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Forest Condition Monitoring in Finland

National report 2001

Edited by
Heli Rautjärvi, Liisa Ukonmaanaho and Hannu Raitio

PARKANON TUTKIMUSASEMA – PARKANO RESEARCH STATION

METLA

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Preface

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 is based on international agreements on the long-range transportation of air pollutants (LRTAP). In member countries of the European Union, forest condition monitoring is based on regulations enacted in 1986 and 1994, and on modifications subsequently made to these regulations. In Finland, the Finnish Forest Research Institute (Metla) is responsible for carrying out annual forest vitality and health surveys on a 460 permanent plot network (Level I, extensive monitoring), and for studying the relationships between forest condition and air pollution and other stress factors on a network of 31 stands located throughout the country (Level II, intensive monitoring). This report presents the results of monitoring carried out within the framework of the Finnish ICP Forests programme during 1998–2001, as well as the results of other studies related to forest health.

Alkusanat

Suomi on vuodesta 1985 lähtien osallistunut yleiseurooppalaiseen metsien terveydentilan seurantaohjelmaan (ICP metsäohjelma), joka perustuu kansainväliseen ilman epäpuhtauksien kaukokulkeutumista koskevaan sopimukseen (LRTAP). Euroopan unionin jäsenmaissa metsien terveydentilan seuranta pohjautuu vuosina 1986 ja 1994 vahvistettuihin säädöksiin ja niihin myöhemmin tehtyihin täydennyksiin. Metsäntutkimuslaitos (Metla) inventoi puiden kunnon vuosittain kansainvälisesti sovituin menetelmin noin 460 pysyvällä havaintoalalla (Taso I, laaja-alainen seuranta). Metsien kunnon ilman epäpuhtauksien sekä muiden stressitekijöiden välisiä vuorosuhteita tutkitaan 31 metsikössä eri puolilla Suomea (Taso II, intensiivinen seuranta). Tässä vuosikatsauksessa esitetään ICP metsäohjelman Suomea koskevia tuloksia vuosilta 1998–2001 sekä muiden Suomen metsien terveydentilaa käsittelevien tutkimusten tuloksia.

Summary

This report includes the results of background air quality monitoring in Finland during 2000. The crown condition survey on the extensive monitoring (Level I) plots was carried out in 2001. Deposition monitoring, the crown condition survey and the understorey vegetation survey were carried out on the intensive monitoring plots (Level II) in 2000. Soil solution monitoring on the Level II plots covers the period 1998–2000, and phenological observations were made during 2001. This report also includes biotic and abiotic forest damage in 2001, as well as a report of the international ECE/EU cross-calibration course held in 2001. The needle trace method is presented as a pilot study.

The weather in 2000 was characterised by high annual temperatures throughout the country. It is becoming more apparent that the temperature has increased in comparison with the normal period 1961–1990. This has especially been the case during the winter and autumn seasons. Precipitation has also increased more often in the winter season and, due to the increase in temperature during this season, the precipitation more frequently falls as rain. During summer and autumn the precipitation in 2000 increased in several locations compared to the normal value. The meteorological conditions in Finland result in a clear seasonal behaviour for many of the pollutants in the atmosphere. Due to the abatement programmes, the concentrations of primary pollutants in the atmosphere and the deposition of acidifying components have decreased considerably over the years. Deposition of the major components affecting acidification and many heavy metals clearly decrease from south to north, the southern part of the country receiving 2–8 times that in the northernmost part. Annual deposition values for the acidifying components were lower in 2000 than the mean values for 1987–1996. The concentrations of gaseous pollutants have decreased since 1985. The downward trend during the last ten years is steeper in winter than in summer. The largest decrease was recorded in the south-western part of the country, whereas the change was smallest in the far north and north-east.

The deposition of acidifying and eutrophicating compounds, base cations, chloride and dissolved organic carbon (DOC) were monitored in open areas and within eight Norway spruce and eight Scots pine stands during 2000. Sulphatedeposition in Finland was at a relatively low level compared to the situation in many parts of central Europe. There was a clear decrease in SO_4 deposition in open areas and in stand throughfall on moving from south to north. In general, Norway spruce canopies caused a stronger increase in the SO_4 flux on the forest floor than pine canopies. Nitrogen deposition was relatively low in Finland compared to many parts of central Europe. Nitrogen deposition was the highest in southern Finland. The NH_4, NO_3 and N_{total} fluxes within the stand were lower than in open areas on all the spruce and pine plots, apart from the Uusikaarlepyy plot on the western coast of Finland. Emissions from a local NH_3 point source increased the NH_4 and N_{total} fluxes in stand throughfall on this spruce plot. The DOC fluxes in stand throughfall decreased on moving from south to north, indicating the importance of climatic factors in carbon cycling within the stand.

The proportion of moderately defoliated (over 25 %) or severely (over 60 %) defoliated trees of Scots pine, Norway spruce and broadleaves (all species) decreased slightly compared to 2000 on the Level I plots. The average tree-specific degree of defoliation was 9 % in pine, 19 % in spruce and 12 % in broadleaves in 2000. High stand age and weather and climatic factors have a considerable effect on defoliation in background areas of Finland. There was no correlation between the defoliation pattern and the modelled total sulphur and nitrogen deposition pattern at the national level. The most serious forest damage in 2001 was caused by the November storms, which were estimated to have felled over 7 million m^3 of trees in southern Finland with a

total value of 300 million euros. In addition to storms, heavy snowfall bent and snapped trees in Pohjois-Karjala and Pohjois-Savo especially. Due to the very warm and rainy autumn in 2000, fungal diseases were more common in 2001 than in 2000. Scleroderris pine canker occurred at its highest frequency in ten years, and rust diseases were common throughout the country, but no serious insect outbreaks were reported. Moose damage was estimated to have affected about one fifth of the total area of seedling stands. The vole populations were low in the spring, but started to increase during the summer.

Soil solution monitoring was carried out during 1998–2000 on the 13 Level II plots using zero tension lysimeters and tension lysimeters. The results indicate that the deposition of acidifying compounds has not resulted in the development of extreme values for acidity and acidification parameters, nor were there any indications of a reduction in site fertility as a result of the deposition load. Two of the Norway spruce plots showed signs of strong acidity and acidification, but these were due to natural soil formation processes (Uusikaarlepyy) and to earlier forest management practices (Punkaharju). No clear trends in soil solution parameters along the climatic south-north gradient were found.

The average defoliation level of Scots pine decreased from 10.7 % to 10 % and that of Norway spruce increased from 16.6 % to 17.4 % compared to the situation in 1999 on the Level II plots. The proportion of discoloured Scots pine was 0.7 % (4.7 % in 1999) and that for Norway spruce 14.4 % (17 % in 1999), and 25 % of the discoloured Norway spruces also had signs of fungal infection.

The cover percentages of the understorey plant species have remained relatively constant on six of the ICP Forest/Level II plots during the monitoring period 1998–2000. The changes correlated positively with the amount of precipitation, and the moisture conditions also appeared to regulate between-species changes in the coverages of moss species.

The results of intensive phenological assessments made on four Norway spruce Level II plots in Finland during 2001 are also presented, as well as the connections with temperature data and comparison with the results for 2000.

This report also includes a short and general summary of the technique and possibilities of the needle trace method (NTM) in retrospective studies. Since its introduction at the turn of the 1980's, NTM has become firmly established as a tool in retrospective forest ecology, pathology, entomology, and forest health monitoring. The prospects in dendroecology and dendroclimatology are also promising. NTM readily reveals the needle history of the entire tree during the period prior to the start of regular foliage observations. The results and experiences from the international ECE/EU cross-calibration course, which was held in Finland on 4–6 June, 2001, are also presented.

Yhteenveto

Suomen tausta-alueiden ilmanlaadun seurantatulokset ovat vuodelta 2000. Metsien terveydentilan laaja-alaisen seurannan (taso I) havaintoaloilla arvioitiin latvuskuntoa vuonna 2000. Metsäekosysteemien intensiivisen seurannan (taso II) havaintoaloilla tehdyn laskeuman seurannan sekä latvuskunnon ja aluskasvillisuuden kartoitusten tulokset kertovat vuoden 2000 tilanteesta. Maaveden laadun seuranta intensiivisen seurannan havaintoaloilla (taso II) kattaa ajanjakson 1998–2000 ja fenologinen seuranta on tehty vuonna 2001. Lisäksi kerrotaan metsätuhoista vuonna 2001 ja kesäkuussa 2001 järjestetystä metsien kunnon arvioinnin kalibrointikurssista sekä pilottitutkimuksena neulasjälkimenetelmän periaatteesta.

Vuodesta 1996 lähtien talvikuukausien keskilämpötilat ovat olleet pitkäaikaisia keskiarvoja (1961–1996) korkeampia eikä vuosi 2000 tehnyt poikkeusta. Myös syksy oli varsin lämmin ja Lappiinkin tuli kunnon lumipeite vasta vuoden lopussa. Sademäärä on lisääntynyt varsinkin talvella ja lämpötilan nousun vuoksi talviaikaiset sateet tulivat yhä useammin vetenä. Vuonna 2000 kesän ja syksyn sademäärät olivat normaaliarvoihin verrattuna korkeammat useilla paikkakunnilla. Suomen tausta-alueilla useiden ilman epäpuhtauksien pitoisuudet vaihtelevat vuodenaikojen mukaan johtuen ilmastosta. Viime vuosien aikana ilman primääriepäpuhtauksien pitoisuudet ja happamoittavien yhdisteiden laskeumat ovat vähentyneet merkittävästi päästörajoitussopimusten vaikutuksesta. Happamoittavien yhdisteiden ja eräiden raskasmetallien laskeuma pienenee selvästi etelästä pohjoiseen. Happamoittava laskeuma oli vuonna 2000 alempi kuin vuosien 1987–1996 keskimääräinen arvo. Ilman kaasumaisten yhdisteiden pitoisuudet ovat vähentyneet vuodesta 1985 lähtien. Viimeisten kymmenen vuoden aikana lasku on ollut voimakkaampaa talvella ja suurin muutos mitattiin Lounais-Suomessa. Pohjoisimmassa osassa maata sekä Koillis-Suomessa pitoisuuksien väheneminen oli vähäisintä.

Happamoittavien ja rehevöittävien yhdisteiden, emäskationien, kloridin sekä liukoisen orgaanisen hiilen (DOC) laskeumaa seurattiin vuonna 2000 kahdeksassa kuusikossa ja kahdeksassa männikössä sekä niiden viereisillä avoimilla paikoilla. Sulfaattirikin laskeuma oli Suomessa alhainen verrattuna moniin alueisiin Keski-Euroopassa ja väheni sekä avoimella paikalla että metsikkösadannassa Etelä-Suomesta Pohjois-Suomeen. Kuusen latvukset lisäsivät metsikkösadannan SO_4-laskeumaa enemmän kuin männyn latvukset sadeveden kulkiessa latvuskerroksen läpi. Myös typpilaskeuma oli Suomessa Keski-Eurooppaan verrattuna alhainen. Ammonium-, nitraatti- ja kokonaistyppilaskeuma vähenivät sadeveden kulkiessa latvuskerroksen läpi kaikilla kuusi- ja mäntykohteilla Uudenkaarlepyyn kohdetta lukuunottamatta. Liukoisen orgaanisen hiilen (DOC) laskeuma väheni metsikkösadannassa siirryttäessä eteläisiltä tutkimuskohteilta Pohjois-Suomeen, mikä kertoo ilmastollisten tekijöiden tärkeydestä hiilen kierrossa.

Metsien terveydentilan laaja-alaisen seurannan (Taso I) mukaan harsuuntumattomien mäntyjen (0–10 %) osuus pieneni ja lievästi harsuuntuneiden mäntyjen (10–25 %) osuus kasvoi hieman vuoteen 2000 verrattuna. Kaikilla puulajeilla yli 25 % harsuuntuneiden puiden osuus väheni lievästi. Keskimääräinen harsuuntumisaste on kaikilla puulajeilla pysynyt viime vuosina melko vakaana, männyllä se oli 9 %, kuusella 19 % ja lehtipuilla 12 % vuonna 2001. Ilman epäpuhtauksien ja neulaskadon välillä ei vuonna 2001 havaittu merkitsevää yhteyttä. Sienitaudeista versosurmaa esiintyi männyllä runsaammin kuin vuosikymmeneen ja ruostetaudit olivat yleisiä koko maassa, sen sijaan vakavia hyönteistuhoja ei todettu. Hirvituhoja arvioitiin esiintyneen noin viidenneksellä taimikkopinta-alasta ja myyräkannat kääntyivät nousuun kesän aikana. Merkittävimmät metsätuhot vuonna 2001 aiheuttivat kuitenkin marraskuun myrskyt, joiden arvioitiin kaataneen puuta eteläisestä Suomesta yli 7 miljoonaa kuutiometriä, arvol-

taan miltei 300 miljoonaa euroa. Myrskyjen lisäksi lumi taivutteli ja katkoi puita varsinkin Pohjois-Karjalassa ja Pohjois-Savossa.

Metsäekosysteemien intensiivisessä seurannassa (ICP metsäohjelma/ taso II) oli vuonna 2000 mukana 721 mäntyä ja 800 kuusta. Edelliseen vuoteen verrattuna mäntyjen keskimääräinen harsuuntumisaste aleni hieman 10,7 %:sta 10 %:iin ja kuusten nousi 16,7 %:sta 17,4 %:iin. Männyistä värioireellisia oli 0,7 % ja kuusista 14,4 %, joista neljännes kärsi myös sienitaudeista. Aluskasvillisuuden lajien peittävyyksissä havaittiin vain vähäisiä muutoksia seurantajakson (1998–2000) aikana. Putkilokasvien peittävyyksien muutokset vaihtelivat samansuuruisesti sademäärän kanssa ja kosteustaso näytti säätelevän myös sammallajien peittävyyseroja. Kasvifenologista seurantaa tehtiin vuonna 2001 neljässä intensiiviseurannan kuusikossa. Raportissa tarkastellaan lämpösumman kehitystä keväällä 2000 ja 2001 sekä silmunpuhkeamisen ja kukinnan ajoittumista keväällä 2001.

Maaveden laatua on seurattu intensiivisen seurannan 13 havaintoalalla vajovesi- ja imulysimetrien avulla. Happamoittavien yhdisteiden laskeuma ennen seurantajaksoa (1998–2000) ja sen kuluessa ei ole aiheuttanut poikkeavia arvoja happamuutta ja happamoitumista kuvaavissa maaveden tunnuksissa. Laskeuman ei ole myöskään havaittu aiheuttaneen muutoksia kasvupaikan ravinteisuudessa. Kahdessa maaperältään happamassa kuusikossa havaittiin happamoitumista, joka johtui luontaisista maaperäprosesseista (Uusikaarlepyy) sekä aiemmin tehdyistä metsänkäsittelytoimenpiteistä (Punkaharju). Maaveden tunnuksissa ei havaittu selviä ilmastosta riippuvia muutoksia siirryttäessä maan eteläosista pohjoiseen.

Raportissa kerrotaan myös lyhyesti neulasjälkimenetelmän (Needle Trace Method, NTM) periaatteesta. NTM on vakiinnuttanut asemansa retrospektiivisenä menetelmänä puiden latvushistorian tutkimuksessa niin metsäekologiassa, metsäpatologiassa, metsäentomologiassa kuin metsien yleisen terveydentilan selvittämisessä sekä dendrologian ja -klimatologian alalla. NTM:n avulla selvitetään helposti puiden neulastieto ajalta, jolta ei ole silmävaraista harsuuntumisarviointia. Mikäli puun ydin on terve, neulastieto saadaan puun koko elinajalta. Lisäksi raportissa kerrotaan tuloksia ja kokemuksia Metsäntutkimuslaitoksen järjestämältä Pohjois-Euroopan metsien kunnon arvioinnin kalibrointikurssilta, joka pidettiin Suomessa 4–6. kesäkuuta 2001.

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

Yleiseurooppalainen metsien terveydentilan seuranta (YK-ECE/EK) Suomessa

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Introduction

The International Co-operative Programme on the Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) was established in 1985 under the UN/ECE Convention on Long Range Transboundary Air Pollution (CLRTAP). In 1986 the European Union adopted the Scheme on the Protection of Forests against Atmospheric Pollution, and a legal basis for the co-financing of the assessments in EU member states was provided through Council Regulation (EEC) No. 3528/86. The monitoring activities therefore pursue the objectives of resolution S1 of the Strasbourg, resolution H1 of the Helsinki, and resolution L2 of the Lisbon Ministerial Conference on the Protection of Forests in Europe. Since then, the monitoring of forest condition and development has been carried out in 38 participating countries within these UN/ECE and EC programmes.

Large-scale, extensive monitoring takes place on a network of 5 700 plots arranged on a systematic grid covering the whole of Europe. This Level I network provides an annual picture of large-scale trends in crown condition at the European level. It also offers the possibility to investigate relationships between stress factors and forest condition at the same scale. Finland has been participating since 1985 in the Level I monitoring of forest condition.

In order to gain a better understanding of the effects of air pollution and other stress factors on forests, the Pan-European Programme for Intensive and Continuous Monitoring of Forest Ecosystems (Level II) was implemented in 1995. Approximately 860 intensive monitoring plots have been established in the participating countries. Investigations are carried out on these plots on site and stress factors, as well as on the biological and chemical status of the forest ecosystems. By the end of 1997, 31 intensive monitoring plots had been established in different parts of Finland.

The Finnish Forest Research Institute (Metla) is responsible for forest condition monitoring under the UN/ECE and EC programmes in Finland. The Parkano Research Station of the Finnish Forest Research Institute is responsible for the tasks of the National Focal Centre, and Dr. Hannu Raitio acts as the national coordinator.

Extensive monitoring of forest condition – Level I

The Finnish Forest Research Institute annually inventories tree condition, using internationally standardised methods, on a representative sample of tree stands. The inventory is carried out on about 460 sample plots selected from the permanent National Forest Inventory sample plot network established in 1985 (Fig. 1). A number of parameters are measured on the trees. In addition, soil samples have been collected from all the plots, as well as needle samples for elemental analysis on a reduced number of plots.

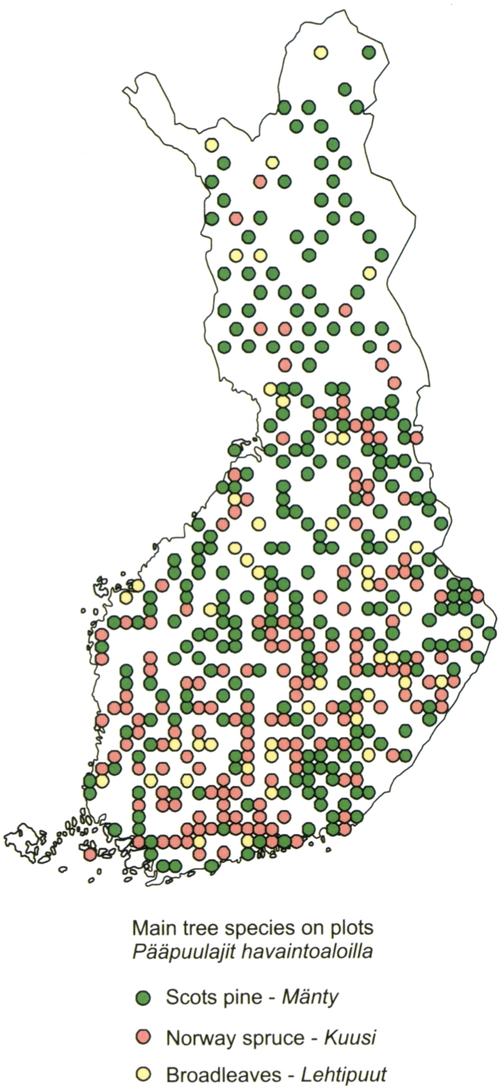

Figure 1. The network of the annual, large-scale crown condition survey (Level I) in Finland.
Kuva 1. *Laajamittainen metsien tilan seuranta (taso I), näytealaverkko Suomessa.*

Intensive and continuous monitoring of forest ecosystems – Level II

When Finland joined the European Union in 1995, some modifications were made to the national forest condition monitoring programme (Level I), and the intensive monitoring of forest ecosystems (Level II) was started at the same time.

Observation network

By 1997, 31 intensive monitoring plots had been established in different parts of the country (Fig. 2, Table 1): 27 of the plots on mineral soil sites and 4 on peatlands. 17 of the plots consist of Scots pine stands and 14 Norway spruce stands. All the plots, except for the four Integrated Monitoring (ICP-IM) plots, are located in commercially exploited forest. The IM plots represent natural stands in catchment areas. A number of the plots are located close to background, air quality monitoring stations primarily run by the Finnish Meteorological Institute.

Four of the 31 permanent observation plots in Finland have been established on peatlands. The sites were originally wet and sparsely stocked pine mires that represent the most typical drained peatland site types in Finland. The peat in these site types has low mineral nutrient concentrations, but usually relatively high nitrogen concentrations. This may result in an unbalanced nutrient status in the tree stand.

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). 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,

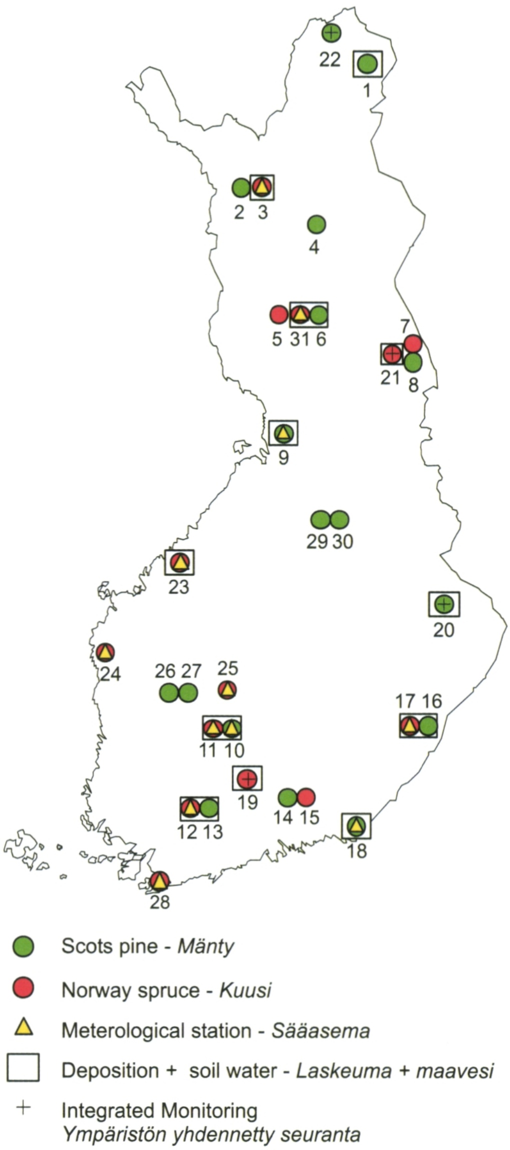

Figure 2. The intensive monitoring network of forest ecosystems in Finland.
Kuva 2. *Metsäekosysteemien intensiiviseurannan havaintoalat Suomessa.*

Table 1. Overview of the intensive monitoring network of forest ecosystems in Finland.
Taulukko 1. Havaintoalojen numero, nimi ja pääpuulaji.

Plot number *Havaintoalan numero*	Plot name *Havaintoalan nimi*	Tree species *Pääpuulaji*
1	Sevettijärvi_P	Scots pine
2	Pallasjärvi_P	Scots pine
3	Pallasjärvi_S	Norway spruce
4	Sodankylä_P	Scots pine
5	Kivalo_S	Norway spruce
6	Kivalo_P	Scots pine
7	Oulanka_S	Norway spruce
8	Oulanka_P	Scots pine
9	Ylikiiminki_P	Scots pine
10	Juupajoki_P	Scots pine
11	Juupajoki_S	Norway spruce
12	Tammela_S	Norway spruce
13	Tammela_P	Scots pine
14	Lapinjärvi_P	Scots pine
15	Lapinjärvi_S	Norway spruce
16	Punkaharju_P	Scots pine
17	Punkaharju_S	Norway spruce
18	Miehikkälä_P	Scots pine
19	Evo_Sim	Norway spruce
20	Lieksa_Pim	Scots pine
21	Oulanka_Sim	Norway spruce
22	Kevo_Pim	Scots pine
23	Uusikaarlepyy_S	Norway spruce
24	Närpiö_S	Norway spruce
25	Vilppula_Spro	Norway spruce
26	Ikaalinen_P	Scots pine
27	Ikaalinen_Pfer	Scots pine
28	Solböle_Spro	Norway spruce
29	Pyhäntä_P	Scots pine
30	Pyhäntä_Pfer	Scots pine
31	Kivalo_Spro	Norway spruce

P = Scots pine – *Mänty*
S = Norway spruce – *Kuusi*
pro = Provenance – *Alkuperä*
Pim = Scots pine, Integrated Monitoring
Mänty, ympäristön yhdennetty seuranta
Sim = Norway spruce, Integrated Monitoring
Kuusi, ympäristön yhdennetty seuranta
fer = Fertilization – *Lannoitettu*

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 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.

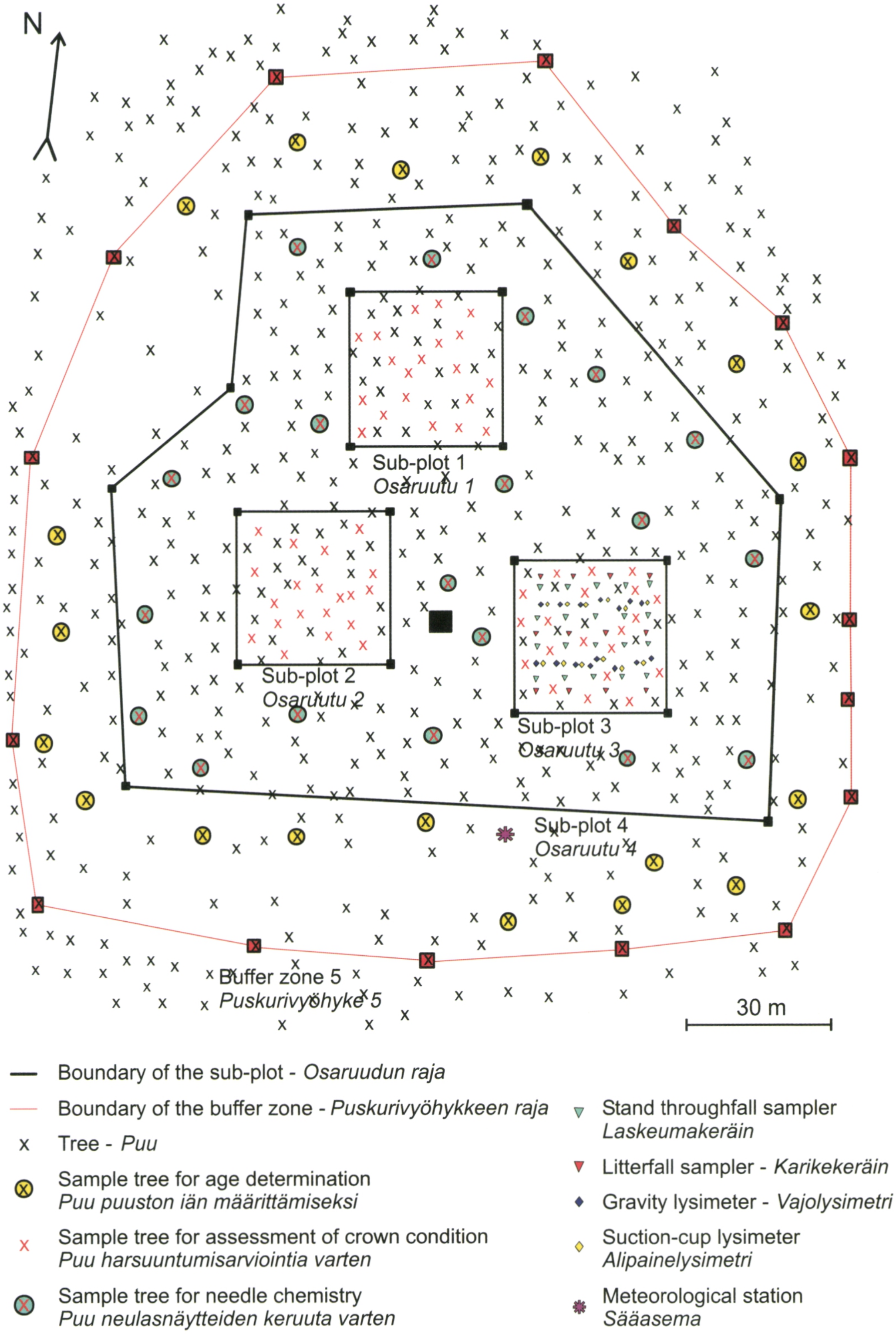

Figure 3. The design of the observation plot and location of the sub-plots.
Kuva 3. *Kaavio metsäekosysteemien intensiivisen seurannan havaintoalasta.*

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 field work 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.

Database and data evaluation

A database has been set up for handling and archiving the Level II data, access to which is restricted to persons participating in the programme. The database is maintained by Jarmo Mäkinen at the Parkano Research Station (Metla) and Olavi Kurttio at the Vantaa Research Centre (Metla).

The database consists of 14 main directories:

WORK: researchers' working directory

ASCII: raw data files in ASCII format

FIMCI: files in ASCII format, prepared from the raw data, for forwarding to the European Forest Intensive Monitoring Co-ordinating Institute (FIMCI) in the Netherlands

DATA: files forwarded annually to FIMCI in the form of Paradox database tables, and information about the tables, and about the tree stands on the monitoring plots

METEO: raw meteorological data from the weather stations, information and instructions about how to download the data-loggers, and descriptions of the weather stations and their maintenance logs

FMI: air quality and deposition data provided by the Finnish Meteorological Institute in the form of Paradox database tables

BAND: raw data from the girth bands, and information and instructions about how to handle them

SCNEED: scanning data from needle samples for the determination of length and surface area

MAP: map directory

PHOTO: photograph directory

FIG: drawing directory

DOCS: information about directory protection, data accompanying report (DARs) questionnaires, reports of meetings abroad, minutes of project meetings, instruction manuals, reports and structure and description of the database

PILOT: pilot study files and financial status files

FIN: financial status directory

A review of the results of the individual surveys and the summaries of the pilot projects are presented each year in the national report. In-depth scientific evaluations of the results will be presented every fifth year.

Monitoring activities

Survey	*No of plots*	*Frequency of assessments*
Crown condition	31	Annual
Soil condition	31	Every 10 years
Needle chemistry	31	Every 2 years
Tree growth	31	Every 5 years
Stem diameter growth	12	Continuous*
Deposition	16	Continuous (Sampling every 4 weeks, but every 2 weeks during the snowfree period)
Soil solution		
- gravity lysimeter	16	Continuous (Sampling every 4 weeks during the snowfree period)
- suction-cup lysimeter	16	Continuous (Sampling every 2 weeks during the snowfree period)
Meteorology	12	
- air temperature		Continuous*
- relative humidity		Continuous*
- soil temperature (-10 cm & -20 cm)		Continuous*
- precipitation		Continuous*
- wind speed		Continuous*
- wind direction		Continuous*
- photosynthetically active radiation (PAR)		Continuous*
- solar radiation		Continuous*
- soil frost (-10, -20, -30, ... -100 cm)		Continuous*
Ground vegetation	31	Every 5 years
	6	Every year
Litterfall	13	Every 2 weeks
Phenology	5	Three times/week during the critical period

* = Hourly measurements

Background information

Table 2. Monitoring activities on the Level II observation plots in 1999–2001.
Taulukko 2. *Metsäekosysteemien intensiivisen seurannan havaintoaloilla (taso II) vuosina 1999–2001 toteutettu seuranta.*

Plot no. and name *Havaintoalan nro ja nimi*	Crown condition *Latvuskunto* 2000–2001	Needle chemistry *Neulas-analyysi* 2001	Soil solution *Maavesi* 2000	Litterfall *Karike* 2000 (* =2001)	Deposition *Laskeuma* 2000	Understorey vegetation *Aluskasvillisuus* 2000	Stem diameter growth *Läpimitan kasvu* 2000–2001	Tree growth *Puuston kasvu* 1999–2000	Meteorology *Meteorologia* 2000	Phenology *Fenologia* 2001
1 Sevettijärvi_P	•	•	•		•			•		
2 Pallasjärvi_P	•	•				•		•		
3 Pallasjärvi_S	•	•	•	•*	•	•	•	•	•	•
4 Sodankylä_P	•	•						•		
5 Kivalo_S	•	•	•	•	•			•	•	•
6 Kivalo_P	•	•	•	•	•			•		
7 Oulanka_S	•	•				•		•		
8 Oulanka_P	•	•				•		•		
9 Ylikiiminki_P	•	•	•		•		•	•	•	
10 Juupajoki_P	•	•	•	•	•		•	•	•	
11 Juupajoki_S	•	•	•	•	•		•	•	•	
12 Tammela_S	•	•	•	•	•	•	•	•	•	
13 Tammela_P	•	•	•	•	•	•	•	•		
14 Lapinjärvi_P	•	•						•		
15 Lapinjärvi_S	•	•						•		
16 Punkaharju_P	•	•	•	•	•			•		
17 Punkaharju_S	•	•	•	•	•		•	•	•	•
18 Miehikkälä_P	•	•	•	•*	•		•	•	•	
19 Evo_Sim	•	•	•	•	•			•		
20 Lieksa_Pim	•	•	•	•	•			•		
21 Oulanka_Sim	•	•	•	•	•			•		
22 Kevo_Pim	•	•						•		
23 Uusikaarlepyy_S	•	•	•	•	•		•	•	•	
24 Närpiö_S	•	•					•	•	•	
25 Vilppula_Spro	•	•					•	•	•	
26 Ikaalinen_P	•	•						•		
27 Ikaalinen_Pfer	•	•						•		
28 Solböle_Spro	•	•						•	•	•
29 Pyhäntä_P	•	•						•		
30 Pyhäntä_Pfer	•	•						•		
31 Kivalo_Spro	•	•					•	•		

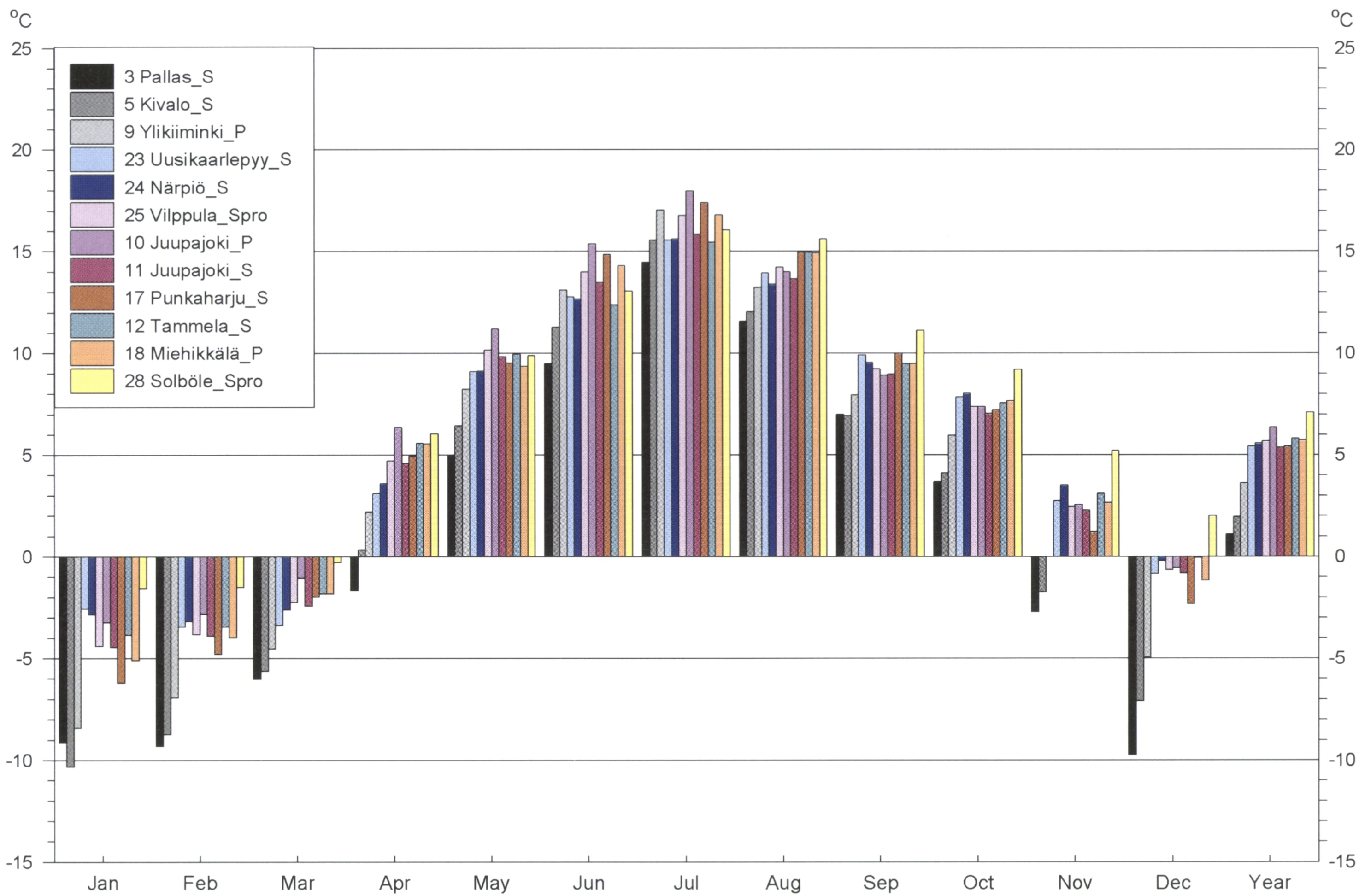

Figure 4. Mean monthly and yearly air temperatures on the Level II plots (from north to south) where continuous meteorological measurements were made in 2000.

Kuva 4. *Ilman kuukausi- ja vuosikeskilämpötilat metsien intensiiviseurannan säähavaintoasemilla v. 2000.*

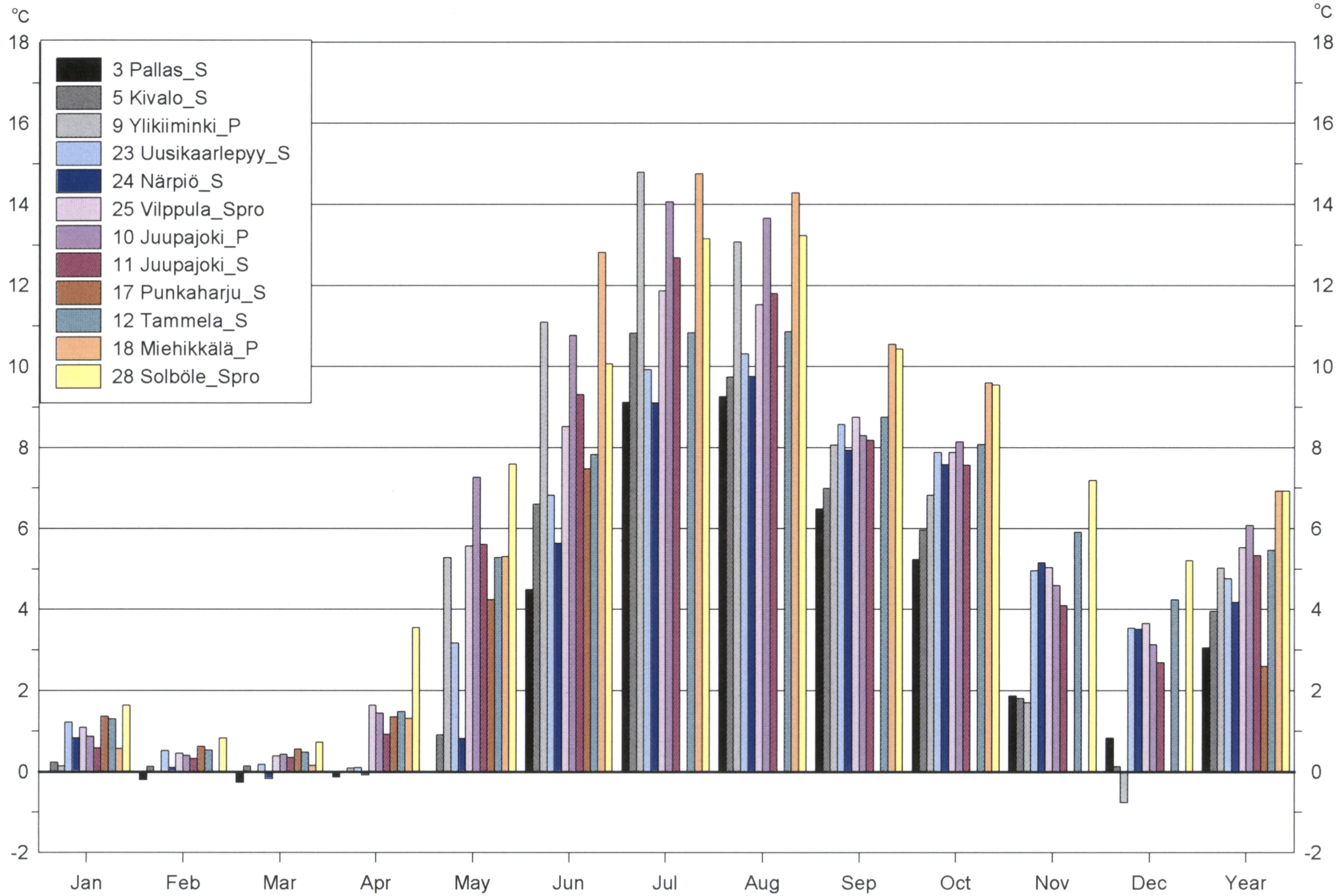

Figure 5. Mean monthly and yearly soil (at 10 cm depth in the mineral soil) temperature on the Level II plots (from north to south) where continuous meteorological measurements were made in 2000.
Kuva 5. *Maan kuukausi- ja vuosikeskilämpötilat 10 cm:n syvyydessä kivennäismaassa metsien intensiiviseurannan säähavaintoasemilla v. 2000.*

Table 3. Winter index[1)] 1999–2000, late frost[2)], growing season[3)] and its length in 2000, long term* and year 2000 summer index[4)] and June–September precipitation, respectively, on Level II plots with meteorological measurements. The gaps in the data set were supplemented by modelling the missing observations using the data from the nearest weather station of the Finnish Meteorological Institute.

***Taulukko 3**. Talven 1999–2000 pakkassumma[1)], hallojen esiintyminen[2)], kesän 2000 kasvukausi[3)], sen pituus ja vertailukauden* sekä vuoden 2000 lämpösumma[4)] ja kesä–syyskuun sademäärä metsien intensiiviseurannan säähavaintoasemilla. Puuttuvat havainnot saatiin mallittamalla lähimmän Ilmatieteen laitoksen havaintojen perusteella.*

Plot no. and name *Havaintoalan nro ja nimi*		Winter index[1)] °C *Pakkassumma[1)] °C*		Late frost[2)] *Myöh. halla[2)]*		Growing season[3)] *Kasvukausi[3)]*		Summer index[4)] °C *Lämpösumma[4)] °C*		Precipitation, mm *Sademäärä, mm*	
		1.10.–1.4.	Total *Kok.summa*	°C *°C*	Date *Pvm*	Period *Jakso*	Length, d *Pituus, pv*	2000	1961–90	2000	1.6.–30.9. 1961–90
3	Pallasjärvi_S	-1235	-1298	-5.8	12.05.	17.05.–22.10.	158	793	684		240
5	Kivalo_S	-1201	-1229	-4.4	12.05.	17.05.–22.10.	158	928	826		250
9	Ylikiiminki_P	-977	-995	-4.7	13.05.	16.05.–25.10.	162	1143	1029		243
10	Juupajoki_P	-419	-422	-7.0	02.04.	16.04.–25.10.	192	1472	1163	221	285
11	Juupajoki_S	-550	-557	-4.9	03.04.	18.04.–25.10.	190	1266	1140	239	285
12	Tammela_S	-480	-486	-7.8	02.04.	16.04.–25.10.	192	1317	1253	246	266
17	Punkaharju_S	-636	-640	-6.1	02.04.	17.04.–06.11.	203	1445	1289	205	264
18	Miehikkälä_P	-525	-528	-5.0	02.04.	17.04.–08.11.	205	1409	1351	250	267
23	Uusikaarlepyy_S	-488	-498	-6.9	03.04.	18.04.–25.10.	190	1247	1131	225	225
24	Närpiö_S	-490	-497	-5.7	10.04.	19.04.–25.10.	188	1226	1187	232	240
25	Vilppula_Spro	-541	-548	-4.6	03.04.	18.04.–25.10.	190	1356	1179	191	291
28	Solböle_Spro	-253	-255	-2.7	05.04.	18.04.–24.11.	220	1491	1357	216	253

*Ojansuu, R. & Henttonen, H. 1983. Kuukauden keskilämpötilan, lämpösumman ja sademäärän paikallisten arvojen johtaminen Ilmatieteen laitoksen mittaustiedoista. Summary: Estimation of local values of monthly mean temperature, effective temperature sum and precipitation sum from the measurements made by the Finnish Meteorological Office. Silva Fennica 17(2): 142–160. (In Finnish).

1) Winter index equals the sum of daily mean temperatures below 0 °C in the period from 1 October to 1 April (degree days below 0 °C). The sum was calculated also for the whole period having daily mean temperatures below 0 °C.

1) *Pakkassumma (vuorokausikeskilämpötilojen summa päiville, joiden keskilämpötila on alle 0 °C) jaksona 1.10.1999–1.4.2000 ja koko termisenä talvikautena.*

2) Late frost: The date of the lowest minimum temperature (below 0 °C) in a period starting 15 days before the beginning of the growing season and ending at June 30.

2) *Alhaisimman minimilämpötilan (<0 °C) esiintyminen ajanjaksona, joka alkaa 15 päivää ennen kasvukauden alkua ja päättyy 30. kesäkuuta.*

3) Growing season is the period during which summer index accumulates.

3) *Terminen kasvukausi on se osa vuodesta, jolloin lämpösummaa kertyy.*

4) Summer index is calculated as an effective temperature sum, which equals the sum of differences between daily mean temperatures during the growing season and a threshold of 5 °C.

4) *Lämpösumma on laskettu tehoisan lämpötilan summana, jolla tarkoitetaan vuorokausikeskilämpötilojen summaa +5 °C ylittävältä osalta.*

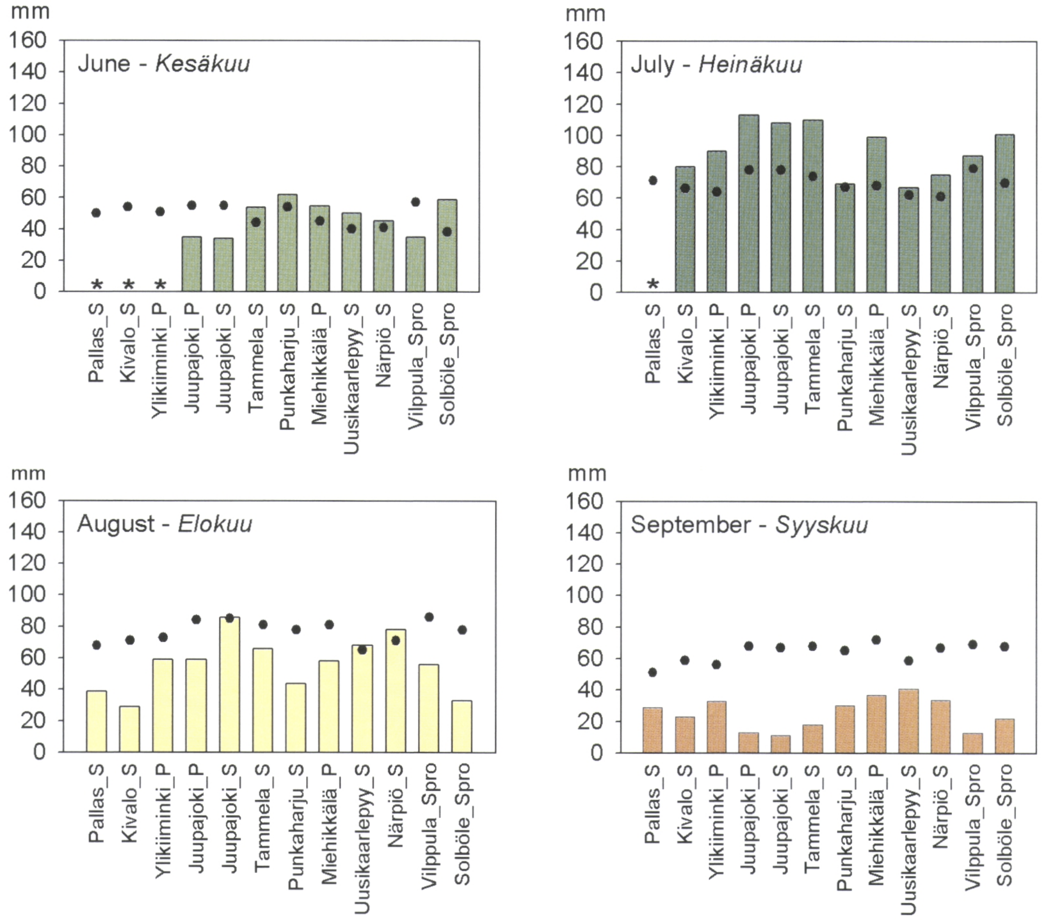

Figure 6. Monthly precipitation during June–September 2000 on the Level II plots where continuous meteorological measurements were made. Long-term averages (1961–90) are indicated with circles. * = missing.

Kuva 6. *Kuukausittaiset sademäärät metsien intensiiviseurannan havaintoaloilla kesä–syyskuussa 2000. Pitkänajan keskiarvot (1961–90) on merkitty ympyrällä. * = puuttuu.*

Table 4. The basic stand characteristics of ICP Level II observation plots.
Taulukko 4. *ICP-havaintoalojen (taso II) keskeisimmät puustotunnukset.*

Plot no. and name *Havaintoalan nro ja nimi*		Basal area with bark *PPA, kuorellinen,* m^2/ha	Stem number *Runko-luku, kpl/ha*	Mean diameter, weighted with basal area *Keskiläpimitta PPA:lla painotettu,* cm	Mean height arithmetical *Keskipituus (aritmeet-tinen),* m	Stem volume with bark *Runkotilavuus (kuorellinen),* m^3/ha	Stand age *Metsikön ikä*	Forest type *Metsätyyppi*	Soil type *: missing *Maannos* **: puuttuu*
1	Sevettijärvi_P	13.4	370.0	24.4	10.1	75.1	200	Uliginosum-Vaccinium-Empetrum Type	Ferric podzol
2	Pallasjärvi_P	12.9	733.3	17.9	8.4	65.0	90	Empetrum-Myrtillus Type	*
3	Pallasjärvi_S	13.0	1107.4	17.2	7.5	66.1	140	Hylocomium-Myrtillus Type	Ferric podzol
4	Sodankylä_P	18.3	1133.3	16.4	11.9	119.8	80	Empetrum-Myrtillus Type	*
5	Kivalo_S	21.6	1663.0	14.8	9.6	117.0	70	Hylocomium-Myrtillus Type	Ferric podzol
6	Kivalo_P	21.3	1748.2	13.3	11.1	126.9	55	Empetrum-Myrtillus Type	Carbic podzol
7	Oulanka_S	25.1	1188.9	22.5	10.6	178.7	190	Hylocomium-Myrtillus Type	*
8	Oulanka_P	18.7	688.9	20.4	14.7	143.0	80	Hylocomium-Myrtillus Type	*
9	Ylikiiminki_P	12.5	548.2	18.3	12.7	83.3	90	Empetrum-Calluna Type	Ferric podzol
10	Juupajoki_P	17.9	377.8	25.7	21.1	181.7	80	Vaccinium Type	Ferric podzol
11	Juupajoki_S	33.2	866.7	24.3	19.8	339.1	80	Oxalis-Myrtillus Type	Dystric cambosol
12	Tammela_S	27.6	677.8	23.9	20.1	273.0	60	Myrtillus Type	Haplic podzol
13	Tammela_P	21.9	603.7	22.2	19.2	202.7	60	Vaccinium Type	Haplic podzol
14	Lapinjärvi_P	25.6	1148.2	17.9	16.0	208.2	50	Vaccinium Type	*
15	Lapinjärvi_S	26.4	655.6	23.9	21.1	278.3	65	Oxalis-Myrtillus Type	*
16	Punkaharju_P	29.4	955.6	20.8	21.4	306.1	80	Vaccinium Type	Ferric podzol
17	Punkaharju_S	28.5	377.8	31.5	26.1	348.2	70	Oxalis-Myrtillus Type	Cambic arenosol
18	Miehikkälä_P	16.9	414.8	23.6	19.4	158.6	120	Calluna Type	Ferric podzol
19	Evo_Sim	54.1	1295.3	30.2	18.6	649.8	170	Oxalis-Myrtillus Type	Cambic podzol
20	Lieksa_Pim	28.8	587.5	31.9	16.9	310.9	130	Empetrum-Vaccinium Type	Haplic podzol
21	Oulanka_Sim	25.6	1741.7	22.9	8.8	176.3	170	Hylocomium-Myrtillus Type	Haplic podzol
22	Kevo_Pim	11.5	693.8	28.2	6.2	65.2	180	Uliginosum-Empetrum-Myrtillus Type	*
23	Uusikaarlepyy_S	34.8	970.4	22.7	18.9	333.5	55	Oxalis-Myrtillus Type	Cambic podzol
24	Närpiö_S	25.3	696.3	26.6	15.2	215.1	55	Myrtillus Type	*
25	Vilppula_Spro	28.3	448.2	29.6	25.9	355.8	75	Oxalis-Myrtillus Type	*
26	Ikaalinen_P	10.3	714.8	16.2	10.5	61.5	90	oligotrophic pine mire (drained)	*
27	Ikaalinen_Pfer	10.3	629.6	16.6	10.7	65.0	100	oligotrophic pine mire (drained)	*
28	Solböle_Spro	25.8	455.6	27.5	23.5	292.7	75	Oxalis-Myrtillus Type	*
29	Pyhäntä_P	13.5	1337.0	13.2	8.9	70.7	110	oligotrophic pine mire (drained)	*
30	Pyhäntä_Pfer	12.5	1255.6	12.6	9.0	64.8	120	oligotrophic pine mire (drained)	*
31	Kivalo_Spro	21.0	1218.5	16.8	10.5	121.8	75	Hylocomium-Myrtillus Type	*

Table 5. Concentrations of heavy metals in mosses on the Level II observation plots in 2000.
Taulukko 5. *Sammalten raskasmetallipitoisuudet metsäekosysteemien intensiivisen seurannan havaintoaloilla (taso II) vuonna 2000.*

Plot number and name *Havaintoalan nro ja nimi*	Cd	Cr	Cu	Fe mg/kg	Ni	Pb	V	Zn
1 Sevettijärvi_P	0.13	0.77	14.0	235	19.6	1.71	<0.10	18.9
2 Pallasjärvi_P	0.12	0.79	2.76	145	1.23	1.49	0.69	23.7
3 Pallasjärvi_S	0.11	0.73	2.44	105	1.43	2.02	0.61	17.0
4 Sodankylä_P	0.13	0.91	3.10	142	1.52	2.13	0.90	22.0
5 Kivalo_S	0.11	1.38	4.18	130	1.64	3.44	1.21	38.0
6 Kivalo_P	0.15	1.39	3.08	145	1.16	2.87	1.01	38.1
7 Oulanka_S	0.11	0.79	2.85	101	1.51	2.62	0.74	19.8
8 Oulanka_P	0.18	0.92	4.06	135	2.18	2.04	1.24	30.5
9 Ylikiiminki_P	0.21	1.50	3.33	258	1.38	3.12	1.45	31.5
10 Juupajoki_P	0.17	0.93	4.42	354	2.06	4.03	1.86	28.9
11 Juupajoki_S	0.16	1.05	3.78	251	1.52	4.66	1.48	28.2
12 Tammela_S	0.13	1.08	4.80	370	1.75	4.94	1.78	23.7
13 Tammela_P	0.21	1.34	5.20	359	1.88	4.71	1.92	41.4
14 Lapinjärvi_P	0.21	1.64	5.06	570	2.19	5.82	3.26	37.2
15 Lapinjärvi_S	0.20	1.20	5.46	396	1.76	6.45	2.73	42.6
16 Punkaharju_P	0.16	0.88	3.19	263	1.62	3.06	1.71	31.5
17 Punkaharju_S	0.12	0.89	4.34	333	1.75	4.31	1.73	22.4
18 Miehikkälä_P	0.24	0.86	2.92	383	1.40	5.61	2.14	33.9
19 Evo_Sim	0.16	1.00	4.48	305	2.04	5.66	2.12	28.2
20 Lieksa_Pim	0.13	0.60	3.22	172	1.17	2.66	1.22	25.2
21 Oulanka_Sim	0.12	0.93	3.14	124	1.93	2.12	0.86	29.7
22 Kevo_Pim	0.09	0.49	4.40	100	3.84	1.67	0.33	19.5
23 Uusikaarlepyy_S	0.15	1.26	6.62	328	2.03	4.10	1.53	45.8
24 Närpiö_S	0.12	1.28	4.78	473	1.70	3.35	1.90	35.9
25 Vilppula_Spro	0.16	0.94	5.81	337	1.44	3.97	1.69	38.8
26 Ikaalinen_P	0.20	0.75	2.89	183	1.23	2.71	1.16	27.3
27 Ikaalinen_Pfer	0.21	0.60	3.34	195	1.27	3.70	1.34	34.2
28 Solböle_Spro	0.23	1.28	5.25	448	1.83	7.64	2.83	44.4
29 Pyhäntä_P	0.13	0.85	5.18	201	0.84	2.53	1.03	24.8
30 Pyhäntä_Pfer	0.13	0.92	2.61	181	0.85	2.29	0.90	26.1
31 Kivalo_Spro	0.11	1.50	4.21	143	1.33	3.22	1.04	28.1

2 Background air quality in Finland in 2000

Tausta-alueiden ilmanlaatu Suomessa 2000

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Summary

The meteorological conditions in Finland give rise to a clear seasonal behaviour for many of the pollutants in the atmosphere. Due to the abatement programmes, the concentrations of primary pollutants in the atmosphere and the deposition of acidifying components have decreased considerably over the years. Deposition of the major components affecting acidification and many heavy metals clearly decrease from south to north, the southern part of the country receiving 2–8 times that in the northernmost part. Annual deposition values for the acidifying components are lower in 2000 than the mean values for 1987–96.

The weather in 2000 was characterised by high annual temperatures throughout the country. It is becoming more apparent that the temperature has increased in comparison with the normal period 1961–90. Especially this has happened during the winter and autumn seasons. The precipitation has also increased more often in the winter season and due to the increased temperature during this season the precipitation is more frequently rain. During summer and autumn precipitation increased in 2000 in several locations compared to the normal value.

The concentrations of gaseous pollutants have decreased since 1985. The downward trend during the last ten years is steeper in winter than in summer. The largest decrease was measured in the south-western part of the country, whereas the change was smallest in the far North and North-East.

Yhteenveto

Suomen tausta-alueilla useiden ilman epäpuhtauksien pitoisuudet vaihtelevat vuodenaikojen mukaan ilmastosta johtuen. Viime vuosien aikana ovat ilman primääriepäpuhtauksien pitoisuudet ja happamoittavien yhdisteiden laskeumat vähentyneet merkittävästi päästörajoitussopimusten vaikutuksesta. Happamoittavien yhdisteiden ja eräiden raskasmetallien laskeuma pienenee selvästi etelästä pohjoiseen. Happamoittava laskeuma vuonna 2000 oli Suomessa alempi kuin vuosien 1987–96 keskimääräinen arvo.

Vuoden 2000 keskilämpötila oli korkea koko maassa. Näyttää yhä ilmeisemmältä, että lämpötila on noussut vertailuajanjaksoon 1961–90 verrattuna, erityisen selvästi tämä näkyy talvi- ja syyskausina. Myös sademäärä on lisääntynyt varsinkin talvella ja lämpötilan nousun vuoksi talviaikaiset sateet tulevat yhä useammin vetenä. Vuonna 2000 kesän ja syksyn sademäärät olivat normaaliarvoihin verrattuna korkeammat useilla paikkakunnilla.

Ilman kaasumaisten yhdisteiden pitoisuudet ovat vähentyneet vuodesta 1985 lähtien. Viimeisten kymmenen vuoden aikana alenema on ollut voimakkaampaa talvikaudella. Suurin pitoisuuksien väheneminen mitattiin Lounais-Suomessa, kun taas pohjoisimmassa osassa maata sekä Koillis-Suomessa muutos oli vähäisin.

Stations and methods

The Finnish Meteorological Institute (FMI) carries out air quality measurements at background stations that are part of several national and international networks. The first measurement station was founded in the beginning of 1970. In 2000 air quality measurements were conducted at seventeen stations throughout Finland. The network of air quality measurement stations in the background areas of Finland is presented in Fig. 1.

The measurements and sampling at the stations and the analysis of the samples in the laboratory are carried out with methods described in detail in the manuals of UN ECE EMEP (EMEP 1996), UN ECE IM (Environment Data Centre 1998) and WMO GAW (Santroch 1994). Deposition samples have been collected using different types of the bulk sampler for summer and for winter. Bulk deposition includes the wet deposition and the part of the dry deposition (gases and particles) that settles in the sampler. Sampling periods range from 24 hours to 1 month. Further information on the background air quality measuring programmes and methods is available in the annual reports of Air Quality Measurements (Leinonen 2001) and in Vuorenmaa et al. (2001).

Figure 1. Finnish background air quality measuring stations in 2000.
Kuva 1. *Taustailman laatua mittaavat asemat Suomessa vuonna 2000.*

Quality assurance of the results is based on guidelines given in the EMEP Data Quality Objectives (EMEP 1996) and by GAW (Mohnen et al. 1992). Samples are analysed in the Air Chemistry Laboratory of the Finnish Meteorological Institute which is the testing laboratory T097 (EN ISO/IEC 17025) accredited by the Centre for Metrology and Accreditation. The scope of accreditation includes the analysis of impurities in precipitation, aerosol and gas samples (Leinonen 2000, www.mikes.fi). Regarding deposition sample measurements, the laboratory participates annually in intercomparisons within the EMEP and GAW programmes in order to achieve international comparability for the results.

For the background air quality measurements the Calibration Laboratory of the Air Quality Research Division provides traceable calibration for ozone measurements, certification of the gas standards used for nitric oxide measurements, and tests of the permeation method against the dynamic dilution method for sulphur dioxide. The laboratory is accredited as a calibration laboratory K043 according to EN ISO/IEC 17025 by the Centre for Metrology and Accreditation. The scope of accreditation includes the production of calibration concentrations of the most important atmospheric pollutants in the range relevant to air quality measurements (www.mikes.fi). Intercalibration exercises are not regularly arranged for gases and particles within the EMEP programme.

The weather in 2000

The meteorological conditions affecting the air quality and the deposition of particulate matter in general have been described in the report for the year 1997 (Waldén et al. 1999). The review of the main features of the weather is based on the meteorological data base of the Finnish Meteorological Institute, on issues 1–12/00 of Ilmastokatsaus (IL 2000), and on Ilmanlaatumittauksia – Air Quality Measurements 2000, both published by the FMI.

Figures 2–4 show some of the meteorological parameters (precipitation, temperature and global radiation) for the year 2000 compared to their long-term means. In 2000, the precipitation levels were slightly above average in the whole country. In the northern part of the country, the annual precipitation amount was 1.2–1.5 times higher than the normal value for the reference time period, 1961–90. In other parts of the country, the annual precipitation amount was only slightly above normal.

In Fig. 2 the mean monthly precipitation in 2000 and the long-term (1961–90) averages at Sodankylä, Kevo, Utö and Ähtäri are shown. The monthly amounts of precipitation in 2000 were 2–2.5 times higher in January and 1.5–2 times higher in April in Lapland than the long term mean values for 1961–90.

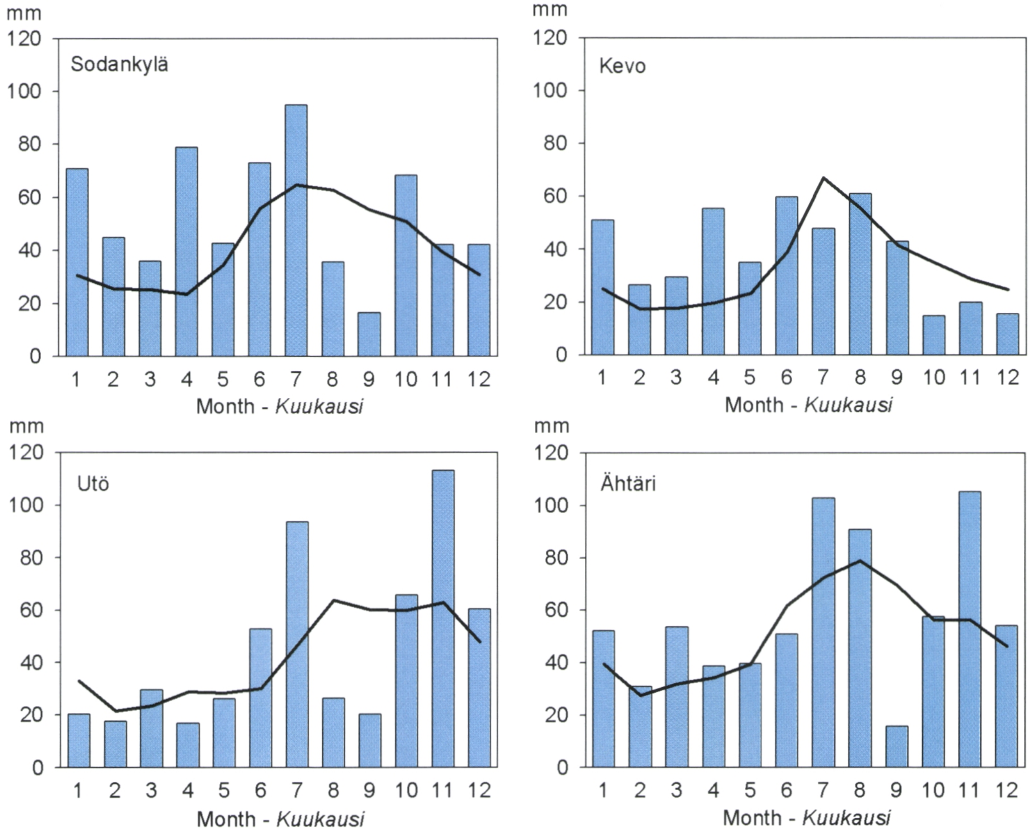

Figure 2. Monthly precipitation in 2000 (bars) and the long-term (1961–90) averages (line) in Sodankylä, Kevo, Utö and Ähtäri.
Kuva 2. *Sademäärä kuukausittain vuonna 2000 (pylväät) ja vertailukauden (1961–90) keskimääräinen sademäärä (viiva) Sodankylässä, Kevossa, Utössä ja Ähtärissä.*

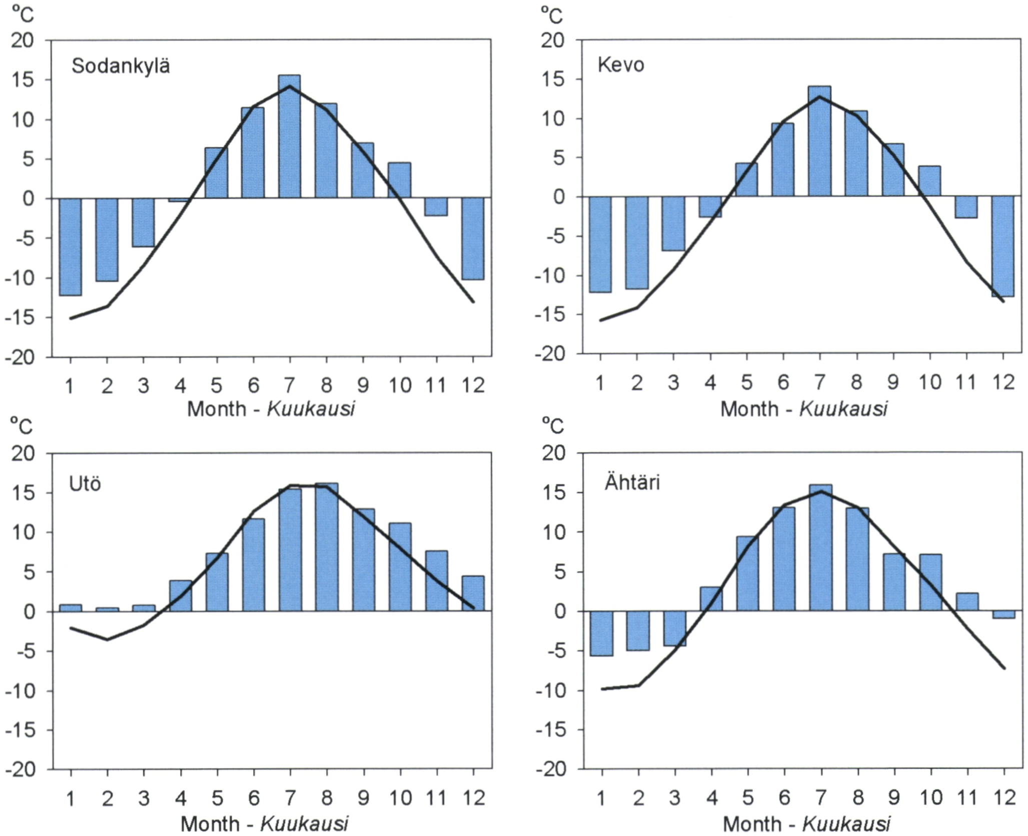

Figure 3. Mean monthly temperatures in 2000 (bars) and the long-term (1961–90) averages (line) in Sodankylä, Kevo, Utö and Ähtäri.

Kuva 3. *Lämpötilan keskiarvo kuukausittain vuonna 2000 (pylväät) ja vertailukaudella (1961–90) keskimäärin (viiva) Sodankylässä, Kevolla, Utössä ja Ähtärissä.*

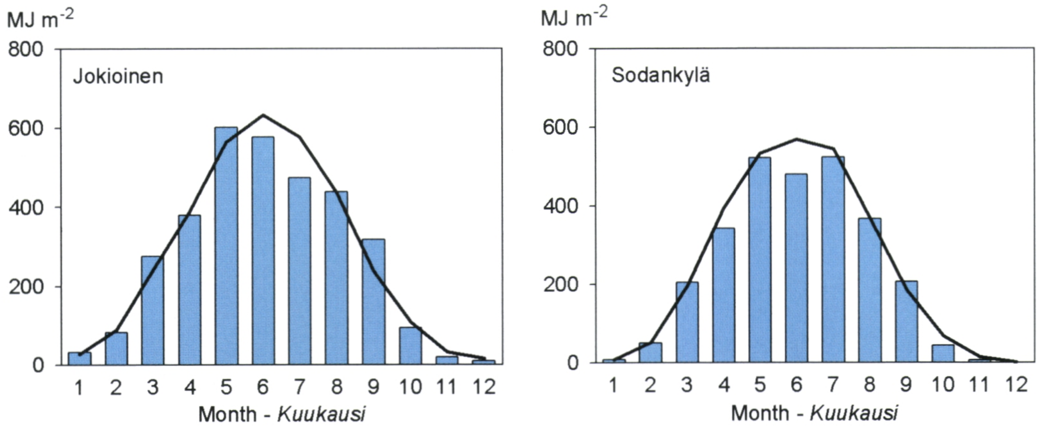

Figure 4. Monthly amounts of global radiation in 2000 (bars) and the long-term (1961–90) averages (line) in Jokioinen and Sodankylä.

Kuva 4. *Globaalisäteilyn kuukausisummat vuonna 2000 (pylväät) ja vertailu-kauden (1961–90) keskiarvot (viiva) Jokioisissa ja Sodankylässä.*

The amount of precipitation in southern Finland was only slightly above normal and especially in January and February the rainfall was more frequently rain than snow. In the southern part of the country the spring was less rainy while in the summer the precipitation exceeded the normal values. As the weather was mild during the last months of the year, the precipitation fell as rain in November and even December. Even in Lapland there was no real snow cover until the end of the year.

Year 2000 was among the warmest 2–6 in the last hundred years, depending on the locality. For the whole country the annual average temperature was about two degrees higher than the long-term average.

The monthly mean temperatures in 2000 and the long-term averages in Sodankylä, Kevo, Utö and Ähtäri are shown in Fig 3. Since 1996 the monthly mean temperatures during the winter (from December to February) have been higher than the normal values for 1961–90. Year 2000 was no exception. In January and in February the mean temperatures were clearly above normal (in January 4 °C) while in March the temperature was in the normal range in most parts of the country. At the end of April and in May there was a very warm period with the temperature exceeding 24 °C. June was close to normal but especially in northern Finland the weather was exceptionally warm in July and in August. The number of days when the temperature exceeded 25 °C was 0 to 4 in southern Finland while in northern Finland it was 2 to 6. In August the only place where the temperature exceeded 25 °C was Sodankylä. The autumn was also very warm. In Jomala, Ahvenanmaa, the monthly mean temperature was even higher in October than in September which is extremely rare.

Solar radiation is essential for many chemical reactions in the atmosphere, e.g. the reactions involved in the formation of ozone and the oxidation of sulphur and nitrogen oxides are photochemical, and are initiated by solar radiation. The mean monthly values for solar radiation at the meteorological observatories of Jokioinen and Sodankylä are shown in Fig. 4. Comparison with the long-term values shows that in southern Finland March, May and September were sunnier than normal while in northern Finland the year was normal.

Deposition

Annual deposition of acidifying components, comparison with mean values for the years 1987–96

The annual deposition of acidifying components at four stations in different parts of the country in 2000 is shown in Fig. 5. The stations have been arranged along the abscissa from south to north.

Deposition of the major components affecting acidification clearly decreases from South to North, the southern part of the country receiving 3–19 times the deposition in the northernmost part. The geographical difference is strongest for calcium and ammonium, and weakest for hydrogen ion deposition.

The annual deposition values in 2000 are lower than the mean values for 1987–96, except for nitrate deposition at the northern station of Sodankylä. The overall result is in agreement with the decreasing acidification trend observed in Finland during the last ten years (Kulmala et al., 1998, Waldén et al., 1999, Leinonen et al. 2001). The decrease in 2000 compared to the period 1987–96 is strongest for the calcium deposition: about 50 % at the southern station, 20 % at the Central Finland station, and 10–30 % in the North. The decline in sulphate deposition was also high: 40 % at the southern and Central Finland stations, and 30 % in the North. Hydrogen ion deposition remained almost unchanged in the South (-5 %) and decreased 20–25 % in the rest of the country.

The deposition of nitrate decreased by 10–20 % at the southern, Central Finland, and far North stations, but increased slightly in southern Lapland. Finally, the ammonium deposition decreased by 20 % at the southern Finland station. In the central part of the country as well as in the far North the decline was strongest: 30–35 %, while southern Lapland received 10 % less ammonium deposition in 2000 compared to the 1987–96 mean value.

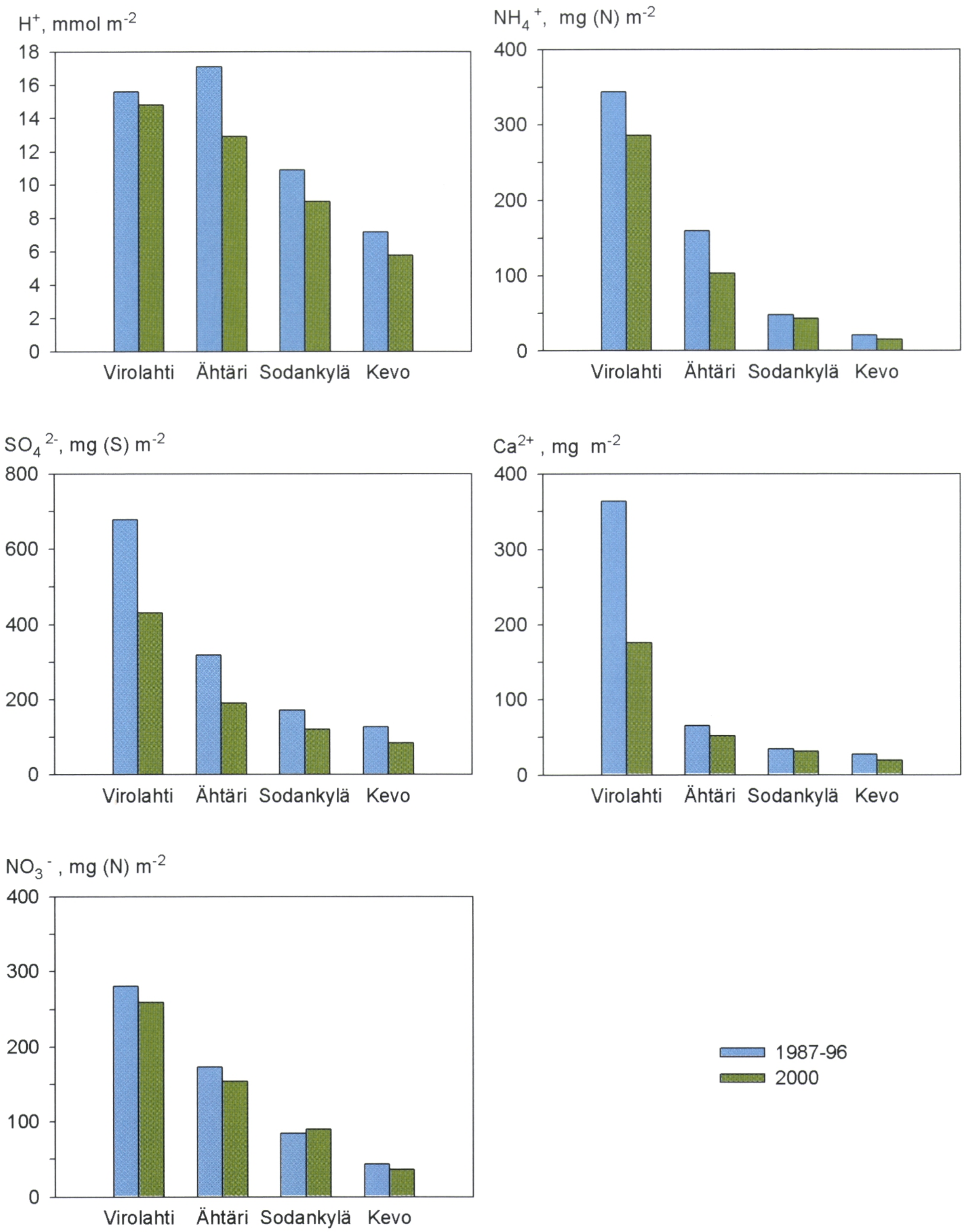

Figure 5. Deposition of components in 2000 compared with the average values in 1987–96.
Kuva 5. *Happamoitumiseen liittyvien yhdisteiden vuosilaskeuma vuonna 2000 verrattuna keskimääräiseen arvoon vuosina 1987–96.*

Annual deposition of some heavy metals

The annual deposition in 2000 of some heavy metals is presented in Fig. 6. The stations have been arranged along the abscissa from South to North.

The deposition mostly decreases from South to North. The differences in the deposition from South to North are rather similar for lead and cadmium: the deposition measured in the far North is only 10–15 % of that in the South. The relatively high deposition at Virolahti is due to the large precipitation amount connected with increased concentration of lead and cadmium in October and November. The South-North gradient in copper and chromium deposition is weaker. The unusually high annual deposition of chromium at Hietajärvi is due to the high monthly deposition in June.

Seasonal variation of deposition

The seasonal variation in the amount of precipitation and the deposition of components affecting acidification is shown in Figs. 7a–f for 12 measurement stations. They have been grouped according to their geographical location stations in the northern part of the country are placed at the top of the figure, stations in Central Finland in the middle, and stations in the South at the bottom.

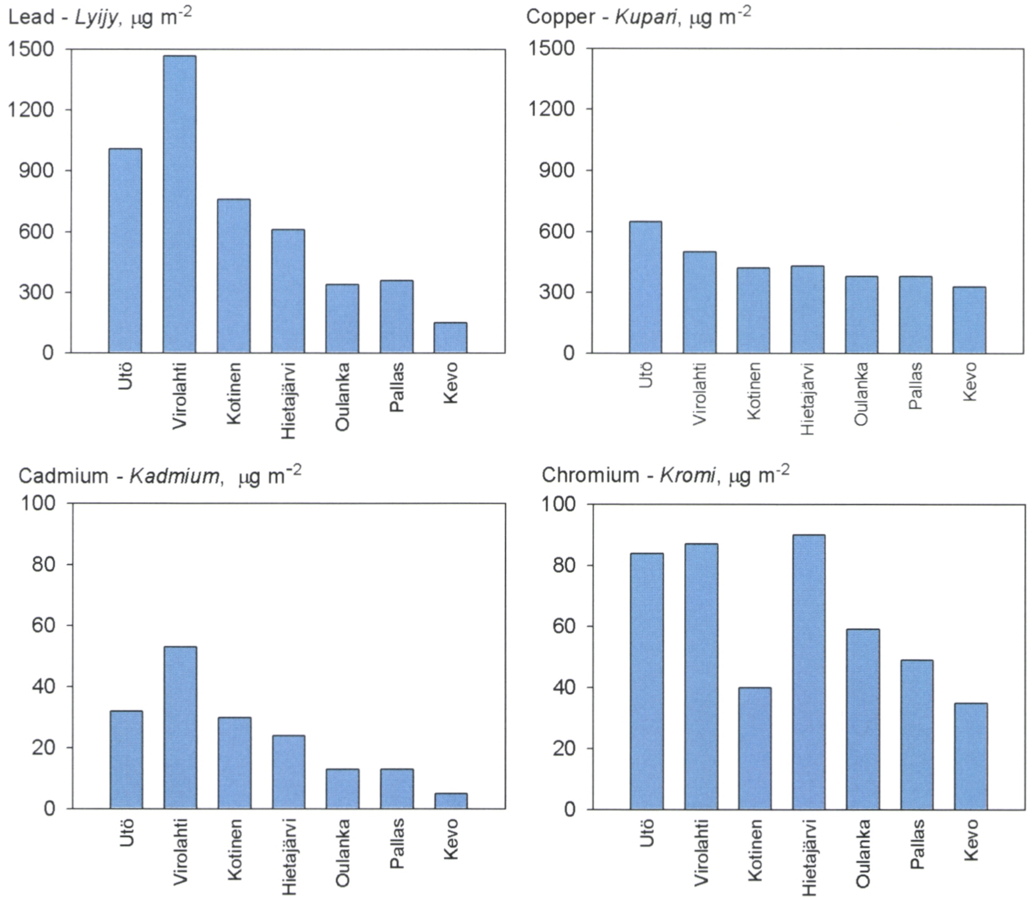

Figure 6. Deposition of some heavy metals in 2000.
Kuva 6. *Eräiden raskasmetallien laskeuma vuonna 2000.*

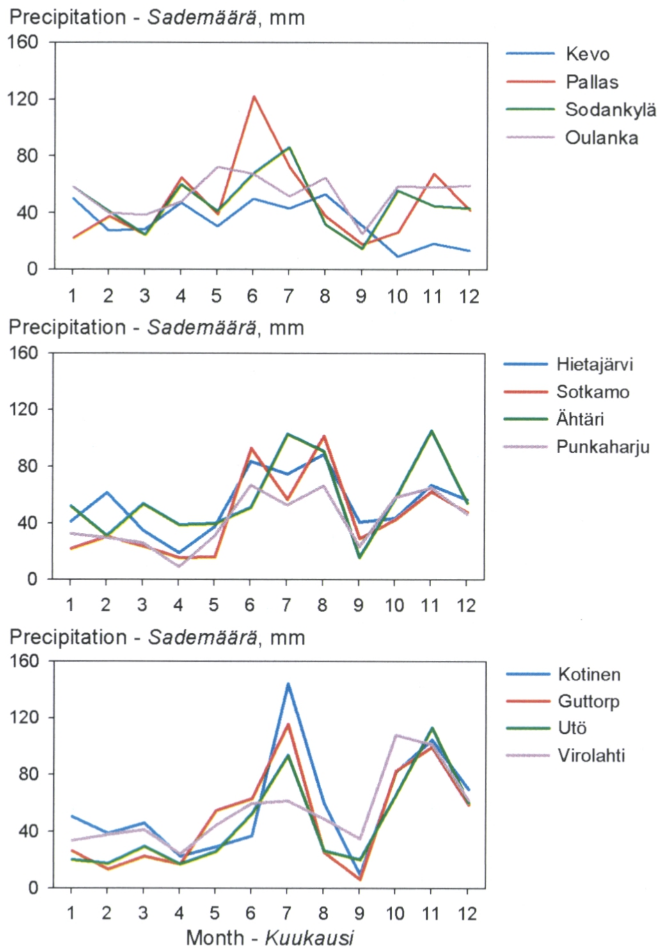

Figure 7a. Seasonal variation in the amount of precipitation in 2000.
Kuva 7a. *Sademäärän vuodenaikaisvaihtelu vuonna 2000.*

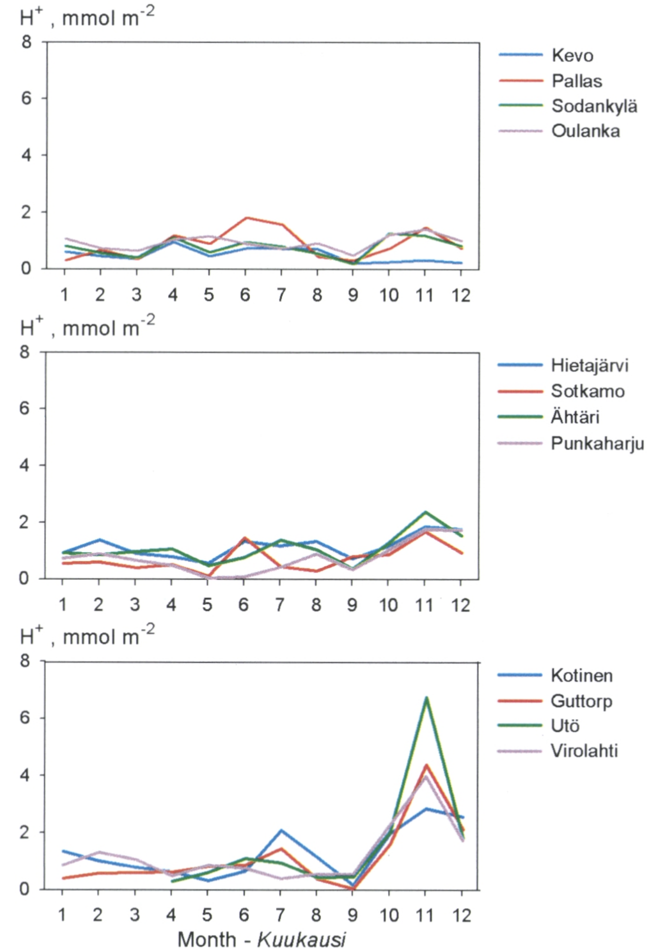

Figure 7b. Seasonal variation in hydrogen ion deposition in 2000.
Kuva 7b. *Vetyionilaskeuman vuodenaikaisvaihtelu vuonna 2000.*

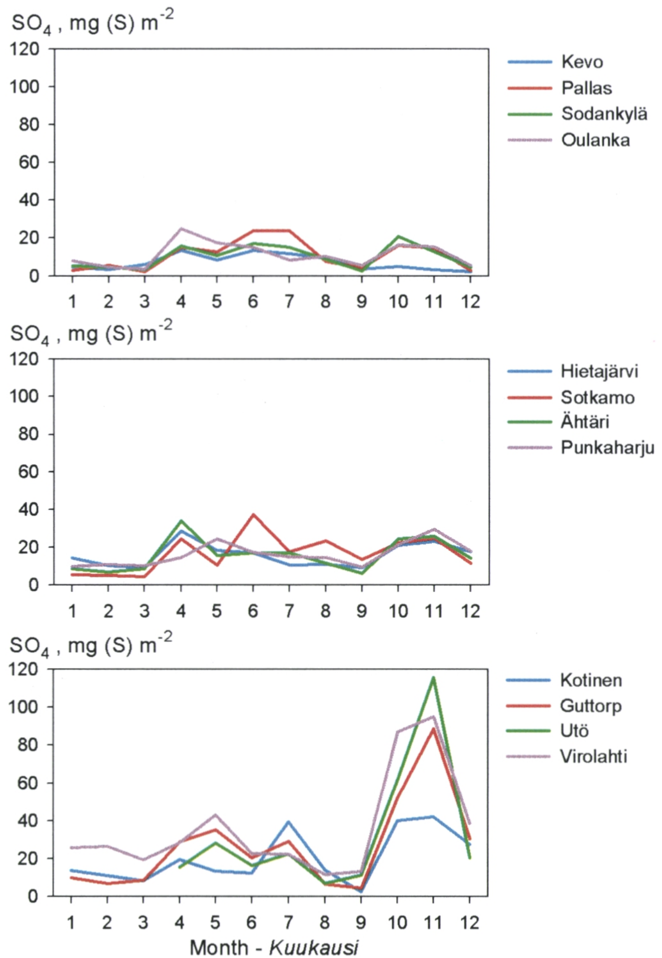

Figure 7c. Seasonal variation in sulphate deposition in 2000.
Kuva 7c. *Sulfaattilaskeuman vuodenaikaisvaihtelu vuonna 2000.*

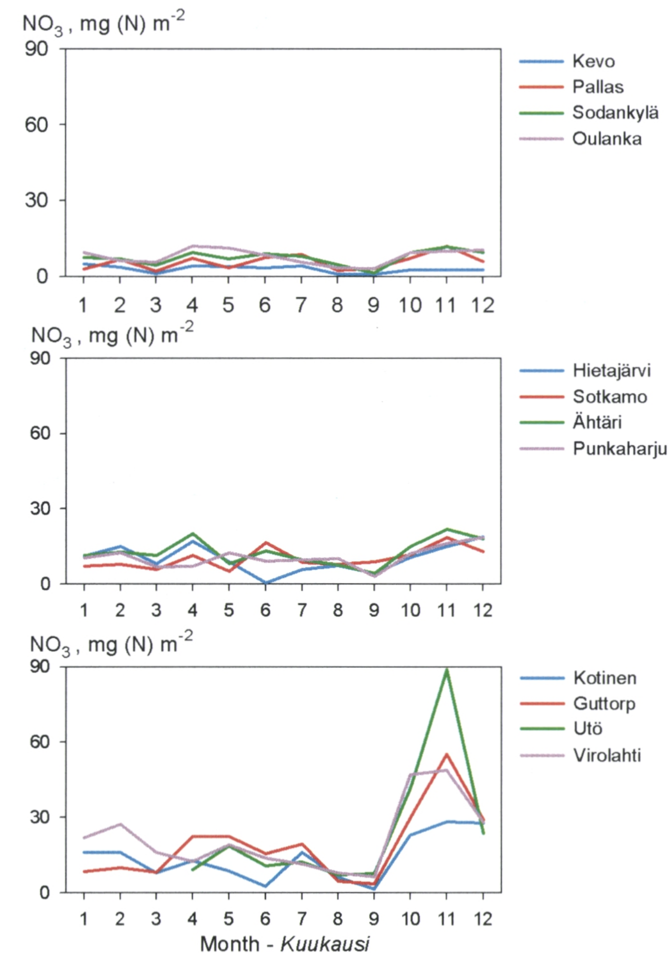

Figure 7d. Seasonal variation in nitrate deposition in 2000.
Kuva 7d. *Nitraattilaskeuman vuodenaikaisvaihtelu vuonna 2000.*

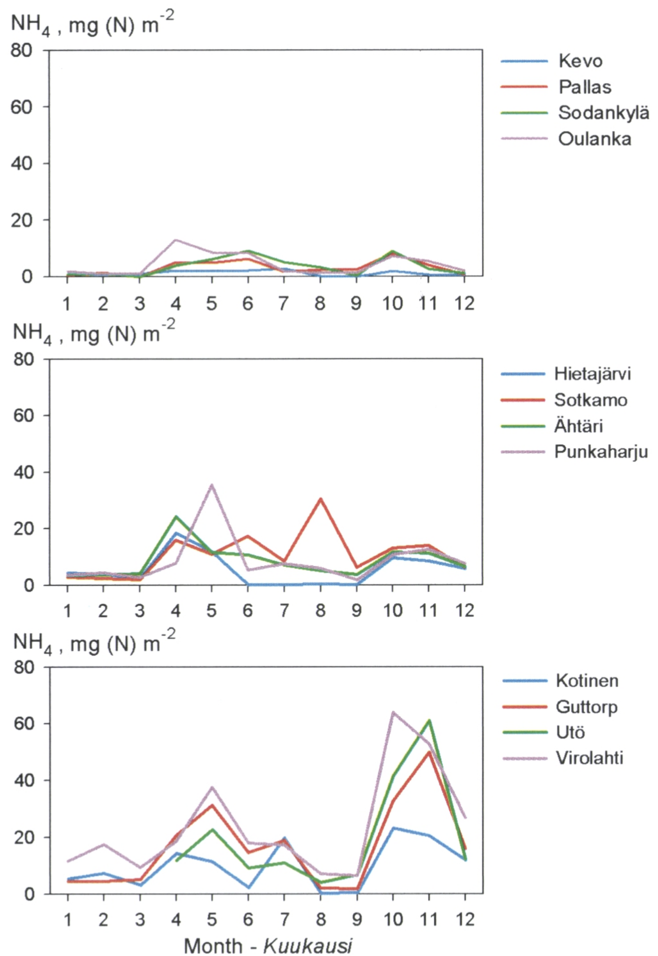

Figure 7e. Seasonal variation in ammonium deposition in 2000.
Kuva 7e. *Ammoniumlaskeuman vuodenaikaisvaihtelu vuonna 2000.*

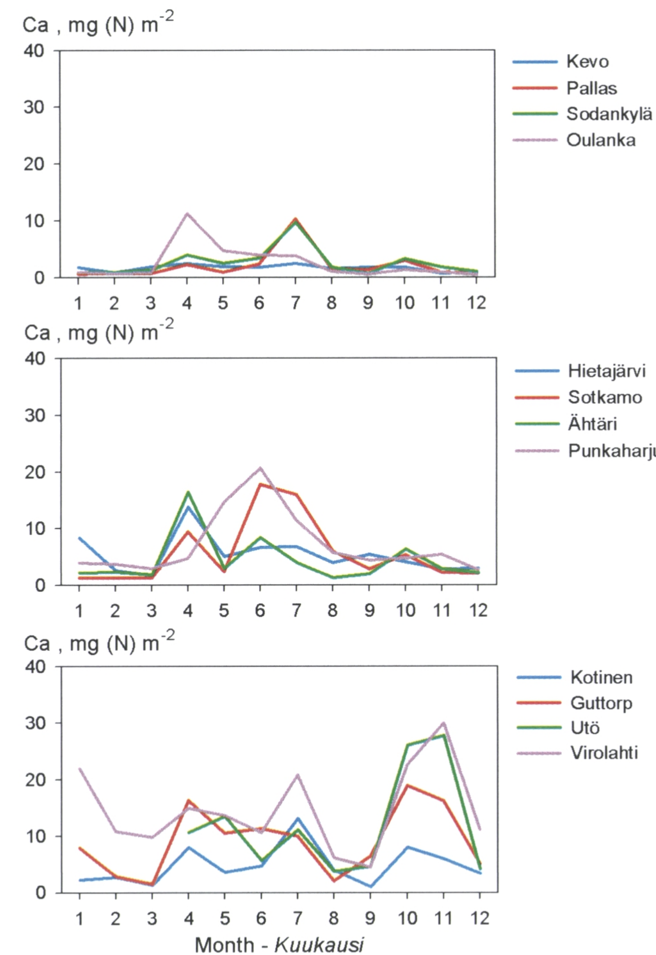

Figure 7f. Seasonal variation in calcium deposition in 2000.
Kuva 7f. *Kalsiumlaskeuman vuodenaikaisvaihtelu vuonna 2000.*

The results for the Kotinen station differ from those of the three other southern stations, which are located on the coast, and correspond better to the results of the Central Finland stations. In order to make the figures as clear as possible, four stations were chosen for each sub-figure.

On the rocky outer island of Utö, the collection efficiency of precipitation samples is poor. Raindrops are transported by the wind over the mouth of the collector, and evaporation is also higher. For these reasons the monthly means for January, February, and March 2000 are missing and December 2000 were calculated from data representing 50–75 % of the official amount of precipitation (Leinonen 2001). Annual deposition of the components in precipitation was calculated from the analysed daily values. The proportion of the missing deposition was corrected by means of the annual mean concentration and the daily precipitation amounts measured by the official rain gauge.

Bulk deposition is highly dependent on the amount of precipitation (Fig. 7a). An exceptionally high precipitation amount was measured in June at Pallas in the North. July was very rainy at the southern stations Kotinen and Guttorp. October and November were also very rainy in southern Finland. Isolated high monthly values were also measured during summer and autumn at some southern and Central Finland stations.

The seasonal variation of hydrogen ion deposition (Fig. 7b) usually follows the variation in the amount of precipitation rather closely. In 2000 the deposition was distributed relatively evenly at the Central and northern Finland stations, in the South peaks occurred in November.

The normal summer maximum of sulphate deposition is not very clear at any of the stations. (Fig. 7c). In the South, a clear autumn maximum is visible at the three coastal and island stations. The monthly deposition values at the central and northern stations fluctuated more, and there maximum values were also measured during the summer months as well as in April.

The overall seasonal variation for nitrate deposition (Fig. 7d) closely resembled that for sulphur deposition, especially at the southern stations. High values were measured at the southern stations in October and November. The seasonal variation in the North was weak and the deposition was very low in August and September.

The overall seasonal variation in ammonium deposition fluctuated, especially in the central part of the country. Most stations received a high monthly deposition in April-May and in October–November. A weak summer maximum in June or July is also visible at some of the southern and Central Finland stations (Fig. 7e). The high precipitation amount at the southern stations combined with elevated ammonium concentration in rain water caused the peak values at the end of the year. Finally, Fig. 7f shows the variation in calcium deposition. In the North peak values were measured in April (Oulanka) and in July (Pallas, Sodankylä). The April maximum at Oulanka is mainly due to an episode at the end of the month (25.4.) when also the sulphate and ammonium deposition was much increased. A summer maximum is visible at the Central Finland stations as well as in the North. High precipitation increased the calcium deposition in autumn in the South.

Gases

Sulphur dioxide

Sulphur dioxide is one of the most important primary pollutants in the atmosphere. It is the key component of the so-called acidification problem in the environment. Although acidification is well understood, research work is still going on, especially on questions as to why acidification is still migrating in the lakes and rivers and in soils.

The main source of sulphur dioxide is industry and energy production. Emissions from natural sources, such as volcanoes and biomass burning, only total 1/6 of the anthropogenic emissions. In Finland, as well as all over Europe, sulphur dioxide concentrations in background areas have decreased rather dramatically since the 1980's (Kulmala et al. 1998).

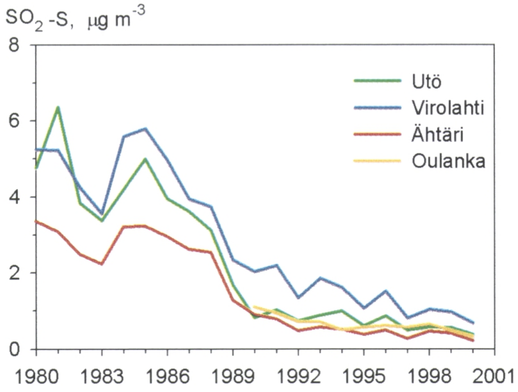

Figure 8. Mean annual sulphur dioxide concentration (expressed as sulphur) in Utö, Virolahti, Ähtäri and Oulanka.
Kuva 8. *Rikkidioksidin vuosikeskiarvo (rikiksi laskettuna) Utössä, Virolahdella, Ähtärissä ja Oulangalla.*

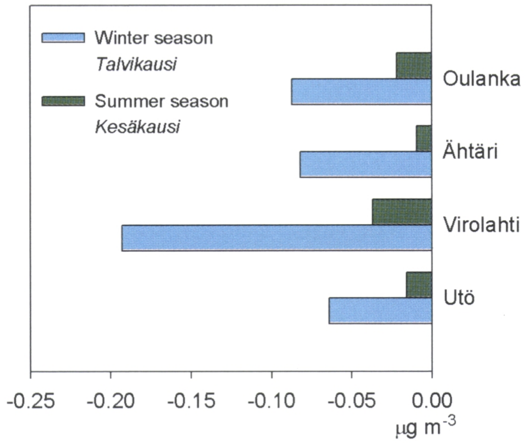

Figure 9. Summer and winter trends (slope estimates) for Utö, Virolahti, Ähtäri and Oulanka from 1990 to 2000.
Kuva 9. *Rikkidioksidin trendien kulmakerroinestimaatit kesä- ja talvikaudella ajanjaksolla 1990–2000 Utössä, Virolahdella, Ähtärissä ja Oulangalla.*

The decrease of the sulphur dioxide concentration in ambient air is due to abatement programmes at the European level and also globally. The Protocol on the Reduction of Sulphur Emissions at the European level, which was adopted in 1985 and came into force in 1987, committed European countries to cut their emissions by 30 % from those of the year 1980 by the year 1993. Furthermore, the Second Protocol of Further Reduction of Sulphur Emissions was adopted in 1994, committing participant countries to further individual reductions of sulphur dioxide. Based on these protocols, the target emission limit for Finland is 116 kt/a as sulphur dioxide by the year 2000. Since 1995, emissions of sulphur dioxide have remained below this target limit, as is the case in many other countries in Europe (SYKE 1999).

The annual mean concentration of sulphur dioxide at the stations of Utö, Virolahti, Ähtäri, and Oulanka is presented in Fig. 8. The reader is reminded of the change in the sampling method for sulphur dioxide within the EMEP-programme which occurred in June 1989. This applies to data from the stations of Utö, Virolahti, Ähtäri and Oulanka. The sampling methods for sulphur dioxide at EMEP stations include both filter pack sampling on a daily basis since 1989 (EMEP 1996), and continuous monitoring by UV-fluorescence analysers starting in 1990. Although the decrease in sulphur dioxide is evident, the decreasing trend since 1989 has not been as clear as earlier. The trend calculated by the Kendall method (Gilbert 1987) is shown for the stations of Utö, Virolahti, Ähtäri, and Oulanka in Fig. 9.

There are spatial differences in sulphur dioxide concentrations across the country. There is an overall decrease in concentrations when moving northwards from the southern coast. In the south-eastern Finland, sulphur dioxide concentrations are also relatively high. The high concentrations in this region originate from local sources, as well as from transboundary pollution from the St. Petersburg area and the Baltic countries.

The measurement stations are also influenced by local sources even when the stations are classified as background stations. At some stations, local emissions can decrease faster than average emissions over the whole country, or in certain wind sectors the concentrations do not reveal the general trend.

The seasonal pattern in sulphur dioxide shown in Fig. 10 is primarily due to the heating period in winter. However, although January is the coldest month of the year, the highest sulphur dioxide concentration is reached in February. The strongest seasonal behaviour occurs at Virolahti, where the concentrations are also the highest.

The spatial variability of sulphur dioxide concentrations during the winter season is illustrated in Fig. 11 where the scatter matrix of the monthly values for the EMEP stations is shown. Note that the station Virolahti has the highest values. The scales for the stations differ; they are shown on the left and right sides and along the top and bottom axes of the figure. The unit of the sulphur dioxide concentration is mg/m^3 expressed as Sulphur (S).

Oxides of nitrogen

Nitrogen is the most abundant gas in the atmosphere. It also oxidises into several other compounds, of which nitrogen monoxide and nitrogen dioxide are the principal compo-

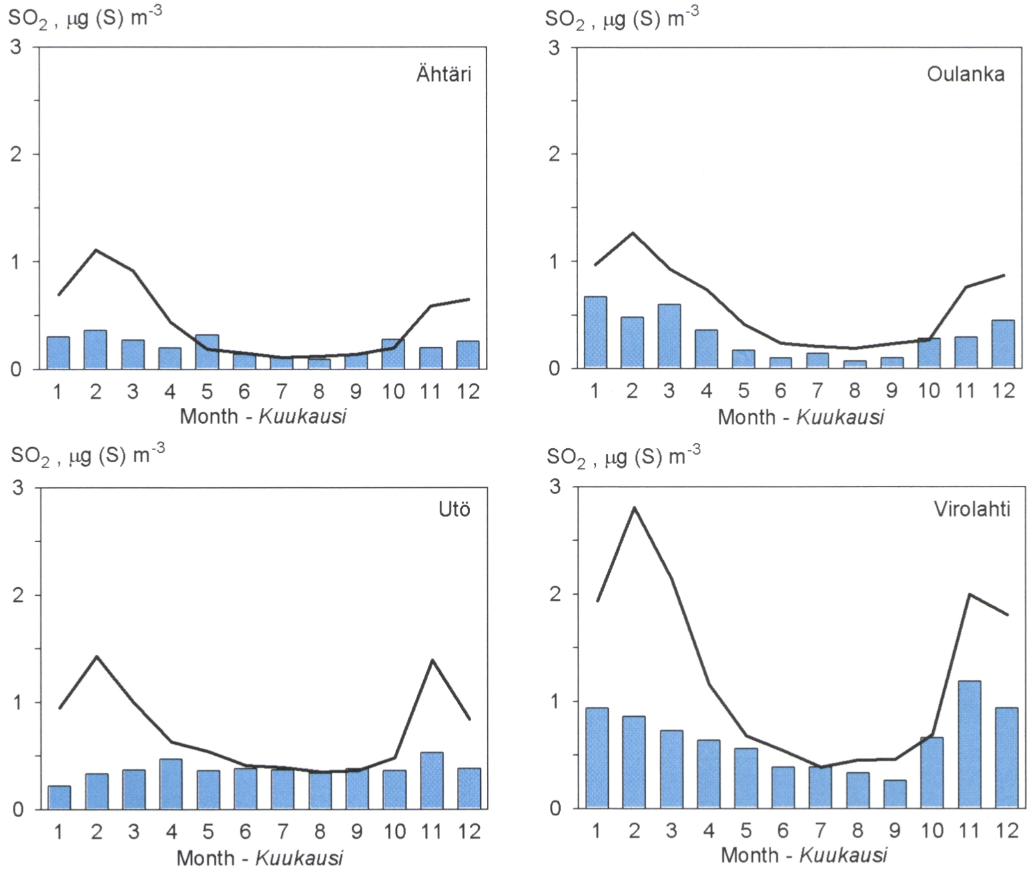

Figure 10. Monthly averages of sulphur dioxide concentrations (expressed as sulphur) in 2000 (bars) compared with the long-term (1992–99) averages (line) in Ähtäri, Oulanka, Utö and Virolahti. ***Kuva 10.*** *Rikkidioksidin kuukausikeskiarvot (rikiksi laskettuna) vuonna 2000 (pylväät) verrattuna pitkän ajan (1992–99) keskiarvoon (viiva) Ähtärissä, Oulangalla, Utössä ja Virolahdella.*

nents. Together they are referred to as nitrogen oxides and expressed as $NO_x = NO + NO_2$. In the atmosphere, nitrogen oxides undergo several chemical reactions, some of which can be cyclic as well as reversible, before being converted to nitrate in clouds or in rain. Oxidised nitrogen compounds as a whole (NO_x, nitric acid, nitrous acid, PAN, nitrate ions, etc.) are commonly known as NO_y. Nitrogen oxides are the most important components in the photochemical production of ozone in the troposphere.

Measurements of oxides of nitrogen at background stations were started in Utö in 1987 with nitrogen dioxide measurements. Difficulties were encountered in detecting low concentrations of nitrogen dioxide with the method used, and it was replaced in 1997 by measurements of nitrogen monoxide and nitrogen dioxide using chemiluminescence analysers.

The seasonal variation of nitrogen dioxide concentration at the EMEP stations together with the monthly averages for the years 1992–99 is shown in Fig. 12.

Ozone

Contrary to most other atmospheric pollutants, ozone is not a primary pollutant, i.e. it has no sources other than atmospheric

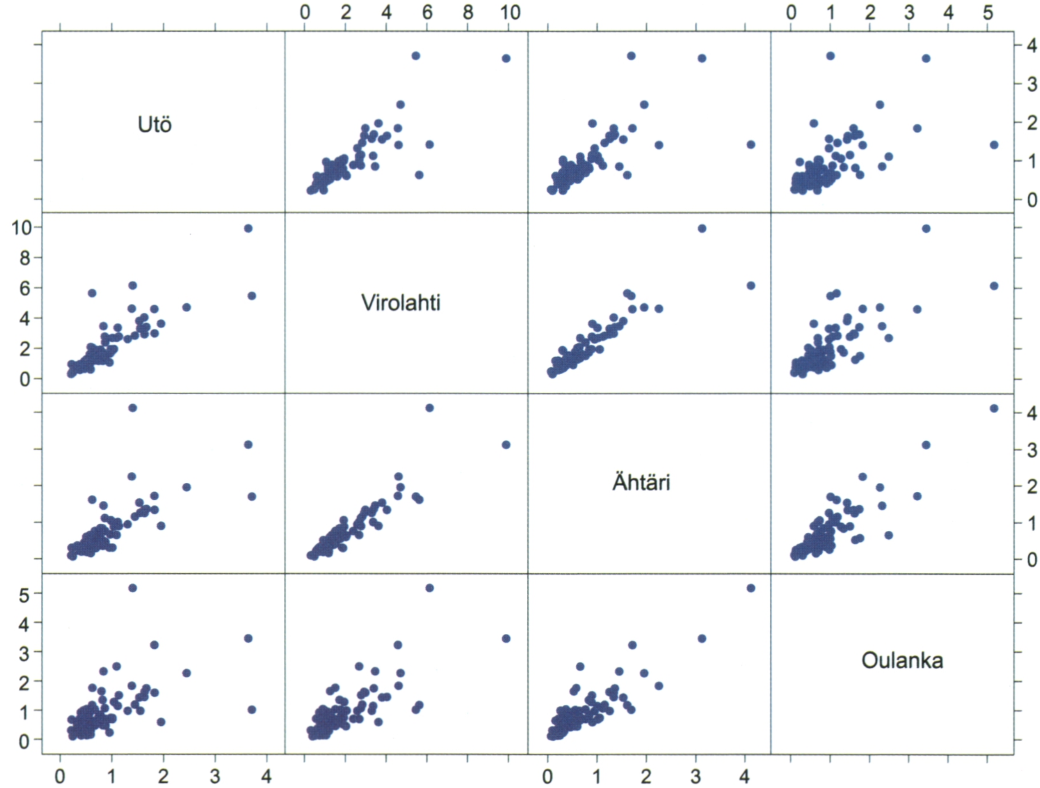

Figure 11. The scatter matrix of monthly values of sulphur dioxide concentrations (mg m[-3] as Sulphur (S)) during the winter season from 1989–2000 in Ähtäri, Oulanka, Utö and Virolahti. The scale for each pair of scatter plots are indicated on the left and right side and upper and lower side of the figure.

Kuva 11. *Rikkidioksidin kuukausikeskiarvon parittaiset pistejoukoti vuosien 1989–2000 talvikuukausiarvoista (mg m[-3] rikkiä (S)) Ähtärissä, Oulangalla, Utössä ja Virolahdella. Kunkin parin asteikot on esitetty kuvan reunoilla pistejoukon kohdalla.*

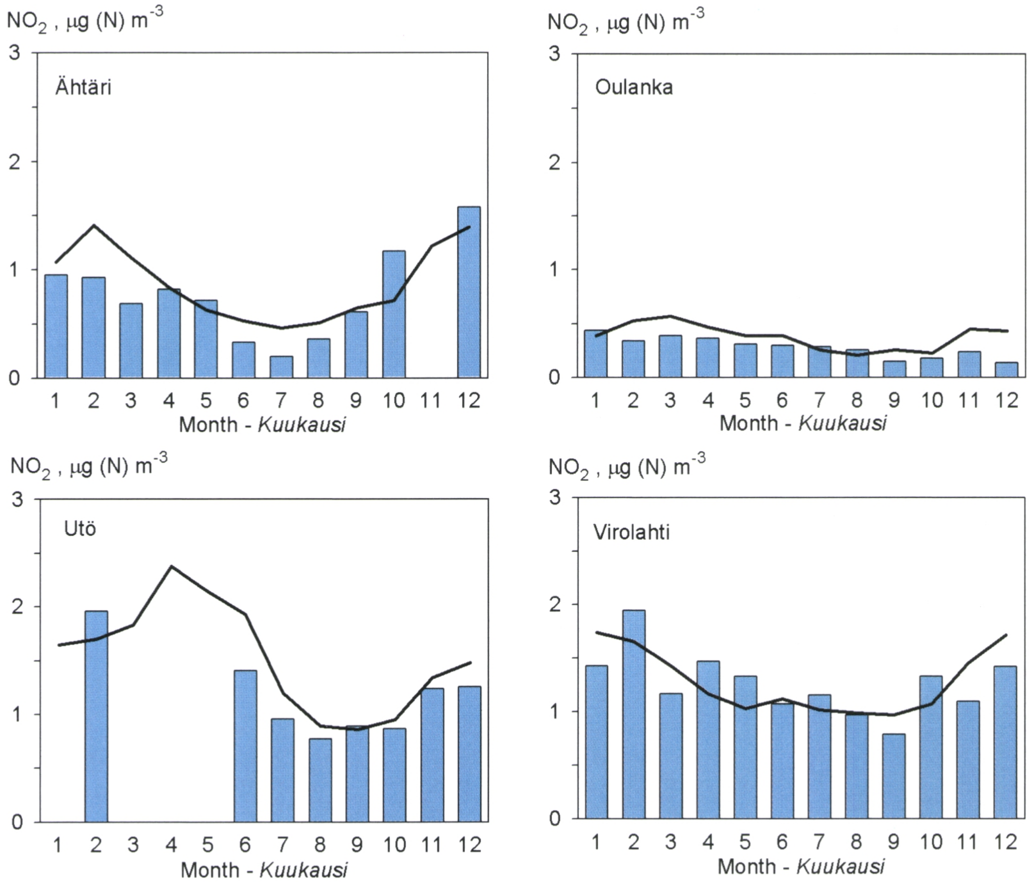

Figure 12. Monthly averages of nitrogen dioxide concentrations (expressed as nitrogen) in 2000 (bars) compared with the long-term (1992–99) averages (line) in Ähtäri, Oulanka, Utö and Virolahti.
Kuva 12. *Typpidioksidin kuukausikeskiarvot (typeksi laskettuna) vuonna 2000 (pylväät) verrattuna pitkän ajan (1992–99) keskiarvoon (viiva) Ähtärissä, Oulangalla, Utössä ja Virolahdella.*

chemical reactions. The annual mean ozone concentrations at the background air quality stations are shown in Fig. 13.

Ozone concentrations at Utö are slightly higher than those in other parts of the country. This may be due to the weaker rate of ozone deposition attributable to the marine location of the station. Elsewhere, the deposition of ozone onto vegetation is more effective and also causes damage to crops. The time series of the ozone concentration seems to support an increasing trend (Kulmala et al. 1998) but during the last five years the trend is not so clear and has even levelled out (Ruoho-Airola et al. 2001).

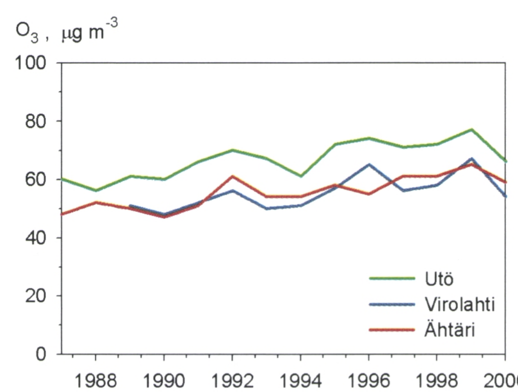

Figure 13. Mean annual concentrations of ozone.
Kuva 13. *Otsonin keskimääräinen vuosipitoisuus.*

The ozone concentrations also display some spatial and temporal features. In Fig. 14 we show the regression matrix for all stations as monthly means during the period 1992 to 2000. There is a good correlation between the coastal stations of Utö and Virolahti. Virolahti, Ähtäri and also Oulanka correlate reasonably well together but Ähtäri and Oulanka have poor correlation with Utö. This seems to be a difference between marine and continental stations.

The seasonal pattern of the ozone concentration has some typical features (Fig. 15). In spring there is often a so-called spring peak, which is mainly caused by increased sunlight and a lower deposition rate onto vegetation. In late spring and summer, due to the growth of vegetation, the deposition of ozone is stronger, causing damage to crops. The increased sunlight in spring and summer maintains ozone concentrations at a relatively high level, especially in anticyclonic weather systems, when polluted air-masses from Europe are transported to Finland.

Particulate matter

Particulate sulphate

The importance of particulate sulphate as a negative forcing agent acting against the atmospheric greenhouse effect has became evident in recent years through global models (IPCC 1995). Sulphate particles reflect sun-

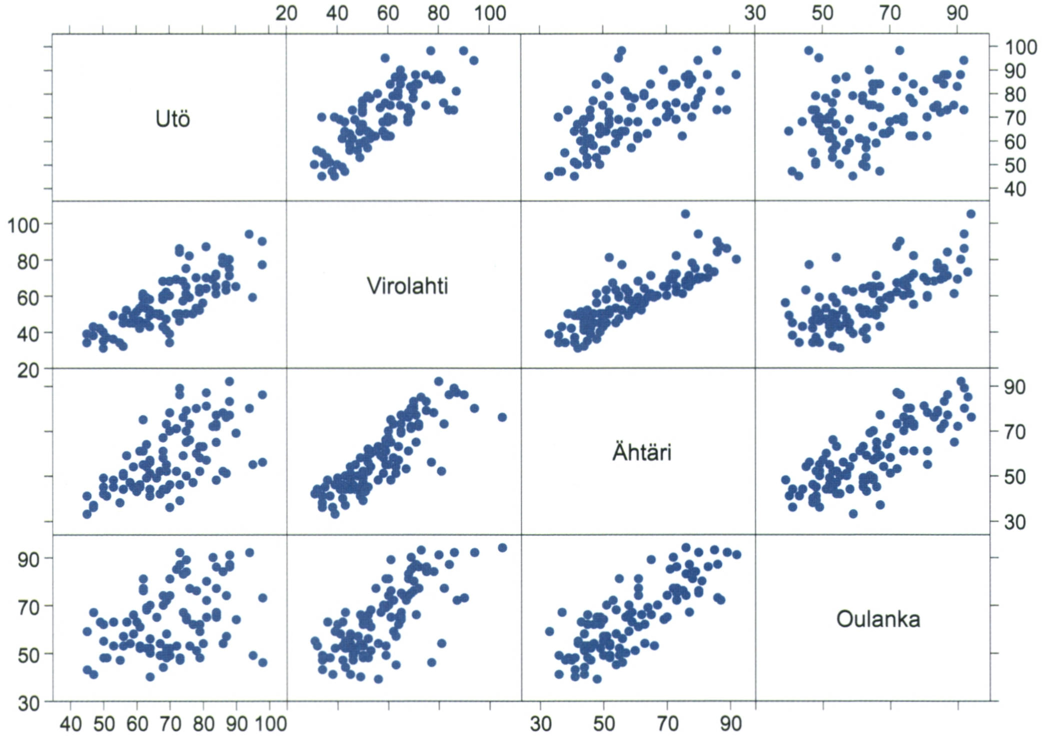

Figure 14. Scatter matrix of the monthly mean ozone concentrations (µg m^{-3}) during the period 1992 to 2000 for Utö, Virolahti, Ähtäri and Oulanka. The scale of each pair of scatter plots is indicated on the left and right side and the upper and lower side of the figure.
Kuva 14. *Otsonin kuukausikeskiarvon parittaiset pistejoukot (µg m^{-3}) Utössä, Virolahdella, Ähtärissä ja Oulangalla ajanjaksolla 1992–2000. Kunkin parin asteikot on esitetty kuvan reunoilla pistejoukon kohdalla.*

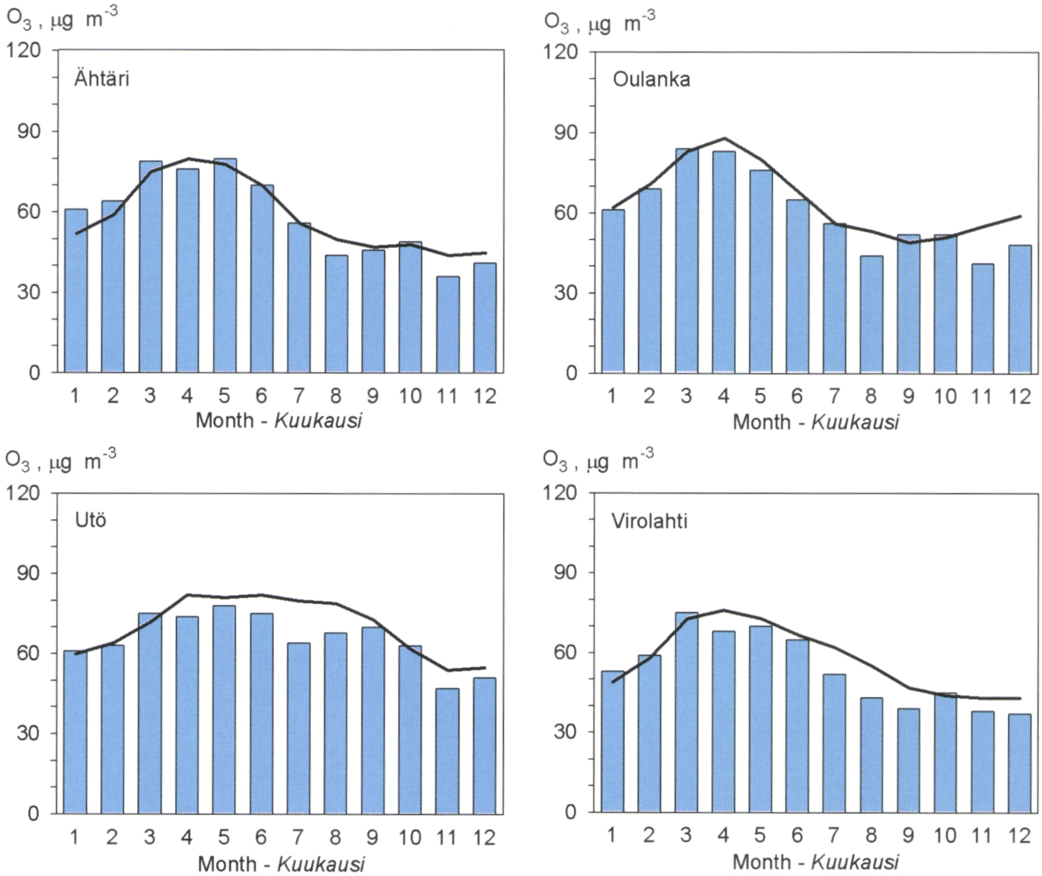

Figure 15. Monthly averages of ozone concentration in 2000 (bars) compared with the long-term (1992–99) averages (line) in Ähtäri, Oulanka, Utö and Virolahti.
Kuva 15. *Otsonin kuukausikeskiarvot vuonna 2000 (pylväät) verrattuna pitkän ajan (1992–99) keskiarvoon (viiva) Ähtärissä, Oulangalla, Utössä ja Virolahdella.*

light back into space, decreasing the intensity of sunlight at the surface. The density of sulphate particles in the atmosphere is highest in mid- and high latitudes (in the northern hemisphere).

The transformation of sulphur dioxide into sulphate is a relatively well-known process under atmospheric conditions. Sulphate is the product of the oxidation processes of primarily-emitted sulphur dioxide. Particulate sulphate has a seasonal variation with a peak in late winter or early spring. The aerosol sulphate concentration therefore behaves similarly to that of sulphur dioxide with a short time lag.

Particulate sulphate is collected together with sulphur dioxide in a two-stage filter pack system in which sulphate is first collected on a Whatman 40 filter, while sulphur dioxide is collected in the second stage on an impregnated filter (EMEP 1996). The filter material used is capable of collecting sub-micron particle sizes.

The annual mean concentration of particulate sulphate at the stations of Utö, Virolahti, Ähtäri, Oulanka and Pallas in 2000 together with the mean values for 1995–99 is shown in Fig. 16. Concentrations of particulate sulphate along the South coast of Finland are higher than those in other parts of the country. The spatial variation of particulate sulphate follows that of sulphur dioxide (Fig. 9) and the total deposition of sulphate (Fig. 5).

Particulate nitrate and ammonia

Nitrate particles are formed primarily from nitrogen monoxide and nitrogen dioxide. In the atmosphere nitrogen oxides undergo several chemical reactions before being converted into nitrate ions in clouds or in rain. The details of the different pathways for the formation of nitrate aerosols are described e.g. in Seinfeld (1986). The size of the nitrate particles is dependent on the process in which they are formed.

Particulate nitrate and ammonia are measured using a filter pack method by EMEP (EMEP 1996). For the analysis of nitrate, air is drawn through a Whatman 40 filter similar to that used for sulphate, and analysed with an ion chromatograph. In the case of ammonia, a Whatman 40 filter is impregnated with oxalic acid and analysed by ion chromatography.

The annual concentration of nitrate aerosol together with that of nitric acid (HNO_3) is shown in Fig. 17. The results for 2000 are compared with those for the period 1995–99. The same comparison is shown for ammonium in Fig. 18.

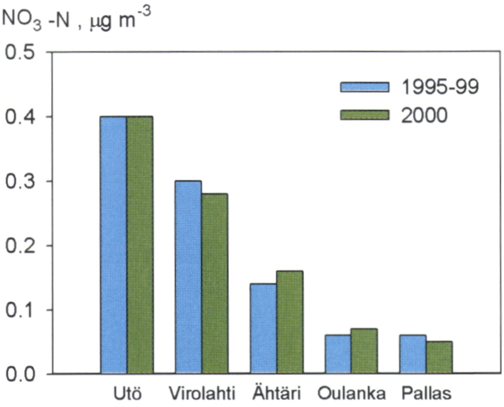

Figure 17. Aerosol nitrate concentrations (expressed as nitrogen) in 2000 compared with the period averages for 1995–99.
Kuva 17. *Leijuman nitraattipitoisuus (typeksi laskettuna) vuonna 2000 verrattuna vuosien 1995–99 keskiarvoon.*

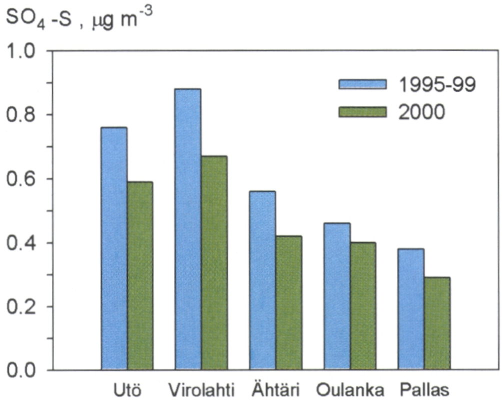

Figure 16. Aerosol sulphate concentrations (expressed as sulphur) in 2000 compared with the period averages for 1995–99.
Kuva 16. *Leijuman sulfaattipitoisuus (rikiksi laskettuna) vuonna 2000 verrattuna vuosien 1995–99 keskiarvoon.*

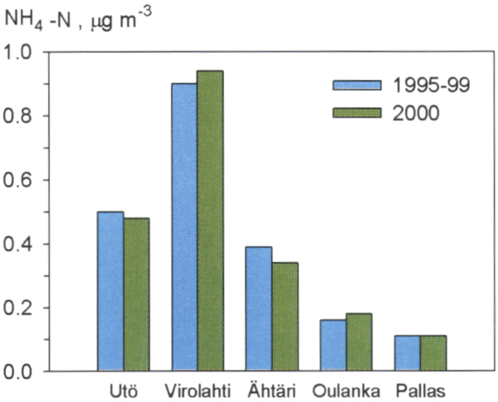

Figure 18. Aerosol ammonium concentrations (expressed as nitrogen) in 2000 compared with the period averages for 1995–99.
Kuva 18. *Leijuman ammoniumpitoisuus (typeksi laskettuna) vuonna 2000 verrattuna vuosien 1995–99 keskiarvoon.*

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3 Results of the 2001 national crown condition survey (ICP Forests/Level I)

Valtakunnallinen latvuskunnon seuranta (ICP metsäohjelma/taso I) vuonna 2001

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Summary

Approximately 450 permanent monitoring plots have been assessed each year since 1986. The degree of defoliation and foliage discoloration on Scots pines, Norway spruces and broadleaves are recorded.

A slight decrease (2.2 %) in the proportion of non-defoliated (0–10 %) trees, and an increase (2.6 %) in slightly defoliated (11–25 %) trees, were detected in Scots pine between 2000–2001. On Norway spruce and broadleaves, the proportion of non-defoliated and slightly defoliated trees remained almost the same as in 2000. The proportion of moderately defoliated (over 25 %) or severely (over 60 %) defoliated trees of all species decreased slightly (0.5–1 %) compared to 2000. The average tree-specific degree of defoliation was 9 % in pine, 19 % in spruce and 12 % in broadleaves in 2000. No marked changes have been observed in the average defoliation level on any tree species in recent years.

High stand age and weather and climatic factors have a considerable effect on defoliation in background areas of Finland. Fungal and insect epidemics have also influenced crown condition. The most extensive cause of forest damage in 2001 were the heavy storms in November, about 7 million m^3 of trees being lost as windthrow in southern Finland. Due to the very warm and rainy autumn in 2000, fungal diseases were more common in 2001 than in 2000. No correlation was found between the defoliation pattern and the modelled total sulphur and nitrogen deposition pattern at the national level.

Yhteenveto

Puiden latvuskuntoa on seurattu vuodesta 1986 pysyvillä havaintoaloilla (454 kpl vuonna 2001), joilla kasvaa yhteensä noin 8700 puuta. Puiden kunnon mittareina käytetään latvuksen harsuuntumisastetta, värioireiden määrää sekä tuhoja.

Harsuuntumattomien mäntyjen (harsuuntumisaste 0–10 %) osuus pieneni ja lievästi harsuuntuneiden mäntyjen (10–25 %) osuus kasvoi hieman edellisestä vuodesta. Kaikilla puulajeilla yli 25 % harsuuntuneiden osuus väheni lievästi. Männyn keskimääräinen harsuuntumisaste oli 9 %, kuusen 19 % ja lehtipuiden 12 %. Viime vuosina kaikkien puulajien keskimääräinen harsuuntumisaste on kuitenkin pysynyt melko vakaana.

Harsuuntuminen johtuu Suomessa pääasiassa puuston ikääntymisestä, erilaisista epäedullisista ilmasto- ja säätekijöistä sekä erilaista sieni- ja hyönteistuhoista. Vuonna 2001 laajinta metsätuhoa aiheuttivat marraskuun myrskyt, jotka kaatoivat arviolta seitsemän miljoonaa kuutiometriä puuta Etelä-

Suomessa. Sienitaudit olivat yleisempiä vuonna 2001 kuin vuonna 2000, koska lämmin ja kostea syksy 2000 edesauttoi sienien leviämistä. Koko maata tarkasteltaessa ei havaittu merkitsevää yhteyttä ilman epäpuhtauksien ja neulaskadon välillä vuonna 2001.

Introduction

Concern about a large-scale decline in forest vitality in central Europe in the late 1970's and early 1980's led Finland to initiate an extensive national survey of forest condition. The Finnish Forest Research Institute has annually surveyed crown condition since 1986. The surveys have been carried out in accordance with the methodology of the UN/ECE Convention on Long-Range Transboundary Air Pollution of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (Manual on… 1998) and, since 1995, also of Council regulations (EEC) No. 3528/86 and Commission regulations No. 1398/95. According to the latest report on Forest Condition in Europe (Forest... 2000), the forests in Finland were less defoliated than those in the majority of the other European countries.

The aim of the work is 1) to survey the regional distribution of forest condition in Finland, 2) to monitor year-to-year variation in forest condition, and 3) to analyse, using a correlative approach, the factors which may explain the regional pattern and changes in forest condition.

Material and methods

The large-scale crown condition survey (Level I) is carried out in Finland on a systematic network of permanent sample plots established on mineral soil sites (totalling 454 plots in 2001) during 1985–1986 in connection with the 8th National Forest Inventory (NFI). The country was divided into a southern and a northern region (demarcation line 66° N) (Jukola-Sulonen et al. 1990). The network in the southern region is based on a 16 x 16 km grid (391 plots in 2001), and in the northern region on a 24 x 32 km grid (63 plots in 2001). The total forest area covered by the plots is approximately 15 million ha.

According to the Commission regulation (EC No. 1398/95), the minimum number of sample trees per plot must be 20 in southern Finland and 10 in northern Finland. Because a fixed plot size was used in Finland during 1986–1994, the number of sample trees on many of the plots was insufficient to fulfil the minimum criterion for tree number. During summer 1995 over 4000 new trees and 82 new sample plots were added to the network (Table 1). The new trees were added systematically to the network by increasing the radius of the plot. Seven sample plots were terminated owing to cuttings, and eight new plots were added to the network in 2001.

In 2001, the total number of sample trees was 8579, of which 4608 were Scots pine (*Pinus sylvestris*), 2693 Norway spruce (*Picea abies*) and 1278 broadleaves (mainly *Betula* spp.). The number of common sample trees (cst) in 2000/2001 was 8302.

Defoliation and discoloration of Scots pine and broad-leaved trees were estimated on the upper 2/3 of the living crown, and on Norway spruce on the upper half of the living crown, in 5 % classes (Jukola-Sulonen et al. 1990, Salemaa et al. 1991). However, the average defoliation degree was calculated using the same defoliation-class mid-point values as in previous years (0–10 % defoliation = 5 %, 11–20 % def. = 15 %, 21–30 % def. = 25 % etc.). A tree is classified as discoloured when 10 % of its leaf or needle mass has abnormal coloration (e.g. needle yellowing). The degree of easily identifiable damage was also assessed and grouped into three categories: 1) slight, 2) moderate and 3) severe. The survey was carried out by eight forest technicians during the period June 25 to August 31.

Table 1. The number of assessed trees, sample plots and observers during 1986–2001.
Taulukko 1. *Seurantajakson 1986–2001 aikana arvioitujen puiden, näytealojen sekä arvioijien lukumäärät.*

Year *Vuosi*	Number of trees *Puiden lkm*	Scots pine *Mänty*	Norway spruce *Kuusi*	Broadleaves *Lehtipuut*	Number of plots *Näytealojen lkm*	Trees/plot *Puita/ näyteala*	Number of observers *Arvioijien lkm*
1986	3982	2233	1445	304	378	11	4
1987	3971	2171	1432	368	376	11	4
1988	3870	2129	1391	347	370	10	4
1989	3807	2032	1355	500	360	11	4
1990	3746	2002	1329	415	358	10	4
1991	3764	2004	1272	488	356	11	4
1992	4391	2377	1367	647	409	11	4
1993	4276	2347	1307	622	399	11	4
1994	4180	2301	1265	614	392	11	4
1995	8754	4520	2838	1396	455	19	7
1996	8732	4522	2851	1359	455	19	7
1997	8779	4582	2814	1383	460	19	7
1998	8758	4584	2829	1345	459	19	8
1999	8662	4538	2816	1308	457	19	8
2000	8576	4560	2706	1310	453	19	8
2001	8579	4608	2693	1278	454	19	8

Training and check survey

The national training course was held between 12–15 June 2001. During the course the reliability of the observations was studied on the basis of visual estimation of the same trees, which were also assessed during the International Cross-Calibration for Northern Europe on 4–6 June 2001 (Lindgren 2001b). In addition the observers underwent theoretical and practical training in assessment procedures and filling out the forms. The national check survey was carried out on ca 5 % of the sample plots (24 sample plots, 425 trees). According to the comparison of defoliation levels between the observers and the check survey team, 41 % of the pines (n = 214), 32 % of the spruces (n = 133) and 37 % of the broadleaves (n = 78) were assessed uniformly. Allowing for ±5 % tolerance, the corresponding percentages were 88 %, 85 % and 87 % respectively.

Results

Of the 8579 trees examined in 2001, 56 % of the conifers and 58 % of the broadleaves were not defoliated (leaf or needle loss 0–10 %). The proportion of conifers in class 1 (needle loss 11–25 %) was 32 %, and in classes 2–3 (needle loss more than 25 %) 12 %. The corresponding proportions for broadleaves were 33 % and 9 %, respectively. A slight decrease (2.2 %) in the proportion of non-defoliated (0–10 %) pines, and an increase (2.6 %) in slightly defoliated (11–25 %) pines, were detected between 2000–2001 (Fig. 1). On Norway spruce and broadleaves the proportion of non-defoliated and slightly

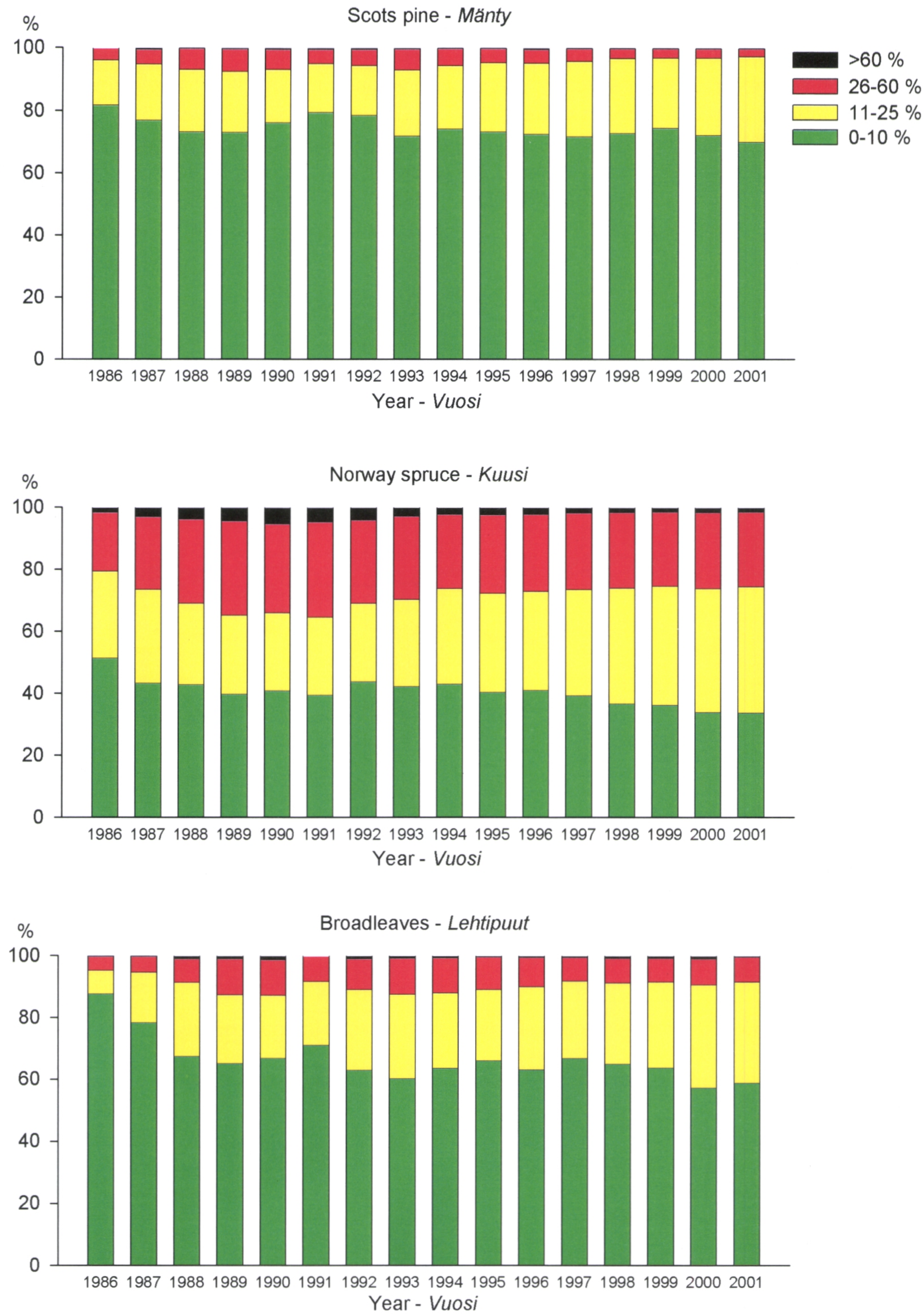

Figure 1. Defoliation frequency distribution for Scots pine, Norway spruce and broadleaves during 1986–2001.
Kuva 1. *Männyn, kuusen ja lehtipuiden harsuuntumisjakaumat kangasmetsissä 1986–2001.*

defoliated trees remained almost the same as in 2000 (Fig. 1). The proportion of moderately defoliated (over 25 %) or severely (over 60 %) defoliated trees of all species decreased slightly (0.5–1 %) compared to 2000 (Fig. 1). In 2001, the average, tree-specific defoliation degree was 9 % (9 % in 2000) in Scots pine, 18 % (19 %) in Norway spruce, and 12 % (11.5 %) in broadleaves (Fig. 2). Tree mortality was at the same level as in the previous years (0.2 %) (Table 2).

The proportion of over-25 % defoliated trees (common sample trees 1986–2001) increased by 0.9 %-units in Scots pine (n = 1468), 11.9 %-units in Norway spruce (n = 868) and 5.4 %-units in broadleaves (n =

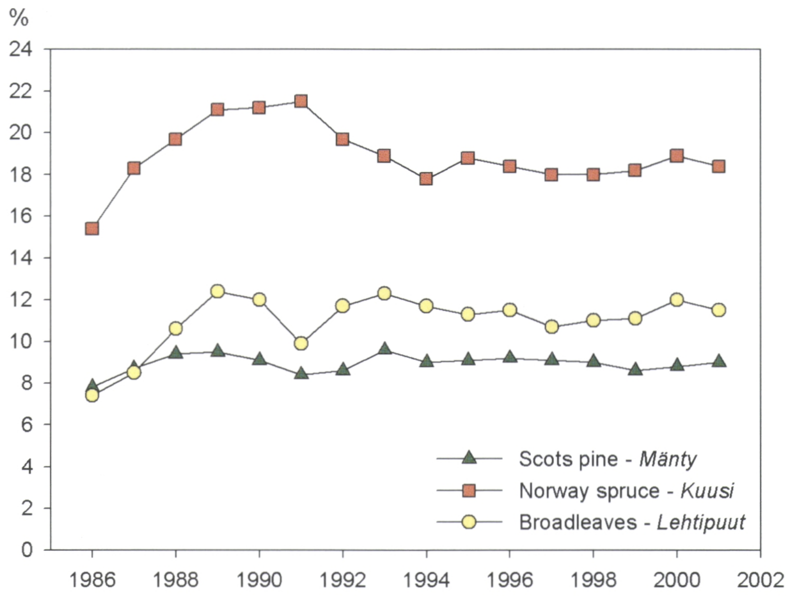

Figure 2. The average defoliation level of Scots pine, Norway spruce and broadleaves during 1986–2001.
Kuva 2. *Männyn, kuusen ja lehtipuiden keskimääräinen harsuuntumisaste vuosina 1986–2001.*

Table 2. Proportion (%) of trees in different defoliation classes in under 60-year-old and over 59-year-old stands in 2001.
Taulukko 2. *Puiden jakautuminen neljään eri harsuuntumisluokkaan alle ja yli 60-vuotiaissa metsiköissä.*

Defoliation class *Harsuuntumisluokka*	Scots pine *Mänty* < 60 yrs *< 60 v.*	 ≥ 60 yrs *≥ 60 v.*	Norway spruce *Kuusi* < 60 yrs *< 60 v.*	 ≥ 60 yrs *≥ 60 v.*	Broadleaves *Lehtipuut* < 60 yrs *< 60 v.*	 ≥ 60 yrs *≥ 60 v.*
0–10 %	91.1	52.0	71.4	16.1	77.5	37.0
11–25 %	8.2	43.1	22.6	49.2	20.4	46.5
26–60 %	0.3	4.3	5.8	32.3	1.9	14.8
> 60 %	0.0	0.5	0.2	2.2	0.0	1.2
Dead – *Kuolleet*	0.4	0.1	0.4	0.2	0.3	0.5

126). The proportion of over 25-% defoliated trees was higher in older (≥ 60 years) than in younger stands (under 60 years) (Table 2). The proportion of over-25 % defoliated stands was 0.9 % (1.2 % in 2000) in Scots pine, 26.5 % (28 % in 2000) in Norway spruce and 4.3 % (5 % in 2000) in broadleaves (Fig. 3).

No correlation was found between the defoliation pattern of conifers or broadleaves and the modelled sulphur or nitrogen deposition at the national level in 2001 (deposition data for 1993 are based on the HILATAR model, Hongisto 1998).

On Scots pine and broadleaves the proportion of discoloured trees (extent of discoloured needle/leaf mass more than 10 %) remained at the same level (under 1 %) as in 2000, and that of Norway spruce decreased from 8 % to 6 %. The most frequent discoloration symptoms were needle tip yellowing and needle yellowing. Discoloration symptoms were mainly restricted to needles older than two years. Moreover, the proportion of slightly discoloured (extent of discoloured needle mass 1–10 %) trees was higher than that in the previous year. This was especially the case on spruce, the first year needle sets of which had turned yellow as a result of fungal diseases. There were no clear differences in the proportion of discoloured trees between under 60-year-old stands and older stands (Table 3). The most discoloured Norway spruce stands were mainly situated in South Finland (Fig. 4).

Altogether 40 % (37 % in 2000) of the Scots pines, 49 % (33 %) of the Norway spruces and 35 % (35 %) of the broadleaves had some kind of abiotic or biotic damage symptom (Fig. 5). The damage was classified as moderate or severe on 4 % of all Scots pines in 2001. The corresponding proportions

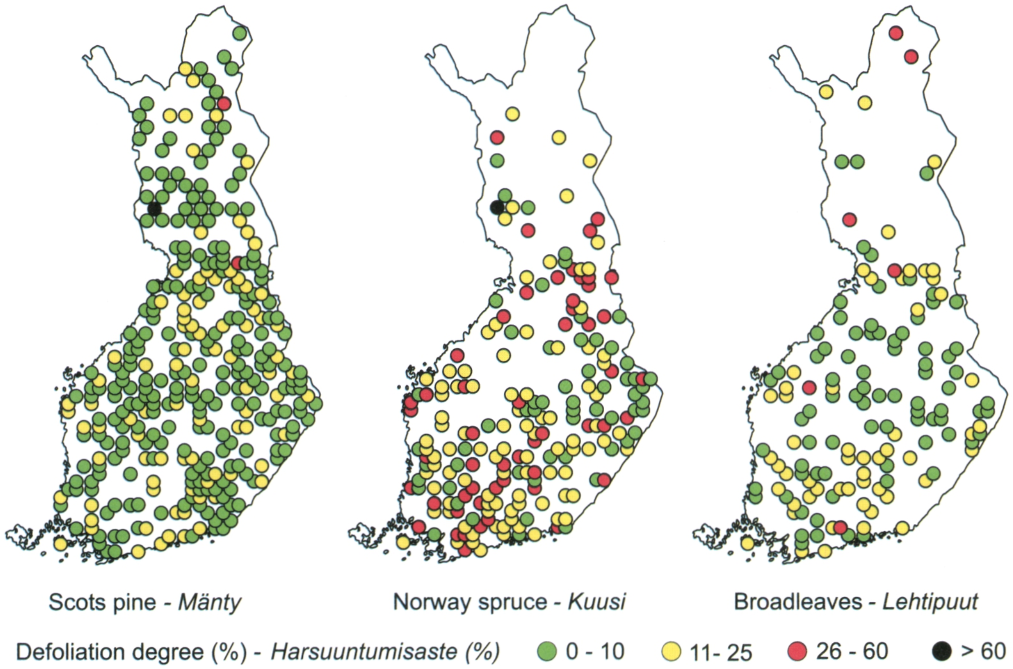

Figure 3. Average defoliation degree of Scots pine, Norway spruce and broadleaves in 2001. The colour of the circle indicates the plot-specific values (see map legend).
Kuva 3. *Männyn, kuusen ja lehtipuiden harsuuntumisen keskiarvot näytealoilla vuonna 2001. Pallon väri ilmaisee näytealakohtaisen arvon (kts. karttaseloste).*

for Norway spruce and broadleaves were 12 and 10 %, respectively. The most common biotic agents were scleroderris pine cancer (*Gremmeniella abietina*), and insects (*Diprionidae, Tomicus* spp.) on Scots pine, and on Norway spruce rust fungi, especially *Chrysomyxa ledi*.

Table 3. Proportion (%) of trees in different discoloration classes in under 60-year-old and over 59-year-old stands in 2001.
Taulukko 3. *Puiden jakautuminen neljään eri värioireluokkaan alle- ja yli 60-vuotiaissa metsiköissä.*

	Scots pine *Mänty*		Norway spruce *Kuusi*		Broadleaves *Lehtipuut*	
Discoloration class *Värioireluokka*	< 60 yrs *< 60 v.*	≥ 60 yrs *≥ 60 v.*	< 60 yrs *< 60 v.*	≥ 60 yrs *≥ 60 v.*	< 60 yrs *< 60 v.*	≥ 60 yrs *≥ 60 v.*
0–10 %	99.0	99.3	93.6	92.3	99.7	98.8
11–25 %	0.5	0.5	5.9	6.8	0.2	0.5
26–60 %	0.1	0.1	0.5	0.6	0.0	0.2
> 60 %	0.0	0.0	0.0	0.1	0.0	0.0
Dead – *Kuolleet*	0.4	0.0	0.4	0.2	0.2	0.5

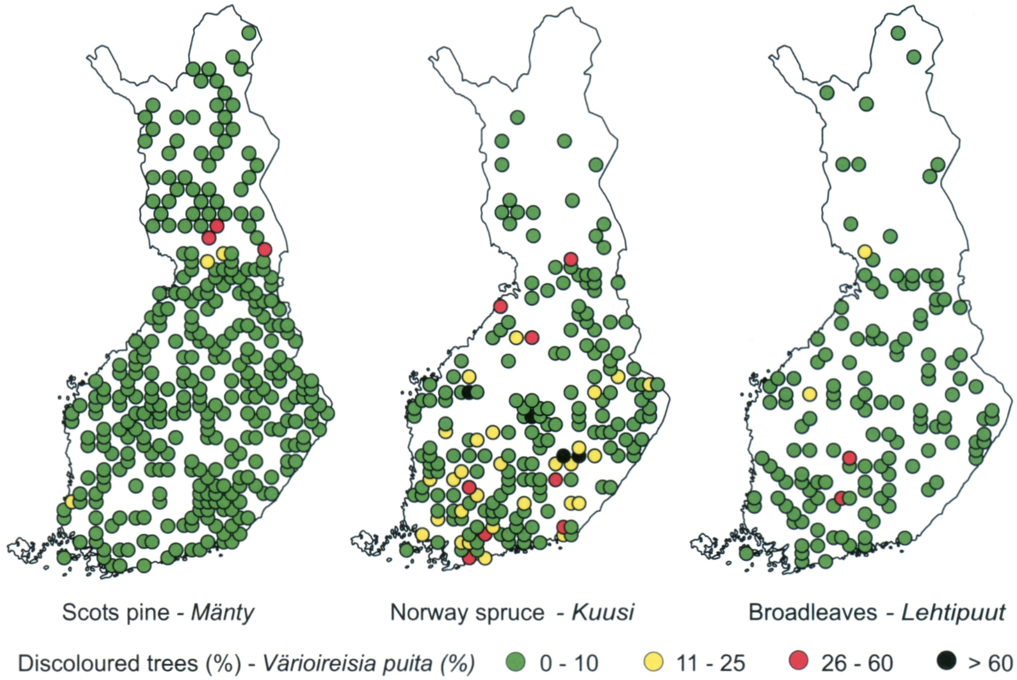

Figure 4. Proportion of discoloured Scots pines, Norway spruces and broadleaves in 2001. The colour of the circle indicates the plot specific values (see map legend).
Kuva 4. *Värioireellisten mäntyjen, kuusien ja lehtipuiden osuudet näytealoilla vuonna 2001. Pallon väri ilmaisee näytealakohtaisen arvon (kts. karttaseloste).*

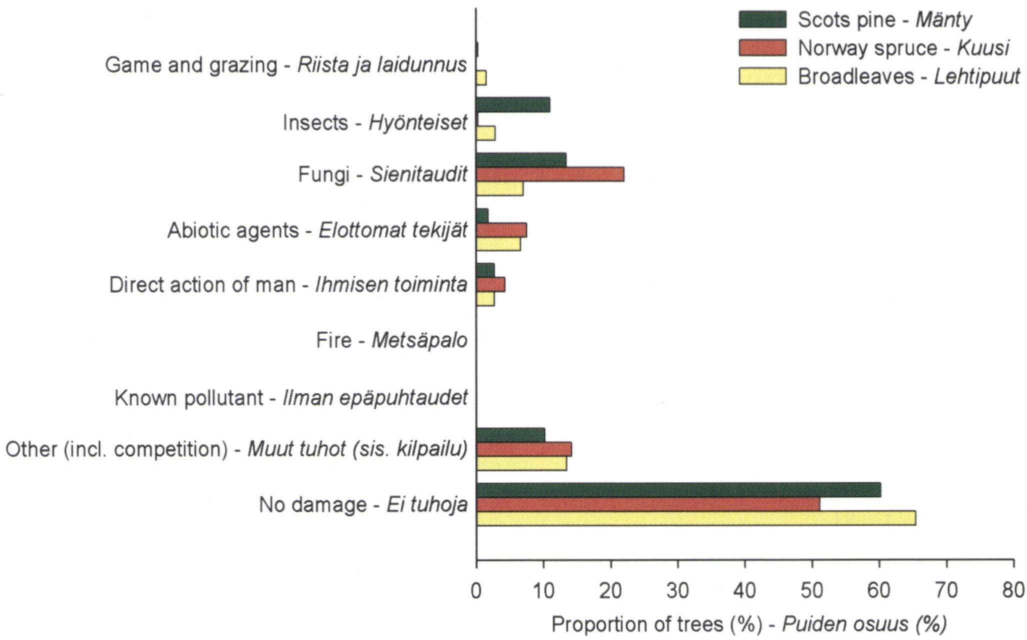

Figure 5. The proportion of trees in eight easily identifiable damage groups in 2001.
Kuva 5. *Puiden osuus kahdeksassa eri vaurio/tuho ryhmässä (ns. helposti tunnistettavat tuhot) vuonna 2001.*

Conclusions

A large number of natural factors, the most important of which are connected with stand age, climate, and weather, and abiotic or biotic damage, affect forest condition in Finland. In the northern parts of the country especially, 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 during 1986 to 1989. Since then the tree crowns have recovered. Defoliation in broadleaves again increased in 1992–1993. A slight increase in Scots pine defoliation was also observed in 1993 and 1997. Although the proportion of non-defoliated and slightly defoliated trees has varied in recent years, no essential changes have been observed in the proportion of moderately or severely defoliated trees, or average defoliation degree, of any of the tree species (Lindgren 2000, 2001a).

According to the more detailed forest damage report (Lipponen et al. in this report), the most extensive cause of forest damage in 2001 were the heavy storms in November, about 7 million m^3 of trees being lost as windthrow in southern Finland. Due to the very warm and rainy autumn in 2000, fungal diseases were more common in 2001 than in 2000. In some regions in southern and western Finland, the outbreak of scleroderris pine cancer (*Gremmeniella abietina*) on pine was the worst for more than a decade. Rust fungi, especially *Chrysomyxa ledi* on Norway spruce, were common throughout almost the whole country. There were no extensive insects outbreaks in 2001.

No correlation was found between the defoliation pattern of conifers or broadleaves and the modelled sulphur or nitrogen deposition at the national level in 2000.

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4 Results of the intensive monitoring of forest ecosystems (ICP Forests/Level II)

Intensiivisen seurannan tuloksia ICP metsäohjelma/ taso II havaintoaloilla

4.1 Crown condition on the intensive monitoring plots in 2000

Latvuskunto intensiivisen seurannan havaintoaloilla vuonna 2000

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Summary

The degree of defoliation, foliage discoloration and abiotic and biotic damage were recorded in 2000 on 721 Scots pines and 800 Norway spruces growing on 27 Level II mineral soil plots. The average defoliation level of Scots pine decreased from 10.7 % to 10 % and that of Norway spruce increased from 16.6 % to 17.4 % compared to the situation in 1999. The proportion of discoloured Scots pine was 0.7 % (4.7 % in 1999) and that for Norway spruce 14.4 % (17 % in 1999). 25 % of the discoloured Norway spruces also had signs of fungal infection.

Yhteenveto

Vuonna 2000 metsäekosysteemien intensiivisessä seurannassa (ICP metsäohjelma/ taso II) oli mukana 721 mäntyä ja 800 kuusta, jotka kasvoivat kivennäismaa-aloilla. Männyn keskimääräinen harsuuntumisaste aleni hieman 10,7 %:sta 10 %:iin ja kuusen nousi 16,7 %:sta 17,4 %:iin verrattuna edelliseen vuoteen. Värioireellisten mäntyjen osuus oli 0,7 %, kun se vuonna 1999 oli 4,7 %. Vastaavasti värioireellisia kuusia oli vuonna 2000 14,4 %, edellisenä vuonna 17 %. Noin 25 % värioireellisista kuusista kärsi myös sienitaudeista.

Introduction

The 2000 annual crown condition assessment was carried out on the 13 Scots pine *(Pinus sylvestris)* and 14 Norway spruce *(Picea abies)* plots located on mineral soil sites, and on the four Scots pine plots on peatland. Defoliation, needle discoloration, and abiotic and biotic damage were assessed on 20 trees on each sub-plot, as well as on the 20 needle sampling trees. The number of assessed Scots pines was 989 (mineral soil) and 320 (peatland), and of Norway spruces 1132 (mineral soil). However, the results for trees used for needle sampling or trees growing on peatland are not included in this report. The results for 2000 are therefore based on 721 Scots pines and 801 Norway spruces growing on the Level II mineral soil plots.

Defoliation of Scots pine was estimated on the upper 2/3 of the living crown, and of Norway spruce on the upper half of the living crown, in 5 % classes. A one-week training course was held before the survey period. Two experts carried out the check survey during the field period. According to the comparison of defoliation levels between the observers and the check survey team, 92 % of the Scots pines and 91 % of the Norway spruces were assessed uniformly (± 5 % tolerance) (Table 1).

Results

In 2000, 72 % (68 % in 1999) of the Scots pines and 35 % (42 % in 1999) of the Norway spruces were not defoliated (needle loss 0–10 %). The corresponding proportions for trees growing on similar site types in the Level I survey were 70 % (72 % in 1999) and 33 % (37 % in 1999), respectively (Fig. 1). Compared to the results of Level II for year 1999, the proportion of slightly defoliated (11–25 % defoliation) Scots pine decreased from 28 % to 23 %, and that of Norway spruce increased from 42 % to 50 %. The proportion of more than 25 % defoliated pines or spruces remained almost at the same level as in 1999. The proportion of defoliated trees of both species clearly increased with stand age on both the Level I and II plots (Fig. 2).

The overall average defoliation level of Scots pine on the Level II plots, decreased from 10.7 % in 1999 to 10.0 % in 2000, but increased from 9.8 % to 10.3 % in Level I. The overall average defoliation level of Norway spruce in Level II plots increased from 16.7 % to 17.4 %, and in Level I from 19.5 % to 20.6 % compared to 1999 (Fig. 1). The plot specific defoliation degree for Scots pine varied from 4.5 % (Punkaharju_P, No. 16) to 23.1 % (Lieksa_Pim, No. 20) (Fig. 3), and for spruce from 8.7 % (Uusikaarlepyy_S, No.23) to 28.1 % (Oulanka_S, No. 7) (Fig. 3).

In 2000, 0.7 % (4.7 % in 1999) of the Scots pines and 14.4 % (17 % in 1999) of the Norway spruces were discoloured (proportion of affected needles in the crown > 10 %) (Table 2). The corresponding proportions for Level I were 0.3 % and 8 %, respectively. The most abundant discoloration symptoms on Norway spruce at Level II were needle tip yellowing and apical yellowing (ca 64 % of discoloured trees) and overall yellowing (ca 35 %) of more than one-year old needles. 25 % of the discoloured spruces had a fungal infection.

Altogether 23 % (24 % in 1999) of the Scots pines and 43 % (32 % in 1999) of the Norway spruces had some kind of damage symptom (Fig. 4). The change in the proportion of damaged Norway spruces between 1999 and 2000 is mainly due to a fungal epidemic, which increased the frequency of spruces with fungal symptoms from 24 % in 1999 to 36 % in 2000. However, about 3 % (2 % in 1999) of all the damage on Scots pine

Table 1. Difference in the assessment of defoliation between the control team and individual observers in 2000. 0 = no difference, minus sign = observer's assessment was lower than that of the check survey team, plus sign = higher than that of the control team.
Taulukko 1. *Tarkastusryhmän ja arvioijien välinen ero harsuuntumisen arvioinnissa vuonna 2000. 0 = ei eroa, – = arvioijien arvio alempi kuin kontrolliryhmän, + = arvioijien arvio korkeampi kuin kontrolliryhmän.*

Difference (%) *Ero*	Scots pine *Mänty* % of trees *% puista*	Norway spruce *Kuusi* % of trees *% puista*
– 15	0.0	0.8
– 10	4.2	4.2
– 5	15.0	33.3
0	52.5	40.8
+ 5	24.2	16.6
+ 10	4.0	4.17
+ 15	4.1	0.9
Number of trees *Puiden lkm*	120	120

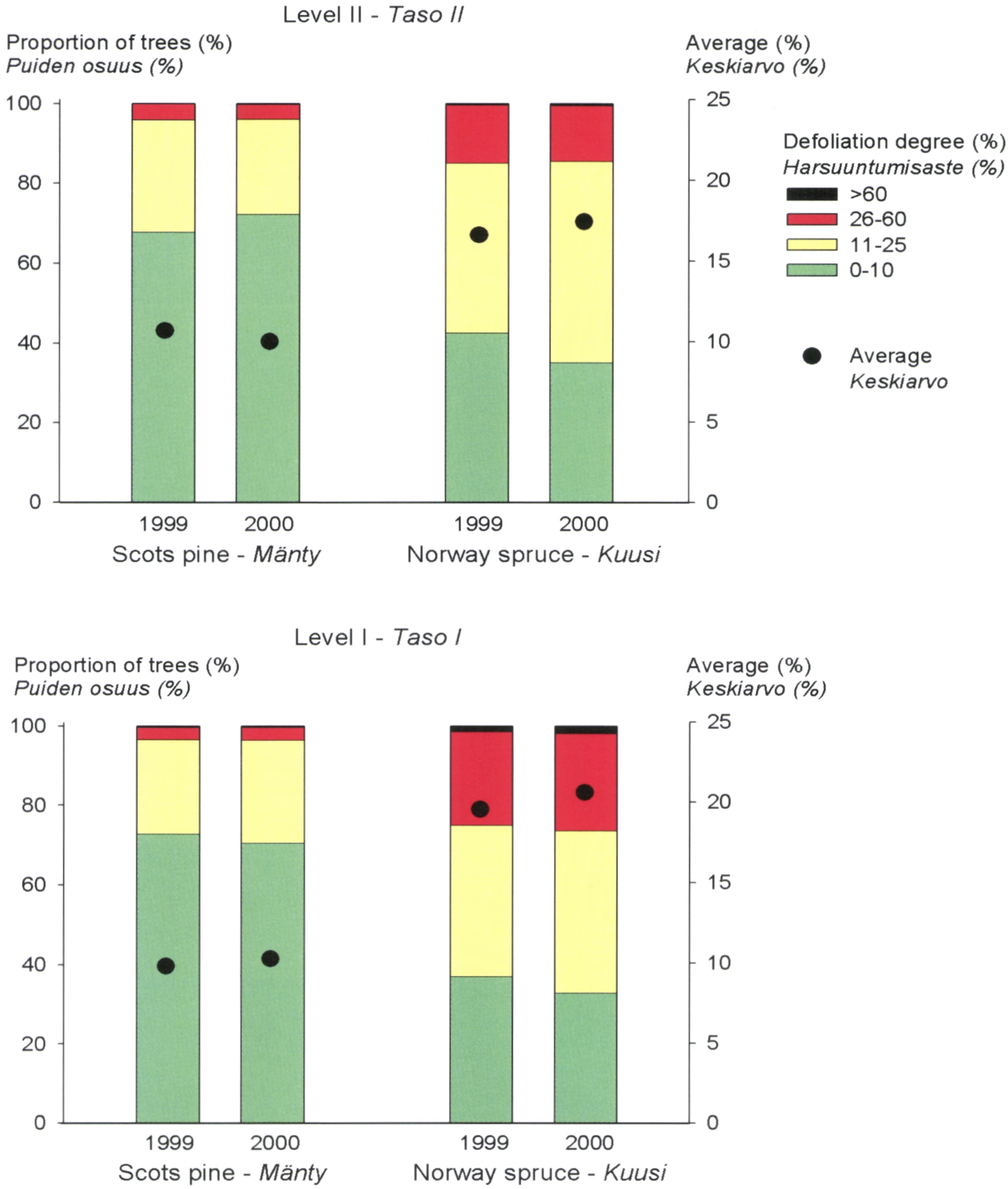

Figure 1. Defoliation frequency distribution and average defoliation degree (black dots) for Scots pine and Norway spruce in 1999 and 2000 on Level II and Level I plots. The number of sample trees on Level II is 721 for pine and 800 for spruce, and on Level I 3883 and 2513, respectively.
Kuva 1. *Männyn ja kuusen harsuuntumisjakauma sekä keskimääräinen harsuuntumisaste (musta ympyrä) vuosina 1999 ja 2000 taso II:n ja taso I:n näytealoilla. Taso II:lla mäntyjen lukumäärä oli 721 ja kuusten 800. Vastaavat lukumäärät taso I:llä olivat 3883 ja 2513.*

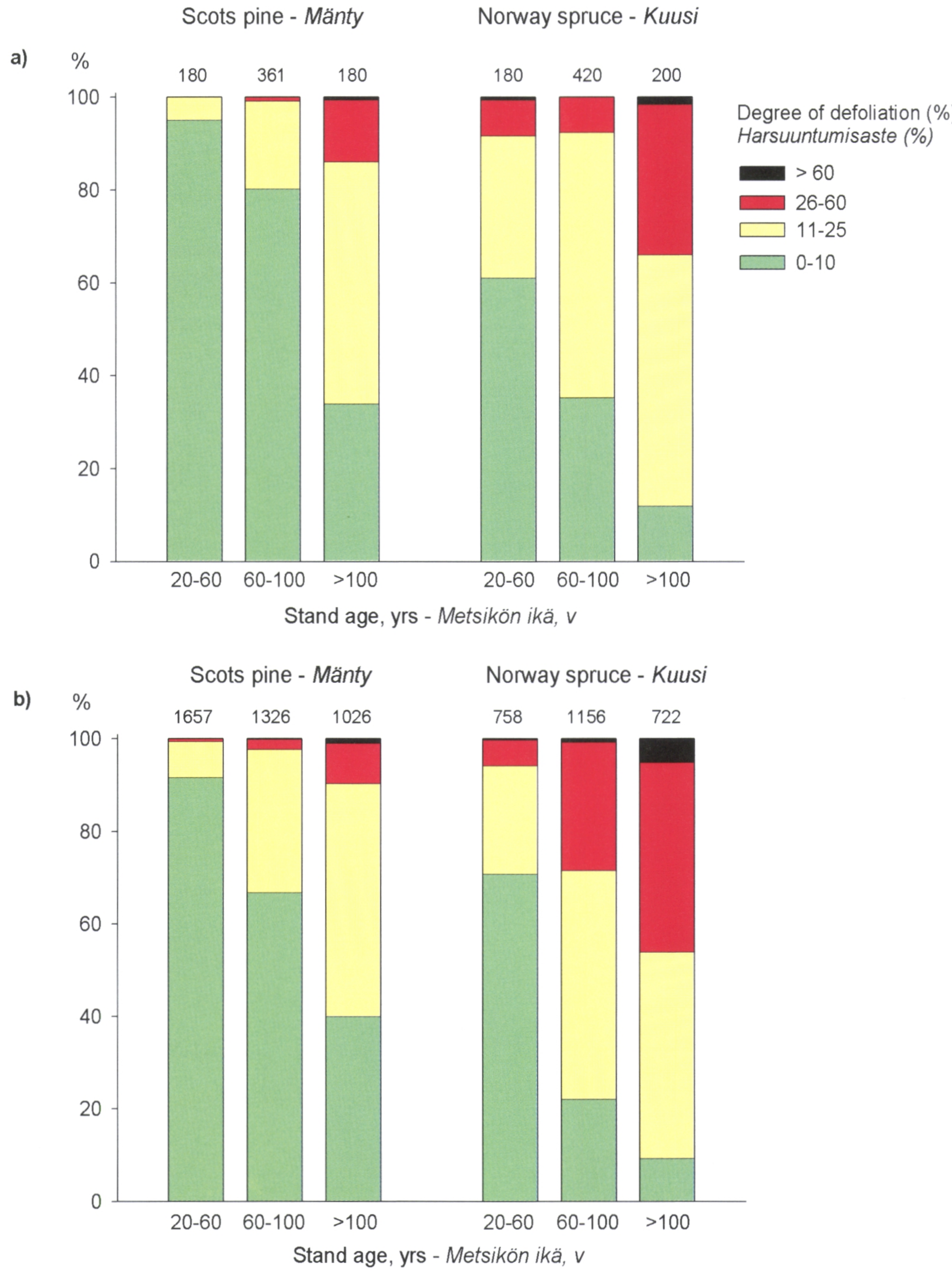

Figure 2. Defoliation frequency distribution for Scots pine and Norway spruce in three stand age classes on Level II (a) and Level I (b) plots in 2000. The number of trees is given above the column.

Kuva 2. *Männyn ja kuusen harsuuntumisjakaumat alle 60 vuotta, 61–100 vuotta ja yli 100 vuotta vanhoissa metsiköissä vuonna 2000. Kuva a = taso II ja kuva b = taso I. Puiden lukumäärä kussakin ryhmässä on ilmoitettu pylvään yläpuolella.*

was classified as moderate or severe, and on spruce 7.5 % (9 % in 1999). The most common biotic agents on Scots pine were sawflies (*Diprionidae*) and scleroderris pine canker *(Gremmeniella abietina)*, and on Norway spruce fungal pathogens (*Chrysomyxa* spp.). According to the results, the defoliation degree was higher on trees that had one or more cause of damage than on trees with no damage (Fig. 5).

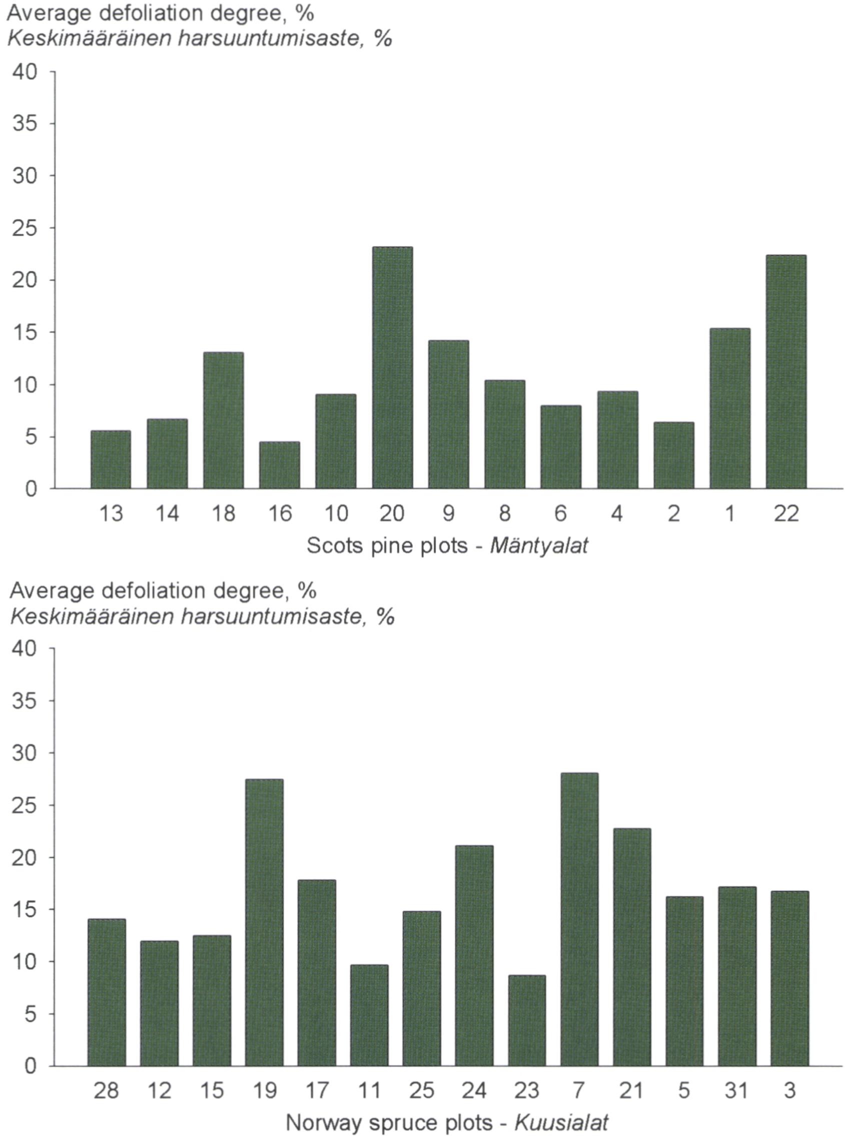

Figure 3. The plot-specific defoliation degree on Scots pine and Norway spruce in 2000. The numbers refer to the monitoring plots (see p. 12, table 1 for plots).
Kuva 3. *Männyn ja kuusen keskimääräinen harsuuntuneisuus havaintoaloittain vuosina 2000. Kuvassa on esitetty havaintoalojen numerot (ks. s. 12, taulukko 1, havaintoalat).*

Table 2. Proportion of discoloured trees in 2000. A tree is classified as discoloured when more than 10 % of the foliage is affected.
Taulukko 2. *Värioireellisten puiden osuus vuonna 2000. Puu luokitellaan värivikaiseksi, kun sen lehdistä tai neulasista yli 10 % on värioireellisia.*

Species *Puulaji*	Number of trees *Puiden lkm*	Proportion of trees (%) – *Puiden osuus (%)* 0–10	11–25	26–60	> 60
Scots pine - *Mänty*	721	99.3	0.7	0.0	0.0
Norway spruce – *Kuusi*	800	85.6	13.4	0.7	0.3

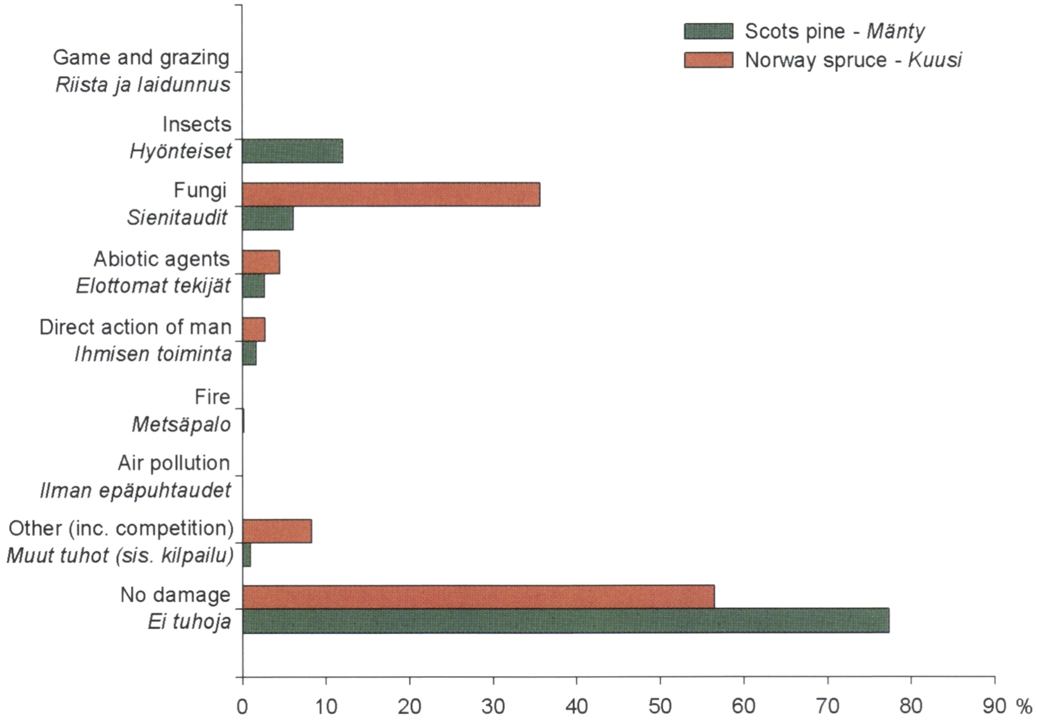

Figure 4. The proportion of trees in easily identifiable damage classes in 2000.
Kuva 4. *Puiden osuus kahdeksassa eri vaurio/tuho ryhmässä (ns. helposti tunnistettavat tuhot) vuonna 2000.*

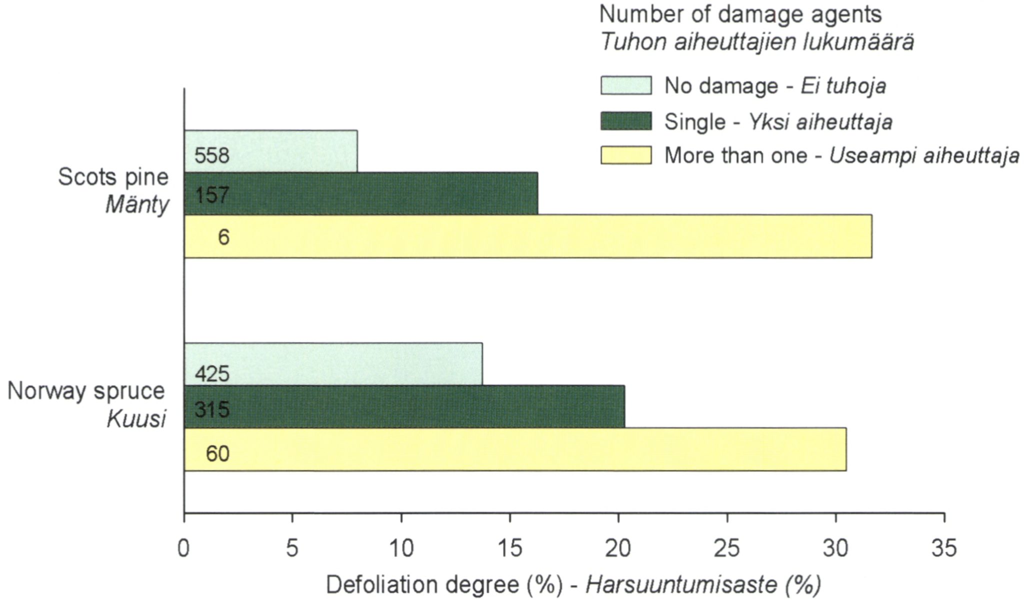

Figure 5. Defoliation degree of Scots pine and Norway spruce in relation to the number of damaging agents. Number of trees is given inside the column.
Kuva 5. *Männyn ja kuusen harsuuntumisaste suhteessa tuhojen määrään. Puiden lukumäärä kussakin ryhmässä on annettu pylvään sisällä.*

Conclusions

In general there were no marked changes in the average defoliation level between 1999 and 2000 on the Level II plots. The average defoliation level of Scots pine decreased slightly (0.7 %) and that of Norway spruce increased slightly (0.8 %) compared to the 1999 survey. In Level I, there was a slight increase in the average defoliation level of both pine and spruce since 1999. In Level II, the most notable changes in the proportion of trees in different defoliation classes was detected in the not defoliated (needle loss 0–10 %) and slightly defoliated (needle loss 11–25 %) trees. The proportion of over 25 % defoliated trees clearly increased with stand age on both Level II and Level I. The incidence of different damaging agents clearly affects the degree and yearly variation of defoliation and discoloration (Lindgren 1999, 2000). Compared to the results for Level I from 2000 (Lindgren 2001), a parallel decrease in the proportion of discoloured trees was also seen on Scots pine but not on Norway spruce in the Level II results.

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4.2 Understorey vegetation survey (ICP Forests/ Level II) in 2000

Aluskasvillisuuden kartoitus (ICP metsäohjelma/taso II) vuonna 2000

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Summary

The cover percentages of the understorey plant species have remained relatively constant on six of the ICP Forest/Level II plots during the monitoring period 1998–2000. The largest annual changes in the coverage of vascular species were 10 % units, and the changes correlated positively with the amount of precipitation. The moisture level also seemed to regulate the between-species changes in the coverages of the moss species.

Yhteenveto

Aluskasvillisuuden lajien peittävyysprosentit ovat pysyneet suhteellisen vakaina kuudella ICP metsäohjelma/taso II:n havaintoalalla seurantajakson 1998–2000 aikana. Putkilokasvilajien peittävyyksien vuosittaiset muutokset ovat olleet suurimmillaan 10 %-yksikköä, ja ne vaihtelivat samansuuntaisesti sademäärän kanssa. Sammalkerroksen kosteus näytti säätelevän myös sammallajien välisiä peittävyyseroja.

Introduction

The main aims of the vegetation monitoring in the ICP Forests/Level II programme are 1) to characterise the current state of forest vegetation on the basis of the floristic composition, and 2) to detect temporal changes in the vegetation in relation to natural and anthropological environmental factors. A complete vegetation survey of the 31 sample plots in the Level II monitoring network was carried out for the first time in 1998, and will be repeated every fifth year. The survey is also being repeated on six of the plots each year. In this report we analyse the change in the cover % of the understorey plant species on the six plots during 1998–2000.

Material and methods

The annual survey of understorey vegetation is carried out on three Scots pine and three Norway spruce plots representing the southern and northern boreal coniferous zones in Finland. The plots selected for the annual survey are: Pallasjärvi_P (No. 2, Empetrum-Myrtillus type), Pallasjärvi_S (No. 3, Hylocomium-Myrtillus type), Oulanka_S (No. 7, Hylocomium-Myrtillus type), Oulanka_P (No. 8, Hylocomium-Myrtillus type), Tammela_S (No. 12, Myrtillus type) and Tammela_P (No.13, Vaccinium type). One sub-plot (30 x 30 m) has been reserved for vegetation monitoring on each plot.

Two botanists carried out the vegetation analysis during 24 July – 7 August 2000. A total of 16, permanently marked sample units (2 m^2 quadrates) were analysed on each subplot. The visual coverage of the plant species was assessed using the following scale: 0.01, 0.1, 0.2, 0.5, 1, 2, ...99, 100 %. The bottom layer (mosses and lichens), field layer (< 50 cm herbs, grasses and dwarf shrubs) and shrub layer (50–150 cm) were analysed. Plants growing on stones or on rotten wood were excluded. Cover % of litter, dead branches, fallen tree stems, stumps, exposed mineral soil and stones were also assessed. Field tests were carried out on each sample plot to check that the assessment level remained uniform between the two botanists. Samples of unknown plant species (mainly mosses and lichens) were later identified by specialists. A detailed description of the methods has been given in Salemaa & Korpela (2000).

Results

The change in the total cover % of vascular plant species during 1998–2000 was relatively small on most of the sample plots (Table 1). The largest annual changes were approximately 10 % units, but in most cases the variation was within ± 5 % units. At Pallasjärvi_P (No. 2) and Pallasjärvi_S (No. 3) the total cover of vascular plant species was about 10 % units higher in 2000 than in 1999. This was mainly caused by the increase in the cover of *Vaccinium myrtillus* (Fig. 1). In contrast, the abundance of *Vaccinium vitis-idaea* increased slightly at Tammela_S (No_12) and Tammela_P (No_13) in 2000 (Fig. 1). *Linnaea borealis*, which usually grows in distinct patches, showed high within plot variation and increased at Tammela_P (No_13) (Fig.1).

The amount of precipitation seemed to affect the shoot growth of vascular plant species and contributed to the changes in coverage. For instance, the annual change in the coverage of *V. myrtillus* (Fig. 1) correlated positively with the annual amount of throughfall at Pallasjärvi_S (No. 3) (1998: 550 mm,

Understorey vegetation assessment using a 2 m^2 frame. (Photo: Maija Salemaa).
Aluskasvillisuuden arviointi 2 m^2 kehikon avulla. (Kuva: Maija Salemaa).

1999: 484 mm and 2000: 526 mm). Similar temporal correlation between the coverage of *V. vitis-idaea* (Fig. 1) and the amount of throughfall was found at Tammela_P (No_13) (throughfall 1998: 490 mm, 1999: 556 mm and 2000: 613 mm) (throughfall data: Lindroos et al. 2000, Lindroos et al. 2001. Lindroos et al. in this report).

The change in the total coverage of bryophytes and lichens was relatively small during 1998–2000 (Table 1). Within the bryophytes group, however, there were changes in the relative coverages between the species. The proportion of *Hylocomium splendens* and *Dicranum* coll. increased, whereas the proportion of *Pleurozium schreberi* decreased on most of the plots in 1998–1999 (Fig. 1). The changes were smaller in 1999–2000. The moisture conditions in the moss layer seemed to regulate the between-species changes. The coverage of *Dicranum* species, especially, was larger when the shoots were moist. Also the amount of needle litterfall, decaying wood and branches on the ground, all affect the space available for species in the bottom layer (mosses and lichens).

Visual assessment of the cover percentage of the plant species is always susceptible to subjective errors (Vanha-Majamaa et al. 2000). Because the objective of monitoring forest vegetation is to produce information about changes in the abundance of plant

Table 1. The mean cover % of the field layer (the total of vascular plant species), the bottom layer (bryophytes and lichens) and their sum (all species), needle litter and decaying wood on the six vegetation plots during 1998–2000.
Taulukko 1. *Kenttäkerroksen (kaikki putkilokasvilajit), pohjakerroksen (sammalet ja jäkälät) ja niiden summan (kaikki lajit), neulaskarikkeen ja lahopuun keskimääräiset peittävyydet kuudella kasvillisuuden seuranta-alalla vuosijaksollla 1998–2001.*

Plot number	Year	Field layer	Bottom layer	Bryophytes			Lichens			All species	Needle litter	Decaying wood
				Hepaticae	other	sum	*Cladina*	other	sum			
Koealan no	*Vuosi*	*Kenttä-kerros*	*Pohja-kerros*	*Sammalet*			*Jäkälät*			*Kaikki lajit*	*Neulas-karike*	*Lahopuu*
				Hepaticae	*muut*	*summa*	*Cladina*	*muut*	*summa*			
2. Pallasjärvi_P	1998	45.4	49.4	3.0	32.5	35.5	10.0	3.9	13.9	94.8	51.0	6.6
	1999	43.1	60.6	3.7	42.7	46.4	7.8	6.4	14.2	103.7	33.4	9.1
	2000	54.0	53.2	1.8	39.4	41.3	9.3	2.7	11.9	107.2	36.5	10.2
3. Pallasjärvi_S	1998	70.2	87.7	3.0	84.3	87.3	0.1	0.3	0.4	157.8	6.7	4.4
	1999	58.0	84.1	2.7	81.2	84.0	0.1	0.1	0.2	142.1	6.4	3.8
	2000	71.0	89.6	2.9	86.5	89.4	0.1	0.1	0.2	160.6	9.5	3.0
7. Oulanka_S	1998	72.1	88.0	3.3	84.6	88.0	0.0	0.0	0.0	160.0	4.7	2.1
	1999	68.8	90.8	3.0	87.8	90.8	0.0	0.0	0.0	159.6	1.5	2.0
	2000	75.5	99.3	1.6	97.7	99.3	0.0	0.0	0.0	174.8	2.9	6.9
8. Oulanka_P	1998	83.3	82.6	0.2	82.3	82.5	0.0	0.0	0.0	165.8	23.9	6.9
	1999	79.8	87.4	0.5	86.8	87.4	0.0	0.0	0.0	167.2	9.9	6.8
	2000	87.3	89.3	0.1	89.2	89.3	0.0	0.0	0.0	176.6	11.2	8.0
12. Tammela_S	1998	47.3	77.4	0.0	77.4	77.4	0.0	0.0	0.0	124.7	15.7	8.8
	1999	49.7	71.5	0.0	71.5	71.5	0.0	0.0	0.0	121.2	13.9	11.9
	2000	46.4	69.0	0.2	68.8	69.0	0.0	0.0	0.0	115.4	12.5	14.1
13. Tammela_P	1998	33.5	86.7	0.0	86.1	86.1	0.2	0.4	0.6	120.2	21.4	14.8
	1999	40.2	81.6	0.0	80.9	80.9	0.3	0.3	0.6	121.8	19.8	16.2
	2000	46.0	72.4	0.0	72.0	72.0	0.3	0.1	0.4	118.4	20.3	23.8

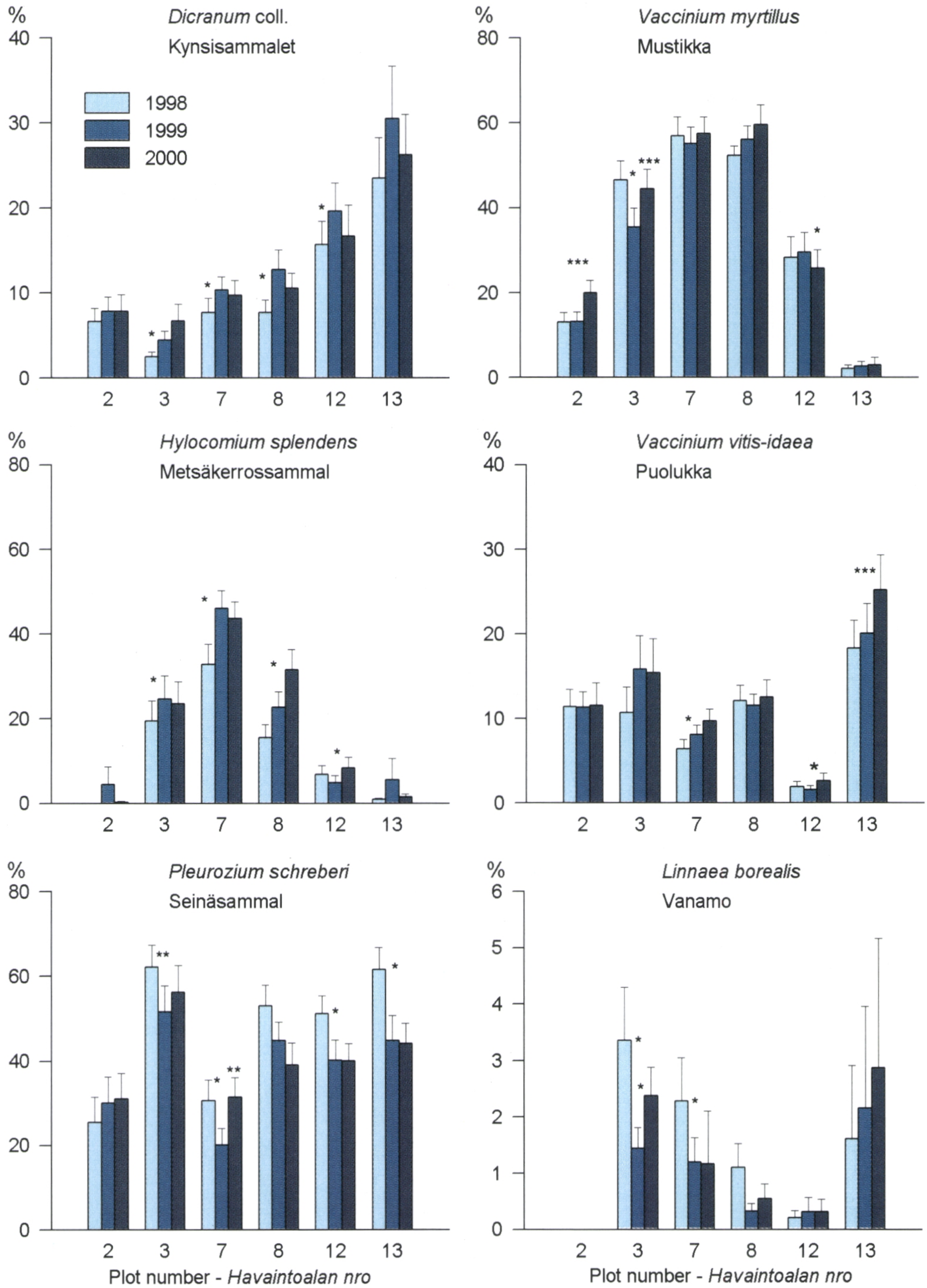

Figure 1. The change in the mean cover (%) of the most common bryophytes and vascular plant species on the six vegetation plots during 1998-2000. Statistical significances (paired t-test): o = $p < 0.10$, * = $p < 0.05$ (see p. 12 for plots).

Kuva 1. *Tavallisimpien sammal- ja putkilokasvilajien keskimääräisten peittävyyksien muutokset kuudella kasvillisuuden koealalla vuosijaksolla 1998-2000. Tilastolliset merkitsevyydet (parittainen t-testi): o = p < 0.10, * = p < 0.05 (ks. s. 12 havaintoalat).*

Table 2. The similarity of the assessment levels of the two botanists in 2000, tested by paired t-tests. The number of test quadrats was 6.
Taulukko 2. *Kahden havainnoitsijan arviointitasojen samanlaisuus vuonna 2000 tutkittuna parittaisilla t-testeillä. Testiruutujen lukumäärä oli 6.*

	Mean difference in the cover (%) *Peittävyyksien (%) keskimääräinen ero*	sd	t	df	p
Vaccinium myrtillus	-1.33	0.49	-2.70	5	0.043
Vaccinium vitis-idaea	-0.67	0.80	-0.83	5	0.444
Sum of vascular species *Putkilokasvit yhteensä*	-3.52	1.82	-1.93	5	0.111
Dicranum coll.	-0.97	1.39	-0.69	5	0.518
Hylocomium splendens	-2.17	2.12	-1.02	5	0.354
Pleurozium schreberi	7.67	3.41	2.25	5	0.075
Sum of bryophytes *Sammalet yhteensä*	2.33	3.73	0.63	5	0.559

species, it is important to keep the assessment level of the observers constant. According to the field tests in which the two botanists assessed the same quadrats (one test quadrat per plot, n = 6) independently, there were some statistically significant differences in the assessment level between the botanists in 2000 (Table 2). When differences in the assessment level were found, the level was harmonized during the actual field work (Table 2).

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4.3 Deposition on the forests and forest floor in 2000

Metsiin ja metsämaahan kohdistuva laskeuma vuonna 2000

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Summary

The deposition of acidifying and eutrophicating compounds, base cations, chloride and dissolved organic carbon (DOC) were monitored in open areas and within 8 Norway spruce and 8 Scots pine stands during 2000. The SO_4 deposition in Finland was at a relatively low level compared to the situation in many parts of central Europe. There was a clear decrease in SO_4 deposition in open areas and in stand throughfall on moving from south to north. The highest SO_4 deposition in stand throughfall in Norway spruce stands was recorded in Tammela, southern Finland (477 mg S m^{-2} yr^{-1}) and the lowest in Pallasjärvi, northern Finland (146 mg S m^{-2} yr^{-1}). In Scots pine stands, the highest SO_4 deposition in stand throughfall was in Miehikkälä, southern Finland (460 mg S m^{-2} yr^{-1}), and the lowest in Sevettijärvi, NE Finland (184 mg S m^{-2} yr^{-1}). In general, Norway spruce canopies caused a stronger increase in the SO_4 flux on the forest floor than pine canopies.

Nitrogen deposition was relatively low in Finland compared to many parts of central Europe. Nitrogen deposition was the highest in southern Finland. The NH_4, NO_3 and N_{total} fluxes within the stand were lower than in open areas on all the spruce and pine plots, apart from the Uusikaarlepyy plot on the western coast of Finland. Emissions from a local NH_3 point source increased the NH_4 and N_{total} fluxes in stand throughfall on this spruce plot. The DOC fluxes in stand throughfall decreased on moving from south to north, indicating the importance of climatic factors in carbon cycling within the stand.

Yhteenveto

Happamoittavien ja rehevöittävien yhdisteiden, emäskationien, kloridin sekä liukoisen orgaanisen hiilen (DOC) laskeumaa seurattiin 8 kuusikossa ja 8 männikössä sekä niiden viereisillä avoimilla paikoilla vuonna 2000. Sulfaattirikin laskeuma oli alhainen Suomessa verrattuna moniin alueisiin Keski-Euroopassa. Sulfaattirikin laskeuma avoimella paikalla ja metsikkösadannassa väheni Etelä-Suomesta Pohjois-Suomeen. Korkein metsikkösadannan SO_4-laskeuma kuusikoissa mitattiin Tammelassa, Etelä-Suomessa, 477 mg S m^{-2} yr^{-1}. Alhaisin vastaava arvo oli Pohjois-Suomessa Pallasjärvellä, 146 mg S m^{-2} yr^{-1}. Männiköiden korkein metsikkösadannan SO_4-laskeuma oli Miehikkälässä, Etelä-Suomessa, 460 mg S m^{-2} yr^{-1}. Vastaavasti männiköiden SO_4-kuorma oli alhaisin Sevettijärvellä, Koillis-Lapissa, 184 mg S m^{-2} yr^{-1}. Kuusen latvukset lisäsivät enemmän metsikkösadannan SO_4-laskeumaa kuin männyn latvukset sadeveden kulkiessa latvuskerroksen läpi.

Typpilaskeuma oli Suomessa alhainen verrattuna moniin alueisiin Keski-Euroopassa. Typpilaskeuma oli korkein Etelä-Suomes-

sa. Ammonium-, NO_3- ja kokonaistyppilaskeuma vähentyivät sadeveden kulkiessa latvuskerroksen läpi kaikilla kuusi- ja mäntykohteilla lukuunottamatta Uudenkaarlepyyn kohdetta, joka sijaitsee Länsi-Suomessa. Paikalliset NH_3-päästöt lisäsivät metsikkösadannan NH_4- ja kokonaistyppikuormaa tällä kuusialalla. Liukoisen orgaanisen hiilen (DOC) laskeuma väheni metsikkösadannassa siirryttäessä eteläisiltä tutkimuskohteilta Pohjois-Suomeen. Tämä heijastaa ilmastollisten tekijöiden tärkeyttä hiilen kierrossa.

Introduction

The deposition of acidifying and eutrophicating compounds, base cations, chloride and dissolved organic carbon (DOC) on the forests and forest floor has been monitored as a part of the Finnish ICP Forests monitoring programme since 1995. The monitoring results for the years 1996–1999 have been published in Lindroos et al. (1999, 2000a, 2001).

The amount of precipitation and deposition of SO_4, S_{total}, NH_4, NO_3, N_{total}, Ca, Mg, K, Na, Cl and DOC in open areas and in stand throughfall on the ICP Forests Level II monitoring plots in 2000 are presented in this report. This information is required when evaluating the effects of air pollution on forest ecosystems, which is one of the key aims of the ICP Forests monitoring programme. Information about DOC fluxes is needed in carbon cycling studies related to climatic change.

Material and methods

Deposition samples were collected throughout the year 2000 from 8 Norway spruce and 8 Scots pine stands (stand throughfall) and adjacent open areas (bulk deposition) (see Fig. 2, p. 12). The stand throughfall and bulk deposition samples were collected at 4-week intervals during the winter and spring, and at 2-week intervals (bulked to give one sample per 4-week interval) during summer and autumn. There were 20 systematically located precipitation collectors (Ø = 20 cm, h = 0.4 m) within the stand during the snow-free period, and 6 snow collectors (Ø = 36 cm, h = 1.8 m) during wintertime. The corresponding number of collectors for the adjacent open area was 3 and 2, respectively. The samples were pre-treated and analysed according to the manual of the ICP Forests Programme.

Results and discussion

Precipitation

The amount of precipitation varied between 488–789 mm in the open areas (Tables 1 and 2). On the average, the spruce stand canopies intercepted 25 % and the pine canopies 19 % of the precipitation measured in the open. Spruce canopies retain a higher proportion of the precipitation than pine canopies due to differences in the crown structure of these tree species (Hyvärinen 1990, Lindroos et al. 2000b).

Sulphur deposition

The SO_4 deposition in the open varied between 120–374 mg S m^{-2} yr^{-1} (Tables 1 and 2). There was a clear decrease in SO_4 deposition in the open and in stand throughfall on moving from south to north. The highest SO_4 deposition in stand throughfall in Norway spruce stands was recorded in Tammela, southern Finland (477 mg S m^{-2} yr^{-1}), and the lowest in Pallasjärvi, northern Finland (146 mg S m^{-2} yr^{-1}). In the Scots pine stands, the highest SO_4 deposition in stand throughfall was in Miehikkälä, southern Finland (460 mg S m^{-2} yr^{-1}), and the lowest in Sevettijärvi, NE Finland (184 mg S m^{-2} yr^{-1}). In general, the SO_4 deposition was low in Finland compared to the situation in many parts of central Europe (Forest... 2001).

Table 1. Bulk deposition in the open (BD) and deposition in stand throughfall (TF) on 8 Norway spruce plots in 2000. The plots are arranged in the table to correspond to the south-north gradient through Finland (see Latitude degree = Lat.).

***Taulukko 1**. Laskeuma avoimella paikalla (BD) ja metsikkösadannassa (TF) 8 kuusialalla vuonna 2000. Näytealat on järjestetty taulukossa vastaamaan etelä-pohjoisgradienttia Suomen läpi. (katso Leveysaste = Lat.).*

Sample plot *Havaintoala*	Nr	Lat		Prec. mm	SO_4-S	S_{total}	NH_4-N	NO_3-N	N_{total}	Ca	Mg	K	Na	Cl	DOC
					mg m^{-2}										
Pallasjärvi	3	67	BD	640	120	141	50	69	144	31	9	55	81	59	938
			TF	526	146	182	26	43	110	72	29	474	127	169	2469
Kivalo	5	66	BD	725	201	231	116	130	272	48	12	46	102	95	1212
			TF	663	220	274	44	85	190	110	37	531	159	209	3415
Oulanka	21	66	BD	488	123	138	57	82	162	30	7	26	67	59	815
			TF	523	188	223	25	57	123	88	39	388	117	132	2885
Uusikaarlepyy	23	63	BD	628	189	219	207	151	381	78	25	108	154	166	1189
			TF	329	302	419	315	117	700	145	84	1619	307	693	7392
Juupajoki	11	61	BD	667	237	254	145	180	339	67	15	50	110	88	1036
			TF	493	335	422	90	81	321	205	74	1324	195	299	7156
Punkaharju	17	61	BD	570	238	261	155	147	344	79	17	87	96	80	1212
			TF	343	433	531	111	63	312	237	100	1477	140	343	7073
Evo	19	61	BD	688	244	275	150	174	358	62	16	53	133	120	1339
			TF	486	414	499	51	87	277	334	129	1220	247	407	7051
Tammela	12	60	BD	691	279	311	190	216	430	80	23	43	191	205	1299
			TF	494	477	600	61	105	366	333	129	1236	451	683	9337

Table 2. Bulk deposition in the open (BD) and deposition in stand throughfall (TF) on 8 Scots pine plots in 2000. The plots are arranged in the table to correspond to the south-north gradient through Finland (see Latitude degree = Lat.).

Taulukko 2. *Laskeuma avoimella paikalla (BD) ja metsikkösadannassa (TF) 8 mäntyalalla vuonna 2000. Näytealat on järjestetty taulukossa vastaamaan etelä-pohjoisgradienttia Suomen läpi. (katso Leveysaste = Lat.).*

Sample plot	Nr	Lat		Prec.	SO_4-S	S_{total}	NH_4-N	NO_3-N	N_{total}	Ca	Mg	K	Na	Cl	DOC
Havaintoala				mm					mg m^{-2}						
Sevettijärvi	1	69	BD	503	132	145	22	43	81	26	32	32	307	464	671
			TF	436	184	200	14	33	72	63	62	120	461	747	1793
Kivalo	6	66	BD	789	193	216	100	132	263	48	11	41	95	85	1179
			TF	638	191	228	54	90	198	85	28	281	127	126	3125
Ylikiiminki	9	64	BD	750	230	256	146	160	356	50	12	58	98	75	1292
			TF	623	225	273	80	113	256	100	37	292	131	128	3782
Lieksa	20	63	BD	656	233	258	111	147	318	57	16	86	117	97	1310
			TF	567	233	278	88	102	272	149	48	343	149	157	4549
Juupajoki	10	61	BD	667	237	254	145	180	339	67	15	50	110	88	1036
			TF	554	269	312	83	142	294	147	48	384	192	227	4388
Punkaharju	16	61	BD	570	238	261	155	147	344	79	17	87	96	80	1212
			TF	358	244	290	69	83	227	161	42	389	112	144	4253
Tammela	13	60	BD	738	279	320	192	231	470	81	24	45	205	216	1363
			TF	613	288	366	67	167	355	231	80	591	289	385	6606
Miehikkälä	18	60	BD	666	374	414	228	206	458	132	22	54	134	141	1125
			TF	570	460	537	143	211	444	304	66	358	238	325	4310

Norway spruce canopies caused a stronger increase in the SO_4 flux on the forest floor than pine canopies (Fig. 1). This indicates that the leaching of e.g. dry deposition from the tree canopies is dependent on the canopy structure, which is different in these two tree species. Therefore, it is extremely important to take into account the tree species and stand structure when estimating the SO_4 input to the forest soil within the stand.

Nitrogen deposition

Nitrogen deposition was relatively low in Finland compared to the situation in many parts of central Europe (Forest...2001). The highest nitrogen deposition values were recorded in southern Finland. The highest NH_4 deposition in an open area was recorded in Miehikkälä (228 mg N m^{-2} yr^{-1}), the highest NO_3 deposition in Tammela (231 mg N m^{-2} yr^{-1}) and the highest N_{total} deposition in Tammela (470 mg N m^{-2} yr^{-1}) (Tables 1 and 2).

The NH_4, NO_3 and N_{total} fluxes on the forest floor were lower than in open areas on all the spruce and pine plots, apart from the Uusikaarlepyy plot on the western coast of Finland (Tables 1 and 2, Figs 2 and 3). Emissions from a local NH_3 point source caused an increase in the NH_4 and N_{total} fluxes in stand throughfall on the Uusikaarlepyy spruce plot compared to the deposition in the open.

Other parameters

Nutrient leaching and wash-off of dry deposition in the spruce and pine canopies increased the Ca, Mg, K, Na and Cl fluxes in stand throughfall compared to deposition in the open (Tables 1 and 2). The DOC flux in stand throughfall varied from 2.47 to 9.34 g C m^{-2} yr^{-1} in the spruce stands. The corresponding range for the pine stands was 1.80–6.61 g C m^{-2} yr^{-1}. The DOC fluxes clearly decreased with increasing latitude, indicating the importance of climatic factors in carbon cycling in forest ecosystems.

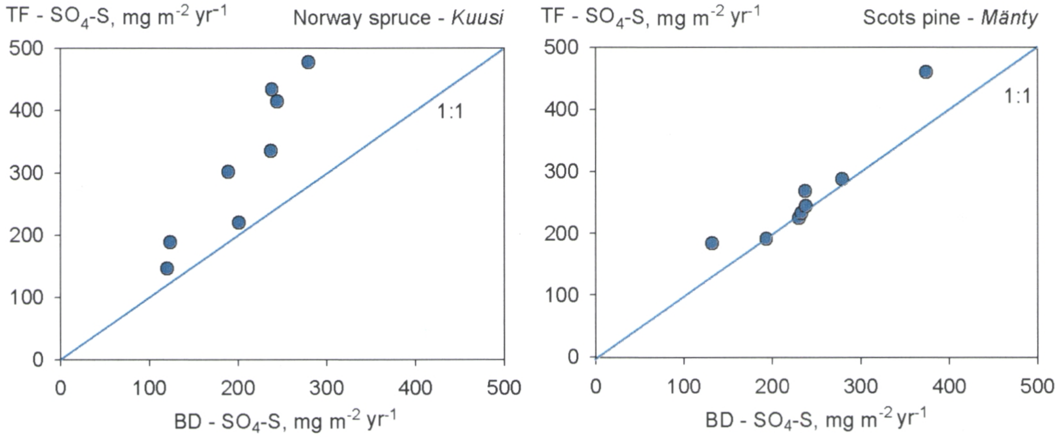

Figure 1. The relationship between the SO_4-S deposition in bulk deposition in the open (BD) and in stand throughfall (TF) on 8 Norway spruce and 8 Scots pine stands in 2000.
Kuva 1. *Avoimen paikan SO_4-S-laskeuman (BD) ja metsikkösadannan laskeuman (TF) välinen suhde kahdeksalla kuusialalla ja kahdeksalla mäntyalalla vuonna 2000.*

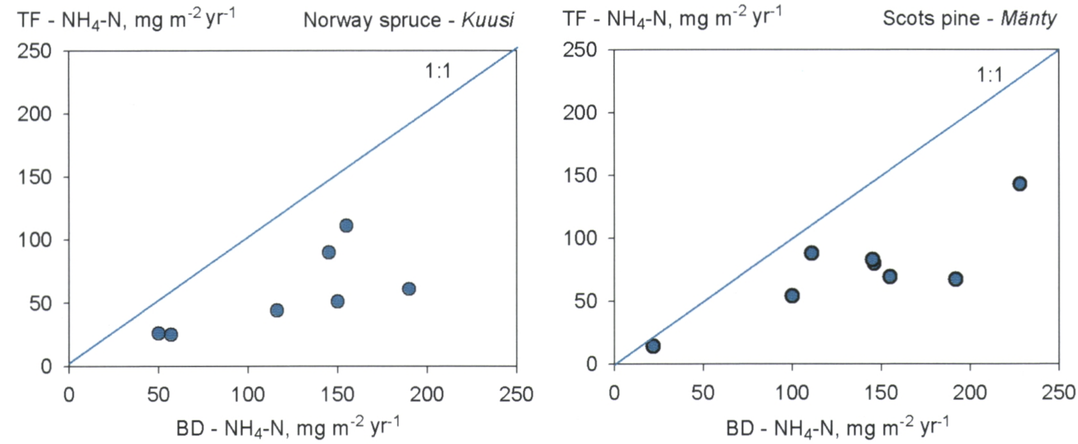

Figure 2. The relationship between the NH_4-N deposition in bulk deposition in the open (BD) and in stand throughfall (TF) on 7 Norway spruce and 8 Scots pine stands in 2000. The Uusikaarlepyy plot is not included in the figure.
Kuva 2. *Avoimen paikan NH_4-N-laskeuman (BD) ja metsikkösadannan laskeuman (TF) välinen suhde seitsemällä kuusialalla ja kahdeksalla mäntyalalla vuonna 2000. Uusikaarlepyyn kuusiala on jätetty kuvasta pois.*

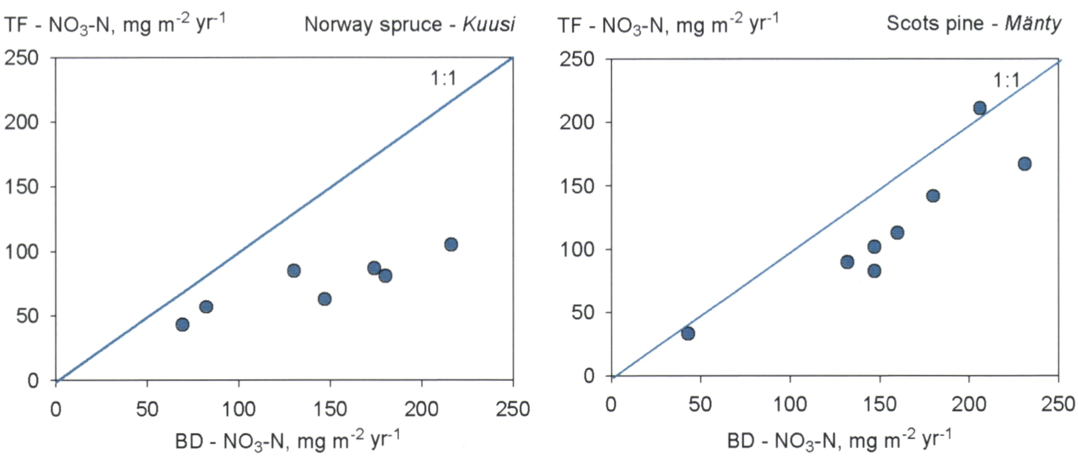

Figure 3. The relationship between the NO_3-N deposition in bulk deposition in the open (BD) and in stand throughfall (TF) on 7 Norway spruce and 8 Scots pine stands in 2000. The Uusikaarlepyy plot is not included in the figure.
Kuva 3. *Avoimen paikan NO_3-N-laskeuman (BD) ja metsikkösadannan laskeuman (TF) välinen suhde seitsemällä kuusialalla ja kahdeksalla mäntyalalla vuonna 2000. Uusikaarlepyyn kuusiala on jätetty kuvasta pois.*

Conclusions

In the year 2000, SO_4 deposition in Finland was low compared to the levels in many parts of central Europe. The highest SO_4 deposition values were recorded in southern Finland. Norway spruce canopies caused a stronger increase in the SO_4 flux within the stand than pine canopies. It is extremely important to take into account the tree species and stand structure when estimating the SO_4 input to the forest soil within the stand. Nitrogen deposition in Finland was low compared to the levels in many parts of central Europe. The highest nitrogen deposition values were recorded in southern Finland. Local NH_3 emissions can have a considerable effect on nitrogen cycling in forest ecosystems. This was the case on the spruce plot on the western coast of Finland. There seems to be very strong variation in the DOC fluxes in stand throughfall in different parts of Finland. The decrease in DOC fluxes with increasing latitude indicates the importance of climatic factors in carbon cycling.

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4.4 Soil solution quality during 1998–2000 on 13 of the Level II plots

Maaveden laatu vuosina 1998–2000 intensiivisen seurannan havaintoaloilla

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Summary

This report presents the results of soil solution monitoring carried out during 1998–2000 in the 13 even-aged stands. Percolation water was collected at 4-week-intervals during the snowfree period in 1998, 1999 and 2000, using zero tension lysimeters located at depths of 5, 20 and 40 cm from the ground surface, and tension lysimeters (ceramic suction cups, type P80) located at depths of 20 and 40 cm. The results indicate that the deposition of acidifying compounds on the 13 Level II monitoring plots, before and during the monitoring period (1998–2000), has not resulted in the development of extreme values for acidity and acidification parameters, nor were there any indications of a reduction in site fertility as a result of the deposition load. The two Norway spruce plots showed signs of strong acidity and acidification, but these are due to natural soil formation processes (Uusikaarlepyy) and to earlier forest management practices (Punkaharju). No clear trends in soil solution parameters along the climatic south-north gradient were found.

Yhteenveto

Raportissa esitetään 13 tasaikäisen metsikön maavesiseurannan tulokset vuosilta 1998–2000. Maavettä kerättiin neljän viikon välein lumettomana aikana vuosina 1998, 1999 ja 2000 vajovesilysimetreillä, jotka sijaitsivat 5, 20 ja 40 cm syvyyksillä maanpinnasta. Maavettä kerättiin lisäksi imulysimetreillä (keraamiset imukupit, tyyppi P80) 20 ja 40 cm:n syvyyksiltä. Tulosten mukaan happamoittavien yhdisteiden laskeuma intensiivisen seurannan 13 havaintoalalla ennen seurantajaksoa ja sen kuluessa (1998–2000) ei ole aiheuttanut poikkeavia arvoja happamuutta ja happamoitumista kuvaavissa maaveden tunnuksissa. Laskeuman ei ole havaittu aiheuttaneen myöskään muutoksia kasvupaikan ravinteisuudessa. Kahdessa maaperältään happamassa kuusikossa havaittiin happamoitumista, joka johtui luontaisista maaperäprosesseista (Uusikaarlepyy) sekä aiemmin tehdyistä metsänkäsittelytoimenpiteistä (Punkaharju). Maaveden tunnuksissa ei havaittu selviä ilmastosta riippuvia muutoksia siirryttäessä maan eteläosista pohjoiseen.

Introduction

Soil solution has been monitored on the ICP Forests Level II plots since 1995. During the early years (1995–97) of the soil solution monitoring programme in Finland, however, sampling was restricted to 6 plots (Norway spruce and Scots pine stands in Tammela, Juupajoki and Kivalo) where a pilot study was carried out to compare the composition of soil solution collected using tension lysimeters (20 and 40 cm depth) and zero-tension lysimeters (5, 20 and 40 cm depth) (Derome and Lindroos 1997). In 1998 soil solution monitoring was expanded to cover 16 of the Level II plots. 13 of these plots are in semi-natural, even-aged stands subjected to commercial forestry, and 3 in stands in a natural state (ICP IM plots). This report presents the results of soil solution monitoring carried out during 1998–2000 in the 13 even-aged stands. The main purpose of the report is to provide forest researchers with baseline values for a range of soil solution parameters in Scots pine and Norway spruce stands in different parts of the country.

Material and methods

Percolation water was collected at 4-week-intervals during the snowfree period in 1998, 1999 and 2000, using zero tension lysimeters (diam. 20 cm) located at depths of 5, 20 and 40 cm from the ground surface. The installation and construction of the lysimeters have been described in detail in Derome et al. (1991). There were 5 lysimeters at each depth on the sample plots. Soil solution was collected at 4-week-intervals during the snowfree period in 1998, 1999 and 2000, using tension lysimeters (ceramic suction cups, type P80) located at depths of 20 and 40 cm from the ground surface. There were 6 lysimeters at each depth on the sample plots. The soil type on the plots was typically podzolic; most of the pine plots are located on sorted glacifluvial material, and the spruce plots on till soils. The samples were pre-treated and analysed according to the manual of the ICP Forests Programme (ICP Forests, 1998). The pH was measured on unfiltered samples. The samples were filtered through membrane filters (0.45 µm) under positive pressure by means of a peristaltic pump. An aliquot of the filtrate was preserved with concentrated HNO_3 prior to the determination of Ca, Mg, K, Na, Zn, Cu, Al_{tot}, Fe, Mn and Si by inductively coupled plasma atomic emission spectrometry (ICP-AES). Dissolved organic carbon (DOC) was determined on the unpreserved filtrate on a TOC analyser. The rest of the unpreserved filtrate was frozen prior to subsequent determination of N_{tot} by flow injection analysis (FIA), and NH_4, SO_4, NO_3, PO_4 and Cl by ion chromatography (IC). Dissolved organic nitrogen DON was calculated as $N_{tot} - (NH_4\text{-}N + NO_3\text{-}N)$. Aluminium in the samples was fractionated into labile, monomeric aluminium (Al^{3+}) and complexed aluminium (Al_{compl}). The samples were passed through a cation exchange column, and the Al concentration before and after passage through the column was then determined by FIA (Derome et al. 1998). The difference between the two concentrations was the Al^{3+} fraction. The complexed Al fraction was obtained as $Al_{tot} - Al^{3+}$.

Results and discussion

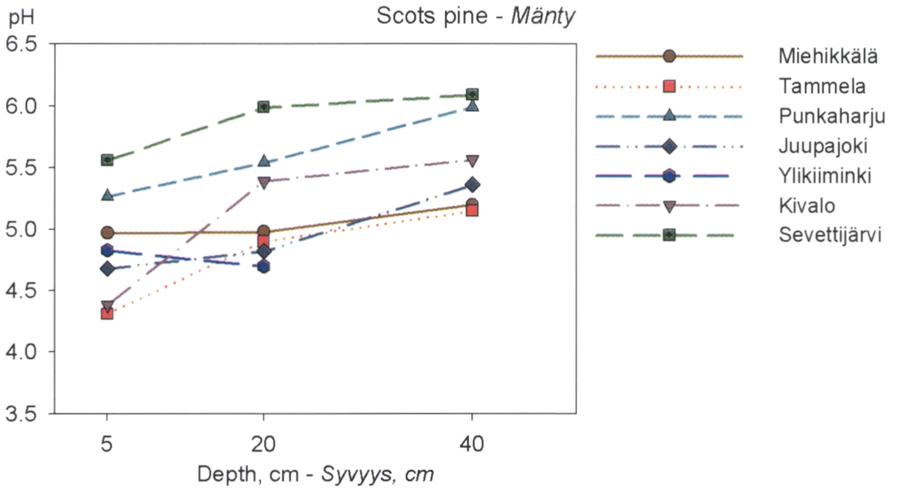
The results presented here represent soil solution collected using two techniques (zero-tension lysimetry and tension lysimetry) that sample different fractions of the soil solution. The soil solution sampled by tension lysimeters provides information about nutrient uptake by the vegetation, and about soil buffering and neutralization processes, while the soil solution sampled by zero-tension lysimeters provides information about the movement of ions between the soil horizons, as well as the situation in the soil prior to e.g. buffering. The parameters that most strongly reflect these differences in the soil solution fractions are pH, SO_4, NH_4, NO_3, Mg and K (Derome et al. 2001a). In this respect, the results given by the two techniques are complementary, and it is recommended that both techniques be used in order to obtain a complete picture of the processes taking place in forest soils.

As the size of this material (13 plots) is relatively limited, and can by no means be considered representative of all upland forest soils in Finland, some care should be taken when making generalizations about the mean values presented in this report. This is demonstrated by the fact that, although there are clear S-N gradients in site fertility, biomass accumulation and S and N deposition in Finland, these features are not very strongly reflected in the results for the 13 plots. The chemical composition of soil solution at a specific site is dependent on a large number of factors (mineral composition of the mineral soil, climatic factors, atmospheric deposition, tree species composition, stage of stand development etc.). There is also very high spatial variation between the sampling points on the individual plots, as well as large temporal variation during the growing season and also between years.

Acidity parameters

Soil acidity and the susceptibility of forest soils to acidification can be expressed using a number of soil solution parameters such as pH, the Al, SO_4 and NO_3 concentrations, and the molar Ca/Al ratio (Derome et al. 2001b). There is normally a clear decrease in the acidity of forest soils (i.e. an increase in pH) with increasing depth. This reflects the capacity of the soil to buffer and neutralise the input of acidity derived from the relatively acidic organic layer, as well as from deposition. A decrease in the capacity of the soil to buffer and neutralize this acidic input is often reflected as an increase in the Al concentration in the soil solution. It is widely accepted that, if the Al concentration exceeds the threshold value of 1.8 mg/l, then there is a high possibility that the fine root systems of the trees will be damaged (de Vries 1993). In relatively acidic, podzolic soils, however, the Al in the soil solution consists of two main components: Al complexed with dissolved organic matter (Al_{compl}), and the toxic form of aluminium, Al^{3+}. When assessing the acidity status of a forest soil, and the possibility of damage occurring to the fine roots, it is therefore important to determine the Al^{3+} concentration in the soil solution, and not merely the Al_{tot} concentration. Another measure of the possible toxic effects of Al on the fine roots is the molar Ca/Al ratio. This is considered to better reflect the ability of fine roots to withstand the toxic effects of aluminium; ratio values of below 1.0 are considered to indicate a high probability of fine root damage (e.g. de Vries 1993). The SO_4 concentration in the soil solution is also an important measure of possible soil acidification because this ion is usually associated with protons (H+) in deposition, and high (or at least elevated) SO_4 concentrations indicate that the deposition load is relatively large, and that there is a danger of base cation (e.g. Ca, Mg) leaching and a subsequent reduction in site fertility. Elevated NO_3 concentrations in the soil solution, especially at greater depths, indicate that the surface layer of forest soils has become saturated with nitrogen, and that nitrification, which is a soil-acidifying process, is occurring.

The mean soil solution pH followed, on all the plots except the Norway spruce plot No. 23 at Uusikaarlepyy, a clearly increasing trend with increasing soil depth (Fig. 1). In contrast, there was no clear trend in the mean pH at different depths in the south – north direction (Appendices 1–10). The Al_{tot} concentrations on all the plots (except the Norway spruce plots at Uusikaarlepyy and at Punkaharju) were well below the critical level of 1.8 mg/l, and the Al^{3+} concentrations were correspondingly much lower (Fig. 2).



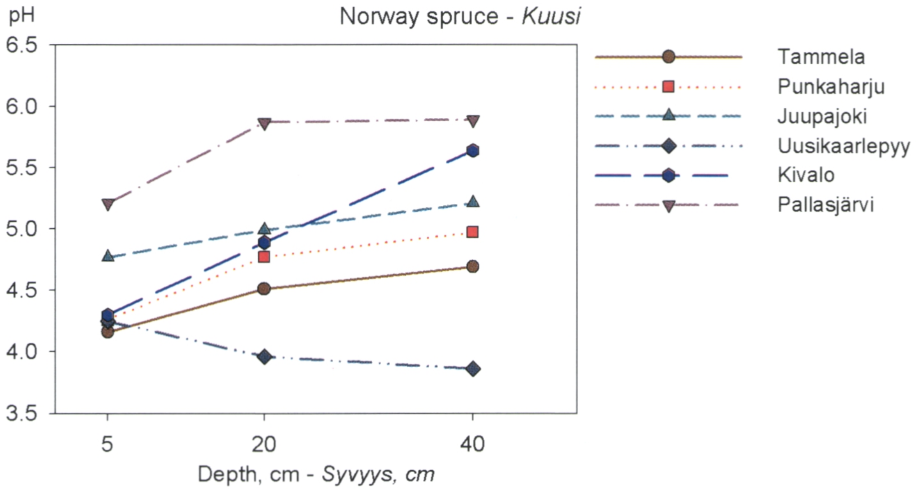


Figure 1. Mean pH in soil solution collected at different depths using zero-tension lysimeters during 1998–2000 on the 13 Level II plots. The names of the plots are listed in the boxes in accordance with increasing latitude, Tammela being the southernmost plot.

Kuva 1. *Maaveden pH:n keskiarvot eri syvyyksillä (vajovesilysimetrit) vuosina 1998–2000 intensiivisen seurannan 13 havaintoalalla. Havaintoalojen nimet ovat kasvavan leveysasteen mukaisessa järjestyksessä. Tammela on eteläisin kohde.*

The Al_{compl} concentrations on most of the plots were considerably higher than the Al^{3+} concentrations. There were no clear south – north trends for any of the Al parameters, and no trends with increasing depth down the soil profile. The value of the molar Ca/Al^{3+} ratio on almost all of the plots was well above the critical value of 1.0. The two exceptions were the Norway spruce plots at Punkaharju (No. 17) and at Uusikaarlepyy (No. 23), but this only applied to soil solution collected using tension lysimeters (Appendices 9 and 10). The mean SO_4 concentration showed a relatively strong increasing trend with increasing depth down the soil profile (Fig. 3). The strongest increase in the SO_4 concentration with increasing depth occurred in the Norway spruce stands at Uusikaarlepyy and Punkaharju. The NO_3 concentrations at all depths on all the plots were extremely low, and in many cases below the detection limit (<0.02 mg N /l) of the analytical equipment. The NO_3 concentrations in soil solution collected using zero-tension lysimeters at Uusikaarlepyy were somewhat elevated.

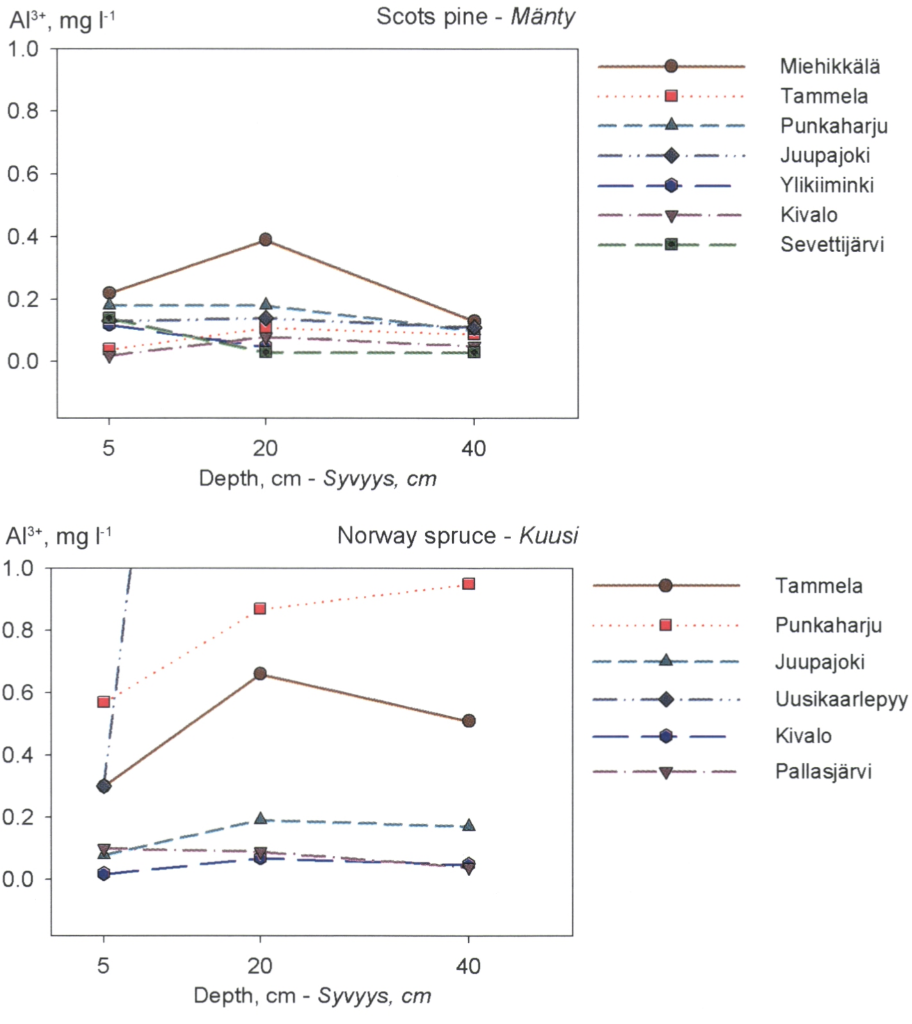
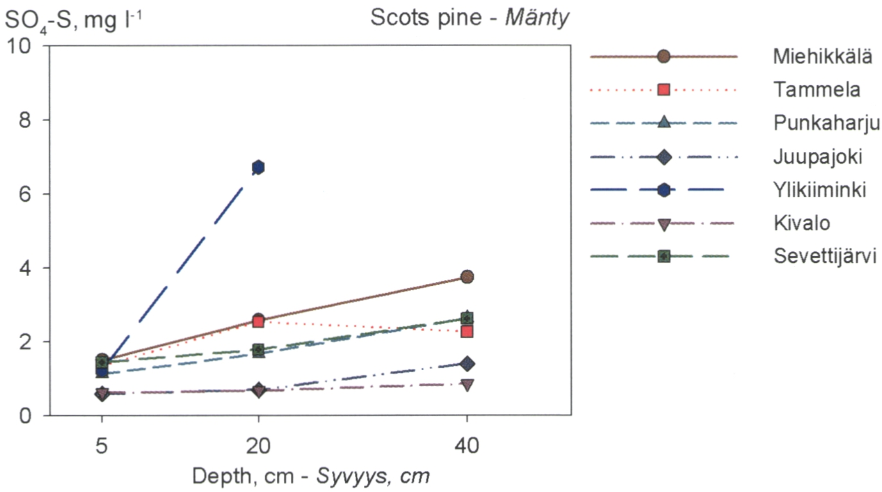


Figure 2. Mean Al^{3+} concentration in soil solution collected at different depths using zero-tension lysimeters during 1998–2000 on the 13 Level II plots. The names of the plots are listed in the boxes in accordance with increasing latitude, Tammela being the southernmost plot. The mean values for the Uusikaarlepyy plot (No. 23) were 4.36 mg/l at a depth of 20 cm, and 6.32 mg/l at 40 cm.

Kuva 2. *Maaveden Al^{3+}:n pitoisuuden keskiarvot eri syvyyksillä (vajovesilysimetrit) vuosina 1998–2000 intensiivisen seurannan 13 havaintoalalla. Havaintoalojen nimet ovat kasvavan leveysasteen mukaisessa järjestyksessä. Tammela on eteläisin kohde. Uudenkaarlepyyn havaintoalan (No. 23) keskiarvot olivat 4,36 mg/l (20 cm syvyydellä) ja 6,32 mg/l (40 cm syvyydellä).*

In conclusion, none of the acidity and acidification parameters in soil solution on the plots showed any signs of extreme acidity that could be attributed to N and S deposition during or before the period 1998–2000. However, the Norway spruce plots at Uusikaarlepyy and Punkaharju had relatively extreme acidity and acidification values. The Uusikaarlepyy plot is located on a sulphate soil in the land uplift area along the western coast of Finland. The site has earlier (about 600 years ago) been under the



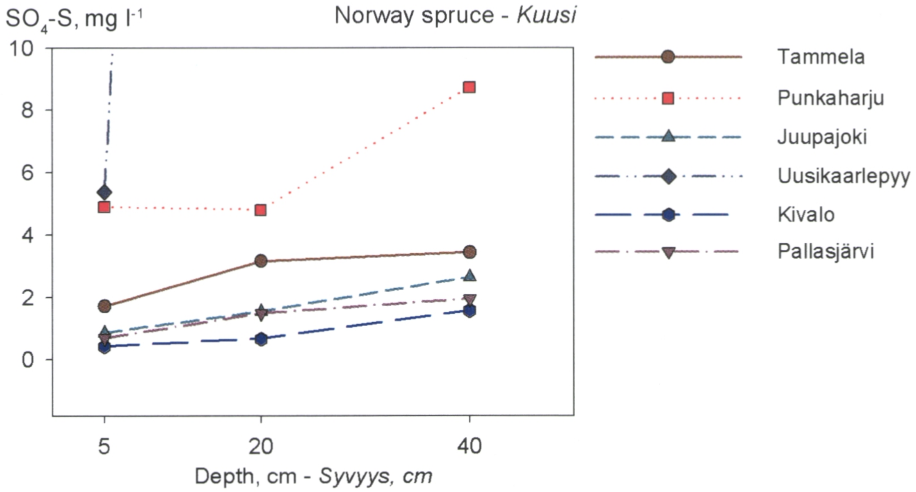


Figure 3. Mean SO_4-S concentration in soil solution collected at different depths using zero-tension lysimeters during 1998–2000 on the 13 Level II plots. The names of the plots are listed in the boxes in accordance with increasing latitude, Tammela being the southernmost plot. The mean values for the Uusikaarlepyy plot (No. 23) were 87.2 mg/l at a depth of 20 cm, and 135 mg/l at 40 cm.
Kuva 3. *Maaveden SO_4-S-pitoisuuden keskiarvot eri syvyyksillä (vajovesilysimetrit) vuosina 1998–2000 intensiivisen seurannan 13 havaintoalalla. Havaintoalojen nimet ovat kasvavan leveysasteen mukaisessa järjestyksessä. Tammela on eteläisin kohde. Uudenkaarlepyyn havaintoalan (No. 23) keskiarvot olivat 87,2 mg/l (20 cm syvyydellä) ja 135 mg/l (40 cm syvyydellä).*

sea, and is therefore characterised by low pH values and high Al and SO_4 concentrations as a result of oxidation of the iron sulphides in the sediments. The slightly elevated NO_3 concentrations at this site are a result of NH_3 emissions from a neighbouring fur farm. The most likely reasons for the relatively acidic conditions on the plot at Punkaharju are the high growth and biomass of the stand, resulting in low base cation concentrations in the soil, and the fact that the site was subjected to intensive slash-and-burn agriculture during the 19th and early 20th century.

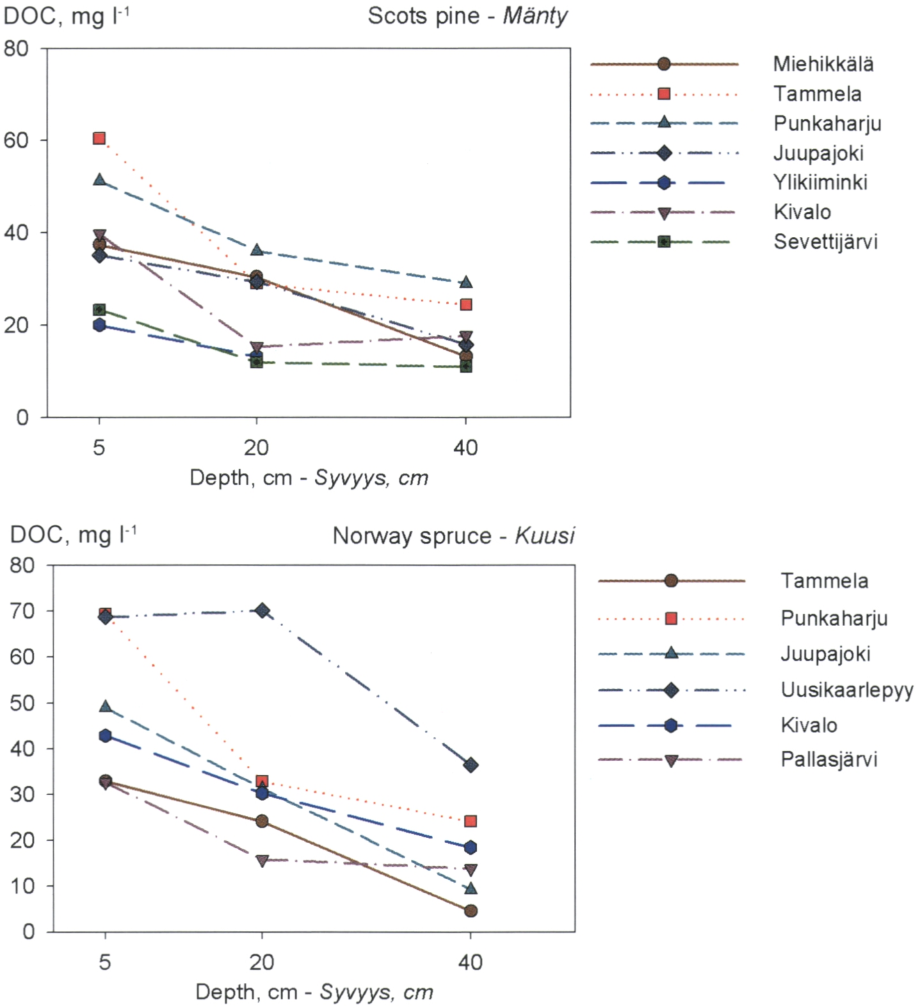


Figure 4. Mean dissolved organic carbon (DOC) concentration in soil solution collected at different depths using zero-tension lysimeters during 1998–2000 on the 13 Level II plots. The names of the plots are listed in the boxes in accordance with increasing latitude, Tammela being the southernmost plot.

Kuva 4. *Maaveden liukoisen orgaanisen hiilen (DOC) pitoisuuksien keskiarvot eri syvyyksillä (vajovesilysimetrit) vuosina 1998–2000 intensiivisen seurannan 13 havaintoalalla. Havaintoalojen nimet ovat kasvavan leveysasteen mukaisessa järjestyksessä. Tammela on eteläisin kohde.*

Dissolved organic carbon (DOC) and dissolved organic nitrogen (DON)

The DOC concentrations in soil solution showed a relatively steep, decreasing trend with increasing depth (Fig. 4). The DOC concentrations in the surface layer (5 cm depth) on the Norway spruce plots were clearly higher than those on the Scots pine plots. No clear south – north trends were found in the DOC concentrations. The variation in DON concentrations down the

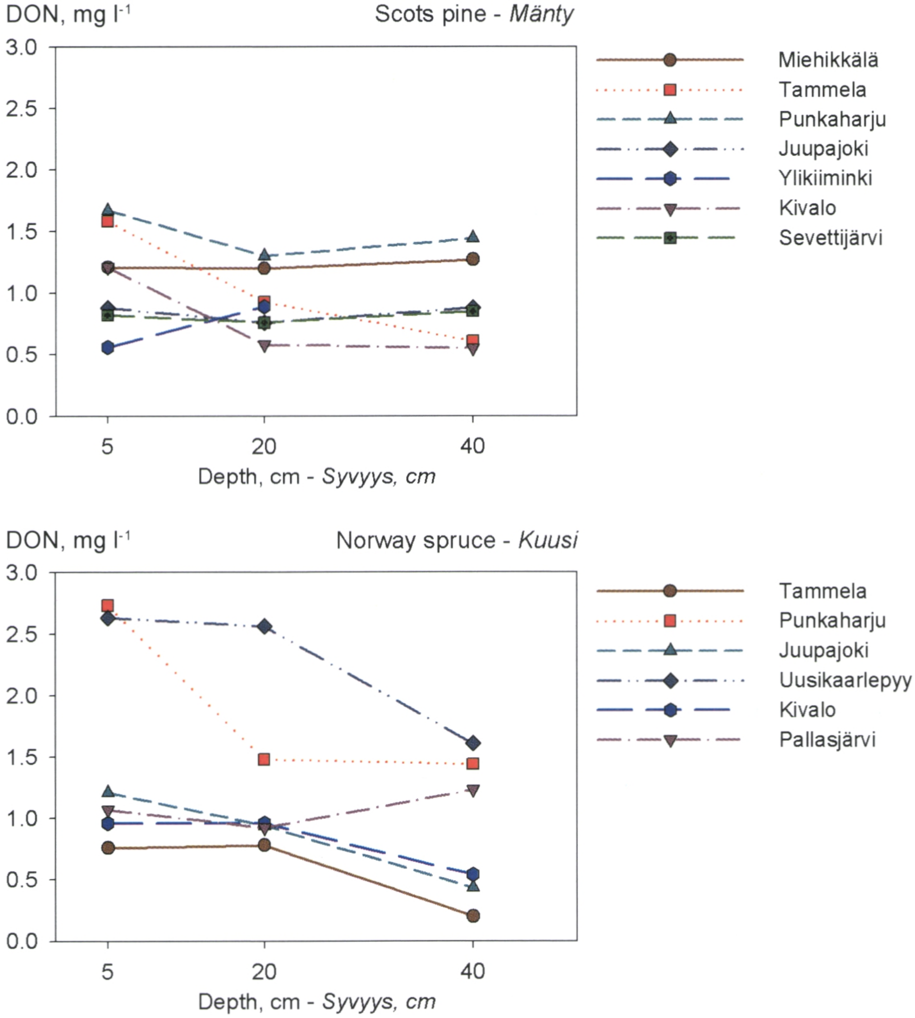


Figure 5. Mean dissolved organic nitrogen (DON) concentration in soil solution collected at different depths using zero-tension lysimeters during 1998–2000 on the 13 Level II plots. The names of the plots are listed in the boxes in accordance with increasing latitude, Tammela being the southernmost plot.

Kuva 5. *Maaveden liukoisen orgaanisen typen (DON) pitoisuuden keskiarvot eri syvyyksillä (vajovesilysimetrit) vuosina 1998–2000 intensiivisen seurannan 13 havaintoalalla. Havaintoalojen nimet ovat kasvavan leveysasteen mukaisessa järjestyksessä. Tammela on eteläisin kohde.*

soil profile was relatively small, and the only clear decreasing trends with increasing depth were found on the Norway spruce plots at Uusikaarlepyy and Punkaharju (Fig. 5).

Fertility parameters

There was considerable variation between the plots in the Ca, Mg, K and NH_4 concentrations, and no clear trends with increasing depth down the soil profile nor in the south – north direction. The Norway spruce plots at Uusikaarlepyy and Punkaharju clearly differed from the others in having relatively high Ca, Mg, K and NH_4 concentrations, despite the fact that the soil solution on these plots was relatively acidic and had high Al and SO_4 concentrations.

Conclusions

The results for soil solution monitoring during 1998–2000 indicate that the deposition of acidifying compounds on the 13 Level II monitoring plots, before and during the monitoring period, has not resulted in the development of extreme values for acidity and acidification parameters, nor are there any indications of a reduction in site fertility as a result of the deposition load. The two Norway spruce plots showed signs of strong acidity and acidification, but these are due to natural soil formation processes (Uusikaarlepyy) and to earlier forest management practices (Punkaharju). No clear trends in soil solution parameters along the climatic south-north gradient were found.

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Appendix 1. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 5 cm in Scots pine stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.
Liite 1. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 5 cm:n syvyydellä männiköissä vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 18, Miehikkälä	No. 13, Tammela	No. 16, Punkaharju	No. 10, Juupajoki	No. 9, Ylikiiminki	No. 6, Kivalo	No. 1, Sevettijärvi
pH	$4.97_{0.06}$	$4.31_{0.03}$	$5.27_{0.07}$	$4.68_{0.05}$	$4.83_{0.07}$	$4.38_{0.04}$	$5.56_{0.05}$
DOC	$37.4_{2.8}$	$60.5_{4.5}$	$51.2_{3.4}$	$35.1_{2.4}$	$20.0_{1.1}$	$39.7_{4.0}$	$23.3_{3.2}$
DON	$1.21_{0.07}$	$1.58_{0.12}$	$1.67_{0.14}$	$0.88_{0.05}$	$0.56_{0.03}$	$1.21_{0.16}$	$0.82_{0.08}$
N_{tot}	$1.37_{0.07}$	$1.85_{0.14}$	$1.89_{0.15}$	$1.15_{0.08}$	$0.86_{0.07}$	$1.53_{0.17}$	$0.89_{0.08}$
NH_4-N	$0.16_{0.03}$	$0.26_{0.05}$	$0.20_{0.04}$	$0.20_{0.04}$	$0.30_{0.05}$	$0.30_{0.04}$	$0.07_{0.02}$
NO_3-N	$0.02_{0.01}$	<0.02	<0.02	$0.09_{0.02}$	<0.02	$0.03_{0.01}$	<0.02
SO_4-S	$1.50_{0.17}$	$1.34_{0.13}$	$1.12_{0.14}$	$0.59_{0.04}$	$1.22_{0.21}$	$0.61_{0.09}$	$1.44_{0.28}$
S_{tot}	$3.79_{0.23}$	$2.67_{0.24}$	$3.49_{0.23}$	$1.70_{0.11}$	$2.18_{0.25}$	$1.77_{0.21}$	$3.18_{0.35}$
PO_4-P	<0.03	<0.03	<0.03	$0.04_{0.01}$	$0.033_{0.01}$	$0.12_{0.02}$	<0.03
Cl	$1.02_{0.08}$	$1.15_{0.12}$	$0.76_{0.07}$	$0.72_{0.09}$	$0.23_{0.03}$	$0.37_{0.06}$	$2.78_{0.35}$
Ca	$1.47_{0.17}$	$3.40_{0.19}$	$2.60_{0.21}$	$1.17_{0.07}$	$0.80_{0.10}$	$1.65_{0.27}$	$1.50_{0.35}$
Mg	$0.27_{0.01}$	$0.40_{0.02}$	$0.48_{0.03}$	$0.35_{0.03}$	$0.15_{0.01}$	$0.21_{0.03}$	$0.51_{0.08}$
K	$2.21_{0.17}$	$1.44_{0.27}$	$3.24_{0.36}$	$0.98_{0.16}$	$0.54_{0.04}$	$1.33_{0.14}$	$1.25_{0.11}$
Na	$0.89_{0.04}$	$0.70_{0.04}$	$0.57_{0.04}$	$0.61_{0.03}$	$0.44_{0.02}$	$0.40_{0.03}$	$1.93_{0.17}$
Zn	$0.04_{0.00}$	$0.06_{0.00}$	$0.04_{0.00}$	$0.03_{0.00}$	$0.04_{0.01}$	$0.04_{0.00}$	$0.04_{0.01}$
Cu	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Al_{tot}	$1.13_{0.08}$	$0.75_{0.05}$	$1.32_{0.10}$	$0.82_{0.07}$	$0.62_{0.05}$	$0.46_{0.05}$	$0.71_{0.13}$
Al^{3+}	$0.22_{0.02}$	$0.04_{0.00}$	$0.18_{0.02}$	$0.13_{0.02}$	$0.12_{0.01}$	$0.02_{0.00}$	$0.14_{0.01}$
Al_{compl}	$0.91_{0.02}$	$0.71_{0.01}$	$1.14_{0.02}$	$0.69_{0.01}$	$0.49_{0.02}$	$0.43_{0.01}$	$0.57_{0.02}$
Ca/Al_{tot}	0.88	3.05	1.33	0.96	0.87	2.41	1.42
Ca/Al^{3+}	4.50	57.2	9.72	6.06	4.49	55.5	7.21
Fe	$0.45_{0.05}$	$0.57_{0.03}$	$0.30_{0.03}$	$0.31_{0.03}$	$0.17_{0.02}$	$0.39_{0.05}$	$0.26_{0.06}$
Mn	$0.33_{0.03}$	$0.48_{0.04}$	$0.43_{0.05}$	$0.11_{0.01}$	$0.11_{0.01}$	$0.25_{0.04}$	$0.51_{0.06}$
Si	$2.49_{0.19}$	$0.80_{0.04}$	$0.97_{0.06}$	$1.09_{0.09}$	$1.22_{0.10}$	$0.58_{0.05}$	$2.49_{0.24}$

Appendix 2. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 20 cm in Scots pine stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.

Liite 2. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 20 cm:n syvyydellä männiköissä vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 18, Miehikkälä	No. 13, Tammela	No. 16, Punkaharju	No. 10, Juupajoki	No. 9, Ylikiiminki	No. 6, Kivalo	No. 1, Sevettijärvi
pH	$4.98_{0.06}$	$4.90_{0.08}$	$5.54_{0.07}$	$4.82_{0.04}$	$4.70_{0.32}$	$5.39_{0.08}$	$5.99_{0.09}$
DOC	$30.4_{2.8}$	$29.0_{4.2}$	$36.0_{3.4}$	$29.3_{2.4}$	$13.2_{2.7}$	$15.3_{1.9}$	$11.9_{1.5}$
DON	$1.20_{0.08}$	$0.93_{0.18}$	$1.30_{0.09}$	$0.76_{0.06}$	$0.89_{0.25}$	$0.58_{0.06}$	$0.76_{0.13}$
N_{tot}	$1.46_{0.11}$	$1.62_{0.28}$	$1.46_{0.10}$	$0.89_{0.07}$	$1.08_{0.20}$	$0.66_{0.06}$	$0.80_{0.14}$
NH_4-N	$0.24_{0.07}$	$0.59_{0.16}$	$0.15_{0.03}$	$0.11_{0.02}$	$0.29_{0.17}$	$0.07_{0.01}$	$0.03_{0.01}$
NO_3-N	$0.04_{0.01}$	$0.14_{0.04}$	<0.02	$0.02_{0.01}$	$0.04_{0.03}$	<0.02	<0.02
SO_4-S	$2.59_{0.27}$	$2.54_{0.38}$	$1.67_{0.21}$	$0.69_{0.06}$	$6.72_{2.88}$	$0.67_{0.07}$	$1.79_{0.32}$
S_{tot}	$4.84_{0.31}$	$3.93_{0.70}$	$4.29_{0.31}$	$1.74_{0.11}$	$8.73_{2.41}$	$1.68_{0.10}$	$3.88_{0.51}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cl	$1.76_{0.17}$	$1.14_{0.17}$	$0.98_{0.19}$	$0.73_{0.07}$	$1.39_{0.51}$	$0.49_{0.07}$	$3.40_{0.62}$
Ca	$1.78_{0.20}$	$2.15_{0.18}$	$2.73_{0.28}$	$1.02_{0.07}$	$3.30_{1.41}$	$0.80_{0.06}$	$1.54_{0.42}$
Mg	$0.31_{0.02}$	$0.39_{0.03}$	$0.57_{0.04}$	$0.40_{0.02}$	$0.40_{0.14}$	$0.19_{0.02}$	$0.53_{0.06}$
K	$2.91_{0.38}$	$1.65_{0.25}$	$3.01_{0.55}$	$1.22_{0.14}$	$0.85_{0.16}$	$1.12_{0.12}$	$1.09_{0.12}$
Na	$1.15_{0.09}$	$1.06_{0.08}$	$0.93_{0.07}$	$0.58_{0.03}$	$1.24_{0.38}$	$0.80_{0.06}$	$2.11_{0.35}$
Zn	$0.04_{0.00}$	$0.04_{0.01}$	$0.04_{0.00}$	$0.03_{0.00}$	$0.04_{0.00}$	$0.02_{0.00}$	$0.09_{0.04}$
Cu	<0.03	<0.03	<0.03	<0.03	$0.03_{0.01}$	<0.03	<0.03
Al_{tot}	$1.30_{0.21}$	$0.79_{0.11}$	$0.87_{0.10}$	$0.85_{0.05}$	$1.24_{0.47}$	$0.57_{0.08}$	$0.10_{0.02}$
Al^{3+}	$0.39_{0.06}$	$0.11_{0.02}$	$0.18_{0.02}$	$0.14_{0.01}$	$0.05_{0.01}$	$0.08_{0.01}$	$0.03_{0.01}$
Al_{compl}	$0.90_{0.06}$	$0.69_{0.02}$	$0.69_{0.02}$	$0.71_{0.01}$	$1.18_{0.02}$	$0.49_{0.02}$	$0.06_{0.01}$
Ca/Al_{tot}	0.92	1.83	2.11	0.81	1.79	0.94	10.4
Ca/Al^{3+}	3.07	13.2	10.2	4.90	44.4	6.73	34.6
Fe	$0.32_{0.07}$	$0.15_{0.03}$	$0.26_{0.04}$	$0.29_{0.04}$	$0.03_{0.01}$	$0.14_{0.03}$	$0.02_{0.01}$
Mn	$0.29_{0.03}$	$0.10_{0.02}$	$0.38_{0.06}$	$0.11_{0.01}$	$0.22_{0.06}$	$0.07_{0.01}$	$0.49_{0.12}$
Si	$2.44_{0.20}$	$2.92_{0.24}$	1.94	$1.29_{0.14}$	$1.04_{0.51}$	$2.61_{0.17}$	$0.86_{0.09}$

Appendix 3. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 40 cm in Scots pine stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry. NS means that no samples were obtained at a depth of 40 cm on the plot in question.

Liite 3. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 40 cm:n syvyydellä männiköissä vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan. NS tarkoittaa, että näytteitä ei saatu 40 cm:n syvyydeltä kyseiseltä havaintoalalta.*

Parameter *Tunnus*	No. 18, Miehikkälä	No. 13, Tammela	No. 16, Punkaharju	No. 10, Juupajoki	No. 9, Ylikiiminki	No. 6, Kivalo	No. 1, Sevettijärvi
pH	$5.20_{0.14}$	$5.15_{0.11}$	$5.99_{0.06}$	$5.36_{0.06}$	NS	$5.56_{0.06}$	$6.09_{0.11}$
DOC	$13.2_{2.6}$	$24.4_{3.6}$	$29.0_{3.3}$	$15.8_{1.8}$	NS	$17.7_{2.3}$	$11.0_{1.2}$
DON	$1.27_{0.19}$	$0.61_{0.13}$	$1.44_{0.15}$	$0.88_{0.18}$	NS	$0.55_{0.08}$	$0.85_{0.11}$
N_{tot}	$1.37_{0.20}$	$1.12_{0.30}$	$1.53_{0.16}$	$1.08_{0.22}$	NS	$0.68_{0.09}$	$0.89_{0.12}$
NH_4-N	$0.07_{0.01}$	$0.43_{0.18}$	$0.08_{0.02}$	$0.17_{0.05}$	NS	$0.12_{0.02}$	$0.03_{0.01}$
NO_3-N	$0.074_{0.05}$	$0.07_{0.02}$	<0.02	$0.03_{0.01}$	NS	<0.02	<0.02
SO_4-S	$3.74_{0.57}$	$2.27_{0.46}$	$2.64_{0.50}$	$1.40_{0.25}$	NS	$0.85_{0.11}$	$2.62_{1.10}$
S_{tot}	$9.17_{2.70}$	$2.93_{0.65}$	$5.85_{0.58}$	$3.64_{0.72}$	NS	$1.79_{0.25}$	$6.12_{1.55}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	NS	<0.03	<0.03
Cl	$2.02_{0.24}$	$1.15_{0.20}$	$1.17_{0.18}$	$0.45_{0.04}$	NS	$0.49_{0.15}$	$1.64_{0.18}$
Ca	$1.78_{0.50}$	$2.16_{0.15}$	$3.70_{0.51}$	$0.91_{0.09}$	NS	$1.41_{0.15}$	$2.60_{1.30}$
Mg	$0.36_{0.05}$	$0.34_{0.02}$	$0.57_{0.05}$	$0.36_{0.05}$	NS	$0.26_{0.03}$	$0.30_{0.02}$
K	$2.55_{0.37}$	$0.99_{0.18}$	$1.50_{0.21}$	$0.97_{0.10}$	NS	$1.53_{0.17}$	$0.86_{0.18}$
Na	$0.98_{0.07}$	$1.07_{0.07}$	$1.04_{0.09}$	$0.52_{0.04}$	NS	$0.72_{0.07}$	$1.93_{0.20}$
Zn	$0.04_{0.01}$	$0.03_{0.01}$	$0.02_{0.00}$	$0.02_{0.01}$	NS	$0.02_{0.00}$	$0.02_{0.01}$
Cu	<0.03	<0.03	<0.03	<0.03	NS	<0.03	<0.03
Al_{tot}	$0.36_{0.06}$	$0.65_{0.09}$	$0.40_{0.12}$	$0.33_{0.04}$	NS	$0.59_{0.12}$	$0.05_{0.01}$
Al^{3+}	$0.13_{0.04}$	$0.09_{0.01}$	$0.10_{0.04}$	$0.11_{0.03}$	NS	$0.05_{0.01}$	$0.03_{0.01}$
Al_{compl}	$0.22_{0.05}$	$0.55_{0.02}$	$0.30_{0.02}$	$0.22_{0.03}$	NS	$0.54_{0.02}$	$0.04_{0.00}$
Ca/Al_{tot}	3.33	2.24	6.23	1.86		1.61	35.0
Ca/Al^{3+}	9.22	16.2	24.9	5.57		19.0	58.3
Fe	$0.02_{0.00}$	$0.13_{0.03}$	$0.10_{0.03}$	$0.03_{0.01}$	NS	$0.11_{0.02}$	$0.02_{0.01}$
Mn	$0.33_{0.07}$	$0.08_{0.02}$	$0.43_{0.09}$	$0.07_{0.01}$	NS	$0.06_{0.01}$	$0.90_{0.13}$
Si	$2.33_{0.34}$	$2.92_{0.26}$	$2.47_{0.11}$	$3.64_{0.20}$	NS	$2.43_{0.15}$	$2.24_{0.26}$

Appendix 4. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 5 cm in Norway spruce stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.
Liite 4. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 5 cm:n syvyydellä kuusikoissa vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 12, Tammela	No. 17, Punkaharju	No. 11, Juupajoki	No. 23, Uusi-kaarlepyy	No. 5, Kivalo	No. 3, Pallasjärvi
pH	$4.16_{0.02}$	$4.26_{0.06}$	$4.77_{0.03}$	$4.25_{0.05}$	$4.30_{0.04}$	$5.21_{0.06}$
DOC	$33.0_{1.8}$	$69.4_{4.9}$	$49.0_{3.1}$	$68.7_{3.5}$	$42.9_{3.0}$	$32.7_{1.8}$
DON	$0.76_{0.04}$	$2.73_{0.33}$	$1.21_{0.06}$	$2.63_{0.14}$	$0.96_{0.05}$	$1.07_{0.08}$
N_{tot}	$1.08_{0.08}$	$3.60_{0.52}$	$1.45_{0.07}$	$4.28_{0.31}$	$1.15_{0.06}$	$1.29_{0.10}$
NH_4-N	$0.30_{0.06}$	$0.80_{0.35}$	$0.18_{0.03}$	$1.22_{0.17}$	$0.18_{0.02}$	$0.14_{0.02}$
NO_3-N	<0.02	$0.07_{0.03}$	$0.04_{0.01}$	$0.43_{0.07}$	<0.02	$0.05_{0.01}$
SO_4-S	$1.71_{0.14}$	$4.89_{1.03}$	$0.86_{0.08}$	$5.39_{1.89}$	$0.42_{0.03}$	$0.69_{0.15}$
S_{tot}	$2.27_{0.19}$	$7.97_{1.21}$	$1.80_{0.10}$	$8.42_{2.47}$	$1.37_{0.07}$	$2.57_{0.35}$
PO_4-P	<0.03	<0.03	$0.11_{0.02}$	$0.18_{0.04}$	$0.06_{0.01}$	$0.04_{0.01}$
Cl	$0.94_{0.10}$	$1.81_{0.17}$	$0.77_{0.07}$	$6.51_{1.57}$	$0.41_{0.06}$	$0.56_{0.08}$
Ca	$0.76_{0.07}$	$2.23_{0.39}$	$2.72_{0.18}$	$1.93_{0.32}$	$1.07_{0.09}$	$1.72_{0.21}$
Mg	$0.42_{0.04}$	$1.14_{0.14}$	$0.58_{0.03}$	$1.61_{0.50}$	$0.35_{0.03}$	$0.49_{0.04}$
K	$0.42_{0.07}$	$3.29_{0.41}$	$2.40_{0.29}$	$6.74_{0.71}$	$2.52_{0.27}$	$1.79_{0.14}$
Na	$1.33_{0.10}$	$2.11_{0.45}$	$0.61_{0.03}$	$3.21_{1.00}$	$0.32_{0.02}$	$0.64_{0.05}$
Zn	$0.01_{0.00}$	$0.04_{0.00}$	$0.03_{0.00}$	$0.07_{0.01}$	$0.03_{0.00}$	$0.02_{0.00}$
Cu	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Al_{tot}	$1.48_{0.07}$	$2.89_{0.28}$	$0.97_{0.05}$	$2.50_{0.66}$	$0.31_{0.03}$	$0.72_{0.04}$
Al^{3+}	$0.30_{0.03}$	$0.57_{0.10}$	$0.08_{0.00}$	$0.30_{0.06}$	$0.02_{0.00}$	$0.10_{0.01}$
Al_{compl}	$1.18_{0.01}$	$2.31_{0.01}$	$0.88_{0.01}$	$2.19_{0.08}$	$0.29_{0.00}$	$0.62_{0.01}$
Ca/Al_{tot}	0.35	0.52	1.89	0.52	2.32	1.61
Ca/Al^{3+}	1.71	2.63	22.9	4.33	36.0	11.6
Fe	$0.48_{0.03}$	$1.35_{0.17}$	$0.53_{0.04}$	$1.59_{0.13}$	$0.42_{0.03}$	$0.36_{0.03}$
Mn	$0.11_{0.01}$	$0.55_{0.08}$	$0.37_{0.03}$	$0.32_{0.03}$	$0.33_{0.03}$	$0.20_{0.02}$
Si	$2.97_{0.14}$	$6.27_{0.94}$	$1.46_{0.07}$	$3.37_{0.26}$	$0.75_{0.09}$	$1.06_{0.07}$

Appendix 5. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 20 cm in Norway spruce stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.

Liite 5. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 20 cm:n syvyydellä kuusikoissa vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 12, Tammela	No. 17, Punkaharju	No. 11, Juupajoki	No. 23, Uusi-kaarlepyy	No. 5, Kivalo	No. 3, Pallasjärvi
pH	$4.51_{0.03}$	$4.77_{0.13}$	$4.99_{0.05}$	$3.96_{0.05}$	$4.89_{0.05}$	$5.87_{0.03}$
DOC	$24.1_{4.6}$	$32.9_{7.0}$	$31.3_{3.2}$	$70.1_{5.2}$	$30.3_{2.5}$	$15.8_{1.2}$
DON	$0.78_{0.26}$	$1.48_{0.42}$	$0.94_{0.07}$	$2.56_{0.16}$	$0.96_{0.08}$	$0.92_{0.10}$
N_{tot}	$0.97_{0.30}$	$1.81_{0.46}$	$1.16_{0.10}$	$3.36_{0.25}$	$1.10_{0.09}$	$1.02_{0.11}$
NH_4-N	$0.19_{0.05}$	$0.21_{0.08}$	$0.17_{0.05}$	$0.63_{0.11}$	$0.10_{0.01}$	$0.06_{0.01}$
NO_3-N	<0.02	$0.12_{0.08}$	<0.02	$0.16_{0.04}$	$0.03_{0.01}$	<0.02
SO_4-S	$3.16_{0.16}$	$4.80_{1.36}$	$1.54_{0.21}$	$87.2_{22.5}$	$0.66_{0.08}$	$1.48_{0.28}$
S_{tot}	$3.67_{0.19}$	$8.89_{2.74}$	$2.87_{0.26}$	$95.5_{22.6}$	$2.19_{0.20}$	$3.83_{0.57}$
PO_4-P	<0.03	<0.03	<0.03	$0.06_{0.02}$	<0.03	<0.03
Cl	$2.26_{0.26}$	$1.40_{0.28}$	$0.97_{0.14}$	$21.6_{5.21}$	$0.35_{0.05}$	$0.63_{0.10}$
Ca	$1.21_{0.12}$	$1.96_{0.76}$	$1.60_{0.14}$	$13.7_{2.75}$	$0.89_{0.10}$	$1.74_{0.34}$
Mg	$0.54_{0.03}$	$1.04_{0.25}$	$0.61_{0.05}$	$13.9_{3.53}$	$0.30_{0.03}$	$0.38_{0.03}$
K	$1.54_{0.57}$	$1.03_{0.20}$	$1.56_{0.17}$	$5.24_{0.44}$	$2.63_{0.19}$	$0.71_{0.10}$
Na	$2.89_{0.55}$	$2.27_{0.47}$	$1.05_{0.10}$	$12.7_{2.95}$	$0.55_{0.03}$	$0.96_{0.10}$
Zn	$0.01_{0.00}$	$0.02_{0.01}$	$0.02_{0.00}$	$0.79_{0.19}$	$0.03_{0.00}$	$0.01_{0.00}$
Cu	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Al_{tot}	$1.47_{0.09}$	$2.01_{0.43}$	$1.03_{0.10}$	$30.5_{7.36}$	$0.84_{0.06}$	$0.34_{0.05}$
Al^{3+}	$0.66_{0.10}$	$0.87_{0.36}$	$0.19_{0.03}$	$4.36_{1.61}$	$0.07_{0.01}$	$0.09_{0.02}$
Al_{compl}	$0.82_{0.02}$	$1.14_{0.03}$	$0.84_{0.02}$	$26.0_{3.14}$	$0.77_{0.01}$	$0.26_{0.02}$
Ca/Al_{tot}	0.55	0.66	1.05	0.30	0.71	3.44
Ca/Al^{3+}	1.23	1.52	5.67	2.12	8.56	13.0
Fe	$0.13_{0.03}$	$0.29_{0.06}$	$0.23_{0.04}$	$2.14_{0.30}$	$0.28_{0.03}$	$0.07_{0.01}$
Mn	$0.12_{0.02}$	$0.26_{0.08}$	$0.16_{0.02}$	$0.61_{0.10}$	$0.19_{0.02}$	$0.17_{0.03}$
Si	$3.67_{0.24}$	$5.78_{0.78}$	$2.35_{0.24}$	$10.7_{1.14}$	$1.76_{0.10}$	$2.29_{0.12}$

Appendix 6. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 40 cm in Norway spruce stands during 1998–2000. The soil solution was collected using zero-tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.
Liite 6. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 40 cm:n syvyydellä kuusikoissa vuosina 1998–2000. Maavettä kerättiin vajovesilysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 12, Tammela	No. 17, Punkaharju	No. 11, Juupajoki	No. 23, Uusi-kaarlepyy	No. 5, Kivalo	No. 3, Pallasjärvi
pH	$4.69_{0.03}$	$4.97_{0.07}$	$5.21_{0.03}$	$3.86_{0.03}$	$5.64_{0.08}$	$5.89_{0.14}$
DOC	$4.5_{0.2}$	$24.1_{3.9}$	$9.2_{1.1}$	$36.5_{2.6}$	$18.4_{5.6}$	$13.8_{2.1}$
DON	$0.20_{0.02}$	$1.44_{0.27}$	$0.43_{0.06}$	$1.61_{0.11}$	$0.54_{0.08}$	$1.23_{0.29}$
N_{tot}	$0.30_{0.02}$	$1.64_{0.30}$	$0.50_{0.07}$	$1.92_{0.13}$	$0.61_{0.08}$	$1.28_{0.30}$
NH_4-N	$0.10_{0.01}$	$0.23_{0.09}$	$0.03_{0.01}$	$0.17_{0.03}$	$0.06_{0.01}$	$0.04_{0.02}$
NO_3-N	<0.02	$0.05_{0.03}$	<0.02	$0.37_{0.20}$	<0.02	<0.02
SO_4-S	$3.43_{0.11}$	$8.73_{1.40}$	$2.64_{0.17}$	$135_{24.7}$	$1.56_{0.28}$	$1.94_{0.46}$
S_{tot}	$3.92_{0.15}$	$14.8_{2.5}$	$3.95_{0.27}$	$149_{25.1}$	$4.79_{2.12}$	$5.47_{1.20}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cl	$1.73_{0.12}$	$1.93_{0.26}$	$1.13_{0.18}$	$20.3_{3.10}$	$0.49_{0.09}$	$0.59_{0.12}$
Ca	$1.07_{0.03}$	$3.93_{1.96}$	$1.49_{0.11}$	$21.9_{3.09}$	$1.23_{0.21}$	$2.35_{0.56}$
Mg	$0.45_{0.02}$	$1.55_{0.11}$	$0.59_{0.05}$	$13.8_{1.70}$	$0.24_{0.03}$	$0.49_{0.04}$
K	$0.23_{0.03}$	$0.59_{0.22}$	$0.95_{0.18}$	$3.75_{0.22}$	$2.73_{0.57}$	$0.68_{0.21}$
Na	$2.51_{0.12}$	$4.71_{0.51}$	$1.40_{0.06}$	$13.5_{1.55}$	$0.71_{0.11}$	$0.88_{0.14}$
Zn	$0.01_{0.00}$	$0.03_{0.01}$	$0.01_{0.00}$	$1.68_{0.34}$	$0.02_{0.00}$	$0.01_{0.00}$
Cu	<0.03	<0.03	<0.03	$0.06_{0.01}$	<0.03	<0.03
Al_{tot}	$0.63_{0.04}$	$1.35_{0.15}$	$0.36_{0.05}$	$50.7_{9.84}$	$0.38_{0.09}$	$0.23_{0.09}$
Al^{3+}	$0.51_{0.04}$	$0.95_{0.13}$	$0.17_{0.03}$	$6.32_{2.03}$	$0.05_{0.01}$	$0.04_{0.01}$
Al_{compl}	$0.12_{0.00}$	$0.39_{0.01}$	$0.19_{0.01}$	$44.1_{3.16}$	$0.33_{0.02}$	$0.20_{0.01}$
Ca/Al_{tot}	1.14	1.96	2.79	0.29	2.18	6.88
Ca/Al^{3+}	1.41	2.78	5.90	2.33	16.6	39.5
Fe	<0.02	$0.10_{0.02}$	$0.02_{0.01}$	$1.35_{0.19}$	$0.04_{0.01}$	$0.07_{0.03}$
Mn	$0.06_{0.01}$	$0.41_{0.16}$	$0.07_{0.01}$	$1.03_{0.13}$	$0.05_{0.01}$	$0.20_{0.03}$
Si	$3.92_{0.08}$	$6.40_{0.35}$	$3.33_{0.20}$	$15.2_{1.22}$	$2.60_{0.23}$	$1.96_{0.00}$

Appendix 7. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 20 cm in Scots pine stands during 1998–2000. The soil solution was collected using tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry. IS means that insufficient sample volumes were obtained to determine the parameter in question.

Liite 7. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 20 cm:n syvyydellä männiköissä vuosina 1998–2000. Maavettä kerättiin imulysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan. IS tarkoittaa, että näytemäärät olivat liian pieniä ks. analyysiä varten.*

Parameter *Tunnus*	No. 18, Miehikkälä	No. 13, Tammela	No. 16, Punkaharju	No. 10, Juupajoki	No. 9, Ylikiiminki	No. 6, Kivalo	No. 1, Sevettijärvi
pH	$6.35_{0.07}$	$5.85_{0.05}$	$6.11_{0.08}$	$5.77_{0.05}$	$6.47_{0.07}$	$6.24_{0.14}$	$6.50_{0.11}$
DOC	$18.8_{1.7}$	$31.8_{2.2}$	$56.3_{3.9}$	$7.5_{0.5}$	$26.9_{1.9}$	$6.4_{1.2}$	$14.3_{0.8}$
DON	$0.43_{0.05}$	$0.87_{0.07}$	$1.16_{0.11}$	$0.35_{0.03}$	IS	$0.41_{0.08}$	IS
N_{tot}	$0.47_{0.05}$	$0.89_{0.07}$	$1.21_{0.11}$	$0.38_{0.03}$	IS	$0.43_{0.08}$	$1.45_{0.09}$
NH_4-N	$0.04_{0.01}$	$0.03_{0.00}$	$0.05_{0.01}$	$0.04_{0.01}$	$0.02_{0.00}$	$0.02_{0.00}$	$0.03_{0.01}$
NO_3-N	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	$0.02_{0.01}$
SO_4-S	$1.44_{0.13}$	$0.77_{0.05}$	$1.09_{0.09}$	$1.01_{0.03}$	$0.24_{0.05}$	$0.27_{0.04}$	$0.84_{0.08}$
S_{tot}	$1.50_{0.09}$	$0.92_{0.04}$	$1.43_{0.12}$	$1.49_{0.07}$	4.66	$0.88_{0.18}$	$2.15_{0.16}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cl	$1.30_{0.12}$	$1.36_{0.21}$	$1.15_{0.25}$	$0.73_{0.04}$	$0.27_{0.04}$	$1.12_{0.75}$	$1.52_{0.47}$
Ca	$1.61_{0.18}$	$2.09_{0.14}$	$2.62_{0.17}$	$0.85_{0.03}$	$0.37_{0.04}$	$0.62_{0.05}$	$0.37_{0.04}$
Mg	$0.30_{0.04}$	$0.47_{0.03}$	$0.78_{0.10}$	$0.30_{0.01}$	$0.19_{0.02}$	$0.18_{0.02}$	$0.40_{0.16}$
K	$1.44_{0.22}$	$1.89_{0.39}$	$2.05_{0.17}$	$0.37_{0.04}$	$0.50_{0.08}$	$0.55_{0.10}$	$0.67_{0.11}$
Na	$1.38_{0.14}$	$1.40_{0.11}$	$1.26_{0.11}$	$0.72_{0.04}$	$1.07_{0.12}$	$1.2_{0.09}2$	$2.37_{0.53}$
Zn	$0.04_{0.01}$	$0.07_{0.01}$	$0.12_{0.02}$	$0.03_{0.01}$	$0.01_{0.01}$	$0.02_{0.00}$	$0.36_{0.19}$
Cu	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Al_{tot}	$0.63_{0.08}$	$0.91_{0.06}$	$1.28_{0.29}$	$0.28_{0.03}$	$0.02_{0.00}$	$0.29_{0.10}$	$0.07_{0.04}$
Al^{3+}	$0.18_{0.02}$	$0.13_{0.01}$	$0.31_{0.04}$	$0.10_{0.01}$	IS	$0.05_{0.02}$	IS
Al_{compl}	$0.44_{0.03}$	$0.77_{0.02}$	$0.96_{0.02}$	$0.17_{0.01}$	IS	$0.24_{0.02}$	IS
Ca/Al_{tot}	1.72	1.55	1.38	2.04	12.5	1.44	3.56
Ca/Al^{3+}	6.02	10.8	5.69	5.72	IS	8.35	IS
Fe	$0.06_{0.01}$	$0.18_{0.01}$	$0.16_{0.04}$	$0.03_{0.01}$	<0.02	$0.03_{0.01}$	$0.02_{0.01}$
Mn	$0.06_{0.01}$	$0.03_{0.01}$	$0.39_{0.19}$	$0.04_{0.01}$	$0.01_{0.00}$	$0.01_{0.00}$	$0.01_{0.00}$
Si	$4.96_{0.48}$	$4.70_{0.17}$	$3.90_{0.27}$	$2.41_{0.08}$	$3.57_{0.28}$	$2.79_{0.26}$	$5.26_{0.35}$

Appendix 8. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 40 cm in Scots pine stands during 1998–2000. The soil solution was collected using tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry. IS means that insufficient sample volumes were obtained to determine the parameter in question. NS means that no samples were obtained at a depth of 40 cm on the plot in question.
Liite 8. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 40 cm:n syvyydellä männiköissä vuosina 1998–2000. Maavettä kerättiin imulysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan. IS tarkoittaa, että näytemäärät olivat liian pieniä ks. analyysiä varten. NS tarkoittaa, että näytteitä ei saatu 40 cm:n syvyydeltä kyseiseltä havaintoalalta.*

Parameter *Tunnus*	No. 18, Miehikkälä	No. 13, Tammela	No. 16, Punkaharju	No. 10, Juupajoki	No. 9, Ylikiiminki	No. 6, Kivalo	No. 1, Sevettijärvi
pH	$6.35_{0.15}$	$6.11_{0.07}$	$6.32_{0.08}$	$5.85_{0.07}$	NS	$6.33_{0.05}$	$5.83_{0.07}$
DOC	$38.3_{4.7}$	$21.1_{2.6}$	$18.3_{2.0}$	$15.3_{5.5}$	NS	$3.7_{0.2}$	IS
DON	$0.91_{0.09}$	$0.64_{0.09}$	$1.04_{0.06}$	$0.47_{0.06}$	NS	$0.12_{0.01}$	IS
N_{tot}	$1.22_{0.23}$	$0.67_{0.09}$	$1.13_{0.05}$	$0.50_{0.07}$	NS	$0.13_{0.01}$	IS
NH_4-N	$0.28_{0.15}$	$0.04_{0.01}$	$0.09_{0.02}$	$0.05_{0.02}$	NS	$0.03_{0.01}$	IS
NO_3-N	$0.03_{0.01}$	<0.02	<0.02	<0.02	NS	<0.02	<0.02
SO_4-S	$2.05_{0.29}$	$1.26_{0.09}$	$1.54_{0.13}$	$1.32_{0.07}$	NS	$0.81_{0.06}$	$2.98_{0.35}$
S_{tot}	$2.35_{0.31}$	$1.39_{0.08}$	$3.18_{0.05}$	$3.74_{1.40}$	NS	$1.34_{0.08}$	$5.44_{1.29}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	NS	<0.03	<0.03
Cl	$1.26_{0.17}$	$1.55_{0.17}$	$0.70_{0.12}$	$0.71_{0.07}$	NS	$0.66_{0.16}$	$5.55_{1.29}$
Ca	$1.76_{0.18}$	$2.08_{0.12}$	$2.19_{0.17}$	$0.86_{0.04}$	NS	$0.97_{0.05}$	$1.70_{0.18}$
Mg	$0.51_{0.08}$	$0.48_{0.04}$	$0.75_{0.06}$	$0.34_{0.03}$	NS	$0.39_{0.03}$	$1.24_{0.18}$
K	$2.79_{0.51}$	$1.86_{0.57}$	$1.38_{0.19}$	$0.55_{0.07}$	NS	$0.36_{0.03}$	$3.82_{0.38}$
Na	$2.27_{0.31}$	$1.74_{0.13}$	$1.53_{0.20}$	$0.97_{0.07}$	NS	$1.46_{0.08}$	$5.41_{0.62}$
Zn	$0.36_{0.14}$	$0.03_{0.00}$	$0.25_{0.04}$	$0.04_{0.01}$	NS	$0.01_{0.00}$	$1.39_{0.18}$
Cu	<0.03	<0.03	<0.03	<0.03	NS	<0.03	<0.03
Al_{tot}	$1.62_{1.43}$	$0.49_{0.08}$	$0.40_{0.07}$	$0.21_{0.02}$	NS	$0.09_{0.03}$	$1.23_{0.58}$
Al^{3+}	$0.06_{0.00}$	$0.07_{0.01}$	$0.02_{0.01}$	$0.09_{0.01}$	NS	$0.01_{0.00}$	IS
Al_{compl}	$1.54_{0.02}$	$0.43_{0.03}$	$0.38_{0.00}$	$0.12_{0.01}$	NS	$0.07_{0.02}$	IS
Ca/Al_{tot}	0.73	2.86	3.69	2.89	NS	7.26	0.93
Ca/Al^{3+}	19.7	20.0	73.7	6.43	NS	65.3	IS
Fe	$0.22_{0.13}$	$0.09_{0.02}$	$0.07_{0.01}$	$0.02_{0.00}$	NS	<0.02	$0.31_{0.18}$
Mn	$0.09_{0.01}$	$0.04_{0.01}$	$0.01_{0.00}$	$0.04_{0.01}$	NS	$0.01_{0.00}$	$0.07_{0.01}$
Si	$6.76_{0.52}$	$5.98_{0.13}$	$4.51_{0.27}$	$2.71_{0.09}$	NS	$4.73_{0.08}$	$2.35_{0.18}$

Appendix 9. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 20 cm in Norway spruce stands during 1998–2000. The soil solution was collected using tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.
Liite 9. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 20 cm:n syvyydellä kuusikoissa vuosina 1998–2000. Maavettä kerättiin imulysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 12, Tammela	No. 17, Punkaharju	No. 11, Juupajoki	No. 23, Uusi-kaarlepyy	No. 5, Kivalo	No. 3, Pallasjärvi
pH	$4.97_{0.05}$	$4.43_{0.03}$	$5.48_{0.06}$	$4.07_{0.07}$	$5.29_{0.14}$	$6.29_{0.03}$
DOC	$12.8_{1.3}$	$30.4_{1.0}$	$17.2_{1.7}$	$74.8_{3.9}$	$28.2_{3.0}$	$10.9_{1.1}$
DON	$0.44_{0.05}$	$0.97_{0.03}$	$0.57_{0.05}$	$2.85_{0.18}$	$0.57_{0.04}$	$0.52_{0.06}$
N_{tot}	$0.45_{0.05}$	$1.01_{0.03}$	$0.62_{0.05}$	$2.93_{0.18}$	$0.62_{0.05}$	$0.57_{0.06}$
NH_4-N	$0.02_{0.00}$	$0.04_{0.00}$	$0.06_{0.01}$	$0.06_{0.02}$	$0.04_{0.02}$	$0.06_{0.01}$
NO_3-N	<0.02	<0.02	<0.02	$0.12_{0.10}$	<0.02	<0.02
SO_4-S	$2.87_{0.14}$	$7.03_{0.64}$	$1.96_{0.13}$	147_{18}	$0.63_{0.06}$	$0.56_{0.03}$
S_{tot}	$3.23_{0.16}$	$7.16_{0.57}$	$2.65_{0.17}$	150_{21}	$1.02_{0.09}$	$1.61_{0.15}$
PO_4-P	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Cl	$1.86_{0.13}$	$2.08_{0.18}$	$1.03_{0.12}$	$16.4_{1.7}$	$1.41_{0.44}$	$0.55_{0.04}$
Ca	$1.03_{0.06}$	$1.12_{0.11}$	$1.72_{0.18}$	$20.1_{2.5}$	$1.02_{0.16}$	$0.94_{0.06}$
Mg	$0.50_{0.02}$	$1.53_{0.12}$	$0.70_{0.05}$	$24.7_{3.0}$	$0.47_{0.05}$	$0.33_{0.02}$
K	$0.20_{0.06}$	$0.39_{0.06}$	$0.67_{0.11}$	$2.88_{0.38}$	$1.86_{0.18}$	$0.33_{0.04}$
Na	$2.70_{0.09}$	$5.80_{0.42}$	$1.56_{0.08}$	$18.2_{1.8}$	$1.18_{0.10}$	$0.85_{0.04}$
Zn	$0.01_{0.00}$	$0.03_{0.01}$	$0.04_{0.00}$	$1.56_{0.19}$	$0.04_{0.01}$	$0.10_{0.02}$
Cu	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Al_{tot}	$0.92_{0.06}$	$3.20_{0.19}$	$0.86_{0.07}$	$55.3_{6.9}$	$1.34_{0.17}$	$0.23_{0.03}$
Al^{3+}	$0.47_{0.03}$	$1.48_{0.13}$	$0.20_{0.01}$	$19.6_{4.35}$	$0.14_{0.01}$	$0.06_{0.01}$
Al_{compl}	$0.45_{0.01}$	$1.71_{0.01}$	$0.67_{0.01}$	$35.6_{5.6}$	$1.19_{0.01}$	$0.17_{0.01}$
Ca/Al_{tot}	0.75	0.24	1.35	0.24	0.51	2.75
Ca/Al^{3+}	1.48	0.51	5.79	0.69	4.90	10.5
Fe	$0.16_{0.03}$	$0.56_{0.08}$	$0.21_{0.02}$	$1.91_{0.20}$	$0.33_{0.04}$	$0.04_{0.01}$
Mn	$0.02_{0.00}$	$0.07_{0.01}$	$0.14_{0.03}$	$0.66_{0.08}$	$0.12_{0.04}$	$0.01_{0.00}$
Si	$5.14_{0.12}$	$8.78_{0.16}$	$4.92_{0.10}$	$16.8_{1.1}$	$5.68_{0.53}$	$2.31_{0.06}$

Appendix 10. Mean values (standard error of the mean as subscript) of different soil solution parameters at a depth of 40 cm in Norway spruce stands during 1998–2000. The soil solution was collected using tension lysimeters. The symbol "<" indicates that the mean concentration was below the limit of quantification, i.e. the value given in the entry.

Liite 10. *Maavesitunnusten keskiarvot (keskiarvon keskivirhe alaindeksinä) 40 cm:n syvyydellä kuusikoissa vuosina 1998–2000. Maavettä kerättiin imulysimetreillä. Symboli < osoittaa, että keskiarvo on alle osoitetun määritysrajan.*

Parameter *Tunnus*	No. 12, Tammela	No. 17, Punkaharju	No. 11, Juupajoki	No. 23, Uusi-kaarlepyy	No. 5, Kivalo	No. 3, Pallasjärvi
pH	$5.51_{0.08}$	$5.03_{0.06}$	$5.77_{0.08}$	$3.97_{0.03}$	$6.32_{0.04}$	$6.48_{0.03}$
DOC	$8.1_{0.8}$	$16.7_{0.9}$	$8.6_{1.3}$	$42.5_{2.6}$	$6.5_{0.9}$	$6.6_{0.7}$
DON	$0.48_{0.08}$	$0.72_{0.04}$	$0.41_{0.08}$	$2.03_{0.16}$	$0.28_{0.05}$	$0.36_{0.05}$
N_{tot}	$0.56_{0.10}$	$0.76_{0.04}$	$0.45_{0.09}$	$2.07_{0.16}$	$0.30_{0.05}$	$0.39_{0.05}$
NH_4-N	$0.08_{0.03}$	$0.04_{0.01}$	$0.04_{0.01}$	$0.03_{0.00}$	$0.02_{0.00}$	$0.03_{0.01}$
NO_3-N	<0.02	<0.02	<0.02	$0.13_{0.11}$	<0.02	<0.02
SO_4-S	$3.73_{0.13}$	$8.18_{0.97}$	$3.12_{0.43}$	156_{22}	$0.61_{0.05}$	$0.75_{0.03}$
S_{tot}	$4.36_{0.32}$	$8.40_{0.90}$	$3.75_{0.50}$	143_{18}	$0.77_{0.06}$	$1.44_{0.10}$
PO_4-P	<0.03	<0.03	<0.03	$0.22_{0.21}$	<0.03	<0.03
Cl	$2.64_{0.16}$	$2.35_{0.36}$	$1.16_{0.13}$	$26.4_{3.9}$	$0.63_{0.10}$	$0.43_{0.04}$
Ca	$1.74_{0.06}$	$1.35_{0.12}$	$1.82_{0.27}$	$22.2_{2.7}$	$0.58_{0.03}$	$1.04_{0.04}$
Mg	$0.76_{0.03}$	$1.65_{0.18}$	$0.66_{0.08}$	$24.2_{3.1}$	$0.30_{0.02}$	$0.39_{0.01}$
K	$0.34_{0.08}$	$0.27_{0.05}$	$0.55_{0.07}$	$2.61_{0.12}$	$0.61_{0.12}$	$0.12_{0.01}$
Na	$3.34_{0.09}$	$5.24_{0.47}$	$1.96_{0.12}$	$22.0_{2.2}$	$1.10_{0.08}$	$0.97_{0.04}$
Zn	$0.01_{0.00}$	$0.13_{0.02}$	$0.01_{0.00}$	$1.40_{0.13}$	$0.01_{0.00}$	$0.03_{0.00}$
Cu	<0.03	<0.03	<0.03	$0.04_{0.01}$	<0.03	<0.03
Al_{tot}	$0.34_{0.04}$	$2.27_{0.34}$	$0.40_{0.05}$	$48.8_{5.7}$	$0.10_{0.02}$	$0.08_{0.03}$
Al^{3+}	$0.19_{0.02}$	$1.85_{0.30}$	$0.15_{0.03}$	$5.92_{1.24}$	$0.02_{0.00}$	$0.02_{0.00}$
Al_{compl}	$0.15_{0.01}$	$0.42_{0.01}$	$0.25_{0.01}$	$42.9_{4.7}$	$0.07_{0.00}$	$0.06_{0.00}$
Ca/Al_{tot}	3.44	0.40	3.06	0.31	3.90	8.75
Ca/Al^{3+}	6.16	0.49	8.17	2.52	19.5	35.0
Fe	$0.03_{0.01}$	$0.08_{0.01}$	$0.03_{0.01}$	$1.07_{0.10}$	<0.02	<0.02
Mn	$0.01_{0.00}$	$0.06_{0.01}$	$0.04_{0.01}$	$1.00_{0.14}$	$0.01_{0.00}$	<0.003
Si	$4.97_{0.10}$	$6.96_{0.09}$	$4.35_{0.22}$	$22.2_{1.0}$	$3.80_{0.14}$	$2.48_{0.06}$

4.5 Phenological observations on Level II plots in 2001

Fenologiset havainnot vuonna 2001

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Summary

Phenology is the study of annually recurring phenomena in the life cycle of an organism. Knowledge about the timing and duration of certain life cycle events provides valuable information about the condition of trees and the effects of climate fluctuations and changes on trees. The results of intensive phenological assessments made on four Norway spruce Level II plots in Finland during 2001 are presented and analysed in connection with temperature data. A comparison with the 2000 results was also carried out.

Yhteenveto

Fenologia on tieteenala, joka tutkii biologisten ilmiöiden rytmiikkaa ja eri tekijöiden vaikutusta siihen. Kasvifenologisen seurannan tavoitteena on tuottaa tietoa metsäpuiden ja muiden metsäkasvien biologisista ilmiöistä ja tutkia miten nämä eri ilmiöt rytmittyvät suhteessa ilmastotekijöihin ja toisiinsa nähden. Tässä esitettävät tulokset ovat neljältä taso II kuusikkokoealalta Suomessa, vuodelta 2001. Lisäksi mukana on vertailu vuoteen 2000.

Introduction

Phenology is the study of annually recurring phenomena (e.g. budburst in spring, flowering, leaf or needle coloration, shedding during autumn) in the life cycle of an organism (life cycle events). Phenological observations have been an optional part of the ICP Level II programme since 2000. In the Level II monitoring programme, phenology is defined as the observation and recording of the yearly development stages of the trees, as well as biotic and abiotic (damaging) events. Its aim is to provide additional and complementary information on the status and development of the condition of forest trees throughout the year. Long term phenological observations help to determine the course of the annual development stages of the trees on the Level II plots. This can then be used to explain possible changes in the timing of phenological phases (starting time, length of period and magnitude) in relation to environmental factors. Knowledge about the timing and duration of certain life cycle events also provides valuable information about the condition of trees. When analysed in combination with other data obtained from the Level II plots, such as meteorological, deposition, crown condition and increment, phenology provides additional background information about possible causes of variation recorded in the crown condition assessments, as well as in the growth assessments.

There are two levels of phenological observation in the Level II programme. The extensive observations, carried out at the plot level, consist of those biotic and abiotic (damaging) events and phenological phenomena which are observed during cursory examination, at regular intervals, of the plot and its buffer zone. This information is used to explain the results of other assessments such as crown condition. Intensive monitoring at the individual tree level consists of more detailed observations on the condition of selected trees. These observations are made at more frequent intervals, especially during critical phases. In Finland, so far only intensive phenological observations have been performed on a limited number of Level II plots.

Assessments and results for 2001

Intensive phenological observations were made during 2001 on 4 Level II plots: Pallasjärvi_S, No. 3; Kivalo_S, No. 5; Punkaharju_S, No. 17 and Solböle_Spro, No.28. Except for Punkaharju, these are the same plots on which assessments were made during 2000. Norway spruce is the dominant species on each plot, and flushing and flowering were the events assessed. On each plot 10 trees were assessed (for Pallasjärvi, Kivalo and Solböle the same trees as in 2000) three times a week (on Monday, Wednesday and Friday) during the critical phases. Binoculars were used to assess the flushing and flowering stages. The assessments were made according to the guidelines given in Chapter 9 of the ICP Forests Manual (Manual .... 1999), and the same observer made the observations on each plot.

In Solböle and Punkaharju flushing started about 2 weeks earlier than in Kivalo and Pallasjärvi, and Kivalo was only a few days earlier than Pallasjärvi (Fig. 1). At Solböle flushing finished about one week later than in 2000 (Beuker 2001). In 2000 the start of flushing was missed in Solböle due to the late start of the assessments, but the completion of flushing (change to stage 5) was several days later in 2001 than in 2000. There was remarkably small variation between the trees within plots at Solböle, Kivalo and Pallasjärvi, whereas in Punkaharju there was a difference of more than one week between the trees in both the start as well as the end of the flushing period. A number of trees in Punkaharju were even earlier than those in Solböle. There was very little difference in flushing between Kivalo and Pallasjärvi. In 2000 Pallasjärvi was almost two weeks later, and there was also more variation between trees within the plots.

In Solböle the temperature sum development at the end of May – beginning of June was about two weeks behind the development in 2000 (Fig. 2). Flushing started during a cool period, shown by the slight increase in temperature sum (Fig. 2), which means that flushing develops slowly. Although Solböle is situated more to the south than Punkaharju, the temperature developed more rapidly in Punkaharju during spring 2001 (Fig. 3). This explains the earlier flushing in Punkaharju. In Punkaharju flushing occurred during a cool period with almost no increase in the temperature sum. As a result, the differences between trees will be larger (Beuker 1994). At Kivalo, the temperature sum development was behind that of 2000 up until June 17th, and at Pallasjärvi up until June 15th, but after this the temperature sum developed more rapidly (Fig. 2). Because the temperature sum curve was steeper during the flushing period in 2001 there was less variation between the trees (Beuker 1994). In 2000 the difference in temperature sum development in Kivalo was about two weeks earlier than at Pallasjärvi, but in 2001 only nearly one week, which explains why flushing occurred at almost the same time in 2001.

The year 2001 was a very poor flowering year for Norway spruce. Significant flowering was recorded only at Pallasjärvi, but about two weeks later than in 2000, and at Kivalo only two trees flowered (Fig. 4).

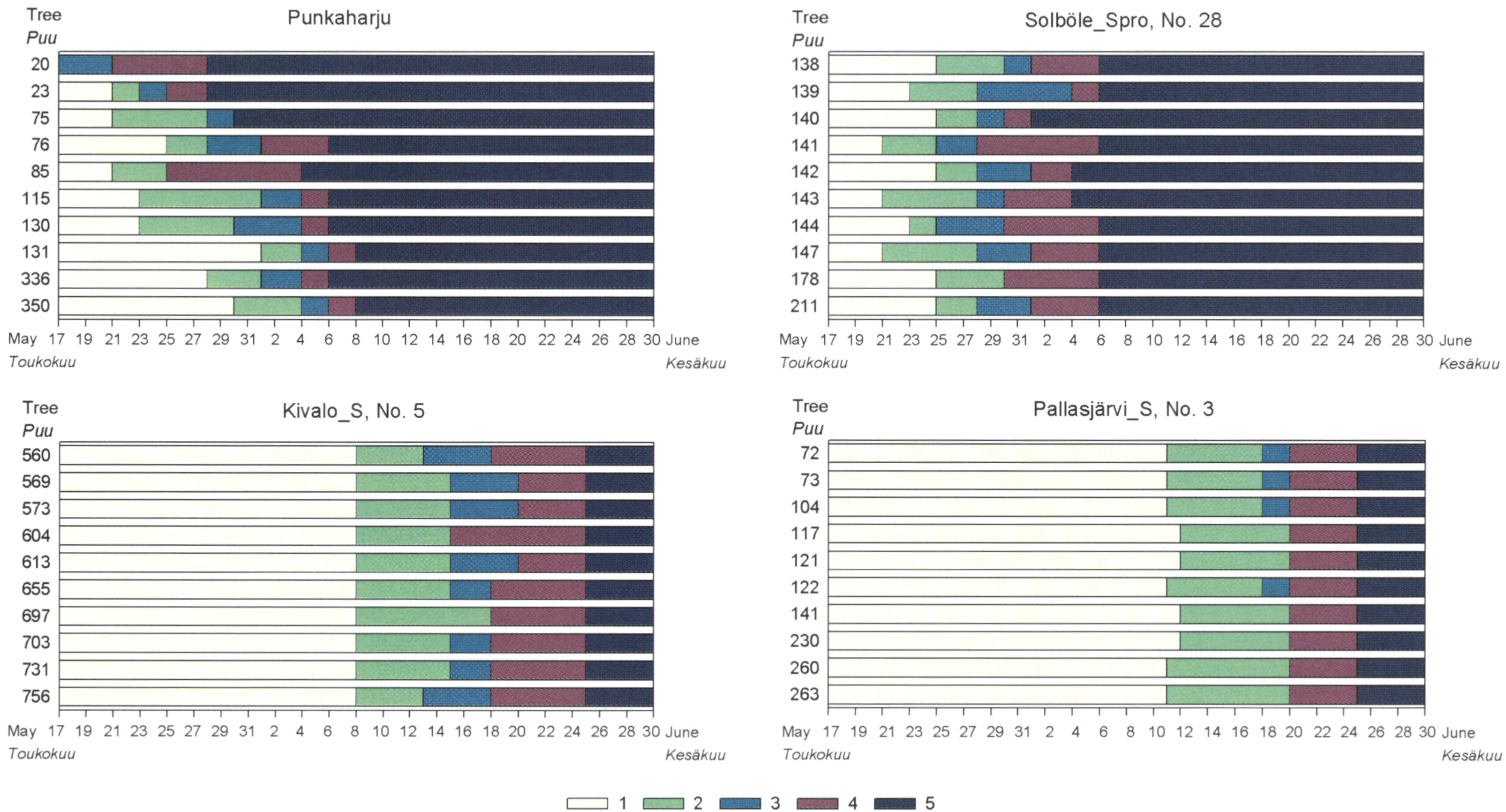


Figure 1. Flushing development in spring 2001 on four Level II plots. The extent of flushing was scored in five classes: 1 = not present, 2 = infrequent, 3 = common, 4 = abundant and 5 = completed.

Kuva 1. *Silmupuhkeamisen kehitys keväällä 2001 neljällä intensiivisen seurannan (taso II) havaintoalalla. Kehitys jaetaan 5 luokkaan: 1 = kaikki silmut levossa, 2 = joitain silmuja auennut, 3 = suuri osa silmuista auennut, 4 = lähes kaikki silmut auenneet ja 5 = kaikki silmut auenneet.*

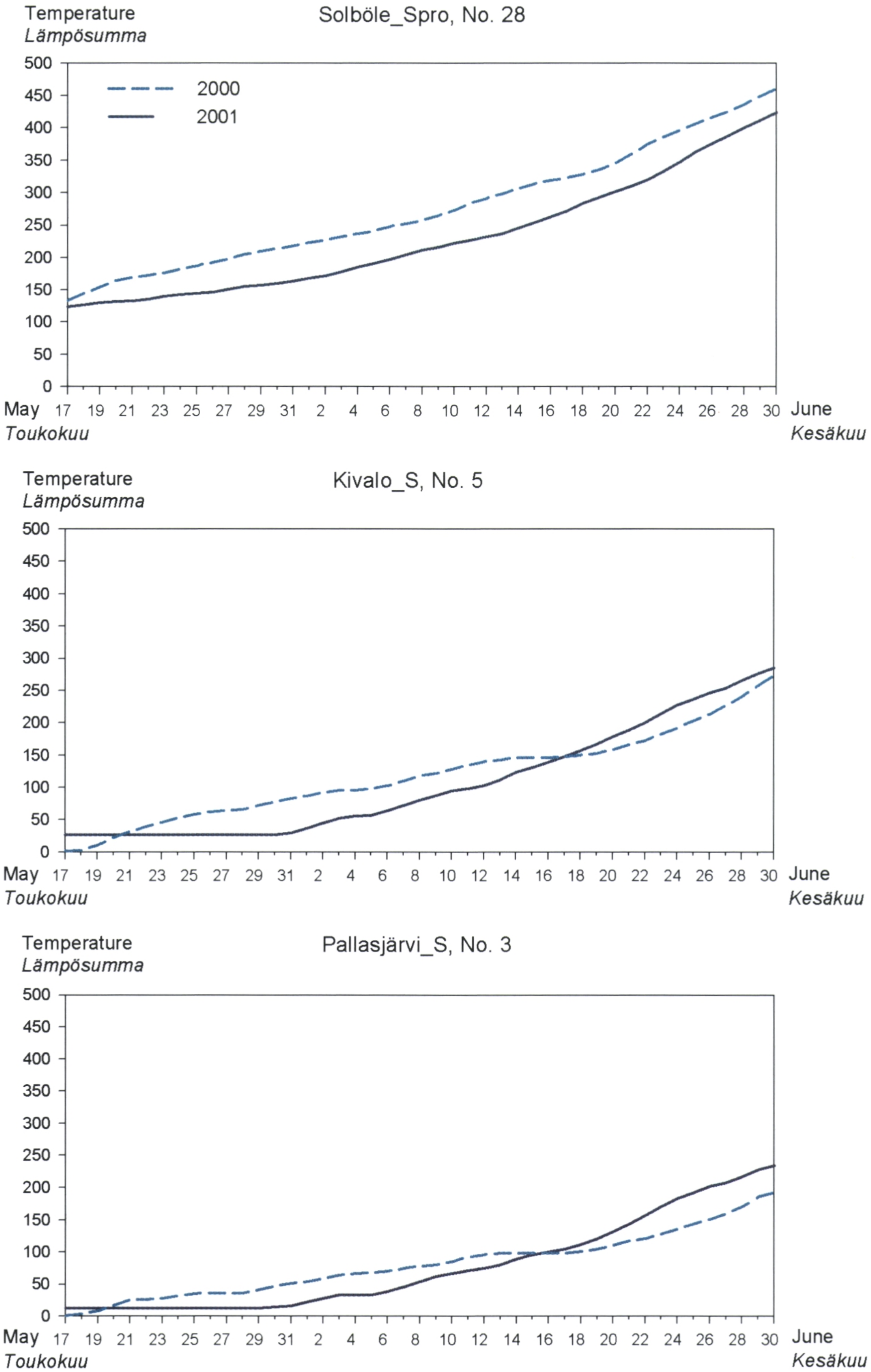


Figure 2. Temperature sum (5 °C threshold) development during spring 2000 and 2001 on three Level II plots.
Kuva 2. *Lämpösumman kehitys (5°C minimilämpötila) keväällä 2000 ja 2001 kolmella intensiivisen seurannan (taso II) havaintoalalla.*

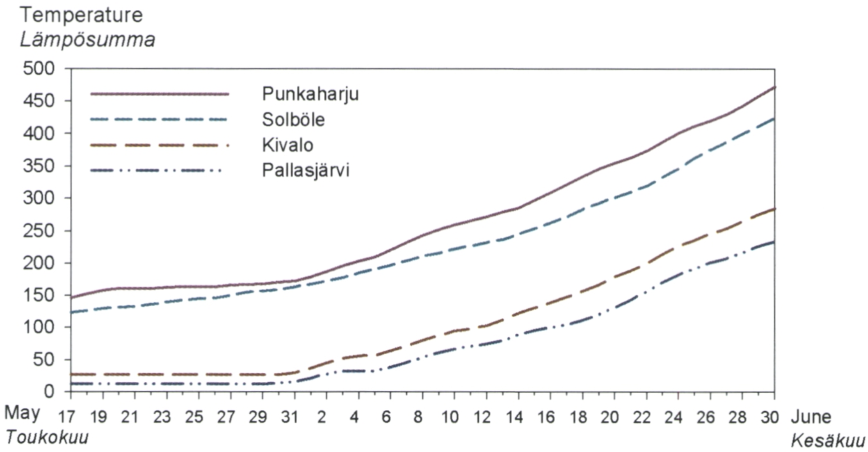
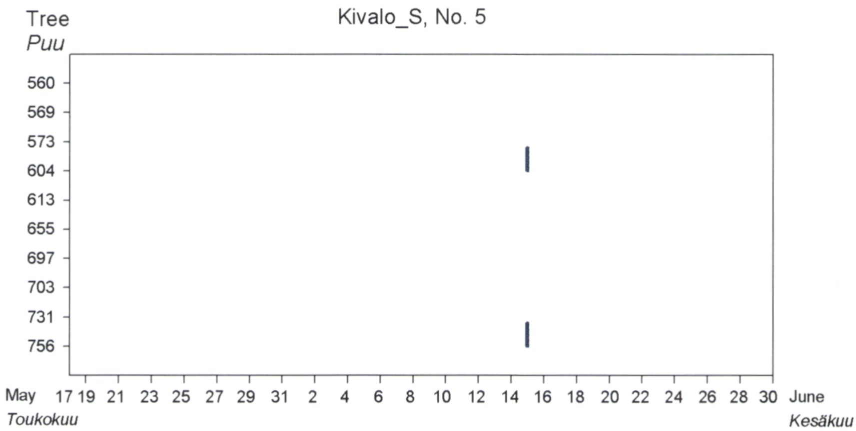


Figure 3. Comparison of the temperature sum (5 °C threshold) development during spring 2001 between the four Level II plots.
Kuva 3. *Lämpösummien kehityksen (5°C minimilämpötila) vertailu keväällä 2001 neljällä intensiivisen seurannan (taso II) havaintoalalla.*



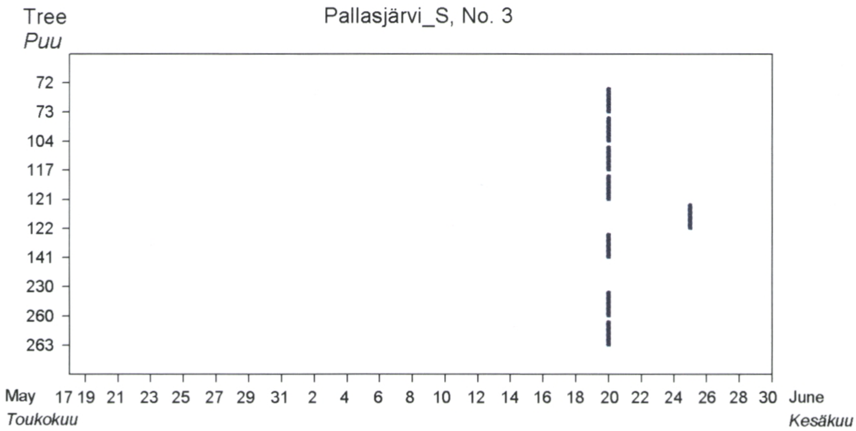


Figure 4. Starting date of flowering during spring 2001 on two Level II plots.
Kuva 4. *Kukinnan alkamisajankohta keväällä 2001 kahdella intensiivisen seurannan (taso II) havaintoalalla.*

Acknowledgements

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5 Biotic and abiotic forest damage in 2001

Metsätuhot vuonna 2001

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Summary

The most serious forest damage in 2001 was caused by the November storms, which were estimated to have felled over 7 million m^3 of trees in southern Finland with a total value of 300 million euros. In addition to storms, heavy snowfall bent and snapped trees in Pohjois-Karjala (number 12 in Fig. 1) and Pohjois-Savo (11) especially.

Fungal diseases were more common in 2001 than during the previous year. Scleroderris pine canker occurred at its highest frequency in ten years, and rust diseases were common throughout the country. No serious insect outbreaks were reported. Moose damage was estimated to have affected about one fifth of the total area of seedling stands. The vole populations were low in the spring, but started to increase during the summer.

Yhteenveto

Vuonna 2001 merkittävimmät metsätuhot aiheutuivat marraskuun myrskyistä, joiden arvioitiin kaataneen puuta eteläisestä Suomesta yli 7 miljoonaa kuutiometriä, arvoltaan liki 300 miljoonaa euroa. Myrskyjen lisäksi lumi taivutteli ja katkoi puita varsinkin Pohjois-Karjalassa ja Pohjois-Savossa.

Sienitaudit olivat yleisempiä kuin edellisenä vuonna. Männyllä versosurmaa esiintyi runsaammin kuin vuosikymmeneen, ja ruostetaudit olivat yleisiä koko maassa. Vakavia hyönteistuhoja ei todettu. Hirvituhoja arvioitiin esiintyneen noin viidenneksellä taimikkopinta-alasta. Myyräkannat olivat keväällä alhaalla, mutta kääntyivät nousuun kesän aikana.

The worst storm damage for decades

Local storms felled trees in Kymenlaakso (8), Etelä-Karjala (9) and Etelä-Savo (10) in July-August. Two extensive storms hit Finland in November, leaving behind them the worst damage for decades. A snow storm on the 1st of November caused the most serious damage in young pine stands that had just been thinned and in seed-tree stands in the southern parts of Etelä-Pohjanmaa (14) and northern parts of Keski-Suomi (13). Trees were snapped or uprooted mainly due to the combined effect of wind and the accumulation of wet snow that froze on the trees. Two weeks later, on the 15th of November, trees were uprooted especially in Uusimaa (1), Häme (5 and 7), Pirkanmaa (6) and Keski-Suomi (13). The estimated damage in southern Finland has now been confirmed as over 7 million m^3. The special inventory was based on the National Forest Inventory sampling plots representing 3.2 million hectares.

1 Uusimaa
2 Varsinais-Suomi
3 Itä-Uusimaa
4 Satakunta
5 Häme
6 Pirkanmaa
7 Päijät-Häme
8 Kymenlaakso
9 Etelä-Karjala
10 Etelä-Savo
11 Pohjois-Savo
12 Pohjois-Karjala
13 Keski-Suomi
14 Etelä-Pohjanmaa
15 Vaasan rannikkoseutu
16 Keski-Pohjanmaa
17 Pohjois-Pohjanmaa
18 Kainuu
19 Lappi
20 Ahvenanmaa

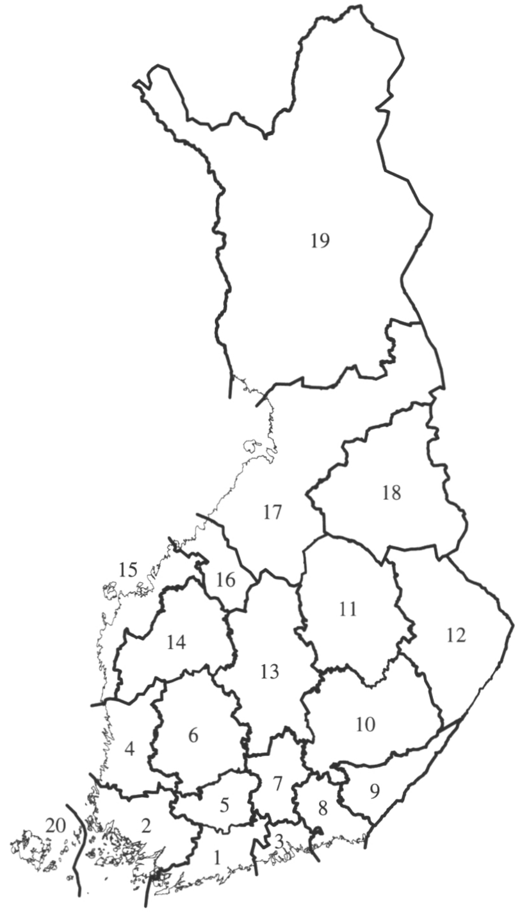

Figure 1. Provinces of Finland.
Kuva 1. *Suomen maakunnat.*

The warm, wet autumn in 2000 affected the occurrence of fungal diseases

The record-breaking warm, rainy autumn in 2000 increased the chances of fungal epidemics breaking out in 2001. In early summer the incidence of both strains of *Gremmeniella abietina* was reported to be the highest for a decade. The worst Scleroderris pine canker damage occurred in young pine stands in western Finland and Häme (5), where the infection was evident in June as browning of the last season's needles and death of the annual shoots. A considerable amount of Scleroderris canker damage was reported in Pohjois-Savo (11) even. The disease also occurred to some extent in Lapland (19).

The development of *G. abietina* takes two years. The epidemic usually goes into a decline during a warm, dry growing season. However, the weather conditions in summer 2001 again favoured *G. abietina*, and there is therefore an increasing risk of damage in summer 2002. In addition to *G. abietina*, there were also sporadic reports of pine needle blight (*Lophodermium seditiosum*) in pine seedling stands and young pine stands in different parts of southern Finland, and of Lophodermella needle cast (*Lophodermella sulcigena*) in Upper Lapland especially.

There were again local outbreaks of rust diseases throughout almost the whole country. The most common was *Chrysomyxa ledi*, which turned the youngest spruce needles yellow especially in Pohjanmaa (14–17), Keski-Suomi (13), Pirkanmaa (6), Pohjois- and Etelä-Savo (10–11) and Etelä-Karjala (9). In some areas this rust was so abundant that the orange-coloured spores formed extensive rafts on the surface of lakes and ponds towards the end of July. *Chrysomyxa ledi* damage was reported exceptionally also on bare-rooted spruce seedlings in nurseries. Owing to needle loss, the seedlings will probably have to be sorted next spring.

Pine twisting rust (*Melampsora pinitorqua*) was clearly more common in different parts of Finland, e.g. in Upper Lapland, than during the previous summer. An epidemic of birch rust (*Melampsoridium betulinum*), on the other hand, was not as evident in southern and central Finland as during the previous summer. However, this rust occurred relatively abundantly in Lapland (19). The fungus *Pyrenopeziza betulicola*, which turns all the leaves yellow on isolated branches on birch, also occurred in Lapland (19).

As well as fungal diseases, a number of types of foliage disturbance were also observed on birch in Lapland. However, these are assumed to be due to a combination of weather and other factors. *Venturia tremulae*, which turned the leaves and shoot tips of aspen black in June, was especially abundant in a belt running from Northern Finland to the Republic of Karelia in Russia. The disease slows down the growth of aspen sprouts, and it may be of economical significance in the future as the cultivation of aspen becomes more common.

The pathogenic fungus *Sirococcus conigenus* was isolated for the first time in Finland from small spruce seedlings that developed from seed sown late in the greenhouse. This fungus has earlier been reported to cause damage in seedling nurseries in Norway, Sweden and the United States. The fungus is favoured by extended rainy periods. Spruce seedlings become diseased from seed-borne inoculum. The seedlings turn brown and become bent at the infection point, while the needles located above the infection point remain green.

Insect damage slight in 2001

The larvae of pine sawflies (Diprionidae) caused only slight needle damage in pine stands, and there were no reports of any new outbreaks during 2001. The populations of these serious insect pests are still being monitored.

The recovery of trees in areas affected a number of years earlier by pine sawfly (*Diprion pini*) larvae continued as new needle age classes were formed. In some areas the sawfly populations are still higher than normal. Damage has been effectively reduced by factors that naturally reduce the insect population (e.g. parasites, predators, diseases) and the prolonged diapause of healthy individuals, i.e. the larvae remain in cocoons for one year or more.

The pines that were defoliated by larvae of the European sawfly (*Neodiprion sertifer*) at Saariselkä in Lapland (19) in summer 2000 have shown good recovery. The low number of larvae in summer 2001 was partly due to the fact that this species has a two-year life cycle in the north of Finland. Larvae may again occur in large numbers during the coming summer, but not to the same extent as during summer 2000. In addition to sawflies, the trees in the area have been partly defoliated by a severe epidemic of Lophodermella needle cast. A small-scale mass outbreak of pine sawfly *Gilpinia pallida* was reported in Kittilä in Lapland (19).

Abundant swarming of spear-marked black moth (*Rheumaptera hastata*) was reported in central Finland in June, which was a continuation of the previous year's outbreak. However, only a few cases of damage were reported in birch stands. Although the larvae of *R. hastata* mainly feed on the leaves of birch, they occasionally feed on willow (*Salix* spp.), blueberry (*Vaccinium myrtillus*) and currant (*Ribes* spp.).

Summer 2001 can be considered to be a relatively normal summer as far as other needle and foliage pests are concerned. The occurrence of pine weevil (*Hylobius abietis*) was normal, and damage was reported in many parts of the country.

The bark beetle risk increases

Fallen trees and trees snapped by snow provide reproduction sites for many insects. The most serious threat to commercial forests is bark beetles, especially the spruce bark beetle (*Ips typographus*), the six-toothed spruce bark beetle (*Pityogenes chalcographus*) and pine shoot beetles (*Tomicus* spp). Although windthrows improve the biodiversity of the forests, care should be taken in the affected areas to ensure that large numbers of freshly fallen windthrows and broken trees are not left in the forest for the summer. The extensive outbreaks of spruce bark beetle damage that occurred in Sweden and Norway in the 1970's and 1980's started from storm damage originating in autumn 1969.

Severe bark beetle damage, i.e. dead standing trees, is not likely to occur before 2003 even if the bark beetle populations increase much in summer 2002. However, pine shoot beetles (*Tomicus* spp.) may cause considerable shoot damage already in summer 2002 when the new generation pass up into the pine crowns to hollow in the pith of the shoots.

Damage caused by mammals in 2001

Cervids, especially moose (*Alces alces*), were estimated to have caused considerable damage in the forests. Damage of varying severity was reported over about 20% of the total area of seedling stands, i.e. at least 20,000 ha. According to preliminary information, compensable damage has again been relatively high, more than 3.4 million euros. White-tailed deer (*Odocoileus virginianus*), which has been increasing in numbers and causing damage in southern and southwestern Finland, has become a damage agent also in the central parts of the country. The size of the roe deer (*Capreolus capreolus*) population has further increased. Deer damage is mainly restricted to small seedlings, which makes it difficult to identify the damaging agent. A reduction in the population of moose and deer would be necessary. In order to avoid future problems, the increase in the roe deer population should be restricted in good time.

The vole populations in spring 2001 were low, apart from in the northernmost part of Finland, and hardly any damage occurred during winter 2000/2001. During summer 2001 the vole populations started to increase strongly in almost all areas in southern and central Finland (1–16). The vole populations in northern Finland were, at the same time, high. In the southern area with increasing vole populations, the bank vole (*Clethrionomys glareolus*) occurred everywhere in the autumn, but the field vole (*Microtus agrestis*) only in certain localities. It is to be expected that local damage will occur already during winter 2001/2002, but the real vole peak will probably not be reached until summer and autumn 2002.

6 The International ECE/EU Cross-calibration Course (ICC) on the Assessment of Forest Damage for Northern Europe (Finland, 4–6. June 2001)

Pohjois-Euroopan metsien kunnon arvioinnin kalibrointikurssi (Suomi, 4–6. kesäkuuta 2001)

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Summary

The international cross-calibration course (ICC) for Northern Europe, arranged by the Finnish Forest Research Institute, was held in Finland on 4–6 June, 2001. During the ICC, the observers assessed a total of 155 trees, including 35 birches (15 *Betula pubescens* on the Korso plot, and 20 *B. pendula* on the Sipoo plot), 60 Norway spruces (*Picea abies*) on three plots, and 60 Scots pines (*Pinus sylvestris*) on three plots. In addition, a special photo test was also carried out on 7 birches, 10 spruces and 10 pines during the ICC. In general, there was no precisely common agreement between the defoliation level of the test trees estimated by the individual countries. None of the trees were classified in exactly the same defoliation class by any of the participants, and we should allow a range of at least 20 % before we can achieve relatively good agreement. However, the results also indicate that the range varies considerable between individual tree species and stands. The duration of the ICC should be at least four days in order to be able to include crown condition parameters other than defoliation in the program. It would also be advisable for the participants to practice assessment on their own national training course before the ICC. At the end of the course all the participants agreed that this kind of Cross-Calibration Course for Northern Europe should be repeated in the future.

Yhteenveto

Metsäntutkimuslaitoksen järjestämä Pohjois-Euroopan metsien kunnon arvioinnin kalibrointikurssi pidettiin Suomessa 4–6. kesäkuuta 2001. Kurssin aikana havainnoijat kuudesta maasta arvioivat kaikkiaan 155 puuta, joista 15 oli hieskoivuja, 20 rauduskoivuja, 60 kuusta ja 60 mäntyä. Lisäksi arvioitiin valokuvista 7 koivun, 10 kuusen ja 10 männyn harsuuntuminen. Yleisesti ottaen eri maiden harsuuntumisarviot erosivat toisistaan, eikä minkään puun kaikki arviot olleet täysin yksimielisiä. Vaihteluväliksi tulisi sallia ainakin 20 %, jotta saavutettaisiin suhteellisen hyvä yksimielisyys arvioinneissa. Tulokset viittaavat arvioiden vaihteluvälin muuttelevan sekä puulajeittain että metsiköittäin. Kurssin keston tulisi olla vähintään neljä päivää, jotta muitakin latvuksen tilan muuttujia harsuuntumisen lisäksi ehdittäisiin käsitellä. Suositeltavaa olisi, että osallistujat harjoittelisivat

arviointia maitten kansallisissa koulutustilaisuuksissa ennen kansainvälistä kurssia. Kurssin lopussa osallistujat totesivat, että tällainen Pohjois-Euroopan yhteinen koulutustilaisuus tulisi toistaa tulevaisuudessa.

Introduction

The international cross-calibration course (ICC) for Northern Europe, arranged by the Finnish Forest Research Institute (METLA), was held in Finland on 4–6 June, 2001. The course was attended by participants from six countries. The countries and number of participants (observers) from each country were: Estonia (EST) 2, Finland (FIN) 2, Lithuania (LIT) 1, Norway (NOR) 2, Russia (RUS) 1 and Sweden (SWE) 2. A representative from the Programme Co-ordinating Centre, Hamburg (PCC), also participated. The general framework of the ICC was based on the guidelines presented by Ferretti and Lorenz (2001), and that for the photo test by Durrant (2001).

Material and Methods

Cross-calibration

According to the guidelines for the ICC, the tree species should represent the most common species in a specific geographical region, and the selected plots should resemble, as closely as possible, the conditions under which the real surveys are carried out (Ferretti & Lorenz 2001). In order to fulfil these requirements, the 2001 cross-calibration exercises were carried out in Finland on real Level I and Level II sample plots, as well as on a number of special sample plots (equivalent to Level I) established for the purposes of the ICC (Table 1). The sample plots were

Table 1. Characteristics of the stands used in the 2001 ICC for Northern Europe.
***Taulukko 1**. Kurssilla käytettyjen metsiköiden kuvaus.*

Sample plot *Havaintoala*	Type of plot *Tyyppi*	Number of trees *Puiden lukumäärä*	Stand age *Metsikön ikä*	Soil unit (FAO) *Maannostyyppi (FAO)*
Birch – *Koivu*				
Sipoo	Level I * *Taso I*	20	60	Cambic podzol
Korso	Special plot for ICC * *Lisähavaintoala*	15	80	Carbic podzol
Norway spruce – *Kuusi*				
Somerniemi	Level 1 * *Taso 1*	20	90	Carbic podzol
Tammela	Level II ** *Taso II*	20	55	Haplic podzol
Korso	Special plot for ICC * *Lisähavaintoala*	20	100	Haplic podzol
Scots pine – *Mänty*				
Porvoo	Level I * *Taso 1*	20	80	Haplic podzol
Tammela	Level II ** *Taso II*	20	45	Haplic podzol
Korso	Special plot for ICC * *Lisähavaintoala*	20	100	Ferric podzol

* circular plots – *ympyrähavaintoala* ** sub-plot – *osa-alue*

situated in southern Finland. During the ICC, the observers assessed a total of 155 trees: 35 birches (15 *Betula pubescens* on the Korso plot and 20 *Betula pendula* on the Sipoo plot), 60 Norway spruces (*Picea abies*) on three plots, and 60 Scots pines (*Pinus sylvestris*) on three plots. In addition, a special photo test (Durrant 2001) was also carried out on 7 birches, 10 spruces and 10 pines during the ICC.

At the beginning of the course it was decided that every country would use its own national assessment and reference methods. The assessment was carried out country-wise. No preliminary discussion was held or special information given about the trees before the exercise. Furthermore, the results of the exercise for each tree species were not discussed until the last plot had been assessed. Because of the limited time span of the ICC, only defoliation was assessed on the trees.

Photo-test

The crown condition assessment included two phase: 1) all the participants (countries) assessed crown condition from the photos (A4-size laserprints), and 2) the crown condition was assessed in the field from the same point that the target tree had been photographed. The test trees were selected subjectively in the vicinity of the Special plots used in the ICC. The following criteria were applied in selecting the trees: 1) a number of good and poor crowns were included, 2) unusual types of defoliation were avoided, 3) optimum conditions were provided by ensuring that the observers/photographers would have a clear view of the crown. Unfortunately only a few free-standing trees, i.e. trees where the whole assessable crown was visible, with no trees in the background or overlapping the sides of the whole assessable crown, were available. Hence the assessable part of the crown was marked on the photos with a red line (Fig. 1). The point where the photo was taken and where the assessment was made was marked with a flag in order to ensure that all the surveyors viewed the tree from the same point.

Results

Cross-calibration

None of the individual trees were scored in the same defoliation class (5 % classes) by any of the participants (countries) (Fig. 2). The tree-specific range of the scores (maximum value – minimum value) between the countries varied from 5 to 40 %. Of all the trees, only 3 % of the birches, 5 % of the spruces and 17 % of the Scots pines were inside the 5 % range. If we allow a 20 % range, the proportion of trees falling in the same class was ca. 85 % for pine, 90 % for spruce and 85 % for birch (Fig. 2). However,

Figure 1. Example of the Norway spruce used in the photo test. The red line indicates the lower limit for the assessable crown. (Photo: Martti Lindgren).

Kuva 1. *Esimerkki valokuvatestissä käytetystä kuusesta. Punainen viiva osoittaa arvioitavan latvusosan alarajan. (Kuva: Martti Lindgren).*

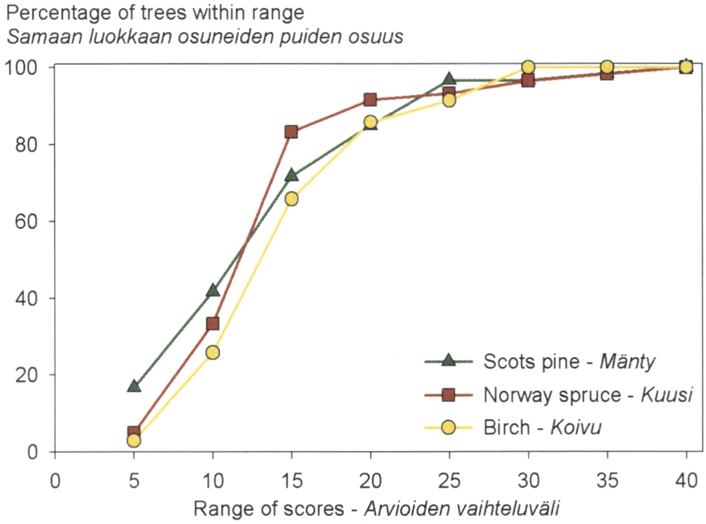

Figure 2. Proportion of trees scored as the same defoliation class according to tree species.
Kuva 2. *Samaan harsuuntumisluokkaan arvioitujen puiden osuus puulajeittain.*

these ranges varied considerably between the individual stands (Fig. 3).

The cross-calibration test included 35 birches on two plots. The average defoliation level of all the birches was 17.7 % (Fig. 4). On the special Korso plot, the average defoliation over the countries ranged from 18 % to 26 % (Fig. 4), and on the Sipoo plot from 9 % to 20 %. The average defoliation level of these plots was 21.8 % and 14.6 %, respectively.

The average defoliation level of all the Norway spruces (60 trees) was 21. 5 % (Fig. 5). The crown condition of spruce was poorest on the Korso plot, where the average defoliation degree was 31.6 %, and the defoliation levels ranged from 26.5 % to 36.3 %. This stand was also the oldest one. The spruce crowns were the least defoliated on the Tammela plot. The average defoliation on this plot was 13.7 %, and on the Somerniemi plot 20.4 %. The defoliation levels on the Tammela plot varied from 10.3 to 17.3 and on the Somerniemi plot from 14.3 % to 27.3 % (Fig. 5).

The average defoliation level of all the Scots pine (60 trees) was 16.1 % (Fig. 6). The crown condition of pine was the poorest on the Korso plot, where the average defoliation degree was 22.2 %, and the defoliation levels varied from 17.8 % to 26.0 %. This stand was also the oldest one. The pine crowns on the Tammela plot were the least defoliated of all the pine stands. On the Tammela plot the average defoliation was 6.7 %, and on the Porvoo plot 19.5 % The defoliation levels on the Tammela plot varied from 3.8 to 11.0 and on the Porvoo plot from 12.5 % to 25 %, (Fig. 6).

Photo test

The country-specific and overall defoliation levels for the photo and field tests are presented in Fig. 7. Because of some problems in the calibration process, the CROCO values are not yet available. There were no clear systematic differences over the countries in the defoliation means of the photo and of the field assessment. In general, the overall defoliation levels assessed from the photos were slightly higher than those of the field tests on

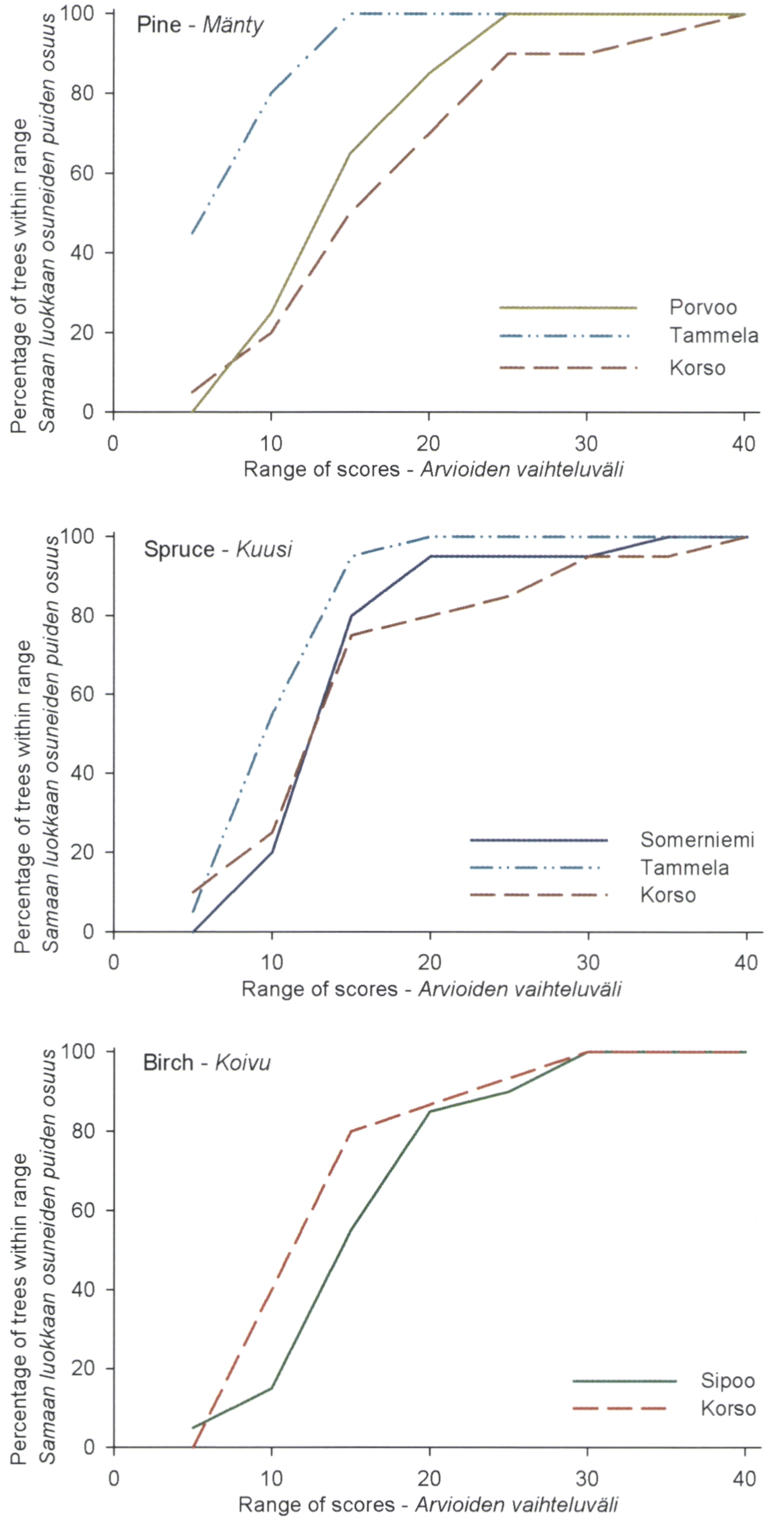

Figure 3. Proportion of trees scored as the same defoliation class in different stands.
Kuva 3. *Samaan harsuuntumisluokkaan arvioitujen puiden osuus eri metsiköissä.*

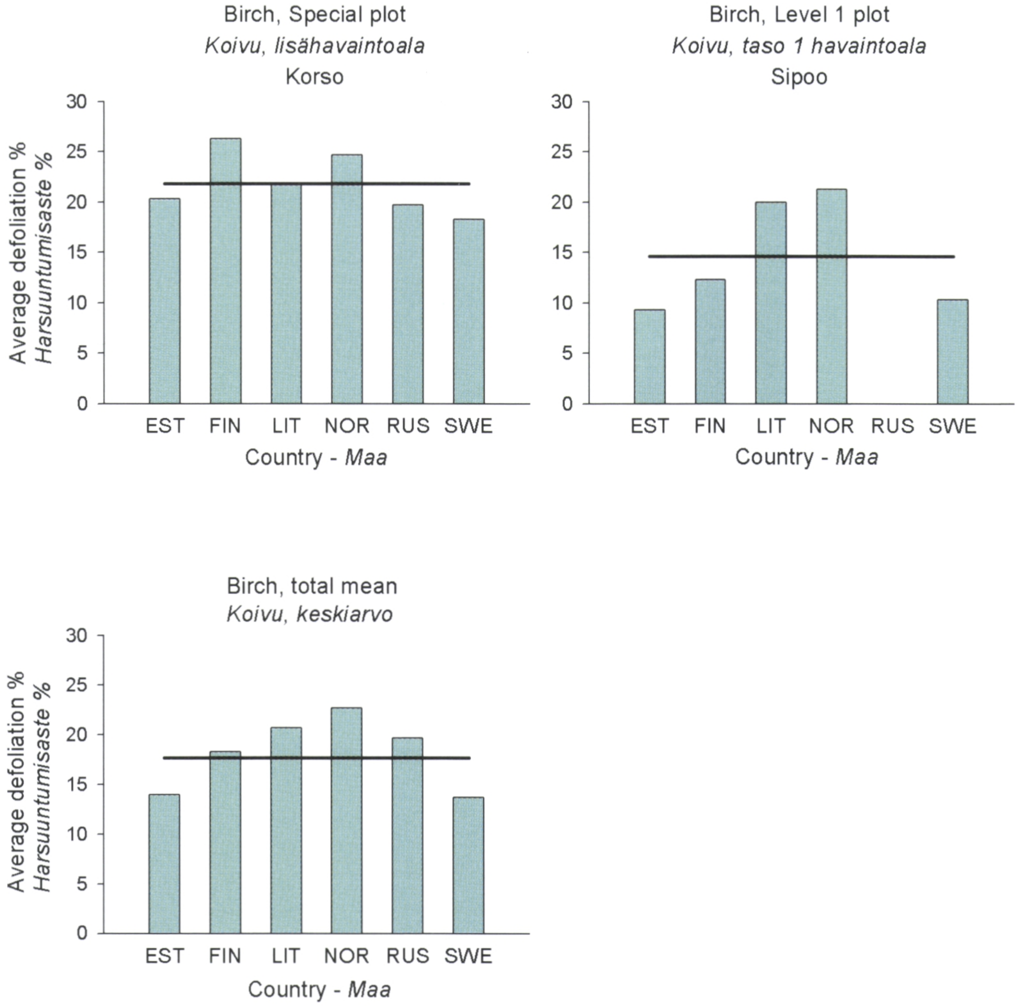

Figure 4. The average country-specific defoliation level of the birches (bars) on the two sample plots, and the overall mean in the 2001 ICC. The solid line indicates the average defoliation level for all the countries.
Kuva 4. *Koivun maakohtaiset harsuuntumisarviot (pylväät) kahdella havaintoalalla ja kokonaiskeskiarvo kurssilla 2001. Yhtenäinen viiva osoittaa kaikkien maiden keskiarvon.*

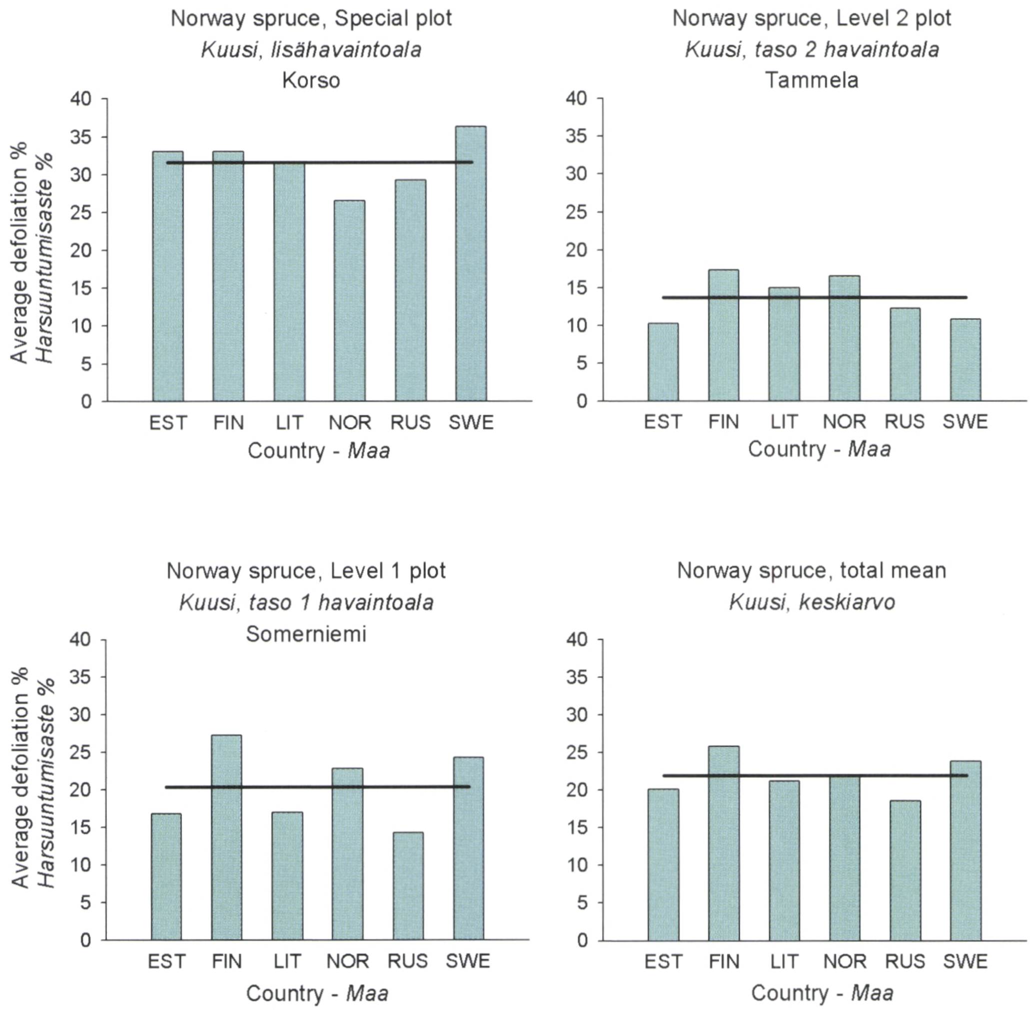

Figure 5. The average country-specific defoliation level of Norway spruce (bars) on the three sample plots, and the overall mean in the 2001 ICC. The solid line indicates the average defoliation level for all the countries.
Kuva 5. *Kuusen maakohtaiset harsuuntumisarviot (pylväät) kolmella havaintoalalla ja kokonais-keskiarvo kurssilla 2001. Yhtenäinen viiva osoittaa kaikkien maiden keskiarvon.*

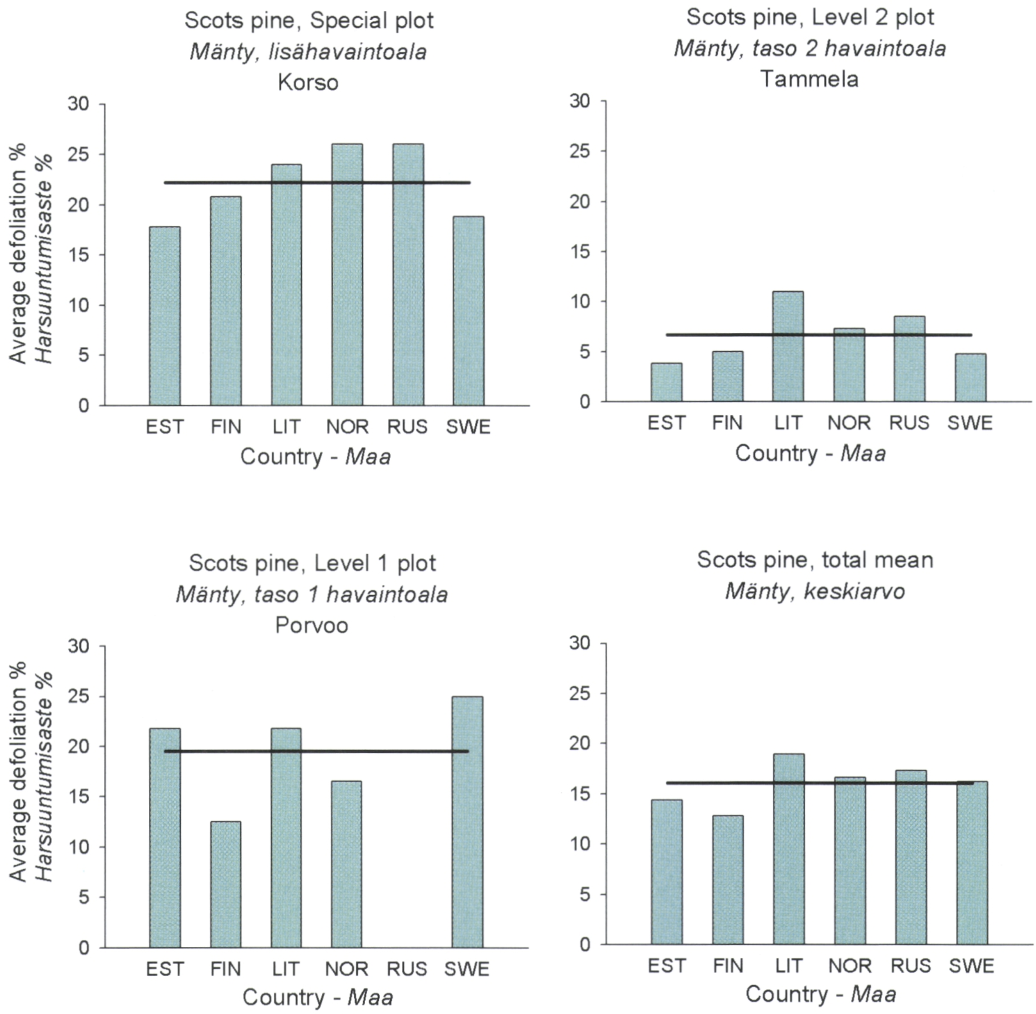

Figure 6. The average country-specific defoliation level of Scots pine (bars) on the three sample plots, and the overall mean in the 2001 ICC. The solid line indicates the average defoliation level for all the countries.

Kuva 6. *Männyn maakohtaiset harsuuntumisarviot (pylväät) kolmella havaintoalalla ja kokonais-keskiarvo kurssilla 2001. Yhtenäinen viiva osoittaa kaikkien maiden keskiarvon.*

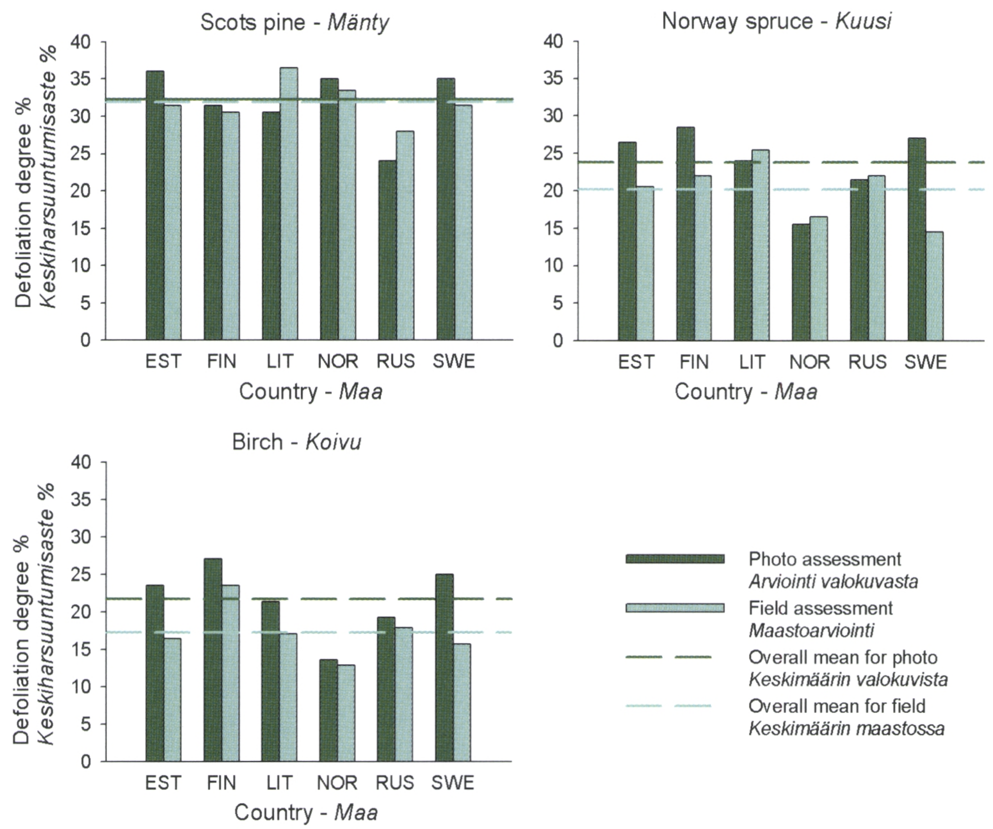

Figure 7. The country-specific and overall defoliation levels of the photo and the field assessment for Scots pine (n = 10), Norway spruce (n = 10) and birch (n = 7).
Kuva 7. *Valokuvista ja maastossa tehdyt maittaiset harsuuntumisarviot männyille (n = 10), kuusille (n = 10) ja koivuille (n = 7) sekä kokonaiskeskiarvot.*

birch (4.4 %) and Norway spruce (3.6 %), but not on Scots pine (0.1 %) (Fig. 7). The mean defoliation degree assessed by Estonia, Finland and Sweden for the photo trees of all three species was higher than that for the real trees in the field tests. Norway and Russia had the smallest difference in defoliation degree between the photo and the field assessment in birch and spruce, and Finland and Norway in pine. The defoliation scores over the countries varied from 0 to 35 for the birch photos, and from 5 to 35 for the field test. The corresponding ranges for Norway spruce were 5 to 35 and 10 to 35, and for Scots pine 10 to 30 and 5 to 30, respectively.

Conclusions

The weather conditions during the ICC varied considerably (sunny/rainy/overcast). It rained especially on the first day when the field test for the photographed trees was carried out (especially in the case of spruce and birch). This may have affected the assessment scores because the photo test trees had been photographed in clear sunny weather. Consequently, the rain during the field part of the photo test may have complicated the comparison between the defoliation assessment of the photo and the field assessment.

In general, the estimates of the defoliation level of the test trees varied between the countries. None of the trees were classified in exactly the same defoliation class by all of the participants, and a range of at least 20 % has to be applied before we can achieve

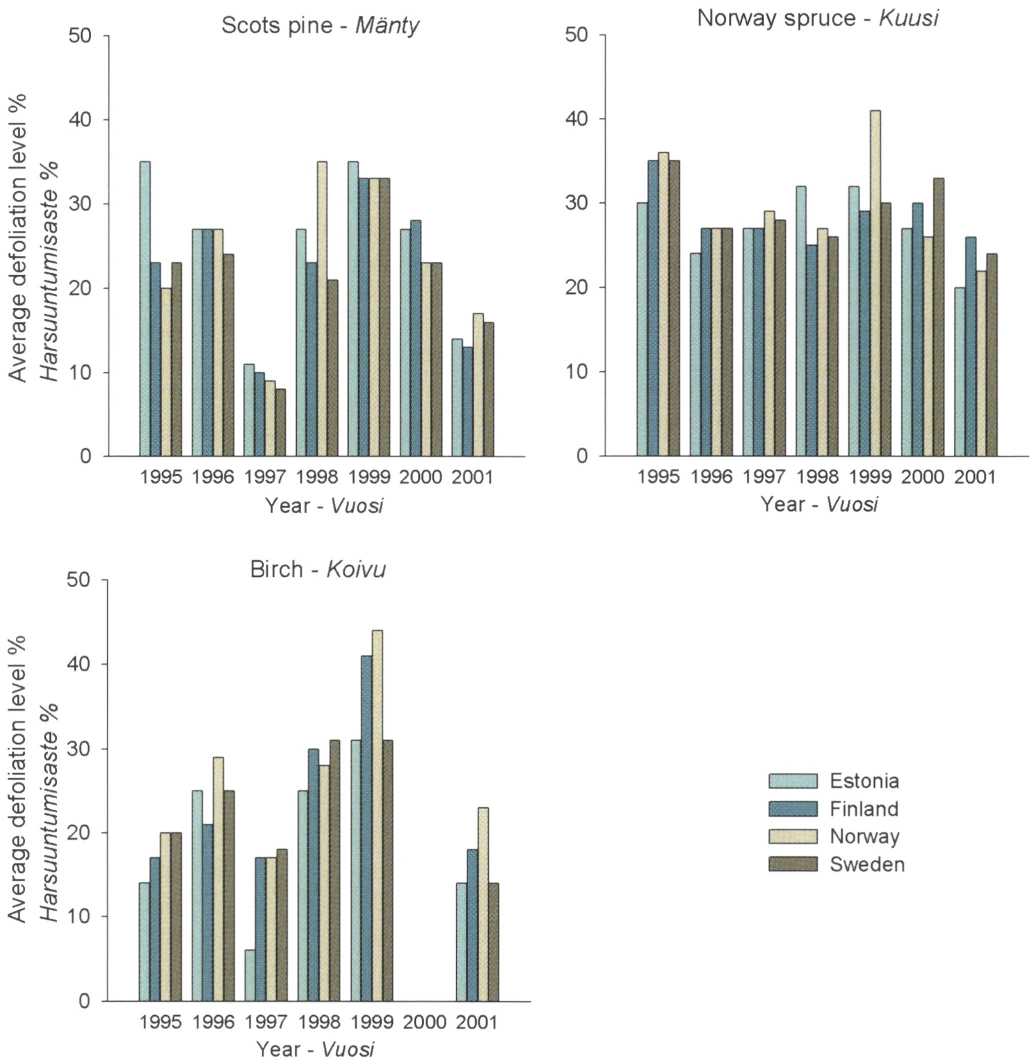

Figure 8. The average defoliation level for Scots pine, Norway spruce and birch during the Calibration Courses for Northern Europe since 1995. Only countries that have participated in all 7 Calibration Courses for Northern Europe are included. The results are based on the yearly reports of the International Calibration Courses (see references).
Kuva 8. *Kalibrointikursseilla arvioidut harsuuntumisen keskiarvot männylle, kuuselle ja koivulle vuodesta 1995. Mukana ovat maat jotka ovat osallistuneet kaikkiin seitsemään Pohjois-Euroopan kurssin. Tulokset perustuvat vuosittaisiin kurssiraportteihin (ks. viiteluettelo).*

relatively good agreement. However, the results also indicate that the range varies considerable between individual tree species and stands.

The results (defoliation level) of the participating countries for each species varied non-systematically between the test stands in the 2001 ICC. This may be due to methodological differences between the countries, e.g. differences in the assessable part of the crown, and the way in which the observers take into account the stand age, site type or stand density (i.e. competition). Slight irregularities in the country-specific defoliation levels were evident when comparing the results of all of the seven calibration courses (Wulff 1995, 2000, Lindgren 1996, Aamlid & Horntvedt 1997, Hansen 1998, Ôunap 2000) held in Northern Europe since 1995 (Fig. 8).

During the final discussions at the 2001 ICC for Northern Europe the participants agreed that the time when the ICC for Northern Europe has so far been held is too early because of yearly variation in the progression of spring. Thus, in the future, the ICC for Northern Europe should be arranged later in June (preferably the third week in June). The duration of the ICC should be at least four days so that crown condition parameters other than defoliation can also be included in the program. It would also be advisable for the participants to practice assessment on their own national training course prior to the ICC. At the end of the course all the participants agreed that this kind of Cross-Calibration Course for Northern Europe should be repeated in the future

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7 Pilot study: the Needle Trace Method

Pilottitutkimus: neulasjälkimenetelmä

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Summary

This review article provides a short and general summary of the technique and possibilities of the needle trace method (NTM) in retrospective studies. Since its introduction at the turn of the 1980's, NTM has become firmly established as a tool in retrospective forest ecology, pathology, entomology, and forest health monitoring. The prospects of its use in dendroecology and dendroclimatology are also promising. NTM readily provides information about the needle history of the entire tree, thus covering the period when no foliage observations were made. As a result, NTM is an ideal technique for revealing long-term changes in needle retention or even crown thinning.

Yhteenveto

Artikkelissa kuvataan lyhyesti neulasjälkimenetelmän (Needle Trace Method, NTM) periaate ja neulastiedon tuottaminen takautuvasti puun koko elinajalta. Sitten kehittämisensä 1980-luvun lopulla NTM on vakiinnuttanut asemansa valovoimaisena retrospektiivisenä menetelmänä puiden latvushistorian tutkimuksessa niin metsäekologiassa, metsäpatologiassa, metsäentomologiassa kuin metsien yleisen terveydentilan selvittämisessä sekä dendrokronologian ja -klimatologian alalla. NTM paljastaa helposti puiden neulastiedon ajalta, jolta ei ole silmävaraista harsuuntumistietoa. Samalla neulastieto saadaan puun koko elinajalta, jos vain puun ydin on terve.

Introduction

During the last 30 years, forest health has been of great concern throughout the world (e.g. Ukonmaanaho & Raitio 2001). Considerable resources have been devoted to determining whether forest health has declined and, if so, in what way. The research and monitoring work has mainly concentrated on determining the current status of forests, primarily through the annual surveys of crown thinning (e.g. Lindgren 2001). Estimates of past crown thinning have mainly been based on comparisons of current photographs and on those taken in the recent past (e.g. Schweingruber 1989). However, such estimates are highly subjective and no objective methods or techniques have been developed for reconstructing crown condition over long time periods. Analysis of data from long-term collection of coniferous litter has shown that the amount of litter shed varies both annually and monthly (Flower-Ellis 1985, Kouki & Hokkanen 1992), thus providing an indirect method of assessing crown condition. It does not, however, resolve the question of what is the normal amount of foliage retained by conifers.

Estimates of needle retention, based on counts made in the field, suggest that needle retention in Scots pine growing in Bohemia and southern Moravia have decreased from the 1960s to the 1980s (Skruhravy 1990). However, these areas have been subjected to relatively high levels of atmospheric pollution (particularly SO_2), and a decrease in needle retention is to be expected. Nevertheless, the study by Skruhravy provides quantitative evidence of changes in needle retention. Unfortunately, similar data are not available from other areas, and the periods covered by field data are usually short (e.g. Jalkanen 1998a).

A promising method for studying needle retention and crown thinning was developed at the turn of the 1980s (Kurkela & Jalkanen 1990). The Needle Trace Method (NTM) was launched during the field excursion of the 5th Task Force Meeting of ECE/ICP (FOREST) to Lapland in May 1989 (Jalkanen & Kurkela 1989). NTM is based on the identification of the length and location of the needle traces embedded in stemwood rather than in the wood of the branches, thus enabling retrospective quantification of the needle retention or crown needle history of pines (*Pinus* spp.) (Jalkanen & Kurkela 1990, Jalkanen 1995a). The aim of this article is to give a short overview of the NTM technique and its possibilities in various forest ecological and environmental studies.

Method

Needle traces connect the pith of the long shoot (stem) and the short shoots with their needles (Fig. 1a). Therefore the exact age of each short shoot can be retrospectively estimated. In order to obtain NTM data, the sample trees have to be felled. The stem is then cut into sections corresponding to the annual shoots, but omitting the branch whorls (Fig. 1b). Each annual shoot is then sampled by cutting a 15-cm-long section from the annual shoot, which is then examined for needle traces in the Needle Trace Laboratory according to the procedure of Aalto & Jalkanen (1998b).

The innermost tree rings, examined ring by ring using a fixed angle and an arc surface (Fig. 1c–d), reveal the location and number of the needle traces. Once the needle trace data have been obtained, chronologies for a number of needle and other parameters can be computed (see Aalto & Jalkanen 1998a, b) for a single tree or a stand (normally 5 to 10 trees) as follows:

Needle retention, summer
Needle retention, winter
Needle shed
Needle age
Total number of needles

Needle production
Needle density
Height increment
Radial growth

Of the nine parameters obtained after felling of the sample tree(s), the last four are based on one annual shoot only. This makes data collection relatively easy, whereas for the first five parameters several subsequent annual shoots have to be studied in order to obtain a single annual value. To take an example: for needle retention one needs to study as many annual shoots and tree rings as the maximum needle longevity in the area requires. For needle age, all annual tree rings with needle traces within one annual shoot provide the variation in needle age in that particular year. For needle density (see Jalkanen et al. 1998), only one of the innermost tree rings of a single annual shoot is needed to obtain a needle-density value.

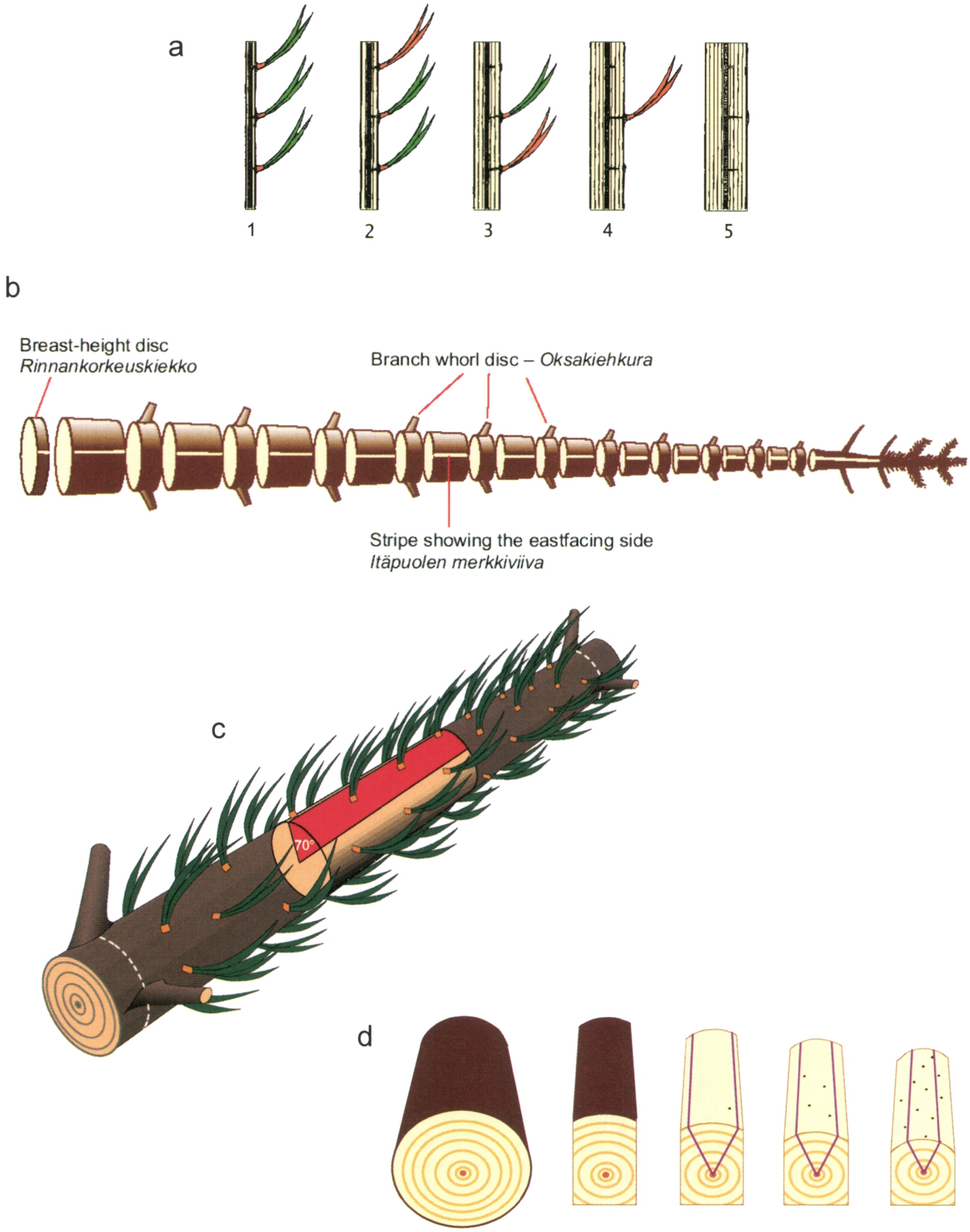

Figure 1. Schematic depiction of the needle trace method; a. Development over five growing seasons of short shoots in Scots pine and associated vascular systems, needle traces, initiated in the pith; b. Cutting a stem into annual sections; c–d. Inventory of needle traces using a fixed angle and an arc surface.

Kuva 1. *Neulasjälkimenetelmän kuvaus piirroksin. a. Neulasjäljen kehitys viiden kasvukauden aikana neulasten synnystä niiden karisemiseen. b. Puun katkonta vuosikasvaimittain näytteiden ottamista varten. c–d. Neulasjälkien inventoinnin periaate vuosikasvaimesta vakiokulmaa ja kaarevaa pintaa käyttäen.*

Applications

Recent studies have well established that NTM can easily and reliably reveal the needle history of important pine species in Europe (Jalkanen et al. 2000), Asia (Konôpka et al. 2000) and America (Hemming et al. 2001), and of Norway spruce (*Picea abies* (L.) H. Karst.) (Sander & Eckstein 1994, 2001). NTM has gradually extended our understanding to cover the whole-tree needle history of Scots pine by using e.g. various retrospective analyses (Jalkanen 1995b). It is now recommended that they be used in addition to traditional techniques (Ferretti et al. 2002). Material is now available throughout Europe which can give us an indication of how needle retention has developed over time in Finland (Fig. 2) and elsewhere in Europe (Jalkanen et al. 1994b; Pensa & Jalkanen 1999; Jalkanen et al. 2000, Pouttu & Dobbertin 2000). The technique reveals old insect or disease epidemics (Fig. 3, Jalkanen & Aalto 2001b), or the gradual defoliation of trees by air pollutants (Fig. 4, Jalkanen & Pensa 2000, Pensa et al. 2001) or reindeer herding (Jalkanen 1998b). It is now known how needle density varies over time (Jalkanen et al. 1998), and even what was the needle history some 4,000 years ago (Jalkanen 2000). A recent innovation has demonstrated that annual needle production is an excellent predictor of climate (Fig. 5, Jalkanen & Tuovinen 2001), and all NTM proxies can be used in climate studies (Jalkanen & Aalto 2001a). Future work will concentrate more on using NTM in climate change and forest health studies. Research on the effect of silvicultural practices will also be continued (see Jalkanen & Levanič 2001).

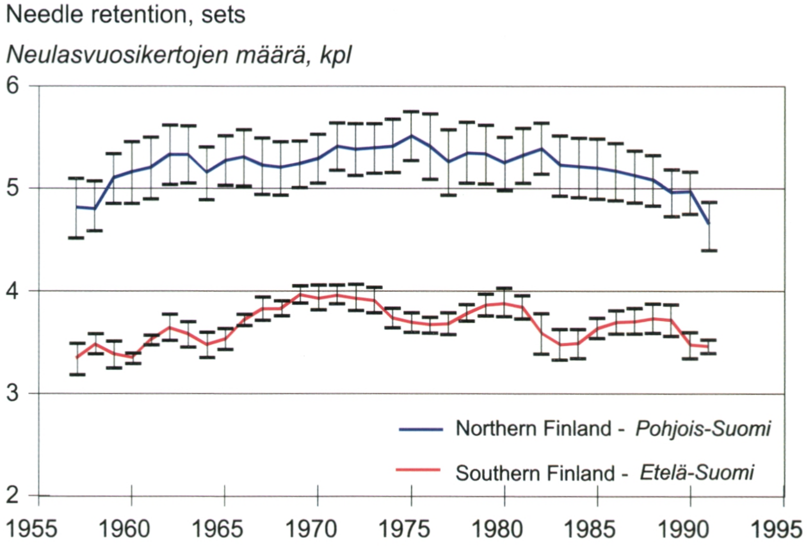

Figure 2. Needle retention patterns on Scots pine in northern and southern Finland in 1957–1991. (Jalkanen et al. 1995).
Kuva 2. *Neulasvuosikertojen määrän vaihtelu männyllä Pohjois- ja Etelä-Suomessa vuosina 1957–1991 (Jalkanen et al. 1995).*

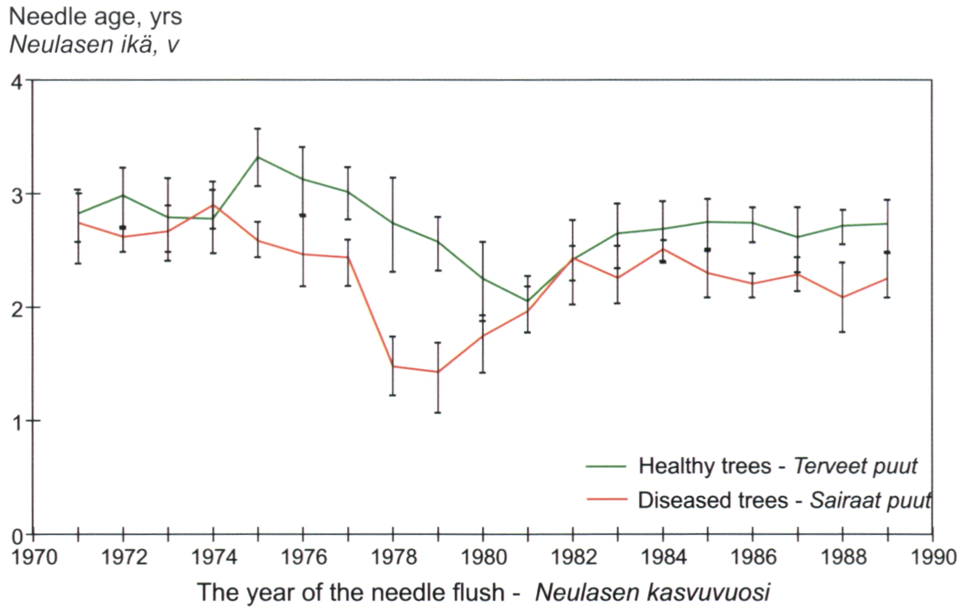

Figure 3. Needle age along the main stem in healthy and diseased Scots pines at Halkivaha, Finland. Diseased trees were severely infected by *Lophodermella sulcigena* in 1977–1981. (Jalkanen et al. 1994a).

Kuva 3. *Neulasen iän vaihtelu terveillä ja harmaakaristeen vaivaamilla männyillä Halkivahassa Lopella. Harmaakariste-epidemia tartutti uusimman neulasvuosikerran neulasia vuosina 1977–1981 (Jalkanen et al. 1994a).*

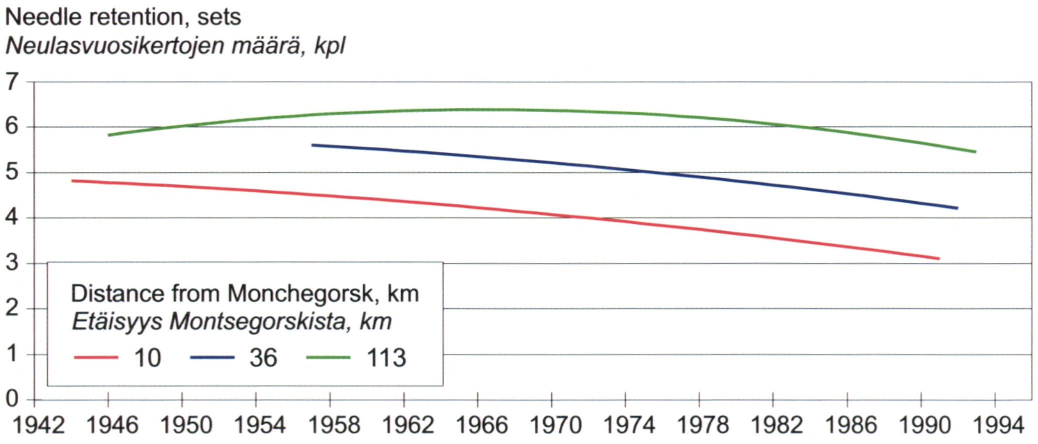

Figure 4. Long-term influence of severe emissions from the Cu–Ni smelter at Monchegorsk, Kola Peninsula. (redrawn from Jalkanen 1996).

Kuva 4. *Rikki-, kupari- ja nikkelilaskeumien pitkäaikaisvaikutus männyn neulasvuosikertojen määrän vaihteluun Montsegorskin sulatosta länteen (uudelleen piirretty julkaisusta Jalkanen, 1996).*

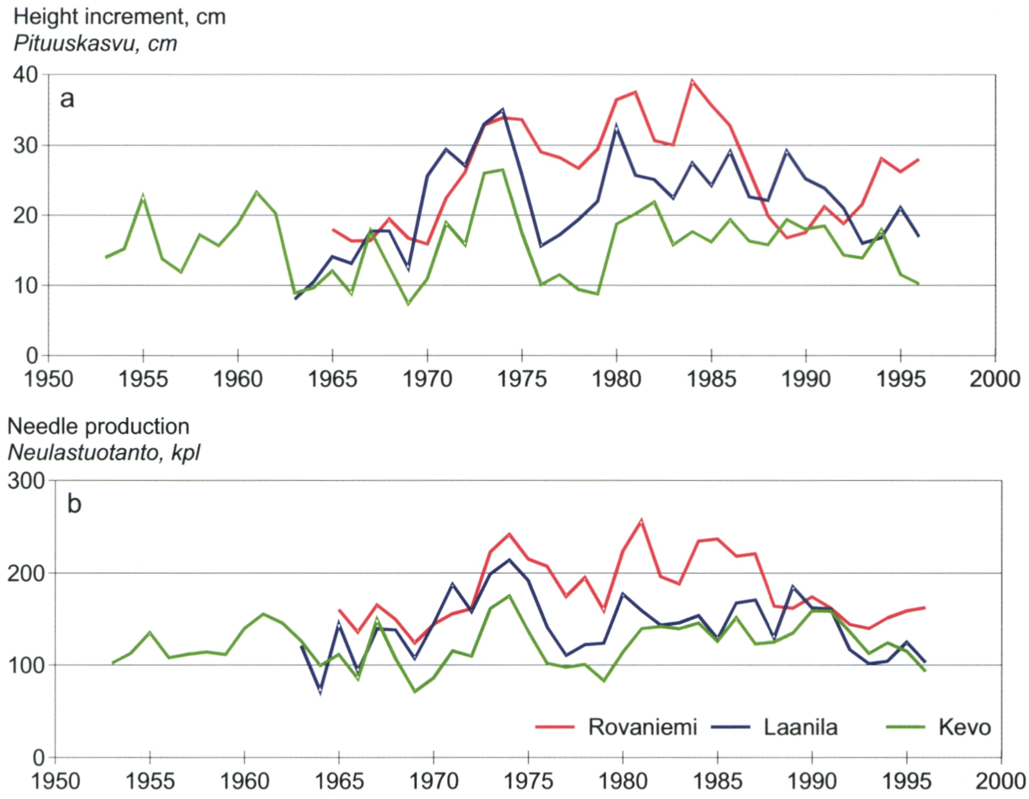

Figure 5. Variation in annual height increment (a) and needle production (b) of *Pinus sylvestris* from Rovaniemi on the Arctic Circle to the northern limit of pine at Kevo. (Jalkanen 1999).
Kuva 5. *Männyn a. pituuskasvun ja b. neulastuotannon pitkäaikaisvaihtelu Rovaniemellä, Laanilassa ja Kevolla (Jalkanen 1999).*

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