. The values ranged from 0.092% in 1985–87 to 0.32% in 1988 and 2002. The dead trees were very evenly distributed throughout the whole country. The relatively high proportion of dead spruces in 2002 was due to the larger number of trees damaged by storms (68%) compared to the situation in other years. In general, wind, snow and *Heterobasidion* sp. were the most common causes of tree mortality.

Material and methods

The large-scale crown condition survey (Level I) has been carried out in Finland on a systematic network of permanent sample plots since 1986, until 2012. Before 2009, a subsample of the permanent plots established during 1985–1986 in connection with the 8th National Forest Inventory (NFI) was used (Jukola-Sulonen et al. 1990).

The integration between ICP Level 1 and NFI was accomplished in 2009 in Finland. The sampling design of the current NFI is a systematic cluster sampling. The distance between clusters, the shape of a cluster, the number of field plots in a cluster and the distance between plots within a cluster vary in different parts of the country. Principally, every fourth cluster is marked as a permanent cluster. Annually, a new set of permanent plots, established during the 9 th NFI in 1996–2003, is assessed in the forest condition survey. Tallied dominant and co-dominant Norway spruce, Scots pine and birch trees from six pre-selected permanent plots from each cluster were assessed. The same permanent plots were to be assessed at five-year intervals. In 2009, all trees were assessed, but -since 2010 a maximum of six trees per appropriate species were included in the sample., which led to a reduction in the number of assessed trees.

Please note that because the plots assessed during 2009–2012 were completely different samples, the results from 2009– 2012 are not directly comparable with each other or with the results from the previous years.

The number of assessed plots and trees at the extensive level (1986–2010) are described in Table 2, pdf.

The most important variables used to describe crown condition were defoliation, discolouration of the crown and abiotic and biotic damage. These variables were assessed visually according to internationally standardized methods (Eichhorn et al. 2010, pdf) and national field guidelines (Lindgren et al. 2005). Defoliation is expressed as the relative leaf or needle loss compared to a reference tree (Lindgren et al. 2000).

Defoliation of Norway spruce was estimated on the upper half of the living crown, and of Scots pine (*Pinus sylvestris* L.) and birches (*Betula* sp.) on the upper two-thirds of the living crown in 5% of classes. The proportion of discoloured needle mass (e.g. needle tip yellowing, needle yellowing and browning) was assessed in five classes (class 1 = 0–5%, 2 = 6–10%, 3 = 11–25%, 4 = 26–60% and 5 = more than 60%). A tree is classified as discoloured when 10% of its leaf or needle mass has abnormal colouration. Please note that in 2010 discolouration was not recorded as a separate variable (but it was included in the damage assessment).

A national system for the description of a symptom, apparent severity (degree of damage) and the cause, as well as the age of the damage, was used prior to 2004. An example of the variables and codes used in the national damage survey before 2004 can be found in Nevalainen (1999) and Lindgren (2002), for example. The ICP Forests manual of damage causes (Eichhorn et al. 2010), was tested in 2004, and fully adopted in 2005 in Finland. Currently, the European assessment of damage consists of symptom description, determination of the causal factor and quantification of the symptoms (extent of damage). The age of the damage (new or old) was also recorded. Several injuries can be recorded for each tree. The principles of the national damage survey in Finland were similar to the international guidelines, except that the coding of damage symptoms and causes used to be less detailed, and the quantification of damage was not systematically used prior to 2004.

In addition to the analysis of all nationwide data, the temporal development of defoliation was also analysed in four different latitudinal zones. The approximate upper latitude limits of the zones were as follows: Zone 4 (the southernmost): 62° N, zone 2: 64 ° N and zone 3: 67 °N (see Salemaa et al. 1990). The generalization of the mapped data was done using the kriging function in ArcMap 9.2. In addition, a trend analysis was computed with the Earth Trend Modeler in Idrisi 16.05 (Taiga edition), and the median (Theil- Sen) slope estimates were used in this study.

[Return to the beginning of the article]

Forest Condition Monitoring in Finland – National report

Preface and contents
Monitoring programmes
Results: crown condition
- Summary
- Extensive monitoring
- **Intensive monitoring**
- Discussion

Results: Intensive monitoring
Results: Related projects
Publication list of the Programme
About the report

Photo: Jouni Hyvärinen

[Return to the beginning of the article]

Results: Intensive monitoring 1995–2013

Defoliation

The average tree-specific degree of defoliation for the period 1995–2013 was 11.3% and 18.2% for Scots pine (total 18 sample plots) and Norway spruce (total 15 sample plots), respectively. The crown condition parameters were assessed in every year only in four pine plots and five spruce plots (table 3, pdf). The proportion of non-defoliated (defoliation less than 10%) Scots pines was 64.9%, and that of Norway spruces 31.5% in the intensive observation plots. In addition, the proportion of moderately or severely defoliated spruces was clearly higher in spruce than in pine (3.9% for pine and 14 % for spruces). During the monitoring period there has been a shift from the 0–10% defoliation class to class 11–25%, due to ageing of the trees.

However, the number of sample plots varied annually during the monitoring period. The low average tree-specific degrees of defoliation (under 5%) in pine was detected e.g. on the Kivalo (plot number 6) in 1995, 1997, 2003 and 2004, on Punkaharju (number 16) in 1999, 2000 and 2001, and on Tammela (number 13) in 2000. The slight or moderate average tree-specific degrees of defoliation (more than10%) were detected in 11 pine plots e.g. on the Sevettijärvi (number 1) and Lieksa (number 20) (please see the interactive Fig.10).

In Norway spruce plots the average tree-specific defoliation was mostly over 10% during the period 1995-2013, with the exceptions of e.g. Juupajoki (number 11) in 1995, 1996 and 1999 (Fig. 10). The highest average tree-specific degrees of defoliation (more than 25%) was detected e.g. on the Evo plot (number 19) in several years during the monitoring period. There was no clear simultaneous increase or decrease in defoliation between Level II observation plots. Rather, the defoliation shows large plot-wise annual variations in the intensive level, too.

The estimated non-parametric monotonic trends (Theil-Sen) usually show a positive trend (increasing defoliation). However, the linear trend was sometimes not significant, because there were sudden annual peaks in defoliation, due to abiotic or biotic damage. The largest significant positive trend was observed on plot number 16 (Norway spruce plot in Hyytiälä) (table 3, pdf).

Discolouration

The proportion of discoloured Scots pines (proportion of discoloured needle mass more than 10%) was very low throughout almost the entire monitoring period 1995-2013 (Fig.10). On average 98% of Scots pines belong to the discolouration class “non-discoloured” (extent of discoloured needle mass 0–10%) during the monitoring period. However, an increase in proportion of discoloured (extent of discoloured needle mass more than 10%) Scots pines was detected in 1999, 2008 and especially in 2006 (see also the results from the extensive level above). However, most of the discoloured Scots pines belong to the 11 to 26% discolouration class and the incidence of moderate (extent of discoloured needle mass 26–60%) or severe (extent of discoloured needle mass more than 60%) discolouration was rare.

In Norway spruce, the proportion of discoloured (extent of discoloured needle mass more than 10%) trees was generally higher and more varied than in Scots pine during the whole monitoring period (Fig.10). In general, 90% of spruces were classified as non-discoloured during 1995–2013. The lowest proportion of non-discoloured spruces (79.4%) was detected in 1996. In the same year, the proportion of moderate and severe discoloured (extent of discoloured needle mass 26–60% and over 60%, respectively) spruces was highest. The proportion of slightly discoloured spruces varied from 0.4% (in 2010) to 15% (in 1999) and was more than 10% in 1995, 1996, 1999, 2000, 2005, 2008 and 2012. There was no clear simultaneous increase or decrease in discolouration between Level II observation plots. Rather, the discolouration shows large plot-wise annual variations. The highest amount of discoloured trees in the plots assesses every year was detected in Pallasjärvi (number. 3) in 1996 where 65% of spruces were discoloured.

Biotic and abiotic damage

In the intensive monitoring plots, biotic and abiotic damage is reported for pine and spruce trees (Fig.10).

As in the extensive monitoring, pine trees had less abiotic damage, but more insect damage than spruce trees. Large annual variations in the occurrence of some main biotic/abiotic causes existed, even in the scarce intensive plot network (Fig.10). The most apparent peaks were due to insect damage, mainly pine sawflies in pine stands (2000) and the high occurrence of fungal diseases in spruce stands (1997 and 1999–2001), and in the spruce stands 3 and 5 in the north also in 2011–2013. Abiotic damage was common e.g. in Scots pine plot 22 in Kevo in 1997–98. The spruce plot number 11 suffers from attacks by bark beetles (Ips. sp) and infection by rot fungi. In addition, spruce plot number 17 in Punkaharju was partly infected with *Heterobasidion parviporum* (Niemelä & Korhonen), and many trees were wind-thrown during the storms in 2013.

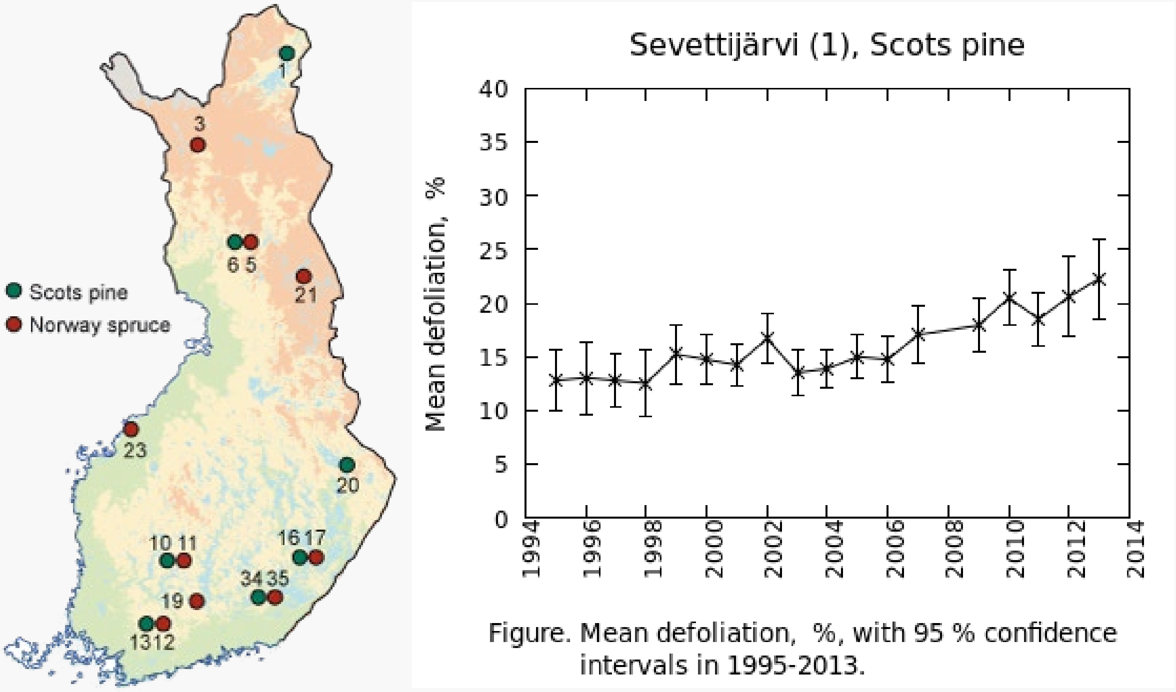


Figure. Mean defoliation, %, with 95 % confidence intervals in 1995-2013.

Figure 10. Please click the plot location on the map (left) and choose the variable to be shown in the graph (right). Please note that plots 1, 19, and 21 were not assessed in 2008.

Material and methods

The annual crown condition assessment was carried out on the Scots pine and Norway spruce and birches intensive monitoring observation plots from 1995. Defoliation, foliage discolouration, and abiotic and biotic damage were assessed on twenty trees on each sub-plot. Depending on the design of the observation plot (see design of the observation plots in Chapter 1), the total number of sample trees per plot varied from 40 to 60. Principally, dead trees were replaced by new trees in the next years's assessment. Moreover, the number of assessed observation plots and trees varied during the monitoring period (see Chapter 1). The assessment of sample trees was carried out according to the ICP Forests manuals (see Eichhorn 2010, pdf). However, instead of whole crown assessment introduced in the ICP Forests manuals, the defoliation and discolouration of spruce were estimated on the upper half of the living crown, and of birch and pine on the upper two-thirds of the living crown in 5% of classes in the same way as in Level I in Finland. Since summer 2004 the new method for damage assessment was applied. In addition to the ICP Forests manual, national field guides were used in intensive monitoring. The Theil-Sen slope, a robust estimator for the magnitude of the linear trend (median of slopes between all data pairs) (Gilbert 1987) was calculated using an Excel macro by Grimwall (Swedish University of Agricultural Sciences).

[Return to the beginning of the article]

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. **www.luke.fi**

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Results: Crown condition » Discussion

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programmes

Results: crown condition

- Summary
- Extensive monitoring
- Intensive monitoring
- **Discussion**

Results: Intensive monitoring

Results: Related projects

Publication list of the Programme

About the report

Photo: Metla/Erkki Oksanen

[Return to the beginning of the article]

Discussion

The monitoring of forest condition has undergone significant changes in recent years in many countries, including Finland. The extensive level survey is now integrated in the NFI. This has the advantage of a more representative sample. On the other hand, the annual time series is lost. This is not so harmful for the time series of defoliation itself, because the variation between the years in defoliation has been found to be negligible compared to the between-plot and other sources of variation (Nevalainen et al. 2010). In the new system, annual records of biotic and abiotic damage, which may explain defoliation, cannot be obtained tree-wise annually, but can be computed for an area (as an example, see Fig. 9). Annual data can now only be obtained from the intensive monitoring plots, but their number has decreased due to restrictions in national funding.

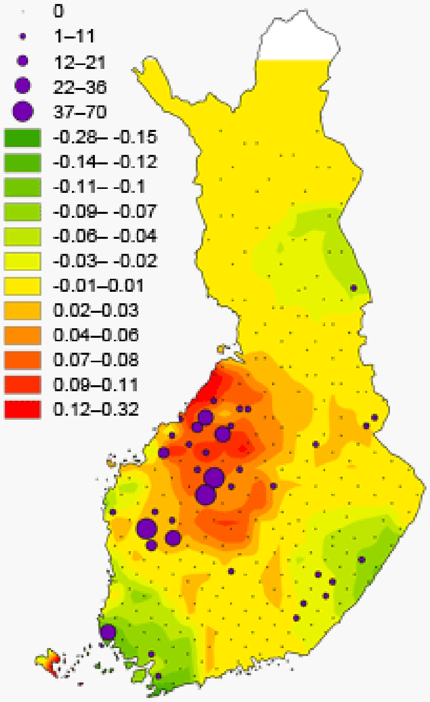


Figure 9. The occurrence of pine sawflies in 2010. The dots show the number of damaged trees per assessment tract. The raster shows the change in the occurrence between 2010 and 2009. Positive values (red) indicate an increase in the damage.

The defoliation method, regularly used to record forest health, has several disadvantages, despite its practicality. Leaf biomass of the crown is greatly affected by tree age, climatic and genetic factors, shading and many abiotic or biotic stresses. We have very little research information about the natural variation of leaf biomass (Westman and Lesinski 1986, Lesinski and Westman 1987, McKay 1988). Older stands are more defoliated than younger stands. In Finland, the mean age of the stand explains more than half of the between-plot variance in defoliation (Nevalainen et al. 2010).

In some country reports, the rapid deterioration in the vitality of forests has been attributed to abiotic or biotic damage (Hütte 1986, Keane et al. 1989, Roloff 1991, Innes and Schwyzer 1994). It has even been suggested that beyond some special pointer years, when growth conditions have been extremely poor, the results from forest health surveys merely reflect the effects of abiotic and biotic damage (Kandler 1989).

In Finland, a large number of natural factors, the most important of which are connected with stand age, climate, weather, and abiotic or biotic damage, affect forest condition (Jukola-Sulonen et al. 1990, Salemaa et al. 1991, Lindgren et al. 2000, Nevalainen & Heinonen 2000). In the northern parts of the country in particular, the harsh climate has a strong effect on forest development. At the beginning of the monitoring period, the increase in defoliation coincided with the extremely cold winter of 1987, and defoliation increased in all tree species between 1986 and 1989. Despite a slight increase in defoliation at the beginning of the study period, the abrupt changes in forest condition during the past 25 years are most often caused by abiotic and biotic stress factors. The intensity of the epidemics vary from year to year, and spatial patterns can change quite rapidly. An example of the local correlation analysis, discussed above (Nevalainen et al. 2010), demonstrated that biotic/abiotic damage can, at the regional level, be strongly correlated with the changes in defoliation. However, some local damage will not be revealed in our sparse monitoring network. These include storm damage and epidemics by bark beetles, especially *Ips*- species in spruce.

The relatively low proportion of severely defoliated conifers and the small number of dead trees, as well as the causes of tree death (primarily storms, snow and chronic decay fungi), suggest that no widespread forest decline was detected in our study in Finland.

The results concerning discolouration are somewhat problematic, because there has been some uncertainty in the international guidelines. Nowadays, some countries do record discolouration as a separate variable, while others record discolouration as a part of the damage symptom, to avoid double markings. The latter approach was adopted in Finland in 2010 in both Level I and Level II. The results from the two approaches do not appear to be comparable. In Central Europe the discolouration of spruce is often connected to the nutrient disturbances such as magnesium or potassium deficiency (Zöttl and Hüttl 1989). One should remember, however, that the visible symptoms are non-specific, and they often express interaction between several factors (Wulff et al. 1996, Aamlid 1997, Solberg and Tørseth 1997). In our crown condition surveys in Finland the extensive discolouration in many cases seems to be connected to very dry summers (e.g. 2006) and fungal diseases. A slight discolouration of older needles is very difficult to interpret due to its unspecific nature, and slight discolouration in spruce needle tips, for example is easily masked by fungal infections.

Our monitoring results seem to suggest that the main immediate threats to the health and condition of Finland’s forests are abiotic and biotic factors, such as storms, drought, insect pests and fungal pathogens. The interactions between stress factors and biotic damage can be very complex, however, and utmost care should be taken in interpreting the forest vitality results (Pearce 1994, Thomsen and Nellemann 1994). Oak decline in Central Europe is a good example of a disease with a complex etiology (Thomas et al. 2002). The stress approach by Manion (1991) is still very relevant. In Finnish conditions, tree age and unfavourable soil conditions (not forgetting the long-term effects of air pollution) can act as predisposing factors. Insect defoliation, infections by *Gremmeniella*, extreme drought, mechanical injury or frost damage may be the most common inciting factors, while bark beetles or root-decay fungi may act as contributing factors. The increasing defoliation trend in the southern parts of the country, suggested in this report, warrants an in-depth-study.

References

Aamlid, D. 1997. Gulfarget bar - en indikator på næringsmangel? - resultateter fra et delprosjekt I “Skogens helsetilstand” Aktuelt fra Skogforskningen 1: 12–17.

Eichhorn, J., Roskams, P., Ferretti, M., Mues, V., Szepesi, A.& Durrant, D., 2010: Visual Assessment of Crown Condition and Damaging Agents. 49 pp. Manual Part IV. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. UNECE ICP Forests Programme Co-ordinating Centre, Hamburg. ISBN: 978-3-926301-03-1. (manual)

Gilbert, Richard O. 1987. Sen's Nonparametric Estimator of Slope. Statistical Methods for Environmental Pollution Monitoring, John Wiley and Sons, pp. 217–219, ISBN 978-0-471-28878-7.

Hütte, P. 1986. Vom Waldsterben Berohte Wälder Polens. Allgemeine Forstzeitung 33: 818–822.

Innes, J.L. & Schwyzer, A. 1994. Stem damage in Swiss Forests: Incidence, causes and relations to crown transparency. European Journal of Forest Pathology 24: 20–31.

Jukola-Sulonen, E.-L., Mikkola, K. & Salemaa, M. 1990. The vitality of conifers in Finland, 1986-88. In: Kauppi, P., Anttila, P. & Kenttämies, K. (eds.). Acidification in Finland. Springer Verlag, Berlin.p. 523–560.

Kandler, O. 1989. Epidemiological evaluation of the course of "Waldsterben" from 1983 to 1987. In: Bucher, J.B. & Bucher-Wallin, I. (eds.). Air Pollution and Forest Decline: Proceedings of the 14th International Meeting for Specialists in Air Pollution Effects on Forest Ecosystems, International Union of Forest Rsearch Organizations, Project Group P2.05, held at Interlaken, Switzerland, 2–8 October, 1988. Eidgenössische Anstalt für das forstliche Versuchswesen (EAFV), Birmensdorf.p. 297–302.

Keane, M., McCarthy, R. & Hogan, J. 1989. Forest health surveys in Ireland: 1987 and 1988 results. Irish Forestry 46(1): 59–62.

Lesinski, J.A. & Westman, L. 1987. Crown injury types in Norway spruce and their applicability for forest inventory. In: Perry, R., Harrsion, R.M., Bell, J.N.B. & Lester, J.N. (eds.). Acid Rain: Scientific and Technical Advances. Selper.p. 647–662.

— 2002. Results of the 2001 national crown condition survey (ICP Forests/Level I). In: Rautjärvi, H., Ukonmaanaho, L. & Raitio, H. (eds.). Forest condition monitoring in Finland. National Report 2001. Metsäntutkimuslaitoksen tiedonantoja 879.p. 42–50.

Lindgren, M., Nevalainen, S. & Pouttu, A. 2007. Results of the national crown condition survey. In: Merilä, P., Kilponen, T. & Derome, J. (eds.). Forest condition monitoring in Finland - National report 2002-2005. Metlan työraportteja/Working Papers of the Finnish Forest Research Institute 45: 46–62.

Lindgren, M., Nevalainen, S., Pouttu, A., Rantanen, H. & Salemaa, M. 2005. Metsäpuiden elinvoimaisuuden arviointi. Maasto-ohje (Field Guide). Metsäntutkimuslaitos. 38 p.

Lindgren, M., Salemaa, M. & Tamminen, P. 2000. Forest condition in relation to environmental factors. In: Mälkönen, E. (ed.). Forest condition in a changing environment - the Finnish case. Forestry Sciences 65. Kluwer Academic Publishers.p. 142–155.

Manion, P.D. 1991. Tree disease concepts Prentice-Hall, Englewood Cliffs, N.J. 402 p. ISBN 0-13-929423-6.

McKay, H.M. 1988. Non-pollutant abiotic factors affecting needle loss. Scientific basis of forest decline symptomatology. Commission of the European Communities. Air Pollution Research Report 15. SEE CAPE: 31–38.

Nevalainen, S. 1999. Nationwide forest damage surveys in Finland. In: Forster, B., Knizek, M. & Grodzki, W. (eds.). Methodology of Forest Insect and Disease Survey in Central Europe.Second Workshop of the IUFRO Working Party 7.03.10. Swiss Federal Institute for Forest, Snow and Landscape Research, Sion-Chateauneuf, Switzerland.p. 24–29.

Nevalainen, S., Lindgren, M., Pouttu, A., Heinonen, J., Hongisto, M. & Neuvonen, S. 2010. Extensive tree health monitoring networks are useful in revealing the impacts of widespread biotic damage in boreal forests. Environmental Monitoring and Assessment 168(1): 159–171.

Pearce, F. 1994. Damage to Britains trees is not so natural after all. New Scientist 142(1930): 5.

Roloff, A. 1991. Crown structure and tree vitality. In: Longhurst, J.W.S. (ed.). Acid Deposition. Origins, Impacts and Abatement Strategies. Springer-Verlag.p. 193–213.

Salemaa, M., Jukola-Sulonen, E.-L. & Lindgren, M. 1991. Forest condition in Finland, 1986–1990. Silva Fennica 25(3): 147–175.

Solberg, S. & Tørseth, K. 1997. Crown condition of Norway Spruce in relation to sulphur and nitrogen deposition and soil properties in southeast Norway. Environmental Pollution 96(1): 19–27.

Thomas, F.M., Blank, R. & Hartmann, G. 2002. Abiotic and biotic factors and their interactions as causes of oak decline in Central Europe. Forest Pathology 32(4-5): 277–307.

Thomsen, M.G. & Nellemann, C. 1994. Isolation of natural factors affecting crown density and crown color in coniferous forest: implications for monitoring in forest decline. Ambio 23(4-5): 251–254.

Westman, L. & Lesinski, J. 1986. Kronutglesning och andra förändringar i grankronan. Morfologisk beskrivning. Naturvårdsverket Rapport 3632.

Wulff, A., Anttonen, S., Heller, W., Sandermann, H., Jr. & Kärenlampi, L. 1996. Ozone-sensitivity of Scots pine and Norway spruce from northern and local origin to long-term open-field fumigation in central Finland. Environmental and Experimental Botany 36(2): 209–227.

Zöttl, H.W. & Hüttl, R.F. 1989. Nutrient deficiencies and forest decline. In: Bucher, J.B. & Bucher-Wallin, I. (eds.).Air Pollution and Forest Decline.p. 189–193.

[Return to the beginning of the article]

Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Litterfall production and quality at Level II sites

By Liisa Ukonmaanaho

Summary

Litterfall production was monitored in eight Norway spruce, seven Scots pine and two birch stands between 1996–2007. The annual litterfall production varied considerably over the years and from one site to another. The mean annual litterfall sum of spruce stands ranged from 61 to 462 g m^{-2}, for pine stands from 79 to 359 g m^{-2} and for birch stands 146 to 346 g m^{-2}. Average foliar litter production varied from 60% to 78% of the total litterfall flux in the Norway spruce stands and from 32% to 6% in the Scots pine stands. In birch stands, the share of foliar litter was nearly 80% of the total litterfall. In addition to birch stands, the highest litterfall production was observed in Scots pine stands in the autumn, while in Norway spruce stands litterfall production was more evenly distributed throughout the year. The studied nutrient concentrations increased in the following order: birch > Norway spruce > Scots pine, the concentrations usually being higher in foliar than in miscellaneous fraction. The concentration of all other nutrients except Mn and Fe were higher in birch litter than in spruce and pine litter. A slight latitude-related trend was found in S and Mn concentrations; S concentration decreased the further north the stands were located, while Mn concentration showed a corresponding increase. For more information about previous results, see Ukonmaanaho et al. 2008.

Background

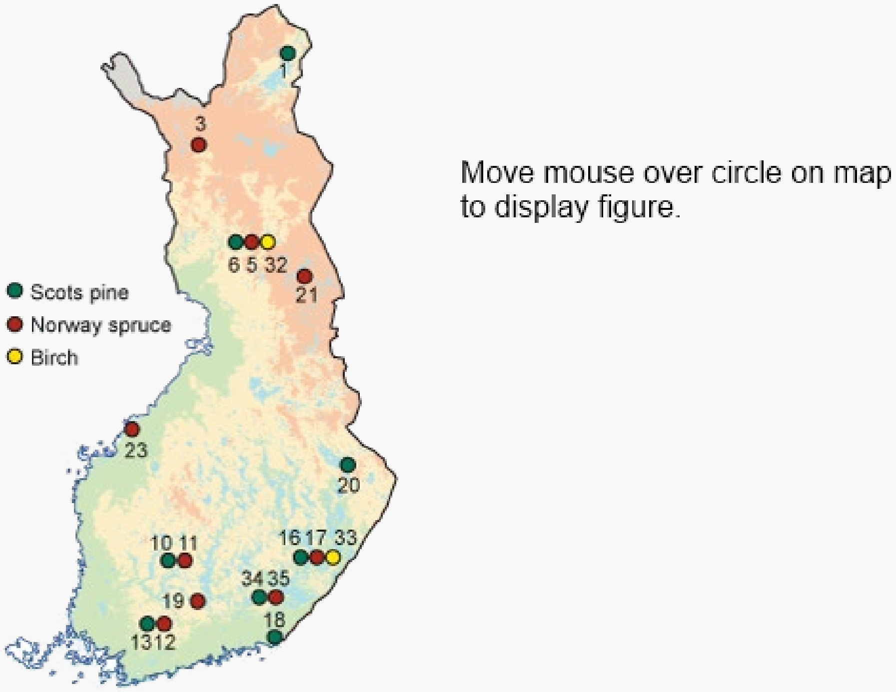
In forested ecosystems, litterfall is the largest source of organic material and nutrients in the soil humus layer. It represents a major pathway through which soils, depleted of nutrient uptake and leaching, are replenished. In addition, litterfall represents one of the primary links between producer and decomposer organisms. Therefore, litterfall has a key role in understanding the dynamics of nutrient cycling within the forest ecosystem.

Foliar litter is the major component of aboveground litterfall in boreal forest ecosystems. Litterfall production is found to be strongly correlated with site, stand and climate factors. Annual litterfall can vary considerably, and is related to weather conditions that differ from year to year. In addition, there is a variation between the seasons, e.g. deciduous trees shed most of their foliar biomass in the autumn. The element concentrations in foliar litter are affected by several factors such as tree species, soil properties, climatic factors and tree growth intensity. This report presents the results of litterfall production and quality on Level II sites between 1996 and 2007.

Results and discussion

Litterfall production

The annual litterfall production varied considerably over the years and between stands (Fig. 1, interactive map, below). The mean annual litterfall sum of spruce stands ranged from 61 to 462 g m^{-2}, whereas for pine stands it ranged from 79 to 359 g m^{-2} (Fig. 1, interactive map, below). In the birch stands, the average litterfall production at the northern site of Kivalo (nr. 32) was 146 g m^{-2} and at the southern site of Punkaharju (nr. 33) it was 346 g m^{-2}. The lowest litterfall production in both pine and spruce stands was in the northernmost sites, in the case of spruce at Kivalo (nr. 5) and Pallasjärvi (nr. 3), and at Kivalo (nr. 6) and Sevettijärvi (nr. 1) in pine sites. The general decrease from south to north in litterfall production was apparent, which is obviously related to the species-specific characteristics of these tree species, as well as climate and latitude. For example the height of trees is the lowest in the northern sites (Table 4 in Intensive and continous monitoring of...), indicating the impact of tree height in litterfall production. On average, litterfall production was at its greatest in spruce stands (274 g m^{-2}), at birch stands it was 245 g m^{-2}, and at pine stands 210 g m^{-2}. It can be estimated that roughly half of the litterfall mass is carbon, therefore within litterfall, there is an average carbon return to the forest floor of 137 g m^{-2} in spruce stands, 123 g m^{-2} in birch stands and 105 g m^{-2} in pine stands.



Move mouse over circle on map to display figure.

Figure 1. Location of the study sites. Please move mouse over circle on map to display figure.

The variation in foliar litter (needles and leaves) production was also considerable between the plots and years (Fig. 1). A similar decrease from south to north was observed in foliar litterfall production as with total litterfall production. The average foliar litterfall production varied from 60% (Oulanka nr. 21) to 78% (Pallasjärvi nr. 3) of the total litterfall flux in the Norway spruce stands and from 32% (Lieksa nr. 20) to 69% (Kivalo nr. 6) in the Scots pine stands. On average, there was a slightly greater foliar litterfall production in spruce stands (69%) than in pine stands (55%). It is known that in boreal coniferous forests, needle litter constitutes the main part of the litterfall flux on the forest floor. The rest of the litterfall (miscellaneous) was composed of reproductive structures of trees such as seeds, cones, flower parts and branches, bark and smaller amounts of dead insects and animal faeces. In birch stands, the share of foliar litter was nearly 80% of the total litterfall.

Birch has a clear seasonal pattern in litterfall production due to the abscission of leaves in the autumn (Fig. 2a), however, there was also a clear seasonal pattern in the litterfall production in Scots pine stands (Fig 2b). The highest litter production was observed during the autumn, which is connected with needle senescence. The oldest needle age-class of Scots pine are usually shed between August and October. Litter production was lowest during the winter and early summer. A similar seasonal pattern in Scots pine has been observed in many other previous studies (e.g. Viro 1955, Mälkönen 1974). Norway spruce litterfall production was more evenly distributed throughout the year than that of Scots pine, only a small peak was observed in early summer and autumn (Fig. 2c), which is typical for Norway spruce.

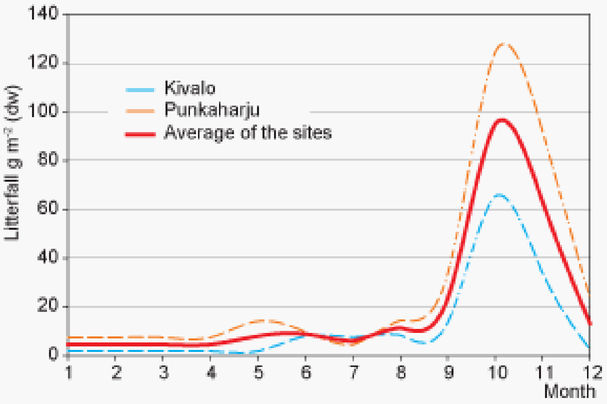


Figure 2a. Monthly litterfall sum during 2005–2007 at birch stands.

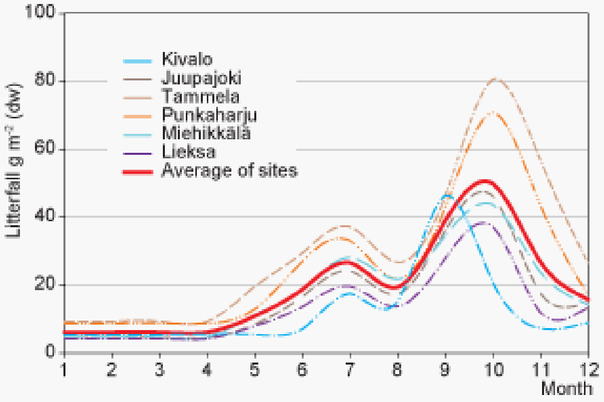


Figure 2b. Monthly litterfall sum during 1996–2007 at pine stands.

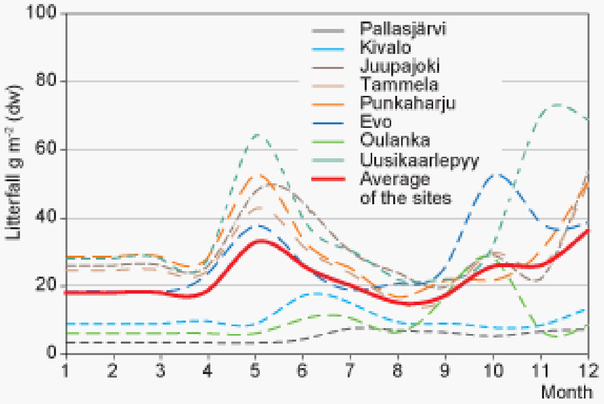


Figure 2c. Monthly litterfall sum during 1996–2007 at spruce stands.

Nutrient concentrations in litterfall

The mean nutrient concentrations in foliar and miscellaneous litter from Norway spruce, Scots pine and birch dominated stands are shown in Tables 1a and 1b. In general, the nutrient concentrations in the spruce litter tended to be higher than those in pine, which is consistent with earlier studies (e.g. Johansson 1984, 1995), but the highest concentrations were usually in birch litter. In fact, the concentrations of all other nutrients except Mn and Fe were higher in birch litter than in spruce and pine litter (Tables 1a and 1b). Nutrient concentrations varied between the fractions, the highest concentrations frequently occurring in the leaf fraction. Iron was the only nutrient with the highest concentration in the miscellaneous fraction in the birch, spruce and pine stands.

The difference in nutrient concentrations of Norway spruce, Scots pine and birch litter is due to many factors. It is generally agreed that tree species differ greatly in their ability to take up elements from the soil, but it is more obvious that other processes such as resorption, retranslocation and leaching together with the age of the needles and leaves greatly affect the chemical composition of litter. For example, spruce needles are normally older at the time of abscission than pine needles, and thus more immobile nutrients such as Ca and Mn are accumulated in senescent tissues over the years. On the other hand, high concentrations in birch leaves might be due to the fact that the resorption of nutrients into woody organs before leaf abscission is greater in coniferous trees than in hardwoods.

Slight latitude-related trends were found in the nutrient concentrations of the two most abundant fractions (needles, leaves and miscellaneous). The most obvious trend was for the Mn and S concentrations in both the spruce and pine stands. The Mn concentration increased the further north the stand was located, while the S concentration showed a corresponding decrease. The northwards-decreasing S trend in the needle and miscellaneous litter fractions followed the general S deposition trend reported in Finland (e.g. Lindroos et al. 2006). If litterfall in a birch stand is ignored, the highest nutrient concentration in litterfall frequently occurred on the Uusikaarlepyy plot (nr. 23). This plot is located on acid sulphate soil and receives an input of $MgSO_4$ from the sea (Gulf of Bothnia) and, in addition, there is a fur farm near the plot. Therefore, the tree canopy on the plot is also exposed to ammonia (NH_3) emissions from the fur farm. All these factors undoubtedly contribute to the relatively high S, N and Mg concentrations in litterfall on the Uusikaarlepyy plot.

Material and methods

Figure 3. The top of the funnel-shaped trapsstood at a height of 1.5 m above the forest floor.

The study was carried out in eight Norway spruce (*Picea abies* L. Karst.), seven Scots pine (*Pinus sylvestris* L.) and two birch (*Betula* sp.) stands between 1996 and 2007; at some of the stands sampling started later than 1996. Litterfall was collected using twelve traps located systematically on a 10 x 10 m grid on one plot (30 x 30 m) in each stand. The top of the funnel-shaped traps, with a collecting area of 0.5 m^2, stood at a height of 1.5 m above the forest floor (Fig. 3). The litterfall was collected in a replaceable cotton bag attached to the bottom of the litterfall trap. Litterfall was sampled bi-weekly during the snow-free period (May to November, depending of the latitude of the plot), and once at the end of winter. After collection, all the litter samples were air-dried and sorted into at least four fractions: Scots pine needles, Norway spruce needles, birch leaves and the remaining material (=miscellaneous). The mass of each fraction was weighed and chemical analyses were performed on the most abundant fractions. Litterfall production (dry mass per unit area) was calculated by dividing the total and needle litterfall masses by surface area of the traps.

Chemical analyses

Litterfall samples were dried at a temperature of 60ºC. The dried samples were milled and wet digested using microwave-assisted digestion in a mixture of $HNO_3 + H_2O_2$. The concentrations of Ca, K, Mg, Mn, P, S, Fe and Zn were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES). The total N concentration was determined with a CHN analyser (LECO).

References

Johansson, M.B. 1984. Litter decomposition rate at burned and clear-felled areas compared to closed stands. Dept. of Forest Soils, Sweden. Univ. Agric. Sci. Uppsala. Reports in Forest Ecology and Forest Soils 49, 35 p.

Johansson, M.B. 1995. The chemical composition of needle and leaf litter from Scots pine, Norway spruce and white birch in Scandinavian forests. Forestry 68 (1): 49–63.

Lindroos, A.-J., Derome, J., Derome, K. & Lindgren, M. 2006. Trends in sulphate deposition on the forests and forest floor and defoliation degree in 16 intensively studied forest stands in Finland during 1996–2003. Boreal Env. Res. 11(6): 451–461.

Mälkönen, E. 1974. Annual primary production and nutrient cycle in some Scots pine stands. Commun. Inst. For. Fenn (Metsäntutkimuslaitoksen julkaisuja). 84(5): 1–87.

Ukonmaanaho, L., Merilä, P., Nöjd, P. & Nieminen, T.M. 2008. Litterfall production and nutrient return to the forest floor in Scots pine and Norway spruce stands in Finland. Boreal Environment Research 13 (suppl.B): 67–91. (pdf)

Viro, P.J. 1956. Investigations on forest litter. Comm. Inst. For. Fenn. 45.6, 65 p.

Citation: Ukonmaanaho, L. (2013). Litterfall production and quality at Level II sites . In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report].
Available at http://urn.fi/URN:NBN:fi:metla-201305087574. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Metla

Understorey vegetation on Level II plots during 1998–2009

By Maija Salemaa, Leena Hamberg, Nijole Kalinauskaite, Leila Korpela, Antti-Jussi Lindroos, Pekka Nöjd & Tiina Tonteri

Summary

Understorey vegetation survey on the Finnish ICP Forests Level II plots has been undertaken in 1998, 2003 and 2009. Here we present an overview of the third inventory (21 plots in the year 2009) and an analysis of the 11 years' change of vegetation (17 common plots during 1998–2009). The structure and composition of vegetation indicated well the site fertility and location on south-north climatic gradient in an ordination analysis (Non-metric Multidimensional Scaling, NMDS) in 2009. Especially the number of herb species showed a high correlation with site fertility. One vulnerable liverwort species (*Anastrophyllum cavifolium*), mentioned in the Red List of Finnish Species, was found on the northernmost plot (nr. 22, Kevo) in 2009.

In general, species turnover was very low during the 11 years. Two opposite forces - natural succession and silvicultural thinnings - explained majority of the observed changes in the understorey vegetation. Changes in the tree layer may have many effects on the understorey vegetation through root competition, canopy shading, litterfall and modifying the chemical composition of precipitation. However, the effect of nitrogen deposition on vegetation could not be separated from the effect of amount of precipitation in this study.

Background

Understorey vegetation considerably contributes to ecosystem properties and biodiversity of boreal forests. It plays an important role in biomass production, nutrient cycling and in forming the organic soil layer. By regulating the temperature and moisture level of soil, the understorey vegetation mediates the carbon storage in boreal soils. Changes in plant communities have a great indicative value in the monitoring of forest

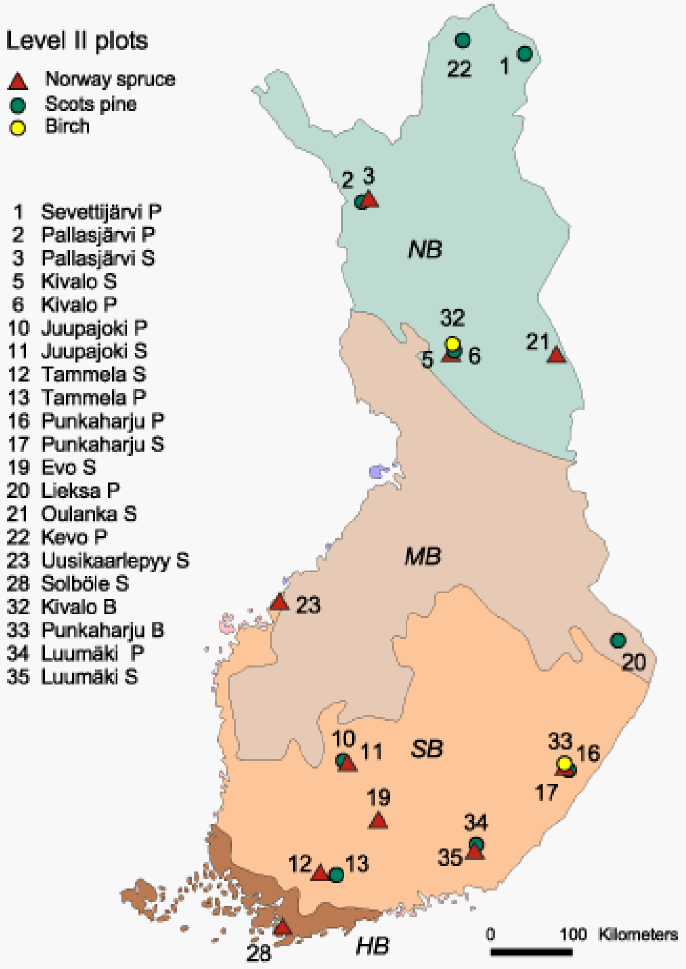


Figure 1. The location of the Level II plots in 2009 and the distribution of the vegation zones in Finland. HB = hemi-boreal, SB = southern boreal, MB = middle boreal, NB = northern boreal. P = Scots pine plot and S = Norway spruce plot.

ecosystems. Long-term series on the occurrence and abundance of plant species offer a possibility to relate the observed changes in vegetation e.g. to shifts in climate or anthropogenically derived factors.

Understorey vegetation survey on the ICP Forests Level II plots (Fig. 1) has been undertaken in 1998, 2003 and 2009. The two birch plots have been studied in 2004/2005 and 2009. The mean percentage cover of the species groups, decaying wood and needle/leaf litter on the ground is given in Table 1 (pdf). We present an overview of the third inventory (21 plots in the year 2009) and an analysis of the 11 years' change of vegetation (17 common plots during 1998–2009). In addition, we compare the changes in the cover of plant species between silviculturally unthinned and thinned plots.

Understorey vegetation serves as an indicator of site fertility

The vegetation data of 21 level II plots (year 2009) were ordinated by global non-metric multidimensional scaling (NMDS) in order to find the main ecological gradients in the vegetation (Vegan package in R software, Oksanen 2004). Plot and species scores of NMDS are displayed in two separate diagrams (Figs. 2a, b, pdf), and we examine them together when interpreting the ordination.

Two-dimensional ordination of the sample plots

The plots were ordered very well according to the Finnish forest types in the two-dimensional projection (Fig. 2a, pdf). The vegetation gradient was differentiated by the overstorey tree species: the more fertile, moist sites dominated by spruce or birch were located on the right, and the nutrient-poor, drier pine plots on the left in the ordination space. There was one birch plot representing herb-rich forests (*Oxalis-Maianthemum* type, Punkaharju nr. 33), and it was located in the utmost right. It was followed by herb-rich heath forests (*Oxalis-Myrtillus* type) and mesic heath forests (*Myrtillus* type in the south, *Hylocomium-Myrtillus* type in the north). Towards the left, there were sub-xeric heath forests (*Vaccinium* type, *Empetrum-Vaccinium* type and *Empetrum-Myrtillus* type from south to north) and xeric heath forests (*Calluna* type in the south, *Uliginosum-Vaccinium-Empetrum* type in the north). Within each site type, the northern plots were located slightly to the left of the southern ones, indicating lower fertility and cooler climate.

Arrangement of the species

The arrangement of the species scores corresponded to the site fertility level and the stand succession stage. For vascular plants, the focus in demanding herbs (e.g. *Oxalis acetosella*) and grasses (e.g. *Milium effusum*) was on the right, in generalist species (e.g. *Vaccinium myrtillus*) in the centre, and in the least demanding species adapted to nutrient-poor, acidic substrates (e.g. *Empetrum nigrum*) on the left in the two-dimensional projection (Fig. 2b, pdf). The demanding bryophyte species (e.g. *Cirriphyllum piliferum*) on the right were replaced by generalist bryophytes in the centre (e.g. *Pleurozium schreberi* and *Dicranum polysetum*), and by drought-tolerant lichens (e.g. *Cladina arbuscula*) on the left in the species ordination (Fig. 2b, pdf). The abundance of moisture-demanding liverworts (e.g. *Lophozia* spp.) increased towards the northern old stands, which can provide suitable humidity and coarse woody debris for their growing substrates (Fig. 2b, pdf).

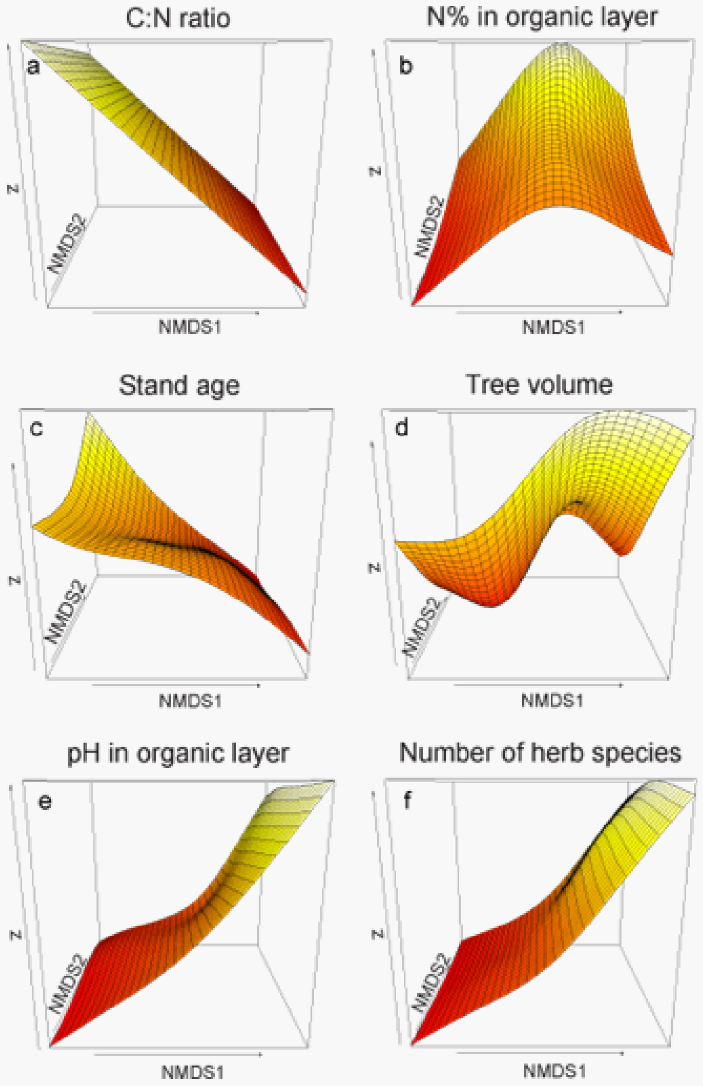


Figure 3. Non-linear surfaces (GAM) of a) C:N ratio of the organic layer, b) N% of the organic layer, c) stand age (years), d) stand volume (m^3/ha), e) pH of the organic layer and f) number of herb species in two dimensional NMDS ordination (see Fig. 2a). The surfaces depict the smooth trends between the environmental variables and plot scores. z = predicted values of the model.

The number of vascular plant species varied from 7 to 44 in southern and from 6 to 20 in northern plots. The number of bryophyte and lichen species increased with latitude on the pine plots, whereas no south-north trend was found on the spruce plots. Liverworts were most abundant in the north. One vulnerable liverwort species (*Anastrophyllum cavifolium*), included in the Red List of Finnish Species (Rassi et al. 2010), was found in the northernmost plot (nr. 22, Kevo) in 2009.

Explanatory variables

In general, the plot ordination was strongly related to the C/N ratio, N % and pH in the organic layer as well as to stand age and volume (Figs. 3a-e) when smooth surfaces were fitted to ordination space using generalized additive models (GAM). The surface pattern for C/N ratio was closely linear with high values on xeric northern plots and low values on southern herb-rich and mesic plots (Figs. 2a pdf, 3a). On the other hand, the surfaces for pH and number of herb species faced to the opposite direction (Figs. 3e, f). Stand age increased almost linearly towards the northern plots in the upper left part of the ordination space, but the surfaces depicting tree volume and N % in the organic layer had maximum values in south (Fig. 3b–d). The number of herb species well depicted the general fertility level of the sites and it showed the highest correlation of the studied explanatory variables with the ordination pattern ($r = 0.900$, $p > 0.001$). In an earlier analysis of the vegetation-stand relationships on Level II plots it was found that the number of herb species was also a good indicator of site index (h 100) (Salemaa et al. 2008).

Silvicultural thinnings explain the change in understorey vegetation

Vegetation change during 1998–2009 (n = 17 plots)

In general, species turnover was very low during the 11 years, but abundance relationships between the species changed in some plots (Table 1, pdf). The cover of dwarf shrubs and tree seedlings increased on the plots where no silvicultural thinnings were carried out (n = 12), especially in South Finland (Fig. 4a, pdf). Simultaneously the abundance ratio between the bryophyte species changed so that shade-tolerant *Hylocomium splendens* increased and more shade-sensitive *Dicranum* spp. decreased (Fig. 4b, pdf). On the other hand, the cover of herbs and grasses increased on the thinned plots (n = 6) with increasing light level, wheareas they decreased on the unthinned plots (Fig 4c, pdf). Also *Vaccinium myrtillus* increased after thinning of the stand (Fig. 4a, pdf), but the cover of lichens decreased (Fig. 4d, pdf).

Two opposite forces – natural succession and silvicultural thinnings - explained the majority of the observed changes in the understorey vegetation. This can also be seen in the ordination solution in which the two surveys (years 1998 and 2009) of 17 Level II plots were analysed together (Fig. 5). Excluding the two most northern plots (Sevettijärvi nr.1 and Kevo nr. 22) the change in the plant communities followed the direction of an increase in stand volume. On the other hand, on the thinned plots the change in the vegetation went to the opposite direction, towards the younger succession phase.

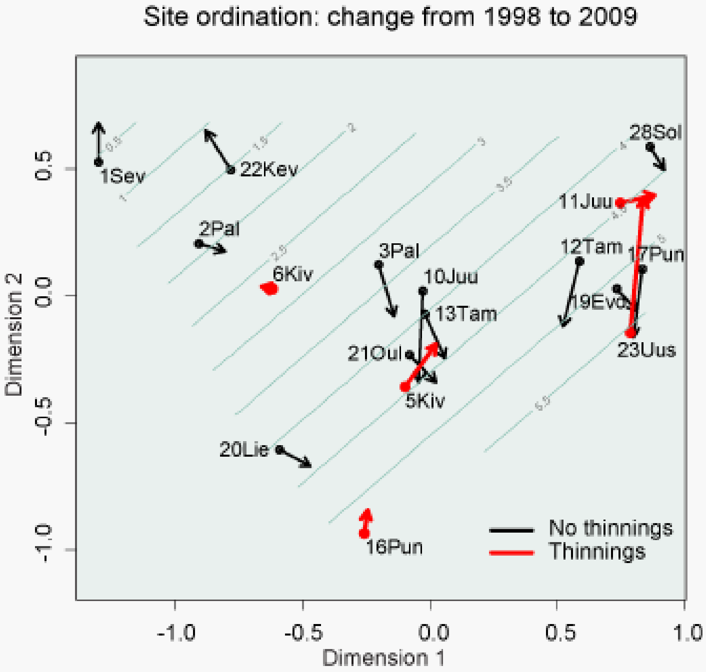


Figure. 5. The NMDS ordination of the same 17 Level II sample plots in 1998 and 2009 (12 unmanaged plots black, 5 thinned plots red). The temporal change of the plots depicted by arrows (1998 base and 2009 point of the arrow). Stand volume is fitted by non-linear GAM surface (lines) to the ordination space.

Probably the tree layer regulates in many ways the dynamics of the understorey vegetation through root competition, canopy shading, leaf/litterfall and throughfall precipitation. In addition, annual variation in temperature and precipitation affected the cover of plant species. Deposition is dependent on the amount of precipitation, and in this data it was not possible to separate the effect of moisture from the effect of nitrogen input on plant occurrence.

Methods

One of the three sub-plots in a monitoring site was selected for vegetation monitoring. The size of the sub-plot is 30 x 30 m. Altogether 16 sample quadrats, each 2 m^2 (1.41 x 1.41 m) in area, were marked out systematically (4 x 4 design) on the sub-plot. The location of the quadrat was moved only in cases where there was an exceptional surface (e.g. path or large stone) occupying more than 20% of the area. In addition, four 10 x 10 m quadrats (A–D) were marked out to give four 100 m^2 areas (Fig. 6). These areas provide vegetation data representing the Common Sample Area (= 400 m^2), which is used in all countries participating in the ICP Forests monitoring programme.

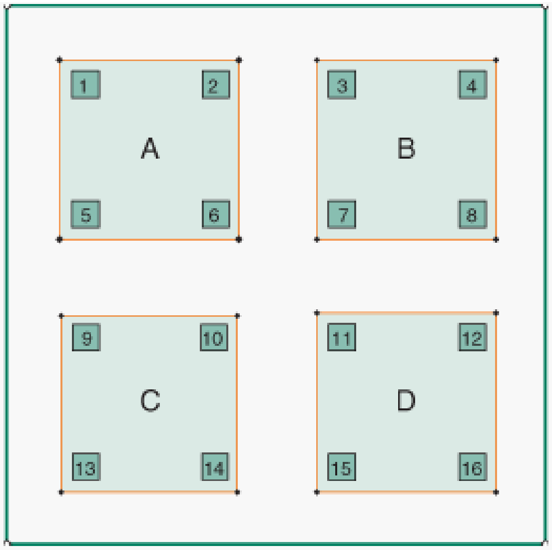


Figure. 6. The plot (30 x 30 m = 900 m^2) used for the inventory of understorey vegetation. Percetage cover (%) of plant species was assessed on the small sample quadrats (16 x 2 m^2). The larger quadrats (A–D) were 10 x 10 m =100 m^2 in area. The additional plant species growing outside the small quadrats were recorded within areas of 4 x 100 m^2 (A–D) forming the so called Common Sample Area (CSA).

Estimation of plant percentage cover

The vegetation inventory was carried out during July - August. The percentage cover (%) of the individual plant species was assessed visually using the following scale: 0.01 (solitary or very sparsely growing shoots), 0.1, 0.2, 0.5, 1, 2, …99, 100 %. The bottom layer (mosses, liverworts and lichens), the field layer (height < 50 cm vascular plants: herbs, grasses, sedges, dwarf shrubs and tree seedlings) and the shrub layer (height 50–150 cm) were analysed. Plants growing on stones, stumps or fallen stems were excluded. The cover of needle and leaf litter, dead plant material, dead branches, fallen tree stems, stumps, bare soil and stones was also assessed. Additional species, i.e. species occurring on the monitoring area (400 m^2 and 900 m^2) but not on the sample quadrats, were recorded. Four to two botanists inventoried the vegetation simultaneously on the same plots. Field tests were carried out to check the assessment level, and to calibrate it when necessary.

A 2 m^2 frame divided into 100 small quadrats by a net of elastic strings was used in the assessment of the plant cover. "An open corner frame" without a net was placed on sites where a tree, shrubs or high vegetation are growing. The cover of withered early summer species (e.g. *Anemone nemoralis*) was assessed according to their expected maximum biomass. The height of the field and shrub layers was measured at 10 points in different parts of the monitoring sub-plot. Samples of unknown plant species (mainly bryophytes and lichens) were later identified on the basis of microscopic characteristics.

Organic layer samples were collected and analysed as described in Lindroos et al. in this publication.

References

Lindroos, A.-J., Derome, K., Nieminen, T.M., Tamminen, P. & Ilvesniemi, H. 2012. Soil condition monitoring on Level II plots – parameters related to acidity and buffering status.

Oksanen J. 2004. 'Vegan' Community Ecology Package: ordination methods and other functions for community and vegetation ecologists. University of Oulu, Oulu, FI. Available at: http://cc.oulu.fi/~jarioksa/softhelp/vegan.html

Rassi, P., Hyvärinen, E., Juslén, A. & Mannerkoski, I. (eds.). 2010. Suomen lajien uhanalaisuus – Punainen kirja 2010. The 2010 Red List of Finnish Species. Edita Ltd. Helsinki. 685 p.

Salemaa, M., Derome, J. & Nöjd, P. 2008. Response of boreal forest vegetation to the fertility status of the organic layer along a climatic gradient. Boreal Environment Research 13(suppl.B): 48–66.

Citation: Salemaa, M., Hamberg, L., Kalinauskaite, N., Korpela, L., Lindroos, A-J., Nöjd, P. and Tonteri, T. (2013). Understorey vegetation on Level II plots during 1998–2009. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087575. [Cited 2013-05-07].

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. www.luke.fi

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Results: Intensive monitoring » Deposition

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents
Monitoring programmes
Results: Crown condition
Results: intensive monitoring
  Foliar chemistry
  Litterfall
  Understorey vegetation
  Deposition
  Soil percolation water
  Soil
  Phenology
  Girth bands
  Canopy cover
  Quality assurance
Results: Related projects
Publication list of the Programme
About the report

Photo: Metla/Erkki Oksanen

Sulphur and nitrogen deposition in bulk deposition and stand throughfall on intensive monitoring plots in Finland

By Antti-Jussi Lindroos, Kirsti Derome & Tiina M. Nieminen

Summary

The sulphur (S) and nitrogen (N) deposition in the open area (bulk deposition) and in stand throughfall on eight Norway spruce and eight Scots pine Level II plots during 1996–2010 are presented in this report. In addition, these results for four more recently established plots are presented (two birch plots in 2006–2010, and a pine and a spruce plot in 2009-2010). Mean SO_4-S deposition in throughfall, as well as NH_4-N and NO_3-N in bulk deposition were clearly higher in southern than in northern Finland during 1996–2010. Sulphur deposition has decreased during the monitoring period; especially during the first years of monitoring and in southern Finland. In general, there was no corresponding decrease in the deposition of inorganic nitrogen compounds.

Background

Sulphur and nitrogen deposition on the forests and forest floor have been considered to be one of the most important parameters in the assessment of forest condition in relation to different stress factors. S and N compounds in the atmosphere and deposition may affect forests in several ways, including direct effects on vegetation or via soil acidification and eutrophication. An important question to be answered by using the deposition data is also how strong reductions in the S emissions are reflected in the condition and biogeochemistry of forest ecosystems, and are the similar kind of reductions needed also for N emissions. Deposition and availability of nitrogen in the forest ecosystems are also linked to carbon cycling and therefore, they are of interest in climate change studies. For example, the S and N deposition results are used in the evaluations of soil and soil solution acidification and buffering status. The effect of acidifying S and N deposition on the soil solution acidification status has earlier been evaluated for the period 2001–2004 by Derome et al. (2007).

Results and discussion

The annual S and N deposition values were in general higher in the southern part of Finland than in the north (Figs. 1–6). Stand throughfall deposition (TF) was generally higher than bulk deposition in the open area (BD) for SO_4-S indicating wash-off of dry deposition. The BD values for NH_4-N and NO_3-N were generally higher than those in TF indicating retention of inorganic N compounds already in the tree canopies. On the Uusikaarlepyy plot (nr. 23), located on the west coast of Finland, local NH_3 emissions were reflected in deposition: the TF values for NH_4-N and NO_3-N were in many cases relatively high compared to the values in BD.

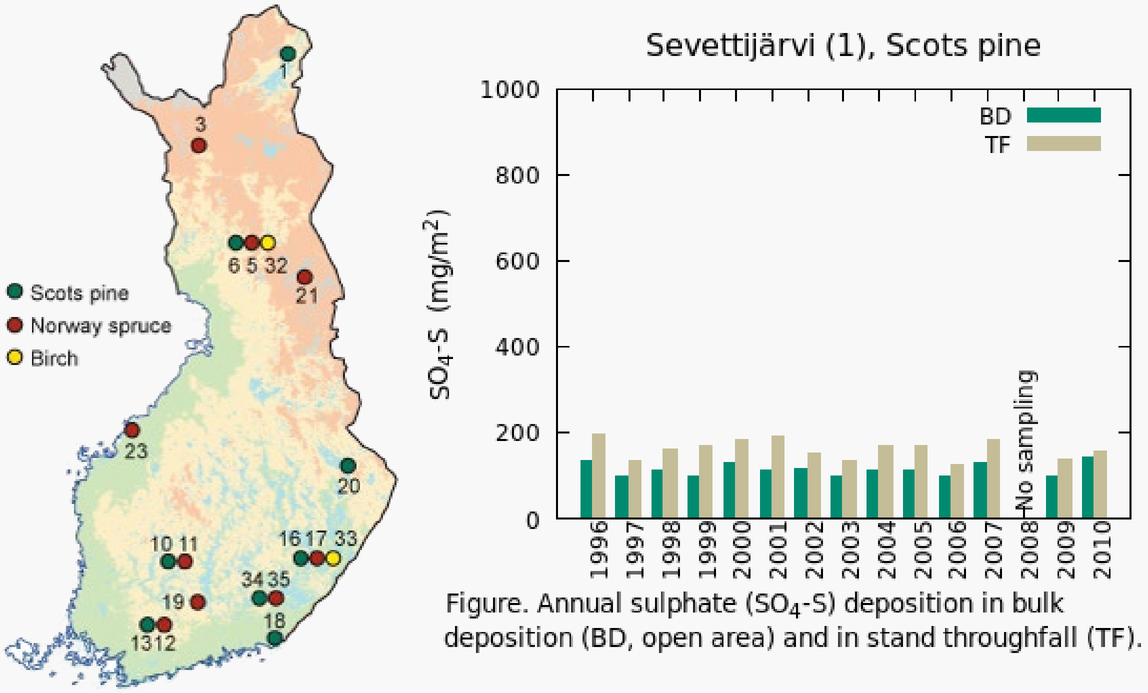


Figure. Annual sulphate (SO_4-S) deposition in bulk deposition (BD, open area) and in stand throughfall (TF).

Figure 7. Please click the plot location on the map (left) and choose the variable to be shown in the graph (right).

The lowest annual SO_4-S deposition load in the open (BD) was recorded on the Oulanka (nr. 21) and Pallasjärvi (nr. 3) plots in northern Finland, 72 mg m^{-2} in 2009, and the highest load on the Miehikkälä plot (nr. 18) in southern Finland, 519 mg m^{-2} in 1996. The lowest SO_4-S deposition in TF was recorded on the birch plot at Kivalo (nr. 32, North Finland), 73 mg m^{-2} in 2009, and the highest value on the spruce plot in Tammela (nr. 12, South Finland), 956 mg m^{-2} in 1996. The lowest NH_4-N deposition in BD occurred at Kivalo (North Finland), 17 mg m^{-2} in 1997, while the corresponding highest deposition load was recorded at Miehikkälä (nr. 18, South Finland), 229 mg m^{-2} in 1996. The lowest NO_3-N deposition in BD occurred at Sevettijärvi (nr. 1, North Finland), 32 mg m^{-2} in 2002 and 2009, while the corresponding highest deposition load was recorded at Tammela (nrs. 12 and 13; South Finland), 290 mg m^{-2} in 2008 (Fig. 7, interactive map, above). Sulphur deposition in BD and TF were the highest during the first years of the monitoring (monitoring started in 1996), and this was especially the case on the plots in southern Finland (Lindroos et al. 2006). This decrease is in accordance with the results for the whole European monitoring network (The Condition of...2005). On the other hand, there was no corresponding decrease in the deposition of NH_4-N and NO_3-N.

Material and methods

Since 1996–1999, deposition on the forests (bulk deposition in the open area, BD) and on the forest floor (stand throughfall, TF) have been monitored on the intensive monitoring plots, including eight Norway spruce and eight Scots pine stands. In addition, two new Silver birch plots (nrs. 32 and 33) were established in 2005 and one pine (nr. 34) and one spruce plot (nr. 35) in 2009. The BD and TF samples were collected in general at 4-week intervals during the winter, and at 2-week intervals during the snow-free period. However, in some of the years, the sample collection was performed at 4-week intervals throughout the year.

There were 20 systematically located bulk deposition collectors (ø = 20 cm, h = 0.4 m) within the stand (TF) during the snow-free period, and 6–10 snow collectors (ø = 36 cm, h = 1.8 m) during the wintertime depending on the structure of the stand. The number of snow collectors in each stand was based on a pre-study using 20 snow collectors located systematically on each plot. From this 20-collector network, 6–10 collectors were selected for sampling such that the mean deposition value was approximately the same as the result obtained with the 20 collectors. The number of collectors in the open area was three (bulk deposition) and two (snow collectors). The samples were pretreated and analysed according to the sub-manual of the ICP Forests Programme (Manual on methods... 2006).

References

Derome, J., Lindroos, A-J. & Derome, K. 2007. Soil percolation water quality during 2001–2004 on 11 Level II plots. Working Papers of the Finnish Forest Research Institute 45: 93–98. (htm)

Lindroos, A-J., Derome, J., Derome, K. & Lindgren, M. 2006. Trends in sulphate deposition on the forests and forest floor and defoliation degree in 16 intensively studied forest stands in Finland during 1996–2003. Boreal Environment Research 11(6): 451–461. (pdf)

Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. 2006. Part VI. Sampling and analysis of deposition. 78 p. UN-ECE. Programme coordination centre, Hamburg. (manual)

The Condition of Forests in Europe. 2005. Executive Report. United Nations Economic Commission for Europe. Federal Research Centre for Forestry and Forest Products (BFH). 33 p.

Citation: Lindroos, A-J., Derome, K. and Nieminen, T. M. (2013). Sulphur and nitrogen deposition in bulk deposition and stand throughfall on intensive monitoring plots in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087576. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Soil percolation water quality during 1996–2010 on Level II plots in Finland

By Tiina M. Nieminen, Kirsti Derome & Antti-Jussi Lindroos

Summary

The slightly decreasing temporal trend in pH values of soil percolation water found in most plots is caused by natural soil acidification taking place in time with tree stand ageing. No general trend corresponding to the observed decrease in SO_4-S deposition could be seen in soil percolation water SO_4-S concentrations, except on pine plots in Sevettijärvi (nr. 1), Kivalo (nr. 6) and Tammela (nr. 13). The NH_4-N and NO_3-N concentrations were generally very low, with the exception of spruce plots in Tammela (nr. 12), Punkaharju (nr. 17) and Uusikaarlepyy (nr. 23), where NH_4-N was relatively high, and in Juupajoki. (nr. 11), Uusikaarlepyy (nr. 23) and Punkaharju (birch, nr. 33), where NO_3-N concentrations were elevated. On Juupajoki plot the NO_3-N concentrations started to increase after stand thinning carried out in 2006. The high NH_4- and NO_3-N concentrations on plot nr. 23 are most probably due to the local emission caused by nearby fur farming. Uusikaarlepyy plot is located on an acid sulphate soil with low pH and high SO_4-S concentrations in soil water.

Percolation water collectors were located under the soil organic layer ca. five centimetres below the soil surface at Level II plots located in Norway spruce, Scots pine and two birch stands. Samples have been collected during the snow free periods at 4-week-intervals and analyzed for pH, NH_4-N, NO_3-N, and SO_4-S. Mean annual values were calculated as an average of all the measurements of the year in question.

Background

Soil solution is the matrix mediating between the solid soil and the tree roots, since roots access nutrients, as well as toxic compounds, in the soil through the soil solution. The chemical composition of percolation water sampled with zero-tension lysimeters provides also information on the passage of ions and compounds down the soil profile. Therefore, soil solution chemistry is a valuable indicator of soil-mediated effects of stress factors on both forests and the surrounding water ecosystems. The chemical composition of the soil solution is governed by a range of biogeochemical processes that comprise the input of atmospheric deposition into the soil, chemical interactions between the soil solid and liquid phases and the soil gas phase, and soil biological processes.

This report presents the results of monitoring carried out on percolation water quality during 1996–2010 on Level II plots located in Norway spruce, Scots pine and two birch stands.

Results and discussion

No dramatic changes or strong trends can be observed in pH values of percolation water during the monitoring period (Fig. 1, interactive map, below). However, a weak decreasing trend is found on most of the plots. This decrease is related to natural acidification taking place in time with tree stand ageing. The NH_4-N and NO_3-N concentrations were generally very low, which is in agreement with the relatively low N deposition in Finland. The only exceptions were plots nr. 12 and 17 (Tammela and Punkaharju spruce plots), where NH_4- was relatively high, and plots nr. 11 (Juupajoki spruce) and nr. 33 (Punkaharju birch), where NO_3-N concentrations were elevated. On plot nr. 11 the NO_3-N concentrations apparently increased after thinning carried out on site in 2006. In addition, the NH_4- and NO_3-N concentrations on plot nr. 23 (Uusikaarlepyy spruce) were exceptionally high, most probably due to the local emission caused by near by fur farm, which was also reflected as elevated NH_4- and NO_3-N deposition in throughfall (Lindroos et al. 2012).

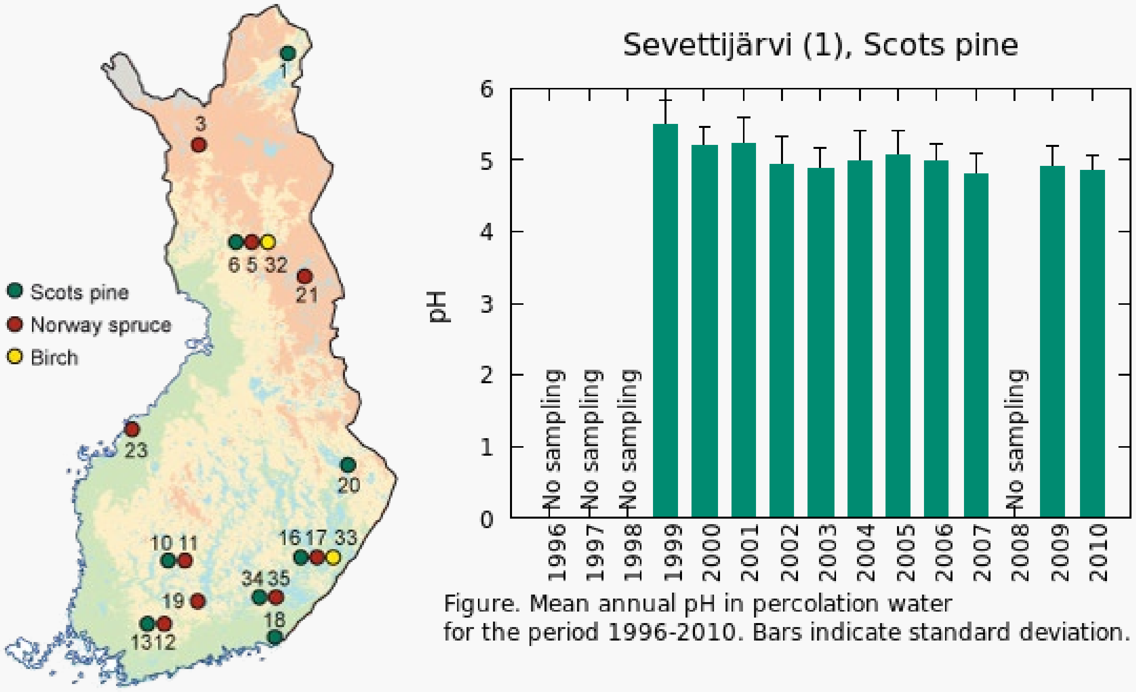


Figure. Mean annual pH in percolation water for the period 1996-2010. Bars indicate standard deviation.

Figure 1. Please click the plot location on the map (left) and choose the variable to be shown in the graph (right).

Plot nr. 23 in Uusikaarlepyy is located on an acid sulphate soil, which explains the extremely high SO_4-S concentrations measured at the site. The observed decrease in SO_4-S deposition during the monitoring period (Lindroos et al. 2012) could not be seen as a corresponding decrease in percolation water SO_4-S concentrations. However, there was a decreasing trend in SO_4-S concentrations at three pine plots, Sevettijärvi, Kivalo and Tammela (nrs. 1, 6 and 13, respectively). Average values of the annual means were calculated for the eight plots with the longest monitoring periods (Table 1). The NH_4-N and NO_3-N concentrations, as well as the SO_4-S concentrations, were lowest at the northernmost Kivalo sites, but no other systematic differences between the locations or tree species can be observed.

Material and methods

Percolation water collectors were located under the soil organic layer ca. 5 centimetres below the soil surface. Samples have been collected during the snow free periods at 4-week-intervals and analyzed for pH, NH_4-N, NO_3-N, and SO_4-S. Mean annual values were calculated as an average of all the measurements of the year in question.

The sample collection and analysis methods are described in the sub-manual of the ICP Forests Programme (Manual on methods... 2010/11).

References

Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests. 2010/11. Part XI: Soil solution collection and analysis. ICP Forests, Hamburg. 30 p. Available at: www.icp-forests.org/manual.htm.

Citation: Nieminen, T. M., Derome, K. and Lindroos, A-J. (2013). Soil percolation water quality during 1996–2010 on Level II plots in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087577. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Kuva: Metla/Erkki Oksanen

Soil condition monitoring on Level II plots – parameters related to acidity and buffering status

By Antti-Jussi Lindroos, Kirsti Derome, Tiina M. Nieminen, Pekka Tamminen & Hannu Ilvesniemi

Summary

S deposition has decreased clearly during the monitoring period, but the acidifying deposition (S and N compounds) is still higher in southern than in northern Finland. At the same time, there is a strong climatic gradient from hemiboreal zone to northen boreal zone affecting many processes in the forest soils. Therefore it is difficult to make a difference between the effects of acid deposition and climatic factors on soil acidity status on the Level II plots in Finland. Base saturation of the topsoil has decreased during the monitoring period on many plots. According to pH values, the plot which is strongly acidified is located on acid sulphate soil. The lowest acidity of the organic and uppermost mineral soil layer as well as the highest base saturation was measured on the birch plot in southern Finland.

Background

Soil properties of the intensive monitoring plots (Level II) have been determined twice since the starting of the monitoring activities in Finland. The first round was associated with the establishment Level II monitoring network during 1995-1998. There have been slight changes in the monitoring network during the study years, so that the last Level II plots were established in 2006 (2 birch plots) and in 2009 (1 pine and 1 spruce plot). The second round of the soil condition monitoring took place for most of the plots as a part of the BIOSOIL project (see Tamminen et al., Level I in this publication).

The aim of this report is to present results of soil condition monitoring related to the acidity and buffering status of forest soil. The results are part of the BIOSOIL project for most of the plots. For 2 plots, the results are part of the EU Life+ project FutMon. The BIOSOIL data were collected in 2006 and FutMon data 2009.

Open figures in a new window →

Results and discussion

Birch plots

The pH of the organic layer (humus) and upper part of the mineral soil was higher on the Punkaharju plot in eastern Finland compared to the Kivalo plot in northern Finland (Fig. 1). The pH values were the highest on the Punkaharju birch plot in the whole Level II plot network, i.e. also compared to the values on all the spruce and pine plots (see below).

Cation exchange capacity (CEC, Fig. 2) and base saturation (BS, Fig. 3) were higher on all the soil layers in Punkaharju than in Kivalo. BS was also generally higher on the Punkaharju birch plot compared to the spruce and pine plots (see below).

The concentration of exchangeable Al was higher in the organic layer in Kivalo than in Punkaharju but vice versa in the mineral soil layers (Fig. 4).

Pine plots

The clearest differences in the soil pH values of the pine plots were found in the deeper layers (Fig. 5). The pH values were the lowest in the soil layers 10–20 and 20–40 cm on the plots in southern Finland. The CEC values varied between the plots (Fig. 6), but the lowest BS values (Fig. 7) were also detected on two southernmost plots, Miehikkälä and Luumäki. The highest exchangeable Al concentrations in the organic and uppermost mineral soil layer were observed on the Juupajoki plot (Fig. 8).

Spruce plots

The pH values of the deeper soil layers 10–20 and 20–40 cm were higher on the plots in northern Finland (Pallas, Kivalo, Oulanka) compared to the other spruce plots in central and southern Finland (Fig. 9). The lowest pH values were measured on the Uusikaarlepyy plot throughout the soil profile reflecting the fact that this spruce stand is located on an acid sulphate soil (see also Nieminen et al., Soil percolation water quality in this publication). Variation in CEC and BS values among the plots is presented in Figs. 10 and 11. BS values in 2006 (Fig. 11) in the organic layer and upper mineral soil have decreased on most of the spruce plots since the establishment of the plots in 1995–1998 (Derome et al. 2001). The exchangeable Al concentrations were lower on the spruce plots located in northern Finland (Pallas, Kivalo, Oulanka) compared to the other spruce plots in central and southern Finland (Fig. 12).

Material and methods

Soil samples were taken from the Level II plots in 2006 as a part of the BIOSOIL project. In addition, the samples were taken from 2 plots in 2009 as a part of the establishment of these plots. The soil types and texture are presented in Table 1 (pdf). Samples were taken from the organic layer and from the mineral soil layers 0–5, 5–10, 10–20 and 20–40 cm. Three composite soil samples were taken from each plot. pH was measured in distilled water, and exchangeable cations were determined using BaCl 2 extraction followed by determination of elemental concentrations with inductively coupled plasma atomic emission spectrophotometer (ICP/AES). Exchangeable acidity (EA) was determined by titration of the extract with NaOH to pH 7.8. Cation exchange capacity (CEC) was calculated as a sum of exchangeable base cations (Ca, Mg, K, Na) and EA. Base saturation (BS) was calculated as a proportion (%) of exchangeable base cations out of CEC (Cools & De Vos 2010).

References

Cools, N. & De Vos, B. 2010. Sampling and analysis of soil. Manual Part X, 208 pp. In: Manual on methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, UNECE, ICP Forests, Hamburg.

Derome, J., Lindroos, A-J., Lindgren, M. 2001. Soil acidity parameters and defoliation degree in six Norway spruce stands in Finland. Water, Air, and Soil Pollution: Focus 1: 169–186.

Citation: Lindroos, A-J., Derome, K., Nieminen, T.M., Tamminen, P. and Ilvesniemi, H. (2013). Soil condition monitoring on Level II plots – parameters related to acidity and buffering status. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087578. [Cited 2013-05-07].

: Updated: 10.05.2013 /SJor | Photo: Erkki Oksanen, Metla, unless otherwise stated | Copyright Metla | Feedback

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. www.luke.fi

Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Phenology

By Egbert Beuker

Summary

Environmental changes such as climate change may cause changes in phenology. This may affect forest growth, as well the risk for biotic or abiotic damages. For this reason phenology is part of the ICP Forests Level II program since 1998. The results so far show for Finland clear geographic North – South trends in the timing of phenological events, but due to the large annual variation no trends of changes over time could be assessed yet. For this longer time series are needed.

Background

Phenological events are mainly driven climatically (temperature and precipitation), but also by other environmental parameters such as seasonal changes in day length and soil conditions. Changes in the timing of life events (phenology), such as bud burst, flowering, leaf coloring or leaf fall, may be caused by changes in climate or other environmental impacts such as air pollution.

Changes in the timing of phenological events may result in a change in the length of the growing season, and thus also in changes in forest growth. On the other hand, it may also increase the risk for abiotical damage, such as late night frost during spring, but also for biotical damage, as the synchrony in phenology between the host on one side and the pest or disease on the other side is disturbed.

Phenology was added to the ICP Forests Level II program in 1998, as an optional parameter. In Finland phenology observations were started in 1999 at two Norway spruce plots in Solböle (nr. 28) and Kivalo (nr. 5), and in 2000 two Norway spruce plots were added in Pallasjärvi (nr. 3) and Punkaharju (nr. 17). Phenology observations on Scots pine plots started in 2003 in Punkaharju (nr. 16) and later (2006) in Kivalo (nr. 6) and Juupajoki (nr. 10).

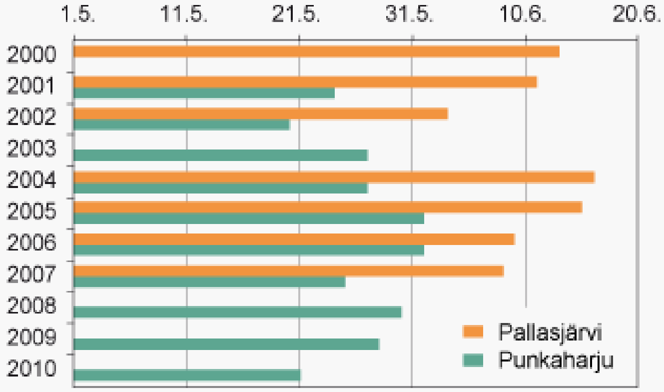


Figure 1. Dates of start of budburst on two Norway spruce Level II plots, Punkaharju and Pallasjärvi.

Results

The timing of budburst in spring is determined mainly by the temperature. Because of this, it is expected that especially in the boreal areas, including Finland, climate warming will result in an advanced flushing of trees during spring. However, the weather conditions vary much between years resulting in a considerable natural annual variation in timing of phenological events as shown in Figures 1, 2 and 3.

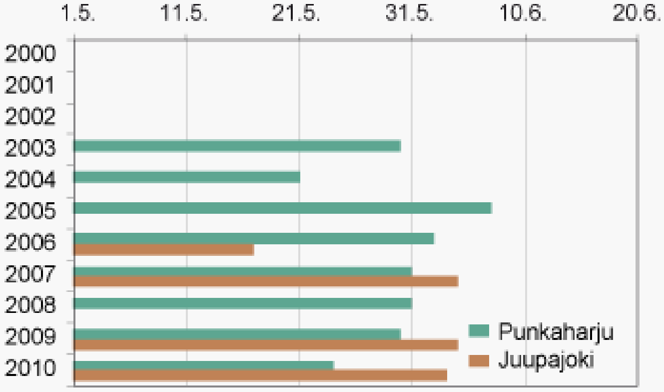


Figure 2. Dates of start of budburst on two Scots pine Level II plots, Punkaharju and Juupajoki.

The bars in the figures give the average start date for a number of observed individual trees. Because of this large annual variation, trends of changes in timing are difficult to assess. This would need longer series of observations than available now.

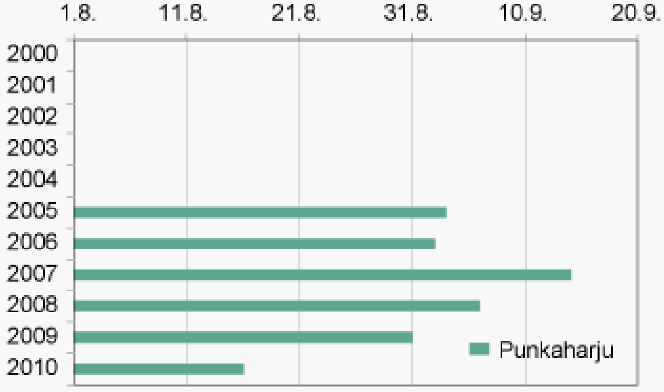


Figure 3. Dates of start of leaf coloring on a silver birch Level II plot in Punkaharju.

The end of the growing season has not been assessed in ever green conifers, because there are no easy to observe events. In broadleaved species, such as birch in Finland the end of the growing season is characterized by leaf coloring and leaf fall (Fig. 3).

Trees growing in the northernmost regions of Finland are adapted to a colder climate than those growing in the south. Although they often flush at lower temperatures than those in the south, they still flush later in time that the southern trees. This is shown in Fig. 1 where the start of flushing is compared between two Norway spruce plots in Pallasjärvi (nr. 3, North) and Punkaharju (nr. 17, South).

Difference in the timing of flushing between two plots at about the same latitude is usually smaller as can be seen in Fig. 2 in which the flushing of two Scots pine plots (Punkaharju and Juupajoki) in Southern Finland is compared. However, due to variation in local weather conditions also here larger differences may occur like in the year 2006.

Material and Methods

In a number of Level II plots 10 trees of which the crown could be seen from below were selected for phenology assessments. During the critical periods the phenological phases of the trees were observed three times a week in spring (budburst and flowering) and autumn (leaf coloring and leaf fall in birch). Table 1 shows the scoring system.

Score	Description
1	Less than 1% of the buds/leaves affected
2	Between 1% and 33% of the buds/leaves affected
3	Between 33% and 66% of the buds/leaves affected
4	Between 66% and 99% of the buds/leaves affected
5	More than 99% of the buds/leaves affected

Table 1. The scoring system.

References

Beuker E., Raspe S., Bastrup-Birk A. & Preuhsler T, 2010. Phenological Observations. In: ICP Forests, 2010. manual on the methods and criteria for harmonized sampling, assessment, monitoring and analyses of the effect of air pollution on forests. UNECE, ICP Forests, Hamburg. ISBN 978-3-926301-03-1. pp. 15.

Noormets A. (Ed.), 2009. Phenology of Ecosystem Processes. Springer. ISBN 978-0-4419-0025-8. pp. 275.

Schwartz M.D. (Ed.), 2003. Phenology: An Integrative Environmental Science. Kluwer Academic Publishers. ISBN 1-4020-1580-1. pp. 592.

Citation: Beuker, E. (2013). Phenology. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087579. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Maija Salemaa

The monitoring of daily and annual growth and other changes in spruce, pine, and birch stem diameters with girth bands in Finland, 2009–2011

By Pentti Niemistö

Summary

Monitoring of daily and annual changes in tree diameters in Finland was performed via automatic and manual girth bands on plots belonging to the European FutMon network. The aim of this study was to date and rate the growth of spruce, pine, and birch. Another aspect of the research was identification of the real growth signals from the girth-band data, including also impacts of temperature, weather conditions, and diurnal rhythm.

The diameter increment of Scots pines and Norway spruces increased year after year in 2009–2011 because of the warm growing season in 2010 and extraordinarily warm one in 2011. In contrast, the diameter increment rate of silver birch in south-eastern Finland decreased over the same time.

On a rainy day, stem diameter suddenly increases as the water content of the stem grows but may decrease again as the water content then falls. These reversible changes in the stem diameter of Norway spruce were as great as 0.5 mm. In silver birch, the reversible changes are smaller than those seen with conifers. In addition, the freezing of stems during winter can be observed as an abrupt decrease in stem diameter. Diurnal rhythm during the growing season was visible in diameter expansion in the evening and at night, with corresponding shrinkage in the morning and daytime.

The manual girth bands produced overestimation in cold weather and underestimation in warm conditions, because of thermal expansion of their plastic material. If temperatures are recorded during the measurement, corrections can be made when results from manual girth bands are used.

Background

Temperatures are the main determinant of the start of the tree growth season in the spring, whereas the end of growth is regulated by the increasing length of nights in late summer. Height growth ceases first, followed by stem diameter growth. Roots continue to grow late into the autumn.

Southern Finland belongs to the southern boreal vegetation zone, while the northernmost part of Finland represents the much colder northern boreal zone. In southern Finland, the diameter increment of common tree species normally starts in May whereas in northernmost Finland it begins in June and usually ceases in August. Outside this period, no diameter increment is normally observed in the harsh climate of Finland.

The measured increase – and occasional decrease – of stem diameter includes both the formation of new cells and changes in the water potential of the stem wood and bark. The effects of rainy periods can be observed as sudden and strong increases in stem diameter. During growing season these increases are partly reversible. A daily pattern of daytime shrinkage and night-time expansion can also be observed, especially during the growing season. In addition, the freezing and melting of stems during winter can be observed as abrupt changes of stem diameter.

The aim of this study was to rate and date the growth and other changes in stem diameter from a daily and an annual perspective in the varying climate conditions of Finland. Another aspect was to compare and test both manual and automatic girth bands for monitoring short and long-term stem diameter changes of the most common trees species in northern Europe. From a longer-term perspective, the results can provide evidence on climate change and may predict the adaptation and growth potential of different tree species in changing conditions.

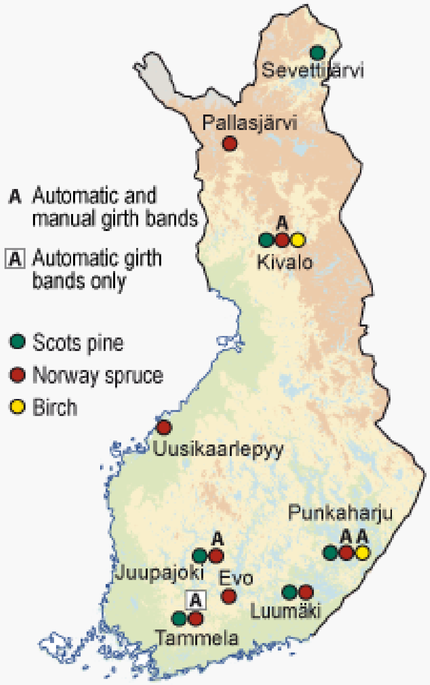


Figure 1. The location of plots with automatic and manual girth bands.

Results

Diameter growth seasons of Norway spruce and silver birch according automatic girth bands

It has been found that birch stem diameter growth begins as soon as the leaves have clearly grown past the budding stage (Niemistö & Beuker 2011). In 2009 and 2010, silver birch began to flower as early as around 1 May in southern Finland, and leaf buds began to open soon after. The automatic girth bands (see Fig 1) were installed in silver birch stands on 25 May 2009, so it was obviously too late to observe the beginning of diameter growth in spring 2009. Later on, the starting dates of diameter increments were 15 May 2010 and 11 May 2011. Every year birch diameter growth ceased between 13 and 15 August (Fig. 2a).

In spruce stands in southern Finland, the girth bands were also possibly installed too late in 2009 at Juupajoki and Punkaharju, but in Tammela, diameter growth started on 19 May 2009. In 2010, spruce diameter growth began on 23 May and in 2011 as early as between 12 and 17 May. In 2009, the spruce diameter growth ceased between 17 and 19 August and in 2010 and 2011 on 10 August in southern Finland (Figs. 2b, 2c and 2d).

In Lapland, spruce diameter growth started between 9 and 15 June but ended as early as 9 July in 2009, but in 2010 and 2011 this occurred a month later (Fig. 2e).

Daytime shrinkage and night-time expansion

Day and night rhythm during the growing season was observed as diameter expansion in the evening and night-time and shrinkage in the morning and daytime. It seems to be most intensive in June and July: expansion in spruces from 7 p.m. to 7 a.m. (Fig. 3a) and in Silver birches from 5 p.m. to 5 a.m. (Fig. 3b). In large spruces at Punkaharju (dbh 30–40 cm), the fluctuation between diameters in the afternoon and the early morning was 0.2 mm on average and 0.3

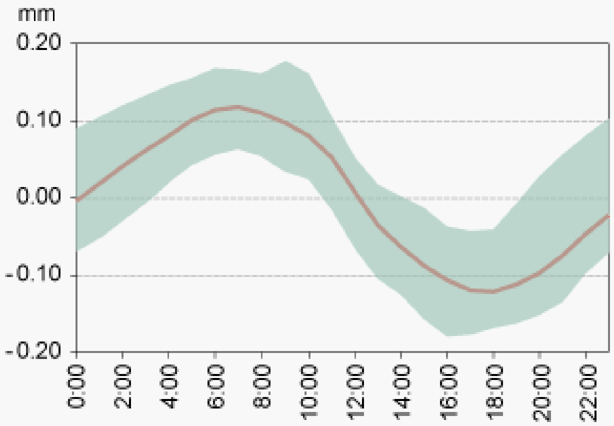


Figure 3a. Day and night rythm of Norway spruce diameter in July 2011: expansion during evening and night, shrinkage during morning and day (the range is shadowed).

mm maximum. In smaller birch stems (dbh 12–16 cm) the difference was smaller, 0.15 mm on average and 0.25 mm maximum.

The shrinkage in the morning and daytime is lower than the expansion, depending on the diameter increment rate during a growing season. The average daily increment in spruce stands was 0.04–0.06 mm during June and July. Therefore, the daily shrinkage is about 70–80% of the expansion that occurred in the previous evening and night. The average daily increment in birch stands was higher, 0.075–0.11 mm and the daytime shrinkage is about 30–50% of the night-time expansion.

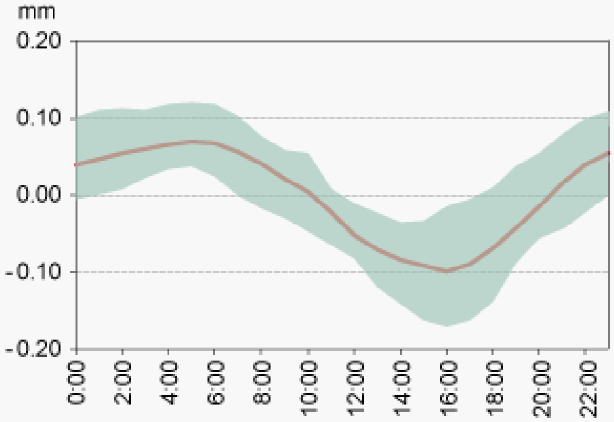


Figure 3b. Day and night rythm of silver birch diameter in July 2011: expansion during evening and night, shrinkage during morning and day (the range is shadowed).

Comparison between automatic and manual girth bands

It was possible to compare the measurements carried out by both types of girth bands, automatic and manual, on the same trees in Punkaharju. On five spruces, the automatic girth bands were installed 3–7 cm above the manual ones. Therefore, the actual difference in growth and other changes of the stem diameter is very low. The mean breast height diameter of spruces was 35 cm and the mean of circumference 110 cm in spring 2009.

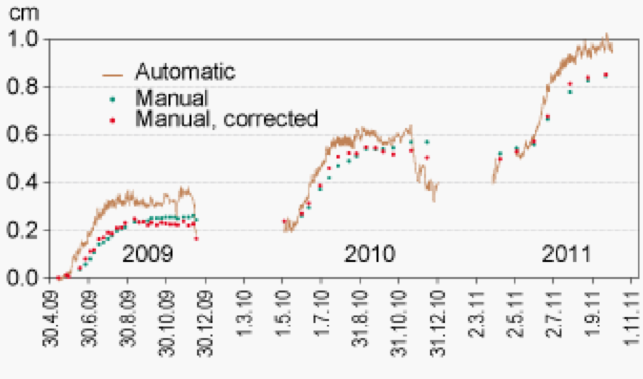


Figure 4. Growth and other changes in diameter of spruces at Punkaharju from spring 2009 to autumn 2011 measured by automatic and manual girth bands.

The first hand comparison between the girth band types demonstrated that the diameter increment was slower during the growing season measured by manual bands than by automatic ones (Fig. 4). However, in autumn and especially in cold weather the shrinkage in diameter was small or unobserved by manual girth bands. One explanation is the thermal expansion of the girth band material. The circumference strip of the automatic girth band is made of invar metal with a thermal expansion coefficient of $1.7*10^{-6}$. In practice, this means that thermal elongation is zero. The manual girth bands are made of a plastic material with a coefficient of $75*10^{-6}$, 44-fold compared with invar. This is why the measurement carried out by the manual girth band is an overestimation in cold weather and an underestimation in warm conditions. The elongation of 30 cm in diameter is

1.35 mm for the usual temperature range in Finland of –30 °C to +30 °C .

In addition to thermal expansion, there may be other differences between the manual and automatic methods (differences in selecting the place around a stem, bark moisture under the band strip, etc.). However, thanks to the correction of thermal expansion (datum level = +15 °C) the measurements by manual and automatic girth bands were closer (Fig. 4). This correction will be carried out when using the results of manual girth bands. The correction of day and night fluctuation is not needed because the observation time is nearly the same from one observation date to another. However, the observation time was registered and the temperature was defined through it.

The same comparison in Silver birch stands brought equal results, but the differences were not so clear because of smaller trees.

Diameter increment during growing seasons 2009–2011 according manual girth bands

In growing season, 2009 temperatures and rainfalls were close to their long term means in Finland. However the temperature sum was circa 100 dd. above the average and the rainfall was weighted on the beginning of season in the north and on the end of season in the south. Instead, growing season 2010 in southern Finland was very warm (250 dd. above the average) and the summer 2011 was record-breaking in the temperature sum (1600–1800 dd., 350 dd. above the average) and in the duration of effective growing season. In northern Finland temperature sum was equal in 2009 and 2010, but exceptional high in 2011 (>1000 dd., 250 dd. above the average).

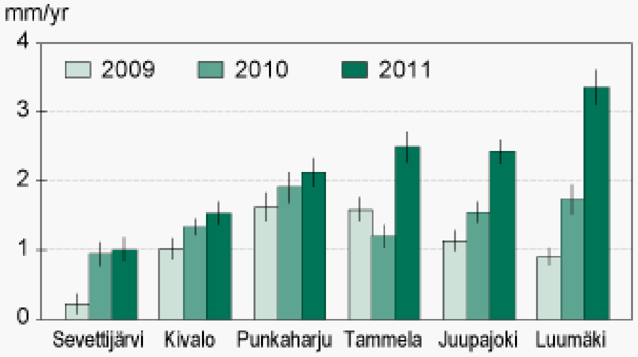


Figure 5a. Diameter growth (mean and standard error of mean, mm) of Scots pine in 2009−2011 according the manual girth bands.

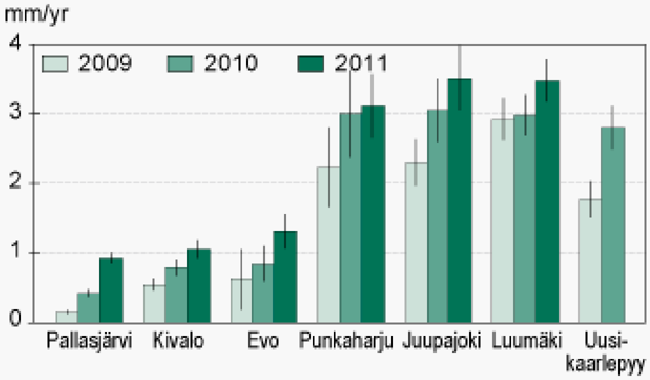


Figure 5b. Diameter growth (mean and standard error of mean, mm) of Norway spruce in 2009−2011 according the manual girth bands.

The diameter increment of Scots pines and Norway spruces in every plot increased year by year in period 2009–2011 (Fig. 5 a-b). In southern Finland, the growing season 2011 can be considered advantageous because of high temperatures and abundant rainfall (50% above the long term average).

In addition, the health and condition of trees was good after previous warm summer. That is why the increment of trees in 2011 could be near to their maximum growth rate in Finland. In 2009 and 2010, the diameter increment rate was 44% and 54% for Scots pine and 71% and 86% for Norway spruce respectively compared to the year 2011. In northern Finland, the trend was equal but the differences between years were larger for spruces than for pines.

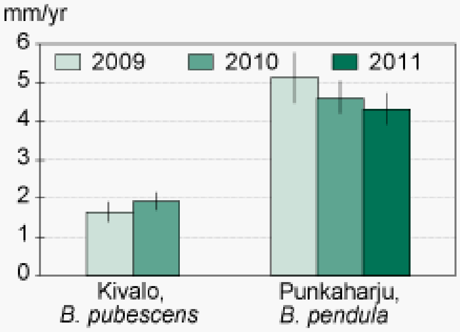


Figure 5c. Diameter growth (mean and standard error of mean, mm) of birch in 2009−2011 according the manual girth bands.

The growth rate of downy birch follows the same trend with pine and spruce, but unfortunately, the monitoring was cancelled in 2011. Instead, the diameter increment rate of silver birch in Punkaharju decreased 16% in the same period 2009–2011 (Fig. 5 c).

Material and methods

Manual girth bands (UMS D1) and automatic girth bands (UMS D6) were installed in May 2009 on the plots belonging to the European FutMon network (Table 1, pdf, fig 1). One experienced person carried out careful installation at the height of 1.3 m. The results of monitoring are now usable up to October 2011.

Table 1 (pdf) presents the basic characteristics for each stand. Note the rather advanced tree ages, which reflect the cold climate of Finland, resulting in long rotation periods. The climatic difference between northern and southern Finland is reflected by the growth difference between the southernmost plots in Tammela (mean temperature sum 1350 dd) and the northernmost plots in Pallasjärvi (700 dd) and Sevettijärvi (600 dd). Norway spruces in Punkaharju have reached a mean diameter of 35 cm in 75 years, while the mean diameter of Scots pines in Sevettijärvi is only 23 cm at the age of 205 years.

Automatic girth bands

Intensive monitoring with automatic data recording once per hour by UMS D6 girth bands was carried out in four Norway spruce stands and in one Silver birch stand, including five sample trees in each (total 25, fig 1, Table 2, pdf). The accuracy of measurement of the stem circumference was 0.01 mm. The intensive monitoring continued in some cases throughout the entire winter, but usually there was a blackout in midwinter because of empty batteries.

Manual girth bands

More extensive manual monitoring by UMS D1 girth bands was carried out in five Norway spruce stands, five Scots pine stands, in one silver birch stand and in one downy birch stand. Manual observations of 190 trees (mostly 15/stand) were taken mainly in two-week periods during the growing season. Outside the growing seasons, the measurements were carried out once per month, but not regularly during hard winters in northernmost stands. The accuracy of measurement of the stem diameter was 0.1 mm. In Punkaharju, both types of girth bands were installed on the same trees, on five spruces and five silver birches, in order to compare these two methods.

Citation: Niemistö, P. (2013). The monitoring of daily and annual growth and other changes in spruce, pine, and birch stem diameters with girth bands in Finland, 2009–2011. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report.
The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087580. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programmes

Results: Crown condition

Results: intensive monitoring

- Foliar chemistry
- Litterfall
- Understorey vegetation
- Deposition
- Soil percolation water
- Soil
- Phenology
- Girth bands
- **Canopy cover**
- Quality assurance

Results: Related projects

Publication list of the Programme

About the report

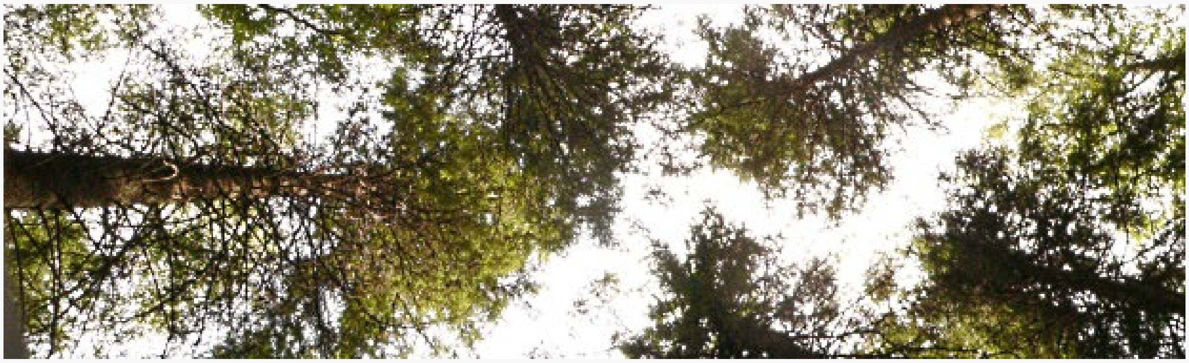


Photo: Liisa Ukonmaanaho

Estimation of canopy cover using planar photography method

By Liisa Ukonmaanaho & Jaakko Heikkinen

Summary

Estimation of forest canopy cover is an important part of forest inventories. We determined canopy cover in 18 Level II plots in August 2010 using digital camera and image analyses technique. Traditional canopy cover varied on Scots pine plots between 32 to 79%, on Norway spruce 30 and 91% and on birch plots 70 to 91%. The effective canopy cover% was less than traditional canopy cover %. In northermost plots the canopy cover was generally less than in southern plots.

Background

Forest canopy cover is an important ecological indicator, that can be used for example to characterize forest microclimate and light environment or to recognize habitants suited for several plant and animal species (e.g. Jennigs et al. 1999, Korhonen & Heikkinen 2009). Canopy cover is also an important ancillary variable in the estimation of leaf area index (LAI) using empirical or physically based vegetation reflectance models (Jasinski 1990, Kuusk and Nilson 2000). In addition, the international definition of a forest is based on canopy cover: at 0.5 ha area potential canopy cover should be at least 10% and potential tree height at least five meters (FAO 2000).

Canopy cover is defined as the proportion of the forest floor covered by the vertical projection of the tree crowns. However, it has been discussed, whether the gaps inside tree crowns should be counted as canopy or not. The traditional definition of canopy cover includes canopy gaps in the cover measurement (=traditional canopy cover). In contrast the term effective canopy cover comprises only the leaves, branches and stems and not the empty spaces between them.

An estimate of the canopy cover can be obtained using e.g. field measurements, statistical models, remotely sensed information or laser scanner data. However, field measurement are the only way to define the true vertical projection of a canopy. Best known field method is the Cajanus tube (Sarvas 1953). However, nowadays canopy cover can be determined reliable and conveniently using digital camera and image analyses techniques.

Results and discussion

The traditional canopy cover was an average 59% on Scots pine stands, 71% on Norway spruce stands and 81% on birch stands (Table 1, pdf). The effective canopy cover was on average 40%, 59% and 63% correspondingly. The traditional canopy cover was on average 30% higher than effective canopy cover in Scots pine, and correspondingly 17% higher in Norway spruce and 22% higher in birch stands. The difference is due to structure of the tree species, obviously in pine stands there are more open gaps between branches and needles compared to spruce and birch stands. The lowest canopy cover % was on the northenmost plots, which are old growth forest with lowest stem volume (Intensive and continuous monitoring...Table 4, pdf).

Material and methods

Photographing

The study was carried out in nine Norway spruce plots, seven Scots pine and two birch plots in August 2010 (Fig 1). Planar photographs were taken using standard digital camera. Digital cameras have considerably higher spatial resolution than traditional AOV (angle of view) instruments (densitometer, moosehorn) and therefore they are suitable for canopy cover measurements. The photos were taken in total 32 points from one of the subplots in each stand. Sixteen of the points were above litterfall collectors which have arranged in a systematic grid (10 x 10 m), other 16 points located in a systematical grid (10 x 10) starting from the south-east corner of the plot, both network covered the subplot area. Average of both network values were used to calculate traditional and effective canopy cover %. The images were taken pointing the camera in a near-vertical, skyward direction at breast height (1.5 m), clear sky in the middlepoint of the photo. It was possible to take photos in varying weather conditions, with the exception of rain, as raindrops in the images disturb analysis. Sunny weather was not an obstacle as long as the sun does not appear directly in the images or result in severe reflections from the canopy.

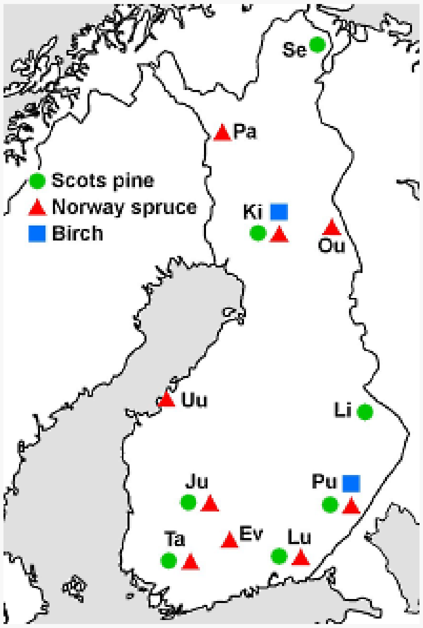
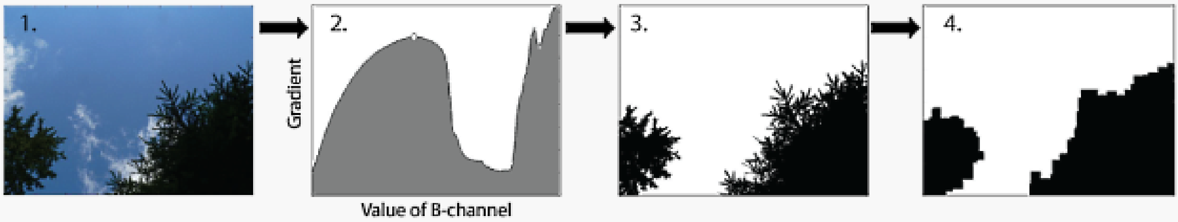


Figure 1. Location of study sites.

Image processing

Main steps of the canopy image analysis is shown in the flow-chart below. Image processing was done using Matlab numerical computing environment (MathWorks Inc. 2008).



1. Original RGB image.
2. Blue component of RGB images is thresholded according to the method proposed by Nobis and Hunziker (2005). The method is based on edge detection. Basically, the idea is to find the value of the blue channel that gives the greatest contrast between the canopy and the sky.
3. Thresholded image. The percentage of black and white pixels in the binary image is calculated -> effective canopy cover.
4. Gaps inside the tree crowns are painted over using morphological dilation and erosion operations -> traditional canopy cover.

The steps of image processing is described in detail in study by Korhonen & Heikkinen (2009). Matlab-script used in canopy image analysis and can be obtained from Matlab file exchange (Heikkinen and Korhonen 2009).

The average cover of images represents the canopy cover of the plot.

References

FAO 2000. On definations of forest and forest change. Forest Resources Assessment Programme, working Paper 33. FAO, Rome, Italy. 15 p.

Heikkinen, J. & Korhonen. L. 2009. MATLAB codes for canopy image analyses.

Jasinski, M. F. 1990. Sensitivity of the normalized difference vegetation index to subpixel canopy cover, soil albedo, and pixel scale. Remote Sensing of Environment 32: 169–187.

Jennigs, S.B., Brown, N.D. & Sheil, D. 1999. Asseessing forest canopies and understorey illumination: canopy closure. canopy cover and other measures. Forestry 72(1): 59–74.

Korhonen, L. & Heikkinen, J. 2009. Automated analysis of in situ canopy images for the estimation of forest canopy cover. Forest Science 55 (4): 323–334.

Kuusk, A. & Nilson, T. 2000. A directional multispectral forest reflectance model. Remote Sensing of Environment 72: 244–252.

MathWorks Inc. 2008. Matlab- the language of technical computing.

Nobis, M. & Hunziker, U. 2005. Automatic thresholding for hemispherical canopy-photographs based on edge detection. Agricultural and Forest Meteorology 128: 243–250.

Sarvas, R. 1953. Measurement of the crown closure of the stand. Communicationes Instituti Foreststalis Fenniae 41 (6). 13 p.

Citation: Ukonmaanaho, L. and Heikkinen, J. (2013). Estimation of canopy cover using planar photography method. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087581. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Jouni Hyvärinen

Quality Assurance for laboratory results from Forest Condition Monitoring in Finland

By Kirsti Derome

Summary

The value of forest monitoring data greatly depends on their quality. Within the ICP Forests Programme, The Working Group on Quality Assurance and Quality Control in Laboratories has been established to improve the comparability and evaluability of the analytical data produced. The most important step in improving quality assurance and control has been the introduction of regular ring tests for water, soil and plant samples. The laboratories of the Finnish Forest Research Institute in Vantaa (foliar, soil, water), Parkano (foliar) and Rovaniemi (soil, water) have regularly participated in the ring tests and gained excellent results.

Background

The overall quality of data collected during ecological monitoring is crucial, especially to integrating the European database and making large-scale assessments. The need for a comprehensive Quality assurance (QA) programme for ecological monitoring has been reported several times (e.g. Ferretti 2009).

Since 2007, a concept for a new QA perspective has been developed and implemented within the ICP Forests (Ferretti et al. 2009). This concept includes four main tasks:

- the revision and harmonisation of the Standard Operative Procedures (i.e. the ICP Forests Manual 2010)
- a new set of Data Quality Requirements (DQRs);
- an extended series of training sessions and
- inter-comparison ring tests. The quality of laboratory work has been developed during this project, particularly with respect to the type of analytics and sample material used. In addition, quality control has been developed for the database, based on a number of checks.

This chapter will focus on the quality of laboratory results with respect to forest condition monitoring.

Quality improvement in the laboratories

The Working Group on Quality Assurance and Quality control in Laboratories was established as part of the ICP Forests programme in 2004. Within this Working Group, laboratory oriented professionals from Expert panels on foliar, soil, deposition and soil solution are working together to improve the comparability and evaluability of the analytical data produced by the ICP Forests programme and the FutMon project.

The aims of this group are

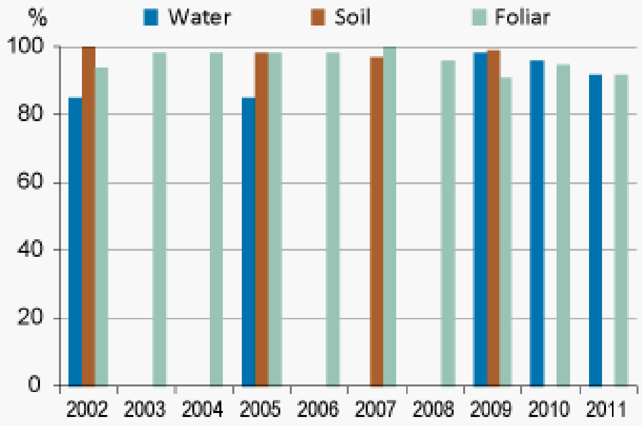
- the evaluation of the analytical methods used, in terms of their comparability and acceptability, and the elimination of unqualified methods
- the amendment of the ICP Forests Manuals with information on methods of sample pre-treatment and analysis
- the development and introduction of new methods of quality control within the laboratories
- the organisation of practical help for laboratories experiencing analytical problems and
- the organisation of ring tests to control the development of quality within the laboratories.

The analytical parts of the ICP Forests manual have been completely revised and unqualified methods eliminated. A review of possible checks and other supporting measures for quality assurance and control in laboratories has been compiled and published. Meetings of the heads of the laboratories have been organised, in order to exchange analytical knowledge and discuss analytical problems and their solutions. An assistance programme has been organised for laboratories with unacceptable ring test results, through co-operation and visits to and from these laboratories. The use of reference methods, various quality checks such as control charts, or ion balance calculations and participation in ring tests, has become mandatory within the ICP Forests programme and the FutMon project. Nowadays, each laboratory involved in the programme must send quality forms containing information on the methods used, on quantification limits, the use of control charts and ring test results, when submitting analytical data to the ICP Forests database.

The most important step in improving quality assurance and control has been the introduction of regular ring tests for water, soil and plant samples. For years previously, foliar and soil ring tests had been conducted more or less regularly, but deposition (esp. throughfall) and soil solution ring tests began as part of the ICP Forests programme. To date, six soil, five water and 14 foliar ring tests have been organised within the ICP Forests and Forest Focus programmes and the EU Life+/ FutMon project. The results of these ring tests show the development of data quality in the laboratories. In water ring tests, the percentage of results outside the tolerable limits has been reduced from 20–60 % to 5–30 % over eight years. A similar improvement can be seen for the results of the last four soil ring tests, where the coefficient of variation (CV in %) for the results of all participants has been reduced from 15–65 % to 10–35 % over seven years. In the case of the foliar ring tests, the improvement in results stabilised in 2005, where 3–10 % results exceeded the tolerable limits, a level that would be difficult to improve upon.

Ring test results suggest lower comparability and quality of soil analysis data, compared to water and plant analysis data. But it is also clear that the quality of water analyses can still be improved. Regular ring tests therefore remain important to improving the quality of analyses in the ICP Forests programme.

The laboratories of the Finnish Forest Research Institute in Vantaa (foliar, soil, water), Parkano (foliar) and Rovaniemi (soil, water) have participated in the ring tests since the beginning.



Over ten years, the results of these laboratories have been excellent: 85 to 100 % of the results have been acceptable (Fig. 1). The Rovaniemi laboratory has been an organiser of water ring tests, by acquiring, preparing and delivering samples to participants.

Figure 1. The percentage of the acceptable intercalibration results of Metla laboratories (Parkano, Rovaniemi, Vantaa) in Water, Soil and Foliar ring tests of ICP Forests/ FutMon -programmes during the years 2002–2011.

Quality improvement in field measurements

ICP Forests measurements cover approximately 260 variables. Before the FutMon project and the manual revision, 33% of the variables were covered by DQRs. Afterwards, coverage was extended to 66% of the variables. In practical terms, this means that it is now possible to document and report on data quality for 2/3 of the variables measured within the ICP Forests. It is remarkable that field measurements such as tree condition, ground vegetation, litter fall, ozone injury, tree growth and phenology are now covered by explicit DQRs (Ferretti et al. 2011).

References

Ferretti, M. 2009. Quality Assurance in ecological monitoring—towards a unifying perspective. Journal of Environmental Monitoring; 11: 726–729

Ferretti, M., König, N., Rautio, P. & Sase, H. 2009. Quality Assurance in international forest monitoring programmes: activity, problems and perspectives from East Asia and Europe. Annals of Forest Sciences 66: 403–415.

Ferretti, M., König, N., Granke, O., Cools, N., Derome, J., Derome, K., Fürst, A., Hosenfeld, F., Marchetto, A. & Mues, V. 2011. Quality Assurance and Quality Control within the monitoring system. In: Fischer, R. & Lorenz, M. (eds.). Forest Condition in Europe, 2011 Technical Report of ICP Forests and FutMon. Work Report of the Institute for World Forestry /1. ICP Forests, Hamburg, 212 pp. (pdf)

Citation: Derome, K. (2013). Quality Assurance for laboratory results from Forest Condition Monitoring in Finland. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087582. [Cited 2013-05-07].

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

From Jan. 1. 2015, Metla is part of the Natural Resources Institute Finland. www.luke.fi

SUOMEKSI PÅ SVENSKA IN ENGLISH AUF DEUTSCH ПО-РУССКИ

Home | Research | Services | Publications | Metinfo | Research forests | About the institute | Strategy | Contact

Metla » Metinfo » Forest condition » Related projects » Extensive forest soil monitoring

Sitemap | Search

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programmes

Results: Crown condition

Results: Intensive monitoring

Results: related projects

- Biosoil vegetation
- **Biosoil soil**
- Litter production
- Soil survey design
- Case Valkea-Kotinen

Publication list of the Programme

About the report

Photo: Metla/Erkki Oksanen

Extensive forest soil monitoring

By Pekka Tamminen & Hannu Ilvesniemi

Summary

Finnish forest soils have been inventoried in years 1986–95 and in 2006–2007. Our forest soils are coarse and acid, they contain more carbon but less heavy metals than soils, on average, in central Europe. Soil fertility, measured e.g. by nitrogen and base cation status and pH, tends to decrease from southern to northern Finland.

Background

The first inventory of upland forest soils in Finland was carried out during the years 1986-1995, to measure soil acidity and nutritional and heavy metal status of upland soils. Another round of the soil survey was accomplished in years 2006–2007 under the EU project BioSoil. These large scale soil monitorings were aimed to give information about soil types, texture, carbon, nutrients, acidity and heavy metals at the time of both inventories and to give a possibility to estimate possible changes in soil properties.

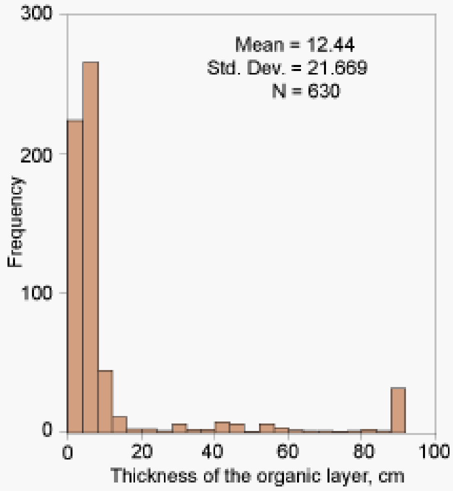


Figure 1. Frequency distribution of organic layer thickness on Level I plots.

Results

The arithmetic mean of organic layer thickness was 12.4 cm, although the median was only 4.8 cm (Fig. 1). The result is influenced by the fact that peatland sites with peat thickness of at least 90 cm were included in the sample. Distribution of humus types were typical for the boreal zone, i.e. mor and peat were dominating (Table 1). However, the proportion of upland sites, i.e. mineral soils, was higher, 84% vs. 76%, and the proportion of peatland sites was lower, 16% vs. 24%, than in average on forest land in Finland (Ylitalo, 2010).

Carbon

Parameter	Missing	Mor	Moder	Mull^a	Peat
Mean	0.2	4.7	3.6	1.3	45.0
Median	0	4.4	3.4	0.1	41.6
n	10	456	39	11	124

Table 1. Mean and median thickness of the organic layer by dominating humus type. ^{a}=Mull was treated as mineral soil.

Amount of carbon in the organic layer on upland soils (thickness of the organic layer ≤ 10 cm) correlated best with variables measuring moisture, i.e. estimated moisture class (r = 0.22) and coverage of peat mosses (r = 0.37) and with age of tree stand (r = 0.18). There was no trend in south-north direction. In the mineral soil layer 0–20 cm the amount of carbon correlated negatively with northing (r = –0.38), site fertility class (r = –0.35; also Table 2) and stand age (r = –0.17) and positively with site moisture class (r = 0.29).

Layer	1	2	3	4	5	6	Average
Organic	16.9	17.3	23.6	21.4	19.5	17.6	21.4
Mineral soil layer	25.0	31.3	20.8	18.3	15.5	14.2	20.9
n	6	81	221	161	31	9	508

Table 2. Amount of carbon (Mg/ha) in the organic layer and mineral soil layer 0-20 cm by forest site type class, when the thickness of the organic layer was under 10 cm. 1-6= Forest site type class, 1=the most fertile, …, 6=the least fertile site

Although very moist and peat rich sites were removed from the material, the amount of carbon in surface soil tended to increase along moisture gradient. The amount of carbon tended to increase in the organic layer and decrease in the surface mineral soil when tree stands become older. It seems that the difference in organic matter concentration between the organic layer and the top-most mineral soil is smallest some years after regeneration and largest just before regeneration. The organic layer was missing most often on very fertile sites including afforested fields (n = 13) – humus form was mull – and on one very dry sandy site.

Nitrogen

Site fertility, measured by C/N ratio in the organic layer and nitrogen concentration in the mineral soil, tended to increase from north to south, correlation coefficients with northing were 0.48 and –0.55, respectively (see also Fig. 2). Correlation coefficient between organic layer C/N ratio and site fertility class was –0.59 and that between mineral soil nitrogen concentration and site fertility class 0.51. Soil nitrogen trends are more likely explained by climate and vegetation than nitrogen deposition.

Soil cations

Latitude showed a positive correlation with exchangeable acidity (H +) and potassium concentration in the organic layer (r = 0.29 and 0.37, respectively), and a negative correlation with organic layer pH, calcium concentration and base saturation (r = –0.29, –0.38, and –0.32, respectively). In the mineral soil layer 0–10 cm the acidity and all cation concentrations correlated negatively with northing (r = –0.20…–0.59). Higher acidity and higher cation concentrations in the southern part of the country may be explained by higher organic matter content in the mineral soil in southern than in northern Finland. Regional distribution of these variables can be seen in Fig. 3

Heavy metals

Heavy metal concentrations in the organic layer were quite low compared to e.g. Central Europe (Vanmechelen et al., 1997) . Lead concentration correlated best with northing (r = –0.51), to some extent with concentrations of cromium, copper, nickel and zink (–0.28 < r < –0.32), and only weakly with the concentration of cadmium (r = –0.12, p=0.003). The pattern of heavy metal concentrations corresponded well with the deposition measured using moss or lichen samples (Kubin et al., 1994; Poikolainen, 2004) (Fig. 4).

Material and methods

Finnish Level I plots are situated in a grid of 16 km*16 km in southern Finland and in a grid of 24 km*32 km in northern Finland. These monitoring plots were established in the course of the 8 th national forest inventory in 1985–86 and were located strictly systematically, i.e. the midpoint of an inventory plot may be situated e.g. on the border of two different sites, like peatland and upland sites or mature and seedling stands. However, only one, at least relatively homogenous compartment was sampled for soil survey.

In the second soil survey in 2006–2007, i.e. in the BioSoil project, the sampled soil layers were as follows: organic layers 0–10, 10–20, 20–40 cm and mineral soil layers 0–10, 10–20, 20–40 and 40–80 cm. From the organic layer, 10 or 20 subsamples were collected with a cylinder (d = 60 mm), depending on the organic layer thickness. From the mineral soil, five subsamples were taken with spades from the layers 0…40 cm, and only one sample from the deepest layer (40–80 cm). Mineral soil layers 0–10 and 10–20 cm were sampled with a volumetric cylinder whenever it was not an overwhelming task because of stoniness. Volumetric proportion of stones (d > 20 mm) in the mineral soil was estimated using a so-called steel rod method (Viro, 1952; Viro, 1958). If mineral soil bulk density was not measured, it was estimated using the equations of Tamminen and Starr (1994).

All soil samples from the second soil survey (BioSoil) have been analysed in the laboratory of the Finnish Forest Research Institute at Vantaa according to the Manual on the methods and criteria for harmonized sampling, assessment, monitoring and analysis of the effects of air pollution on forests, Part IIIa Sampling and Analysis of Soil, updated in 2006 (www.icp-forests.org/pdf/FINAL_soil.pdf).

References

Kubin, E., Poikolainen, J., Lippo, H. 1994. Sammal, jäkälä ja kaarna raskasmetallilaskeuman indikaattoreina. Metsäntutkimuslaitoksen tiedonantoja 527, 109–115.

Poikolainen, J. 2004. Mosses, epiphytic lichens and tree bark as biomonitors for air pollutants - specifically for heavy metals in regional surveys. Acta Universitatis Ouluensis. A Scientiae Rerum Naturalium 421, 69 p + 5 original articles.

Tamminen, P., Starr, M. 1994. Bulk density of forested mineral soils. Silva Fennica 28(1), 53–60.

Vanmechelen, L., Groenemans, R., Van Ranst, E. 1997. Forest soil condition in Europe. Results of a large-scale soil survey United Nations – Economic Commission for Europe and European Commission, Brussels.

Viro, P. 1952. Kivisyyden määrittämisestä. Summary: On the determination of stoniness. Communicationes Instituti Forestalis Fenniae 40, 23.

Viro, P.J. 1958. Suomen metsämaiden kivisyydestä. Summary: Stoniness of forest soil in Finland. Communicationes Instituti Forestalis Fenniae 49, 45.

Ylitalo, E. (Ed.). 2010. Metsätilastollinen vuosikirja 2010. Skogsstatistisk årsbok 2010. Finnish Statistical Yearbook of Forestry 2010. Metsäntutkimuslaitos. Skogsforskningsinstitutet. Finnish Forest Research Institute. Vantaa.

Citation: Tamminen, P. and Ilvesniemi, H. (2013). Extensive forest soil monitoring. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report].
Available at http://urn.fi/URN:NBN:fi:metla-201305087584. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Significance of litter production of forest stands and ground vegetation in the formation of organic matter and storage of carbon in boreal coniferous forests

By Sari Hilli

Summary

In the boreal forests, tree stands, mosses and dwarf shrubs produce the majority of the litterfall, which becomes a component of humus as it decomposes. In this study, we determined the composition of the litter layer in 6 Norway spruce and 6 Scots pine forests and examined the significance of the composition of litter in the formation of humus layer in the forests located in the northern and southern boreal vegetation zones.

In general, the amount of semi-decomposed dwarf shrub and moss litter was higher in the litter layer of pine forests than in spruce forests. Moreover, the role of dwarf shrubs in the formation of forest soil organic matter (SOM) was much greater in the north, and the carbon (C) production of mosses even exceeded that of tree litter in the Hylocomium-Myrtillus type spruce forests in Northern Finland.

Northern and southern forests showed no significant differences in the decomposition rates of needle, moss or bilberry leaf litter, though needle litter decomposed slightly more rapidly in the latter stages of the decomposition in the south. Among the litter types studied, bilberry leaf litter had the highest concentration of water-extractable C and nitrogen, and it decomposed clearly more rapidly than needle or moss litter in the early stages of the decomposition.

The C composition of tree and dwarf shrub litter differed significantly from the C composition of moss litter. The significance of the litter layer to the total SOM in forests and as storage of various C compounds is much greater in the northern boreal zone than in the south. In general, more C accumulated in SOM in spruce forests than in pine forests.

Introduction

Litterfall produced by plants is the main source of organic matter for forest soil. Litter decomposition and the formation of humus are processes that are dependent on vegetation and the quality and quantity of its litter production (e.g. Coûteaux et al. 1995). Litterfall that is not readily degradable has been observed to affect the formation of organic matter in particular (Högberg et al. 2003). Litterfall produced by certain plants may be fully degradable and thus will not turn into highly decomposed organic matter, i.e. humus (Kang et al. 2009).

Furthermore, the structure and activity of the decomposing microbial community affect the properties and formation of humus (Grayston & Prescott 2005). In the course of the litter decomposition process, the microbial community, and fungi species in particular, transform in line with the carbon compounds available (Sinsabaugh 2005, Korkama-Rajala et al. 2008).

According to previous studies, climate and site factors and the chemical properties of a specific litter type affect its decomposition rate on both global and regional levels (e.g. Aerts 1997, Liski et al. 2003). The temperatures in the boreal coniferous forest zone are expected to increase over the next 50 years as a result of the climate change (Carter et al. 2005). Longer and warmer growing seasons may increase primary production, and enhance the decomposition rate of litterfall. Previous studies have suggested that decomposition rates may be enhanced by global warming to a greater extent than primary production (Schimel et al. 1994).

The vegetation composition characteristic of boreal coniferous forests comprises a tree layer, an understorey of dwarf shrubs, and a ground layer of mosses and lichens. Tree litter, its quantity and chemical properties, and the impact it has on the forest ecosystems' ecological processes, such as decomposition, formation of humus, and nutrient cycling, have been studied extensively (e. g. Ukonmaanaho et al. 2008). On the contrary, only in recent years have studies been conducted on the ecological significance of ground vegetation to boreal forest ecosystems (Nilsson & Wardle 2005, Kolari et al. 2006). In previous studies, moss litter has been observed to decompose slowly and to accelerate the decomposition rate of other litter types through its ability to maintain a sufficient moisture level (Wardle et al. 2003). On the other hand, mosses have been found to potentially impede litter decomposition rates, because they buffer soil against temperature changes by increasing surface insulation (Oechel & Van Cleve 1986). Bilberry (*Vaccinium myrtillu*), the most common dwarf shrub species found in boreal forests, produces leaf litter that contains high concentrations of nitrogen (N) and decomposes more rapidly than the litter produced by lingonberry (*Vaccinium vitis-idaea*) and black crowberry (*Empetrum nigrum*; Nilsson & Wardle 2005). Black crowberry litter in turn has been found to produce large quantities of polyphenolic compounds, thus impeding decomposition (Wardle et al. 2003).

Results and discussion

Litterfall produced by plants is the main source of SOM in forests. Each plant species has a different impact on the formation of humus. In the boreal coniferous forest zone, tree stands, mosses and dwarf shrubs produce the majority of the litterfall on the forest floor, which becomes a component of humus as it decomposes. Forest stand litter production (Ukonmaanaho et al. 2008) and the proportion of tree litter from the total quantity of litterfall in the litter layer was greater in the sample plots of the southern boreal zone than in the northern zone (Fig. 1). The tree litter accumulated in the surface layer (L) of the forests in Southern Finland contained far more twigs and cones than the L layer of the forests in Northern Finland (Fig. 2), whereas the relative share of needles from the total amount of tree litter was greater in the sample plots located in Northern Finland (Fig. 2).

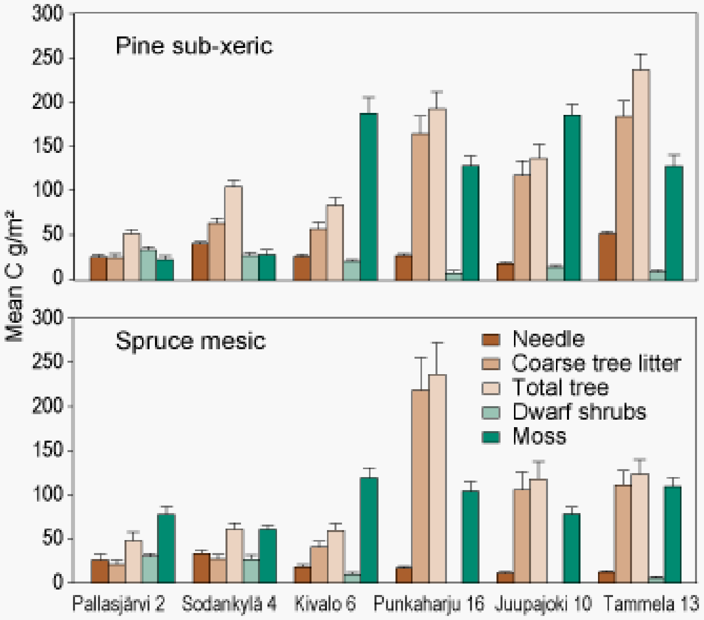


Figure 1. Carbon stocks in main litter fractions of L layers of boreal coniferous forests. The error bar = standard error of the mean.

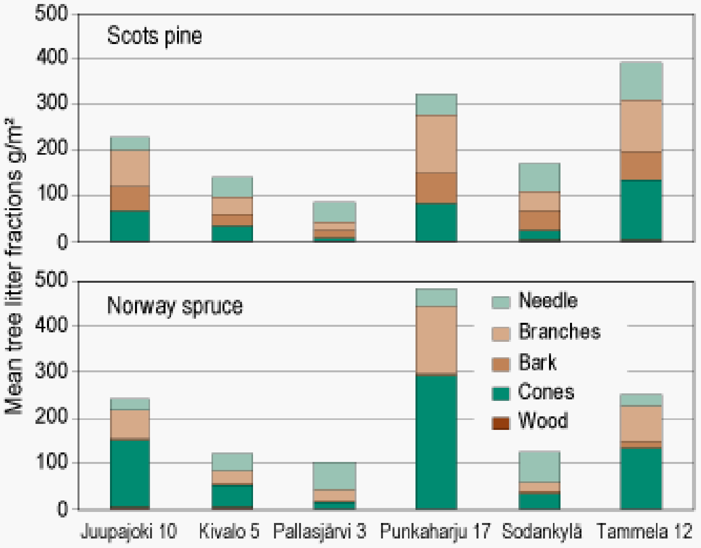


Figure 2. Tree litter composition (fractions) of L layers of boreal coniferous forests.

Larger quantities of semi-decomposed dwarf shrub and moss litter were found in the litter layer of pine forests in comparison to spruce forests, apart from the two northernmost sample plots (Fig. 1). This is largely due to the higher proportion of evergreen dwarf shrubs among the shrub species of pine forests. The litter produced by evergreen dwarf shrubs has a lower decomposition rate than bilberry or lingonberry litter. Stendahl et al. (2010) have shown with their simulations that ground vegetation plays a more significant role in the litter production of pine forests than spruce forests. The quantity of moss litter in the pine forests of Northern Lapland (Pallasjärvi and Sodankylä) reduces significantly due to the increased proportion of dwarf shrubs and lichens among the plant species and their subsequent greater role in the production of litter. This can be seen in the accumulation of organic matter and its total organic carbon content (Fig. 1). The role of dwarf shrubs in the formation of forest soil organic matter and as a source of carbon is much greater in the north, because sparse forest stand does not prevent light from reaching the ground, thus allowing the formation of a dense layer of dwarf shrubs. The carbon production of mosses exceeds the amount of carbon produced by tree litter in the Hylocomium-Myrtillus type (HMT) forests of Northern Finland (Fig. 1).

Significance of litter in the accumulation of carbon and organic matter

Northern and southern boreal forest zones showed no statistically significant differences in the decomposition rates of needle, moss or bilberry leaf , although needle litter did decompose slightly more rapidly in the latter stages of the decomposition process in the southern boreal zone (Fig. 3, Hilli et al. 2010). Among the litter types studied, bilberry leaf litter had the highest concentration of water-extractable carbon (WEC) and N, and it decomposed clearly more rapidly than needle or moss litter and in the early stages of the decomposition process (Hilli et al. 2010). Previous studies have found that under very similar climate and soil conditions, there are differences in the decomposition rates of plant-derived litter types (e.g. Wardle et al 2003). Litterfall with high concentrations of N or WEC has a higher decomposition rate than litterfall that contains low concentrations of N and water-soluble extractives (WSE) and high concentrations of lignin or other acid-insoluble residue (AIR) (Tian et al. 2000, Wardle et al. 2003).

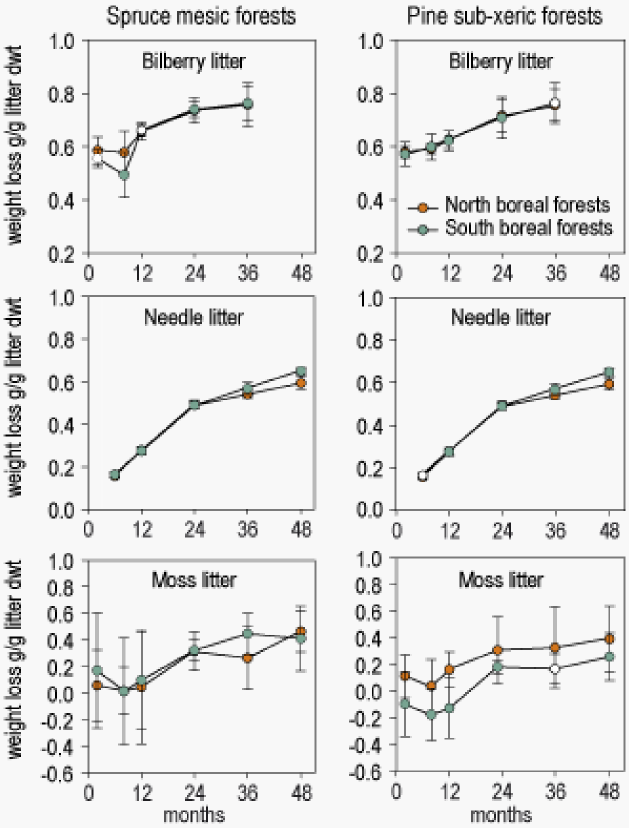


Figure 3. Mass loss of bilberry leaf, needle and moss litter during decomposition in the spruce and pine forests of Northern and Southern Finland. Source: Hilli et al. 2010.

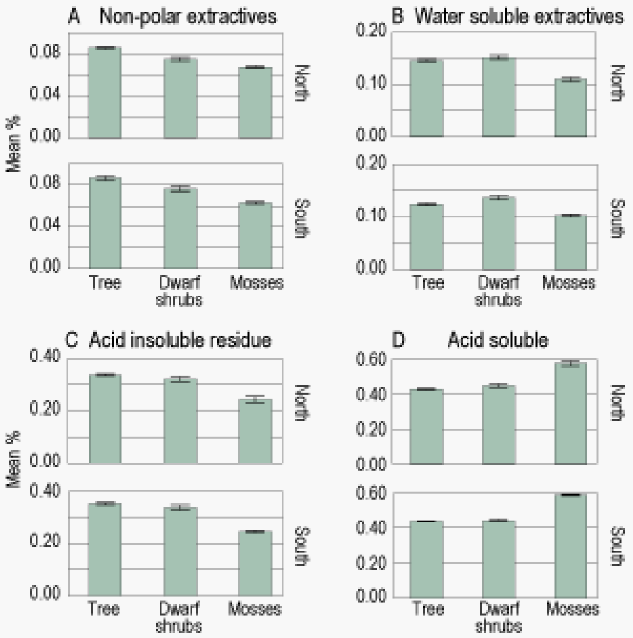


Figure 4. Carbon fractions (NPE, WSE, AS and AIR) of tree, dwarf shrub and moss litter in the sample lots of Northern and Southern Finland.

The carbon compositions of tree and dwarf shrub litter were significantly different from the C composition of moss litter (Fig. 4). Mosses contained clearly more cellulose (acid-soluble fraction, AS) and had much lower concentrations of WSE, non-polar extractives (NPE) and AIR than tree and dwarf shrub litter. According to measurements conducted using the TOC method, the WSE fraction of moss litter contained much lower concentrations of phenols, sugars and WEC than those of tree or moss litter (Fig. 5a–c). On the other hand, mosses contained higher concentrations of water-extractable N (Fig. 5d). Mass loss in the C fractions of litter varied according to the type and decomposition rate of litter, but the differences between northern and southern boreal zones were small when comparing the fractions of a single litter type (Hilli et al. 2010). The decomposition rate of moss litter was clearly lower than the rates of tree or dwarf shrub litter, and there were fewer relative changes in the carbon fractions.

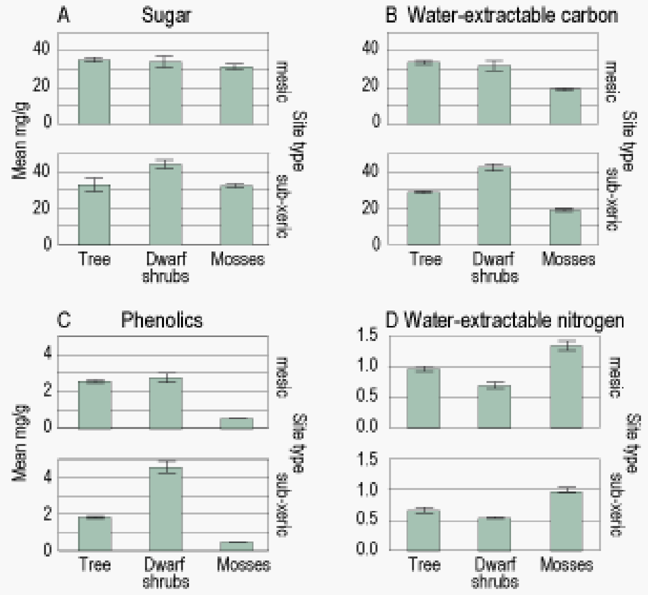


Figure 5. Sugar, WEC, phenol and WEN concentrations of tree, dwarf shrub and moss litter in the L layers of spruce and pine forests

Although the decomposition rates of various litter types did not vary between the northern and southern boreal forest zones, the significance of the litter layer to the total SOM in forests and the storage of various carbon compounds is much greater in the northern boreal zone (Hilli et al. 2008a, b). Especially in northern boreal pine forests, the litter layer contains much larger WEC stocks compared to those in the south, as well as a significant proportion of the total carbon content of the organic horizons (Hilli et al. 2008a, b). More soil C accumulation occurred in spruce forests than pine forests, although there was no variation in the decomposition rate of litter between these two types of coniferous forest (Hilli et al. 2010). Considerably more variation was found in the comparison between spruce and pine forests located in the northern boreal zone than in the comparison between the two types of forest in the southern boreal zone (Hilli et al. 2008a, b). The simulations of Stendahl et al. (2010) have shown that under the same environmental conditions, the spruce forest soil accumulates 22% more carbon than pine forest soil. However, the difference in favour of spruce forests decreased with the increase in temperature (Stendahl et al. 2010). On the basis of the present study, temperature or other site factors do not have a direct influence on the accumulation of organic matter, but instead influence it indirectly through the vegetation and its litter input.

Clear changes in the plant community structure of the understorey and forest floor of coniferous forests may cause significant changes to the quantity and quality of litter, which in turn has a direct impact on soil C accumulation

(Hättenschwiler & Gasser 2005). Because the changes in the litter layer's microbial community structure and decomposer community occur on account of changes in the plant community (Allison et al. 2009), the changes in the species composition and activities of the decomposer community have an indirect impact on the accumulation of organic matter. In particular, changes to the amount of mosses and their litter input combined with tree litter have a significant impact on the amount of organic matter accumulated and, through it, an impact on the carbon stocks of boreal coniferous forest soils.

Material and methods

Three sites including Scots pine and Norway spruce plots located within the northern boreal vegetation zone (Pallasjärvi nrs. 2 and 3, Sodankylä and Kivalo nrs. 5 and 6) and three sites within the southern boreal vegetation zone (Tammela nrs. 12 and 13, Juupajoki nrs. 10 and 11 and Punkaharju nrs. 16 and 17) were selected for the purpose of studying the impact of climate and soil factors and vegetation on the decomposition and formation of organic matter. Vegetation coverage analyses were conducted before taking the soil samples. The decomposition and accumulation of organic matter to forest soil were analysed through decomposition experiments (Hilli et al. 2010), and by taking samples of naturally formed layers of organic matter that were in various stages of decomposition (Hilli et al. 2008a). In total, 28 soil samples measuring 30 x 30 cm^2 were removed from the forest floor of each sample plot and then separated into three individual samples: the litter layer (L), the fermentation layer (F), and the humus layer (H). The litter layer was further characterised into the following fractions: 1) needle litter, 2) coarse tree litter, 3) dwarf shrub litter, 4) moss litter, 5) lichen litter, and 6) litter produced by herbs and grasses.

Chemical analyses

In order to understand the ecology of accumulating C substrates, we characterised the soil organic matter according to Ryan et al. (1990) into the following fractions: non-polar extractives, chloroform soluble (NPE, waxes, fatty acids, oils), water-soluble extractives (WSE, e.g. sugars and phenolics), acid-soluble fraction (AS, e.g. cellulose), and acid-insoluble residue (AIR) (lignin, tannin and cutin) (Ryan et al. 1990, Preston et al. 1997).

In order to characterise the WSE fraction in detail, the water-extractable phenolic concentration was determined by the Folin-Ciocalteu method (Suominen et al. 2003) and the concentration of soluble sugars by the method presented by Wood and Bhat (1988). Water-extractable carbon (WEC) was analysed using a carbon analyser (Shimadzu TOC-5000A) and water-extractable N by flow injection analysis (FIA 5012) after oxidation of N to NO_3-N with alkaline potassium persulphate (Williams et al. 1995).

References

Aerts, R. 1997. Climate, leaf litter chemistry and leaf litter decomposition in terrestrial ecosystems: a triangular relationship. Oikos 79: 439–449.

Allison, S., LeBauer, D.S., Ofrecio, M.R., Reyes, R., Ta, A.M. & Tran, T.M. 2009. Low levels of nitrogen addition stimulate decomposition by boreal forest fungi. Soil Biology and Biochemistry 41: 293–302.

Carter, T.R., Jylhä, K., Perrels, A., Fronzek, S. & Kankaanpää, S. 2005. FINADAPT scenarios for the 21st century: alternative futures for considering adaptation to climate change in Finland. FINADAPT Working Paper 2. Finnish Environment Institute Mimeographs 332, Helsinki, Finland.

Coûteaux, M.M., Bottner, P. & Berg, B. 1995. Litter decomposition, climate and liter quality. Trends in Ecology & Evolution 10: 63–66.

Grayston, S.J. & Prescott, C.E. 2005. Microbial communities in forest floors under four tree species in coastal British Columbia. Soil Biology & Biochemistry 37: 1157–1167.

Hilli, S., Stark, S. & Derome, J. 2008a. Carbon quality and stocks in organic horizons in boreal forest soils. Ecosystems 11: 270–282.

Hilli, S., Stark, S. & Derome, J. 2008b. Water-extractable organic compounds in different components of the litter layer of boreal coniferous forest soils along a climatic gradient. Boreal Environment Research 13 (Suppl. B.): 92–106.

Hilli, S., Stark, S., Derome, J. 2010. Litter decomposition rates in relation to litter stocks in boreal coniferous forestsalong climatic and soil fertility gradients. Applied Soil Ecology 46: 200–208.

Hättenschwiler, S. & Gasser, P. 2005. Soil animals alter plant litter diversity effects on decomposition. Proceedings of the National Academy of Sceinces 102: 1519–1524.

Högberg, M.N., Bååth, E., Nordgren, A., Arnebrant, K. & Högberg, P. 2003. Contrasting effects of nitrogen availability on plant carbon supply to mycorrhizal fungi and saprotrophs - a hypothesis based on field observations in boreal forest. New Phytologist 160: 225–238.

Kang, H.Z., Berg, B., Liu, C.J. & Westman, C.J. 2009. Variation in mass-loss rate of foliar litter in relation to climate and litter quality in Eurasian forests: Differences among functional groups of litter. Silva Fennica 43: 549–575.

Kolari, P., Pumpanen, J., Kulmala, L., Ilvesniemi, H., Nikinmaa, E., Grönholm, T. & Hari, P. 2006. Forest floor vegetation plays an important role in photosynthetic production of boreal forests. Forest Ecology and Management 221: 241–248.

Korkama-Rajala, Tiina; Mueller, Michael M.; Pennanen, Taina. 2008. Decomposition and fungi of needle litter from slow- and fast-growing norway spruce (*Picea abies*) clones. Microbial Ecology 56 (1): 76–89. (html)

Liski, J., Nissinen, A., Erhard, M. & Taskinen, O. 2003. Climatic effects on litter decomposition from arctic tundra to tropical rainforest. Global Change Biology 9: 575–584.

Nilsson, M.-C. & Wardle, D.A. 2005. Understory vegetation as a forest ecosystem driver: evidence from the northern Swedish boreal forest. Frontiers in Ecology and the Environment 3: 421–428.

Oechel, W. C. & Cleve, K. Van. 1986 The role of bryophytes in nutrient cycling in the taiga. In: Cleve, K. Van, Chapin, F. S. III, Flanagan, P. W., Viereck, L. A., & Dyrness, C. T. (eds.). Forest Ecosystems in the Alaskan Taiga. Springer-Verlag, New York, p. 121–137.

Preston, C.M., Trofymow, J.A., Sayer, B.G. & Niu, J. 1997. 13C nuclear magnetic resonance spectroscopy with cross-polarization and magic-angle spinning investigation of the proximate analysis fractions used to assess litter quality in decomposition studies. Canadian Journal of Botany 75: 1601–1613.

Ryan, M.G., Melillo, J.M., & Ricca, A. 1990. A comparison of methods for determining proximate carbon fractions of forest soils. Canadian Journal of Forest Research 20: 166–71.

Schimel, D.S., Braswell, B.H., Holland, E.A., McKeown, R., Ojima, D.S., Painter, T.H., Parton, W.J. & Townsend, A.R. 1994. Climate, edaphic and biotic controls over storage and turnover of carbon in soils. Global Biogeochemical Cycles 8: 279–293.

Sinsabaugh, R.L., Gallo, M.E., Lauber, C., Waldrop, M.P. & Zak, D.R. 2005. Extracellular enzyme activities and soil organic matter dynamics for northern hardwood forests receiving simulated nitrogen deposition. Biogeochemistry 75: 201–215

Stendahl, J., Johansson, M.-B., Eriksson, E., Nilsson, Å. & Langvall, O. 2010. Soil organic carbon in Swedish spruce and pine forests – differences in stock levels and regional patterns. Silva Fennica 44: 5–21.

Suominen, K., Kitunen, V. & Smolader, A. 2003. Charasteristics of dissolved organic matter and phenolic compounds in forest soils under silver birch (*Betula pendula*), Norway spruce (*Picea abies)* and scots pine (*Pinus sylvestris*). European Journal of Soil Science 54: 287–293.

Tian, X., Takeda, H. & Azuma, J. 2000. Dynamics of organic-chemical components in leaf litters during a 3.5-year decomposition. European Journal of Soil Biology 36: 81–89.

Ukonmaanaho, L., Merilä, P., Nöjd, P. & Nieminen, T.M. 2008. Litterfall production and nutrient return to the forest floor in Scots pine and Norway spruce stands in Finland. Boreal Environment Research 13 (suppl.B): 67–91.

Wardle, D.A., Nilsson, M.-C., Zackrisson, O. & Gallet, C. 2003. Determinants of litter mixing effects in a Swedish boreal forest. Soil Biology and Biochemistry 35: 827–35.

Williams, B.L., Shand, C.A., Hill, M., O'Hara, C., Smith, S., Young, M.E. 1995. A procedure for the simultaneous oxidation of total soluble nitrogen and phosphorus in extracts of fresh and fumigated soils and litters. Communications in Soil Science and Plant Analysis 26: 91–106.

Wood, T.M. & Bhat, K.M. 1988. Methods for measuring cellulase activities. In: Wood, W.A. & Kellog, S.T. (eds.). Methods in enzymology vol. 160. Academic Press, San Diego, p. 87–112.

Acknowledgements
The study was co-funded by the European Commission under the Forest Focus programme within the pilot project 'Role of litterfall, ground vegetation and the forest floor in carbon and nutrient cycling'.

Citation: Hilli, S. (2013). Significance of litter production of forest stands and ground vegetation in the formation of organic matter and storage of carbon in boreal coniferous forests . In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087586. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Photo: Metla/Erkki Oksanen

Monitoring changes in the carbon stocks of forest soils

By Raisa Mäkipää, Petteri Muukkonen & Mikko Peltoniemi

Summary

Soil carbon stock changes can have remarkable influence on global climate. Forest management and climate change may enhance release of soil carbon to the atmosphere, which further accelerates climate change. Under the Climate Convention, countries have agreed to monitor and report changes in the soil carbon stock, but majority of the European countries has not established systematic nation-wide soil monitoring. Development of efficient sampling design for soil carbon monitoring requires information on variation of soil carbon stock and expected rate of change. This report is a summary of our studies, where we addressed questions on appropriate sample size and interval of consecutive measurements in the nation-wide soil survey.

Introduction

Forests have been accounted for in the Climate Convention and the Kyoto Protocol because of their importance in atmospheric carbon dioxide concentration (UNFCCC 1992, 1997). The potential of forests in mitigation of climate change has created a need to develop and improve methods to estimate the carbon budgets of forests. Under the Climate Convention, countries have made commitments to report changes in the carbon stocks of forests, including the carbon stock of soils. The IPCC (2003, 2006) has set general requirements for soil inventories, but operational soil monitoring methods applicable on the large scale in question are under development and only some European countries have established a national system of soil carbon monitoring. National and European greenhouse gas (GHG) reporting of forest soil can be based on soil carbon modelling or on empirical data of repeated soil carbon measurements or a combination of these two.

Soil carbon stock is large, and relatively small changes may have a remarkable influence on forest carbon balance. It is a challenging task to detect a small change in a large stock, especially in the case of forest soils where the regional between-site variation and spatial within-site variation are remarkable (Conen et al. 2003, Yanai et al. 2003, Häkkinen et al. 2011). Consequently, a large number of samples is required in order to provide soil carbon estimates that are accurate enough for monitoring purposes. Due to the high costs of the regionally representative soil surveys, sampling efforts need to be effectively allocated within a monitoring programme.

Constructing a sampling design is an optimisation problem, where the trade-off is between required resources and the reliability of resulting estimates. When planning a sampling to detect a potential change, it is necessary to be aware of how many samples need to be taken to estimate the change statistically significantly. Appropriate sampling intensity (sample size) and sampling intervals (time between consecutive measurements) can be designed after collecting information on between-site variation and estimation of the rate of the potential change. Efficiency of the sampling can be improved by stratification, if prior information on the variation of the target variable is available.

In this study, we were aiming to provide means to improve efficiency of soil carbon monitoring. The specific questions addressed by this study were: 1. What is the appropriate sampling intensity – the number of study sites and sampling interval?, 2. How much is model-based stratification expected to improve the efficiency of soil sampling?, 3. What is the appropriate location of sample points and their number at study sites?

What is appropriate sampling intensity – the number of study sites and sampling interval?

The number of plots needed for detection of a change in the soil carbon stock is estimated using the equation:

$\mathbf{n = (t * s/E)^2}$ where **n** is the number of sample plots required, **t** is a value taken from a student's t distribution table for a given number of degrees of freedom and a desired confidence interval, **s** is the estimated standard deviation of the measured soil carbon stock estimates (assuming independence of the observations), and **E** is the desired half of the confidence interval for the carbon stock estimate.

In designing soil monitoring, information on between-site variation of soil properties can guide the decision on the total number of plots to be measured.

The desired confidence interval of a carbon stock estimate should allow detection of the expected change in the soil carbon stock. The true rate of soil carbon change is not known, but it can be estimated with soil modelling. If we assume that the average rate of change is 11 g C m^{-2} yr^{-1} from a modelling study of Liski et al. 2006, the desired half of the confidence interval of the carbon stock estimate (E) is 27.5 g C m^{-2} with a sampling interval of five years, increasing to 137 g C m^{-2} with an extension of the sampling interval to twenty-five years (assuming that the carbon change increases linearly over time) (Mäkipää et al. 2008).

We can assume a standard deviation of 1000 g C m^{-2} (which is the value reported for the mean carbon stock of the uppermost soil layers of boreal soil by Peltoniemi et al. 2004), and apply also standard deviations of 1250 and 1500 g C m^{-2} in order to determine the sensitivity of the results to this assumption. With these assumptions, the approximate estimate for the minimum number of sample plots required to detect a change in this soil layer is 3,000 plots with a sampling interval of ten years (Fig. 1). This sampling intensity allows detection of an expected change of 110 g C m^{-2} per ten-year period if the standard deviation of the measured carbon stock is less than 1500 g C m^{-2}.

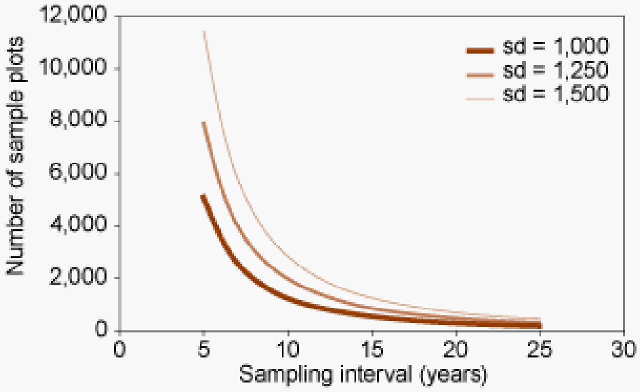


Figure 1. Sample size required with different sampling intervals calculated based on the assumption that the change to be detected is 11 g C m^{-2} per year. Standard deviation (sd) of measured carbon stock was assumed to be 1000 g C m^{-2}. Larger values (1250 and 1500 g C m^{-2}) were applied to show the sensitivity of the results to this assumption. Source: Mäkipää et al. 2008.

How much is model-based stratification expected to improve the efficiency of soil sampling?

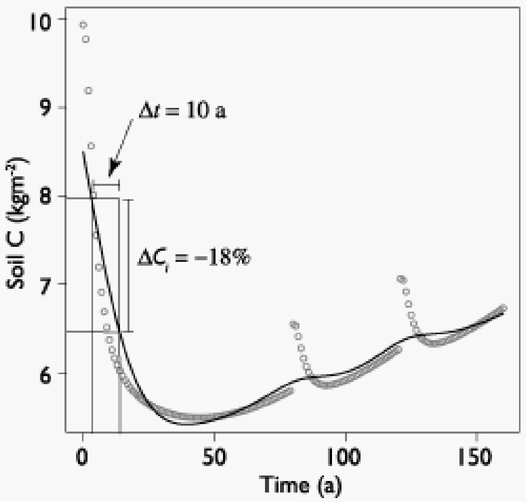


Figure 2. Example simulation of soil carbon stock using a Motti stand simulator combined with the Yasso soil carbon model. Predictions of soil carbon stock changes (with scenario uncertainties) were used as the basis of stratification of soil sampling. Source: Peltoniemi et al. 2007.

The efficiency of soil carbon monitoring can be improved and costs can be reduced by stratification. Stratification increases efficiency if a subdivision of the population is made so that within-stratum variability is lower than the variability within the entire population. Stratification by land-use category, soil type, and so on, i.e. by groups where the rates of soil carbon change are similar will improve the efficiency of the sampling targeted for soil carbon monitoring. Target variable in soil carbon monitoring is a change in soil carbon stock, but there is far less information on spatial variation of soil carbon changes than on soil carbon stock (Häkkinen et al. 2011). Therefore, information on the variation of carbon stock (or other measured soil variables) may be used for sampling design, but such information on stocks cannot be used for stratification since large soil carbon stock do not necessarily indicate a large change.

Soil models can help to design effective soil sampling. We tested how stratified sampling on an existing grid of forest inventory plots by model-predicted changes in soil C affects sampling efficiency (Fig.2) (Peltoniemi et al. 2007). Model-based stratification improved the sampling efficiency, even though the uncertainties both in model predictions and measurements are large. Stratification with the optimal allocation of plots can reduce the standard error of the mean by 20–34% relative to simple random sampling, with different assumptions of harvesting (and thinning) timing uncertainties. The use of optimal allocation (Neyman) is recommended for soil C change sampling design, since it succeeded up to 10% better (relative to SRS) than proportional or equal allocation (Peltoniemi et al. 2007).

What is the location and number of sampling points required within a plot to obtain a reliable carbon stock estimate?

Knowledge on the within-site variation in the soil carbon stock is used to determine the number of sub-samples per plot that yield estimates accurate and precise enough for monitoring purposes. The accuracy of the mean estimate increases with the number of samples per plot.

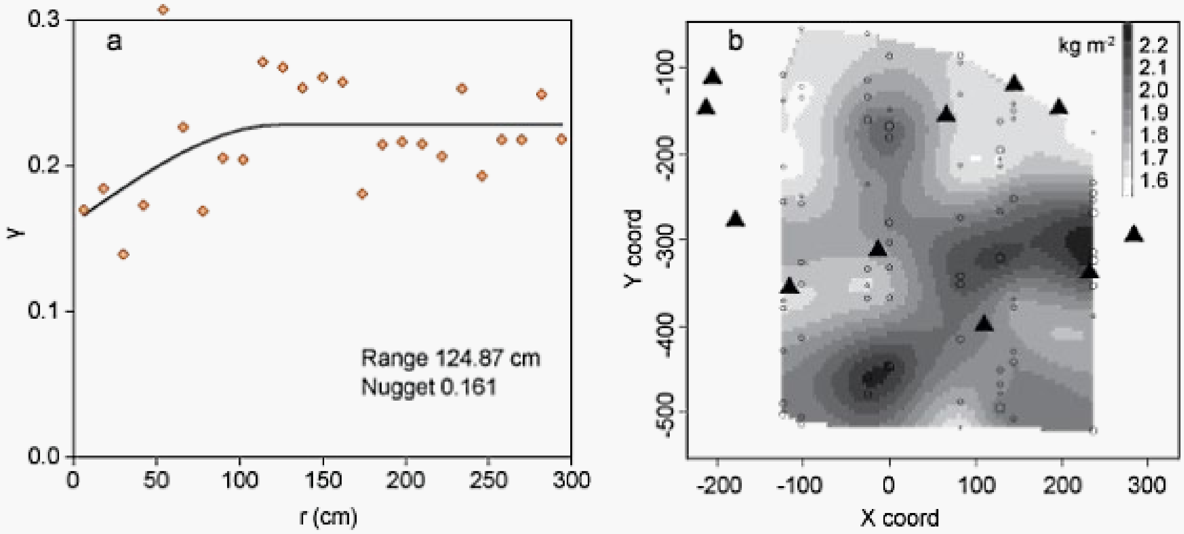


Figure 3. Example of variogram (A) and kriking interpolation (B) for soil C in the organic layer of one Scots pine stand. In the

figure 3B, the black triangles refer living trees and small circles refer soil sampling points. Source: Muukkonen et al. 2009.

We analysed within-site spatial variation of the carbon stock of humus layer on the basis of a total of 1,107 soil samples taken from eleven forest stands (six Scots pine stands and five Norway spruce stands) (Muukkonen et al. 2009). Spatial autocorrelation of carbon stock was lost in distances larger than 0.7–8.2 m depending on the site (Fig. 3). This indicates that the distance between non-correlated sampling points should be several metres (up to 8 m). More than twenty sub-samples per site should be taken to gain a reliable plot level estimate of the mean carbon stock of humus layer (Fig. 4) (Muukkonen et al. 2009, Mäkipää et al. 2010).

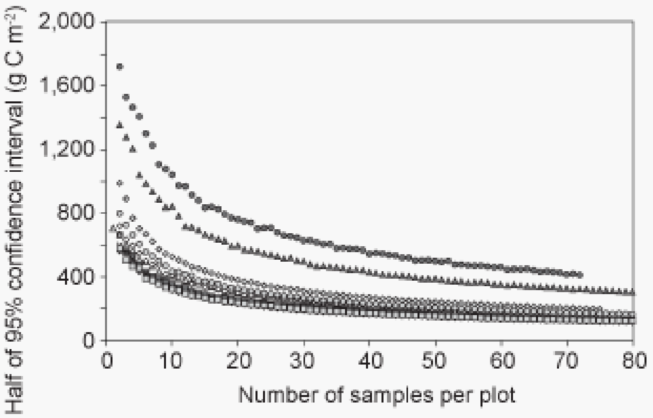


Figure 4. Confidence intervals of the carbon stock of organic layer according to sample size for ten different study sites. Source: Mäkipää et al. 2008.

References

Conen, F., Yakutin, M. V., & Sambuu, A. D. 2003. Potential for detecting changes in soil organic carbon concentrations resulting from climate change. Global Change Biology 9: 1515–1520.

Häkkinen, M., Heikkinen, J. & Mäkipää, R. 2011. Soil carbon stock increases in the organic layer of boreal middle-aged stands. Biogeoscience 8: 1279–1289.

IPCC 2003. Good practice guidance for land use, land-use change and forestry. IPCC, National Greenhouse Gas Inventories Programme, Kanagawa, Japan.

IPCC 2006. Guidelines for national greenhouse gas inventories. IPCC, National Greenhouse Gas Inventories Programme, Kanagawa, Japan.

Liski, J., Lehtonen, A., Palosuo, T., Peltoniemi, M., Eggers, T., Muukkonen, P. & Mäkipää, R. 2006. Carbon accumulation in Finland's forests 1922-2002 - an estimate obtained by combination of forest inventory data with modelling of biomass, litter and soil. Annals of Forest Science, 63: 687–697.

Mäkipää, R., Häkkinen, M., Muukkonen, P. & Peltoniemi, M. 2008. The costs of monitoring changes in forest soil carbon stocks. Boreal Environment Research, 13 (suppl. B): 120–130.

Muukkonen, P., Häkkinen, M. & Mäkipää, R. 2009. Spatial variation in soil carbon in the organic layer of boreal forest soil – implications for sampling design. Environmental Monitoring and Assessment, 158: 67–76.

Peltoniemi, M., Mäkipää, R., Liski, J. and Tamminen, P. 2004. Changes in soil carbon with stand age – an evaluation of a modeling method with empirical data. Global Change Biology 10: 2078–2091.

Peltoniemi, M., Heikkinen, J. & Mäkipää, R. 2007. Stratification of regional soil sampling by model-predicted change in soil carbon. Silva Fennica, 41: 527–539.

UNFCCC 1992. The United Nations Framework Convention on Climate Change.

UNFCCC 1997. Kyoto Protocol to the United Nations Framework Convention on Climate Change.

Yanai, R. D., Stehman, S., Arthur, M., Prescott, C., Friedland, A., Siccama, T., and Binkley, D. 2003.Detecting change in forest floor carbon. Soil Science Society of America Journal 67: 1583–1593.

Citation: Mäkipää, R., Muukkonen, P. and Peltoniemi, M. (2013). Monitoring changes in the carbon stocks of forest soils. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report]. Available at http://urn.fi/URN:NBN:fi:metla-201305087586. [Cited 2013-05-07].

Forest Condition Monitoring in Finland – National report

Preface and contents

Monitoring programmes

Results: Crown condition

Results: Intensive monitoring

Results: related projects

- Biosoil vegetation
- Biosoil soil
- Litter production
- Soil survey design
- **Case Valkea-Kotinen**

Publication list of the Programme

About the report

Photo: Metla/Erkki Oksanen

Valkea-Kotinen – long-term results from a Finnish ICP Integrated Monitoring (IM) catchment

By Jussi Vuorenmaa[1], Lauri Arvola[2], Martin Forsius[1], Tarja Hatakka[3], Petri Horppila[4], Martti Rask[5], Tuija Ruoho-Airola[6], Samuli Sairanen[2], Michael Starr[2], Liisa Ukonmaanaho[7], and Matti Verta[1]

1) Finnish Environment Institute, 2) University of Helsinki, 3) Geological Survey of Finland, 4) Centre for Economic Development, Transport and the Environment of Häme, 5) Finnish Game and Fisheries Research Institute, 6) Finnish Meteorological Institute, and 7) Finnish Forest Research Institute

Summary

Intensive and multidisciplinary ecosystem monitoring has been carried out in the Valkea-Kotinen Integrated Monitoring (UNECE IM) catchment since 1987, which is located in the Kotinen Nature Reserve area, Evo, Hämeenlinna. IM-progamme focuses on monitoring the long-term effects of air pollution and climate change to ecosystems. In this report we present the long-term effects of air pollutants and climate variation on forest condition, water chemistry and aquatic biota, and soil and ground water at Valkea-Kotinen Integrated Monitoring site. Furthermore, future scenarios for climate change and air pollutants, and their ecosystem effects in the Valkea-Kotinen area, are also assessed.

Introduction

The International Cooperative Programme on Integrated Monitoring of Air Pollution Effects on Ecosystems (ICP IM), like the ICP Forests programme, is part of the Effects Monitoring Strategy under the Convention on Long-range Transboundary Air Pollution (LRTAP). In Finland, the ICP IM programme was started in 1987 at four catchments: Valkea-Kotinen (Kotinen Nature Reserve area, southern Finland), Hietajärvi (Patvinsuo National Park, eastern Finland), Pesosjärvi (Oulanka National Park, northeastern Finland) and Vuoskojärvi (Kevo Strict Nature Reserve area, Lapland). Since 1999, the terrestrial ICP IM programme carried out on the intensive permanent monitoring plots in Hietajärvi and Valkea-Kotinen catchments has been integrated into the ICP Forests/EU Forest Focus Intensive Monitoring (Level II) programme, and monitoring activities at the two northernmost sites has been reduced. Since 2000, the entire ICP IM programme has been carried out in the Valkea-

Kotinen and Hietajärvi areas, and in 2006, the intensive and multidisciplinary ecosystem research and monitoring carried out on the Pallas area (Pallas-Yllästunturi National Park, Lapland) was integrated into the ICP IM programme. The IM areas Valkea-Kotinen and Pallas belong also to the Finnish Long-Term Socio-Ecological Research Network (FinLTSER).

In over 20 years of intensive research and monitoring in collaboration with universities and research institutes, the Valkea-Kotinen Integrated Monitoring site has gained invaluable scientific information on different ecosystems components. In this report we present some of our results on the long-term effects of air pollutants and climate variation on forest condition, water chemistry and aquatic biota, and soil and ground water at Valkea-Kotinen Integrated Monitoring site (see also Vuorenmaa et al. 2011). Furthermore, future scenarios for climate change and air pollutants, and their ecosystem effects in the Valkea-Kotinen area, are also discussed.

The ICP IM Programme

Integrated monitoring of ecosystems means the physical, chemical and biological measurements over time of different ecosystem compartments simultaneously at the same location. In practice, monitoring is divided into a number of compartmental subprogrammes that are linked by the use of the same parameters (cross-media flux approach) and/or same or close stations (cause-effect approach).

The main objectives of the ICP IM are:

- To monitor the biological, chemical and physical state of ecosystems (catchments/plots) over time in order to provide an explanation of changes in terms of causative environmental factors, including natural changes, air pollution and climate change, with the aim to provide a scientific basis for emission control.
- To develop and validate models for the simulation of ecosystem responses.
- To carry out biomonitoring to detect natural changes, in particular to assess effects of air pollutants and climate change.

The ICP IM sites (mostly forested catchments) are located in undisturbed areas, such as nature reserve areas or national parks. The ICP IM network presently covers 43 sites in 15 countries. The international Programme Centre is located at the Finnish Environment Institute in Helsinki. A manual detailing the protocols for monitoring each of the necessary physical, chemical and biological parameters are applied throughout the programme.

The Finnish ICP IM programme is coordinated by an expert group consisting of scientists from the key participating governmental institutes (Finnish Environment Institute, Finnish Game and Fisheries Research Institute, Finnish Meteorological Institute, Finnish Forest Research Institute, Geological Survey of Finland, Centres for Economic Development, Transport and the Environment in Häme, Pohjois-Karjala and Lapland) and Universities of Helsinki and Eastern Finland. The many others key Finnish research institutes, regional authorities and universities involved in environmental research have participated in the ICP IM Programme and have made considerable contributions.

The Valkea-Kotinen IM catchment

The Valkea-Kotinen catchment is located in the Kotinen Nature Reserve area in southern Finland (61° 14’ N, 25° 04’ E). It can be considered remote and is unaffected by local sources of air pollution. The study catchment is the smallest of the Finnish sites belonging to the ICP IM network. The catchment covers an area of 30 ha and has a range in relief of 25 m (Fig. 1). Map of the Valkea-Kotinen Integrated Monitoring area.). Upland forests cover about 62% and peatlands 25% of the total area. The

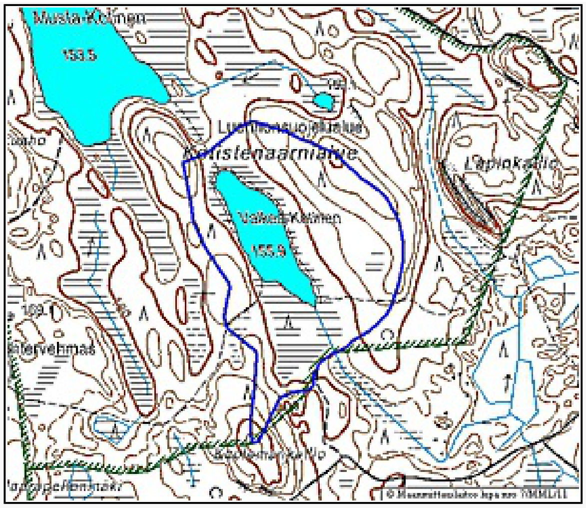


Figure 1. Map of the Valkea-Kotinen Integrated Monitoring area.

forests are mainly old virgin forests with several canopy layers. The area has a lot of dead standing trees and fallen decaying logs. The dominant trees are 100–170 years old Norway spruce (*Picea abies*). Old birch (*Betula spp.*), aspen (*Populus tremula*) and Scots pine (*Pinus sylvestris*) occur among the spruce. The oldest emergent trees are Scots pine over 350 years old. Traces of forest fires can be seen on old tree trunks. Forest fires occurred every 25–30 years in the late 18th and 19th centuries. The fires usually affected only a small part of the catchment.

The study catchment contains one headwater lake, Valkea-Kotinen. It is a small (3,6 ha), humic (mean TOC and water colour 12,9 mg l^{-1} and 110 mg Pt l^{-1}, respectively), acidic (mean pH-value 5,4 and alkalinity 0,021 mmol l^{-1}) and mesotrophic (mean total P 17 µg l^{-1}) lake. Lake Valkea-Kotinen is quite shallow (max. depth 6,5 m and mean depth 3,5 m) and usually frozen over between November and April. Runoff from the catchment is via a small outlet stream that flows southwards from Lake Valkea-Kotinen.

Most of the terrestrial monitoring has been carried out at eight permanent plots, in which two of plots (2 and 3) the monitoring of throughfall, stemflow, soil water and litterfall has been carried out.

The bedrock at the Valkea-Kotinen catchment is part of an old peneplane. The dominant bedrock type is 1900-million-year-old mica gneiss which had originally been clay and sand sediments. These sediments were then thoroughly metamorphosed so that their original structures are no longer apparent. The area is supra-aquatic, i.e. above the highest shoreline of the former stages of the Baltic. The highest coastline of the postglacial Yoldia Sea in the area is about 139 m above sea level. The area is covered with a 1-3-m-thick silty till. Histosols (peat) acount about one fifth of the the land area of the catchment and are located mainly around the lake. Most of the the nonorganic soil may be classified as dystric cambisols with transition to podzols, particularly on the upper slopes.

The annual mean (1971–2000) temperature is +3,9 °C, and precipitation averaged 631 mm per year. During the period 1989–2009, the annual mean runoff was 200 mm per year (Vuorenmaa and Horppila 2011).

Open figures in a new window →

Deposition of acidity and heavy metals

Bulk deposition in open

The monitoring of air quality and deposition started in 1987. Valkea-Kotinen is situated in a background area, without nearby sources of air pollution. Most of the deposition has been transported long distances and from beyond Finland. The air masses reaching Valkea-Kotinen are mostly from the west, and different directions between the north and south-west. Climatological data from nearby meteorological stations have also been used in modelling exercises and in evaluating IM data.

The monitoring results clearly confirm the success of international emission reduction measures. The acidity and associated concentrations of sulphate (SO_4) in precipitation have strongly declined over the period of monitoring

(Fig. 2) (Ruoho-Airola et al. 2004, 2011). The acidifying sulphate deposition in the area has decreased by around 70% from the levels of late 1980s. Ammonium (NH_4) concentrations in precipitation have declined similarly as those of sulphate. Concentrations of nitrate (NO_3), however, have declined much more slowly. Decreasing trend for concentrations of ammonium, nitrate and hydrogen ion (H^+) was leveled off in the mid-1990s, and changed little in recent years.

A decrease was also detected in deposition of harmful substances. Heavy metal deposition has been monitored at Valkea-Kotinen since 1990, and forms one of the longest time series in Finland. The deposition load of trace elements has decreased, particularly those of aluminium (Al), arsenic (As), lead (Pb) and mercury (Hg) (Kyllönen et al. 2009; Wännberg et al. 2010; Ruoho-Airola et al. 2011). Unfortunately, a favourable development cannot be seen for all heavy metals. For example, concentrations of chrome (Cr) in precipitation have increased significantly during the past 10 years (Fig. 3). The deposition of persistent organic pollutants (PCDD/F, dioxin-like PCB compounds) has decreased during the past ten years of monitoring (Ruoho-Airola et al. 2011, Korhonen et al. 2012).

Canopy interactions and throughfall

Because of the reactivity and large surface area of the canopy, forests are particularly effective receptors of airborne material arriving in both wet and dry forms. Thus, precipitation is intercepted and modified (substances withdrawn or added) by the canopy, and the loads of substances reaching the forest floor, termed throughfall, differs from the bulk deposition recorded in the open (see previous section).

Concentrations of base cations, SO_4 and dissolved organic carbon (DOC) are higher in throughfall than in open area bulk deposition, while concentrations of inorganic nitrogen compounds, NO_3 and NH_4, in throughfall are less than in open area bulk deposition (Table 1, pdf). Enrichment of ions in throughfall is due to the washing-off of dry deposition intercepted by the canopy or by canopy (tissue) leaching, while depletion is due to canopy uptake, either by foliage or canopy dwelling epiphytes.

As with bulk deposition, throughfall has shown a marked decline in acidity over the monitoring period, with concentrations of sulphate declining by an average of 0.05 mg l^{-1} a^{-1} (Fig. 4), Ukonmaanaho et al. 2009). Increasing trends of base cation concentrations and ANC (Acid Neutralizing Capacity), indicating recovery from acidification, have also taken place over the monitoring period. It is interesting that increasing trend of DOC concentrations in throughfall are detected during the past 20 years, at the same time than recovery from acidification. This may be due to improved forest conditions, resulting in increased tree biomass and litterfall, and consequently, increased decomposing organic matter.

Changes in aquatic and terrestrial ecosystems

Continuous measurement of runoff and regular monitoring of physicochemical properties of surface waters in the Valkea-Kotinen catchment started in 1987. Regular biological monitoring of aquatic ecosystem started in 1990. Aquatic biota, such as algae, zooplankton, macroinvertebrates and fish are sensitive indicators of environmental change, reflecting changes in the physical and chemical conditions of the aquatic ecosystem. Valkea-Kotinen is an important national reference lake in biological and chemical studies, since there are no direct human impacts on the biota and water quality. Permanent monitoring plots for forest and soil research were established in 1988/89.

Decreased anthropogenic deposition load has resulted in positive responses both to the aquatic and terrestrial ecosystems. For example, recovery from acidification in surface waters has taken place, indicated by decreases in sulphate, and increases in alkalinity and pH (Fig. 5). There are no clear signs that aquatic biota in the Lake Valkea-Kotinen has been affected by acid deposition (Arvola et al. 2011, Rask et al. 2011, Sairanen et al. 2011). Instead, the fish populations in Lake Valkea-Kotinen have been exposed to mercury, but the accumulation of mercury in fish over the long-term has decreased (Fig. 6) .

There are also indications of a recovery in the forest ecosystem (see above). However, the chemistry of soil-water and groundwater has not changed as markedly as that of lake water.

Impacts of climate change

At the same time, the Valkea-Kotinen area has experienced change in its local climate. During the last 50 years, the air temperature in Häme has risen by some 0.3–0.4 degrees per decade. In two decades, it is estimated that temperatures in Häme will be 1–2 degrees higher than in the reference period 1971–2000 (Fig. 7, Jylhä et al. 2011). A similar trend can be seen in research results for the whole of Finland (Tietäväinen et al. 2010). Researchers also forecast a rise in annual precipitation in Häme (Fig. 8, Ylhäisi et al. 2009, Jylhä et al. 2011). In the coming decades, however, this increase is expected to be slight in comparison to natural variations in rainfall. Although the relative increase in precipitation amounts is higher in winter than in summer, summertime rainfall will continue to be heavier than in wintertime. Heavy precipitation will intensify in all seasons. The proportion of precipitation falling as snow will decrease and snow cover diminish, especially in the early and late winter months.

Conditions in the water body of Valkea-Kotinen have changed due to a rise in air temperatures, which is affecting the functioning of ecosystems in small forest lakes. A clear indicator has been the length of ice-cover period, which has shortened by approximately 1,5 days each year in the course of the last 20 years (Fig. 9). During the same period, the temperatures of the lake's surface water layers have risen and the spring overturn of water column i.e. mixing of the lake water in May has weakened (Vuorenmaa and Horppila 2011). This has caused deteriorated oxygen conditions in the bottom and middle layers of the lake, and consequently, resulted in increased release of phosphorus from the bottom sediment.

The interaction of climate change with changing deposition has resulted in increasing leaching of organic carbon from the catchment, and increasing organic carbon concentration in the lake (Fig. 10). As the water colour turns darker, this will have an impact on temperatures. Weaker light will decrease phytoplankton production and the amount of zooplankton in the lake (Fig. 11, Arvola et al. 2011). With regard to fish, the slowdown in perch growth is the clearest change (Sairanen et al. 2011). Some of the changes can also be related to the food-web interactions.

Modelling the future

The large and long-term data sets of Valkea-Kotinen have been used for modeling purposes as well. According to the modeling results international emission control programmes for long-range transported air pollutants and greenhouse gases may have a great role in determining the future environmental conditions and ecosystem services during the next 100 years in the study area. For example, concentrations of DOC in the Lake Valkea-Kotinen are anticipated to increase due to climate change and changes in sulphate deposition (Fig. 12, Futter et al. 2009, Forsius 2011). The impacts of climate change on hydrological processes of Valkea-Kotinen have been studied using MyLake model (Saloranta et al. 2009). The results with model predict (according to SRES A2 scenario) an increase in lake surface temperatures of 4,6–5,1 °C in April and 3,5–4,6 °C in May by 2100. Correspondingly, the length of ice-cover period will be shortened by 56–89 days. These changes would probably have substantial effects on chemical and biological properties of the lake.

References

Arvola, L., Keskitalo, J., Lehtovaara, A., Peltomaa, E., Tulonen, T., Salonen, K. & Järvinen, M. 2011. Valkea-Kotisen planktonyhteisö ja sen muutokset.

Forsius, M. 2011. Valkea-Kotisen massataselaskelmat ja ekosysteemimallien sovellukset. In: Vuorenmaa, J., Arvola, L. & Rask, M. (eds.). Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, p. 84–87.

Futter, M., Forsius, M., Holmberg, M. & Starr, M. 2009. A long-term simulation of the effects of acidic deposition and climate change on surface water dissolved organic carbon concentrations in a boreal catchment. Hydrology Research 40: 291–305.

Jylhä, K., Ruosteenoja, K., Räisänen, J., Venäläinen, A., Tuomenvirta, H., Ruokolainen, L., Saku, S. & Seitola, S. 2009. Arvioita Suomen muuttuvasta ilmastosta sopeutumistutkimuksia varten. ACCLIM-hankkeen raportti 2009. Ilmatieteen laitos, Raportteja 2009:4. 102 s. (In Finnish, abstract, extended abstract and captions for figures and tables also in English)

Jylhä, K., Kersalo, J., Laapas, M. & Arvola, L. 2011. Ilmasto ja sen muuttuminen Lammin alueella. In: Vuorenmaa, J., Arvola, L. & Rask, M. (eds.). Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, p. 27–31.

Korhonen, M., Verta, M., Salo, S., Vuorenmaa, J., Assmuth, T., Kiviranta, H. & Ruokojärvi, P. 2012. The deposition of PCDD/Fs and dioxin-like PCBs in Finland (manuscript).

Kyllönen, K., Karlsson, V. & Ruoho-Airola, T. 2009. Trace element deposition and trends during a ten year period in Finland. Science of the Total Environment 407: 2260–2269.

Rask, M., Määttänen, K., & Vinni, M. 2011. Valkea-Kotisen rantavyöhykkeen ja syvänteen pohjaeläimistö. In: Vuorenmaa, J., Arvola, L. & Rask, M. (eds.). Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, p. 75–77.

Ruoho-Airola, T., Anttila, P. & Salmi, T. 2004. Airborne sulphur and nitrogen in Finland — trends and exposure in relation to air transport sector. Journal of Environmental Monitoring 6: 1–11.

Ruoho-Airola, T., Verta, M. & Korhonen, M. 2011. Ilmasta tuleva kuormitus ja sen muutokset Valkea-Kotisen alueella. In: Vuorenmaa, J., Arvola, L. & Rask, M. (eds.). Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, p. 21–26.

Sairanen, S., Vesala, S. & Rask, M. 2011. Valkea-Kotisen ahvenpopulaatiossa tapahtuneet muutokset. In: Vuorenmaa, J., Arvola, L. & Rask, M. (eds.). Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, p. 78–83.

Saloranta, T. M., Forsius, M., Järvinen, M. & Arvola, L. 2009. Impacts of projected climate change on thermodynamics of a shallow and deep lake in Finland: Model simulations and Bayesian uncertainty analysis. Hydrology Research 40: 234–248

Starr, M. & Ukonmaanaho, L. 2004. Levels and characteristics of TOC in throughfall, forest floor and soil solution in undisturbed boreal forest ecosystems. Water, Air and Soil Pollution: Focus 4: 715–729.

Tietäväinen, H., Tuomenvirta, H. & Venäläinen, A. 2010. Annual and seasonal mean temperatures in Finland during the last 160 years based on gridded temperature data. International Journal of Climatology 30 (15): 2247–2256. DOI: 10.1002/joc.2046

Ukonmaanaho, L. & Starr, M. 2002. Major nutrients and acidity: budgets and trends at four remote boreal stands in Finland during the 1990s. The Science of the Total Environment 297: 21–41.

Ukonmaanaho, L., Starr, M., Lindroos, A.-J. & Derome, J. 2009. Long-term changes in sulphate and acid neutralizing capacity of throughfall and effects on soil water DOC concentrations in Finnish forests. In: Kaennel Dobbertin, M. (ed.). Long-term ecosystem research: understanding the present to shape the future. Birmensdorf. P. 106.

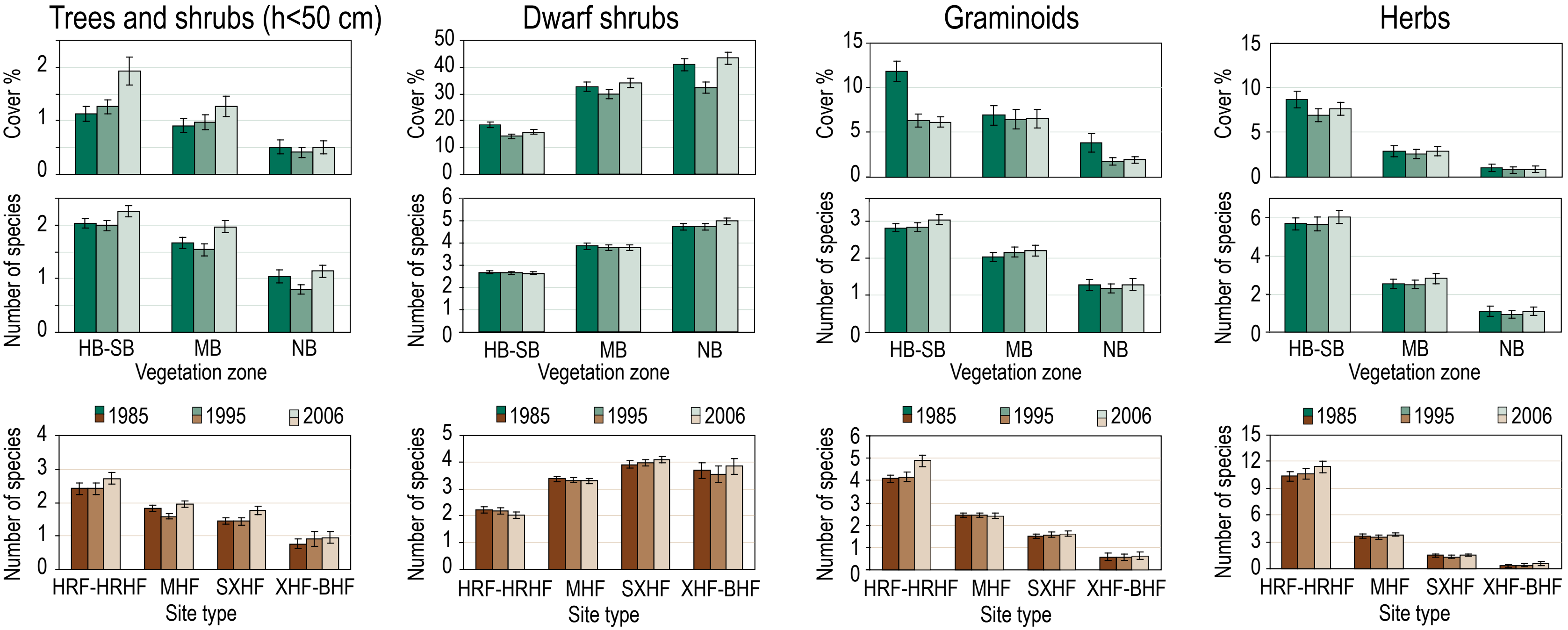
Vuorenmaa, J. & Horppila, P. 2011. Valkea-Kotisen veden laatu ja valuma-alueen hydrologiset olot sekä niiden pitkäaikaismuutokset.

Vuorenmaa, J., Arvola, L. & Rask, M. (eds.).2011. Hämeen ympäristö muutoksessa. Kaksikymmentä vuotta ympäristön huippututkimusta Valkea-Kotisen alueella. Suomen ympäristö 34/2011, 104 p.

Wängberg, I., Aspmo Pfaffhuber, K., Berg, T., Hakola, H., Kyllönen, K., Munthe, J., Porvari, P. & Verta, M. 2010. Atmospheric and catchment mercury concentrations and fluxes in Fennoskandia. TemaNord 2010:594. Nordic Council of Ministers, Copenhagen 2010.

Ylhäisi, J. S., Tietäväinen, H., Peltonen-Sainio, P., Venäläinen, A., Eklund, J., Räisänen, J. & Jylhä, K. 2010. Growing season precipitation in Finland under recent and projected climate. National Hazards and Earth System Sciences 10:1563–1574. DOI:10.5194/nhess-10-1563–2010.

Citation: Vuorenmaa, J., Arvola, L., Forsius, M., Hatakka, T., Horppila, P., Rask, M., Ruoho-Airola, T., Sairanen, S., Starr, M., Ukonmaanaho, L. and Verta, M. (2013). Valkea-Kotinen – long-term results from a Finnish ICP Integrated Monitoring (IM) catchment. In: Merilä, P. & Jortikka, S. (eds.). Forest Condition Monitoring in Finland – National report. The Finnish Forest Research Institute. [Online report].
Available at http://urn.fi/URN:NBN:fi:metla-201305087587. [Cited 2013-05-07].



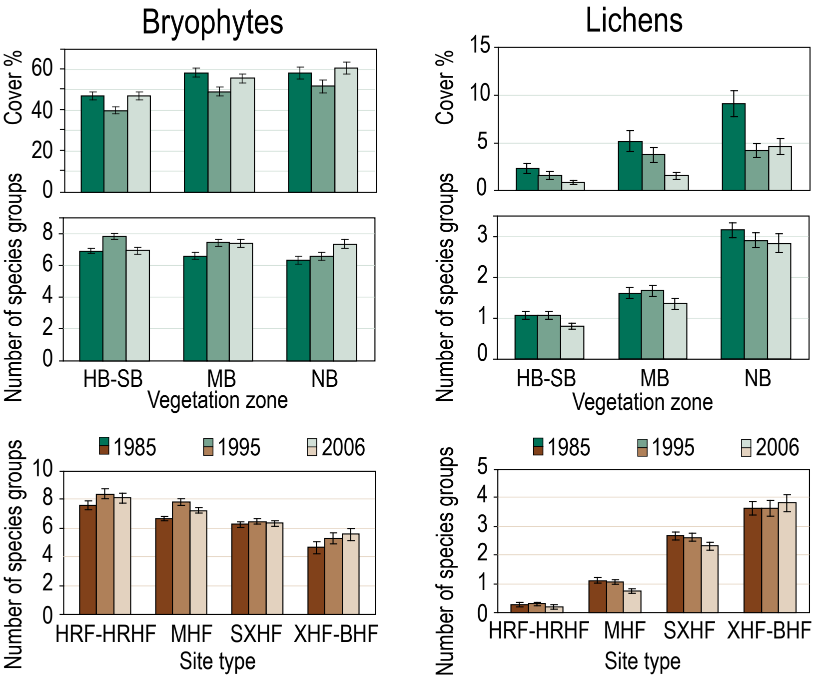


Figure 2. Mean percentage cover and number of species (± standard error) in different plant groups. Percentage cover and number of species are calculated across the boreal subzones. Number of species is also given across forest site types (fertility levels).

Subzones of the boreal zones
HB-SB = Hemiboreal and Southern boreal
MB = Middle boreal
NB = Northern boreal

Forest site types
HRF-HRHF = herb rich forests and herb-rich heath forests
MHF = mesic heath forests
SXHF = sub-xeric heath forests
XHF = xeric heath forests

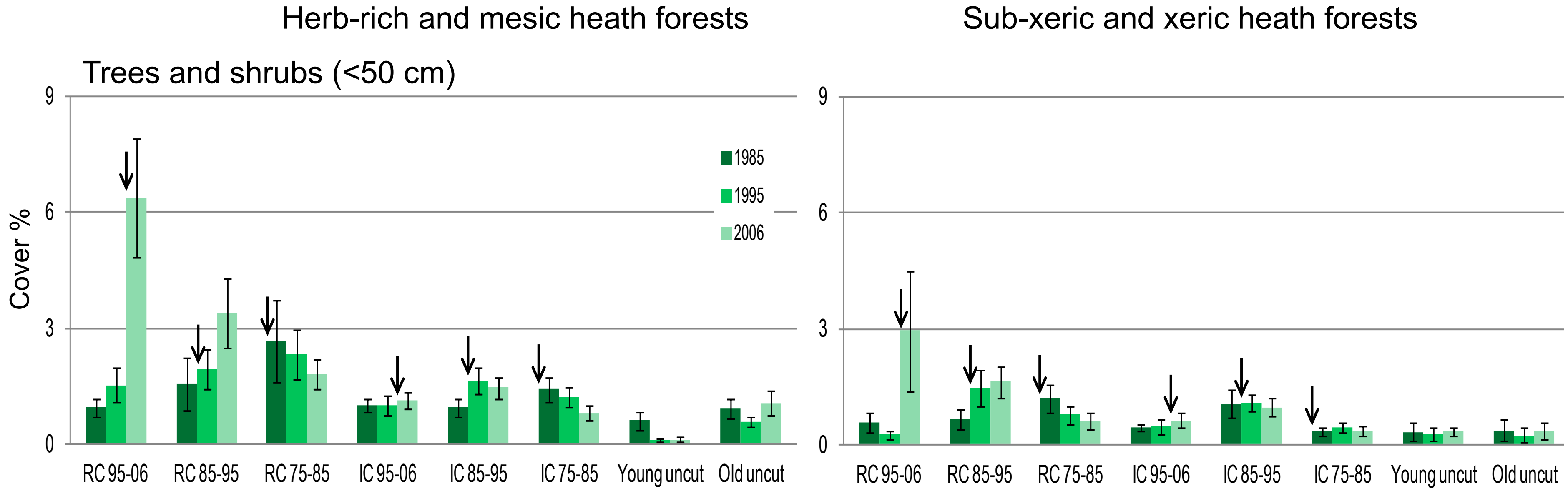


Figure 3a. Mean percentage cover (± standard error) of tree seedlings/saplings and shrubs (height <50 cm) in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

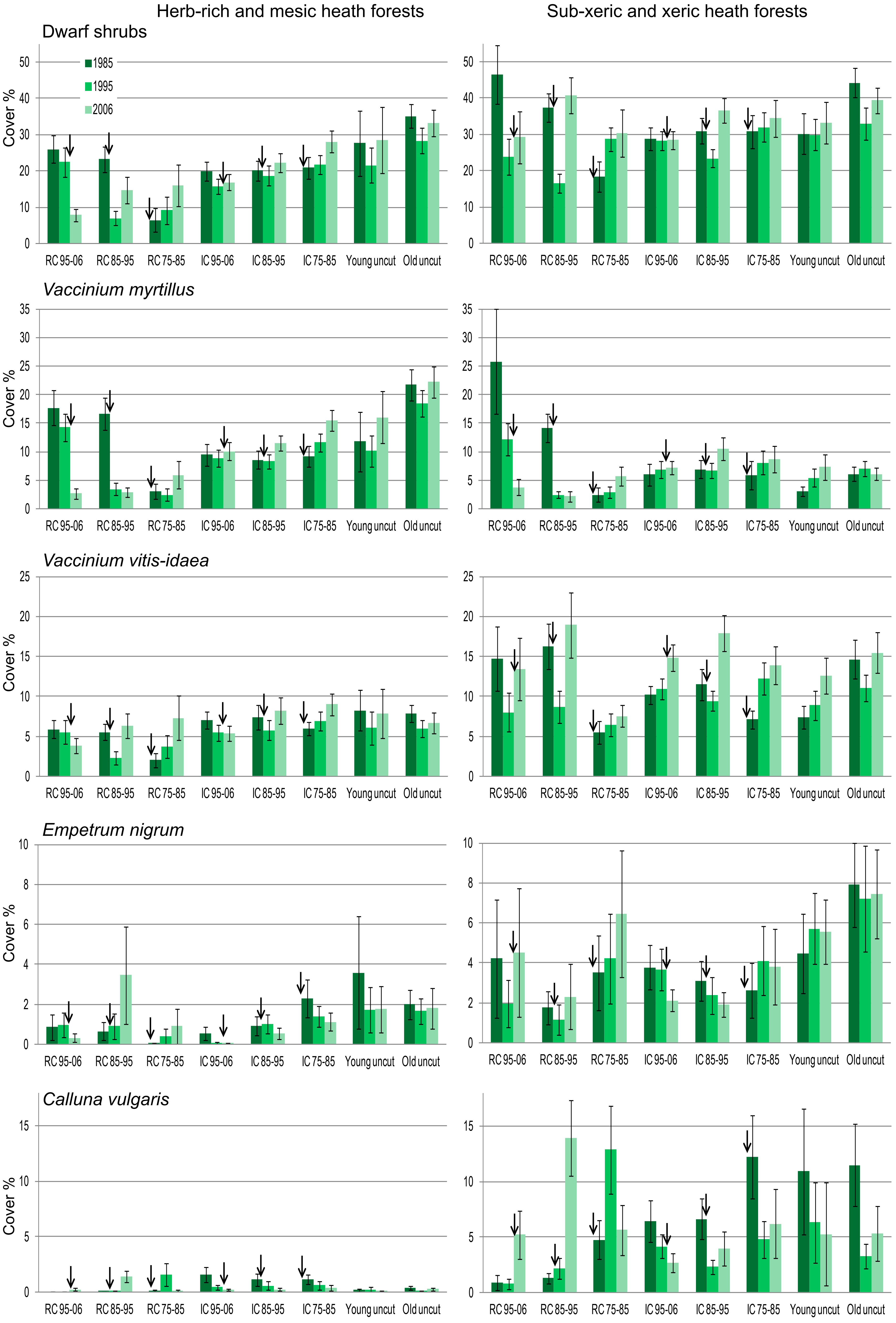


Figure 3b. Mean percentage cover (± standard error) of dwarf shrubs and some selected taxa in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

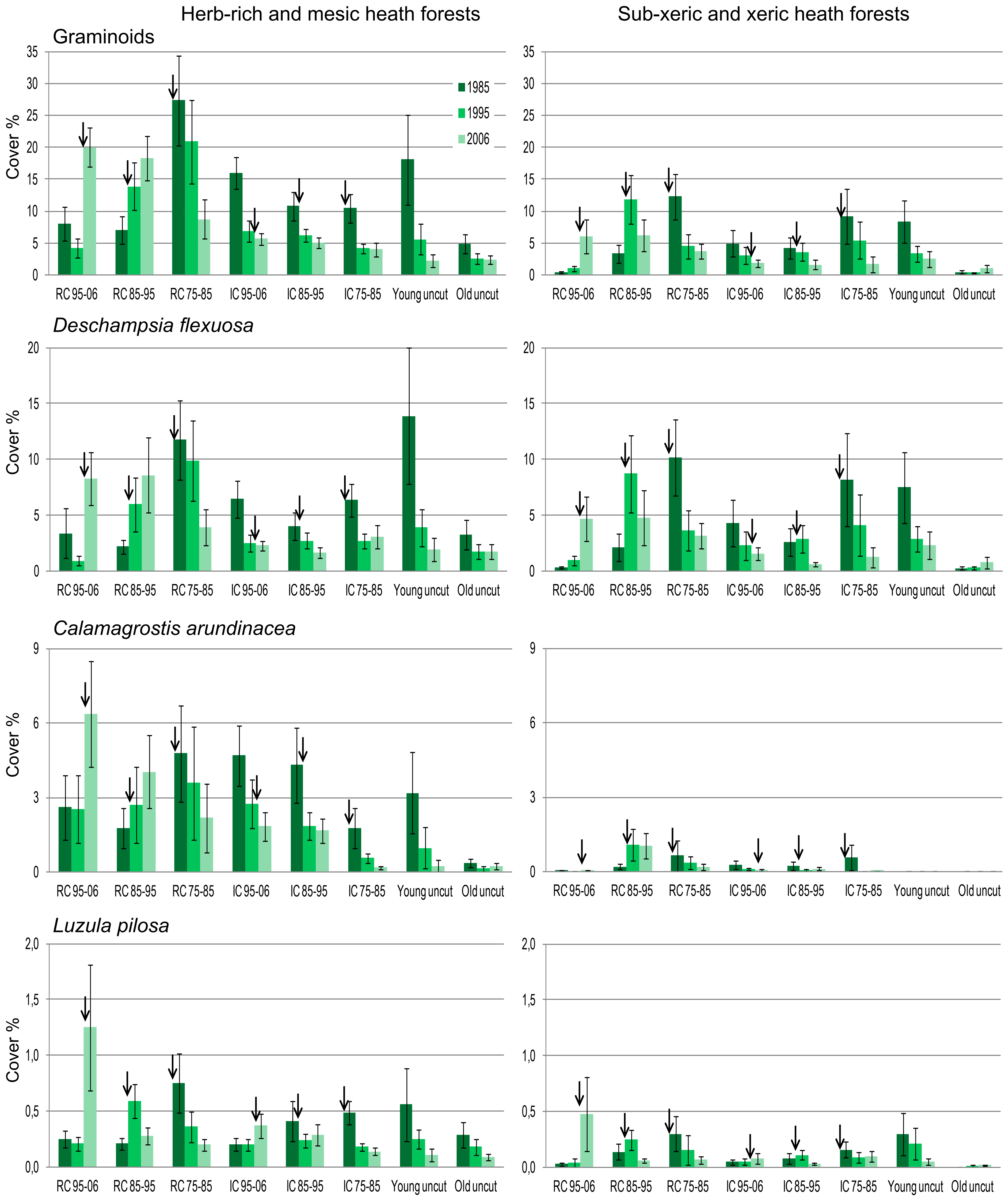


Figure 3c. Mean percentage cover (± standard error) of graminoids and some selected taxa in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

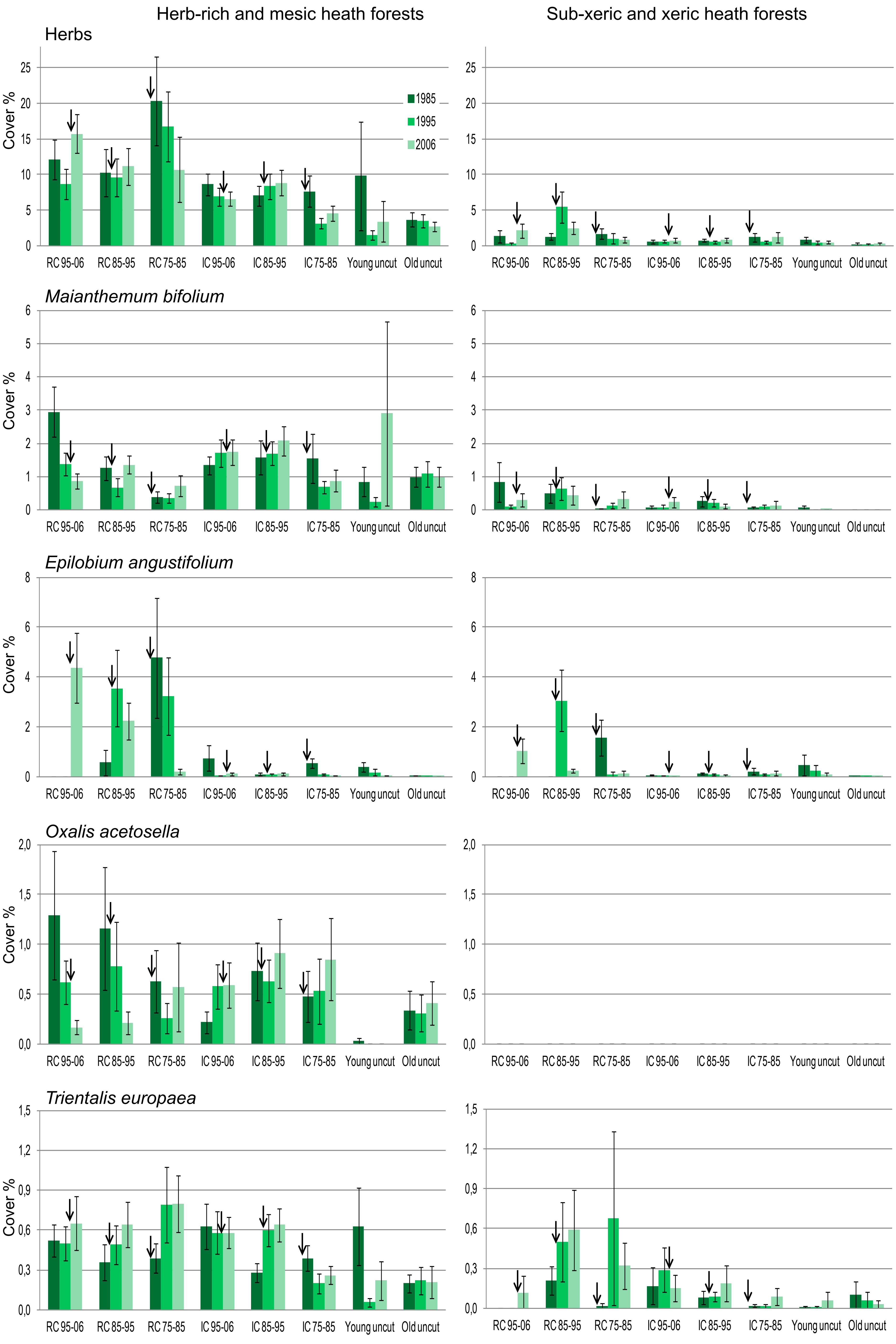


Figure 3d. Mean percentage cover (± standard error) of herbs and some selected taxa in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

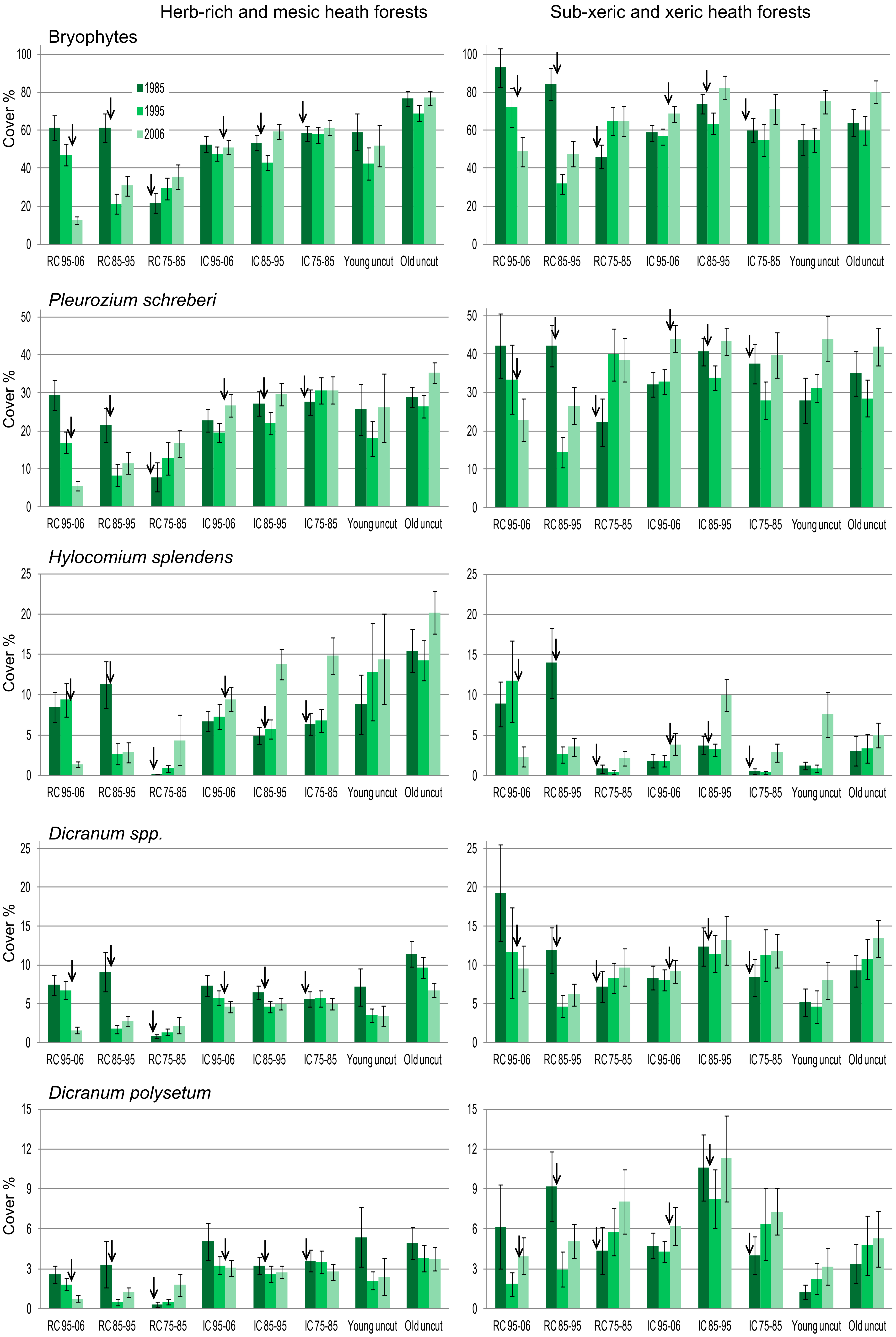


Figure 3e. Mean percentage cover (± standard error) of bryophytes and some selected taxa in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments

Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.

RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

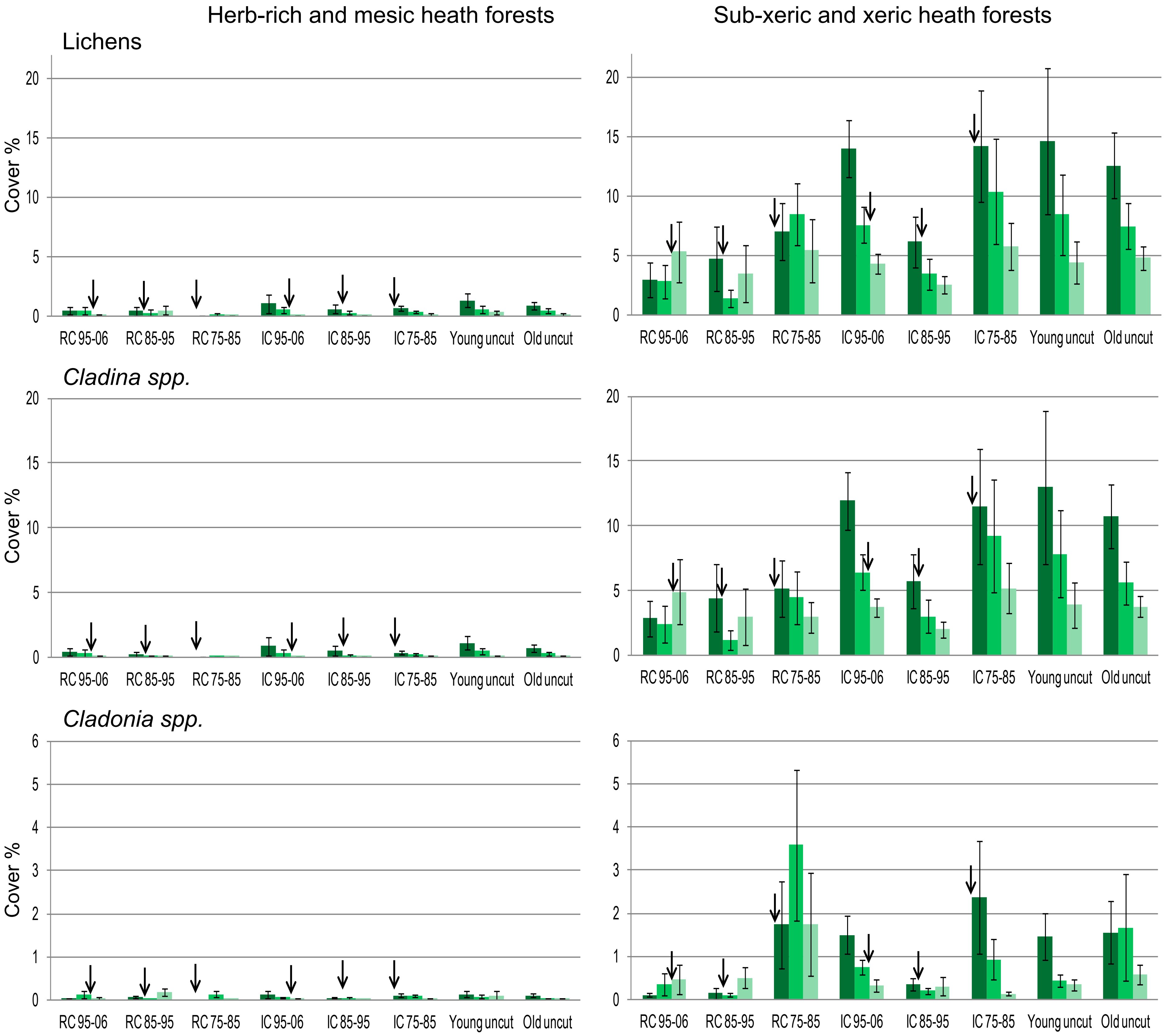


Figure 3f. Mean percentage cover (± standard error) of lichens and some selected taxa in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting.

Silvicultural treatments

Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.

RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

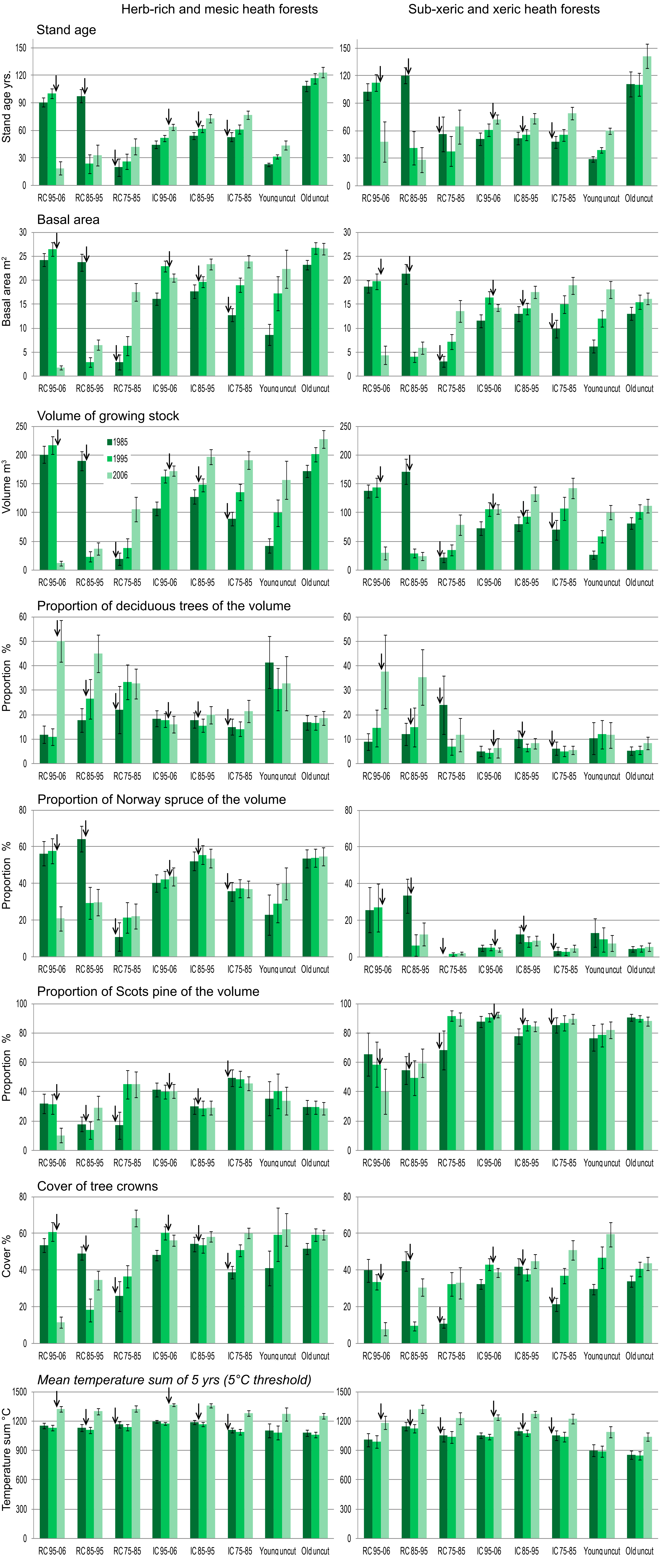


Figure 3g. Mean values (± standard error) of stand characteristics and the effective temperature sum in herb-rich and mesic heath forests (left panel) and in sub-xeric and xeric heath forests (right panel). The arrows denote the time of forest cutting. Please notice that these results represent the included sample plots rather than Finland's forests in general. For information on Finland's forests, please see Finnish Statistical Yearbook of Forestry (Aarne & Ylitalo 2012).

Silvicultural treatments
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).

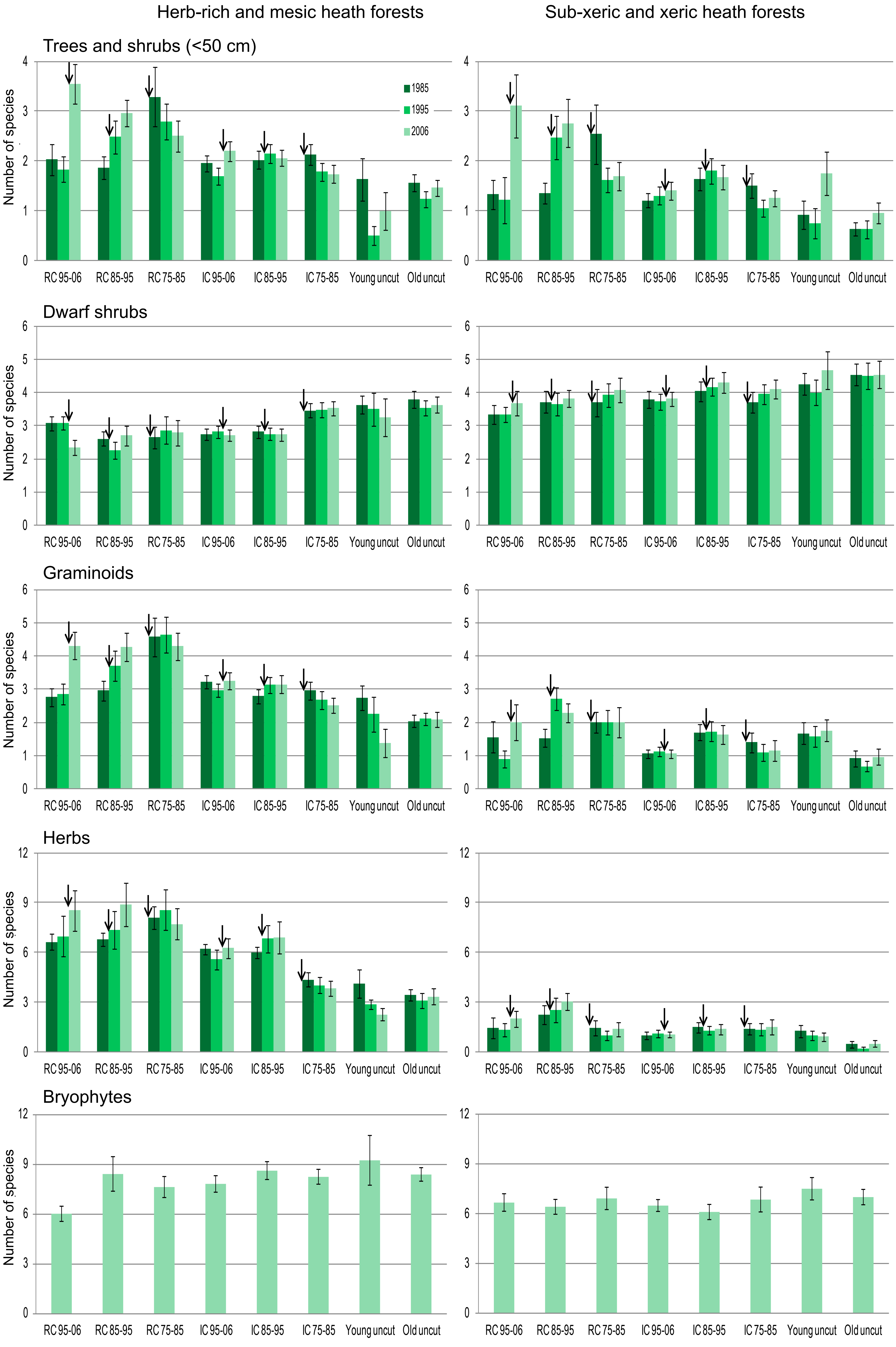


Figure 4. Mean number of species (± standard error) in different plant groups. Arrows denote the time of forest cutting. For bryophytes, only the year 2006 is included.

Silvicultural treatments.
Number of plots (n) given first for herb-rich and mesic heath forests and then for sub-xeric and xeric heath forests.
RC 95-06 = regeneration cutting in 1995-2006 (n = 29 and n = 9)
RC 85-95 = regeneration cutting in 1985-1995 (n = 23 and n = 17)
RC 75-85 = regeneration cutting in 1975-1985 (n = 14 and n = 13)
IC 95-06 = intermediate cutting in 1995-2006 (n = 59 and n = 43)
IC 85-95 = intermediate cutting in 1985-1995 (n = 48 and n = 30)
IC 75-85 = intermediate cutting in 1975-1985 (n = 46 and n = 20)
Young uncut = under 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 8 and n = 12)
Old uncut = over 55-year-old stands (in 1985), no cuttings in 1975-2006 (n = 48 and n = 24).