METLA

European Programme for the Intensive Monitoring of Forest Ecosystems

National report 1996, Finland

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1. Introduction

Finland has been participating since 1985 in the European Forest Condition Monitoring Program (ICP Forests). The Finnish Forest Research Institute (METLA) has been responsible for monitoring the health and vitality of the forests in Finland by carrying out an annual survey of the overall condition of the trees on a permanent network of systematically selected sample plots (level I, totalling 490 plots) using internationally standardised methods. The parameters that are estimated on the individual trees include defoliation, needle discoloration and biotic and abiotic damage. A survey of needle chemistry on the plots was started in 1987, and a soil survey carried out during 1985-89 (supplemented in 1995).

In 1995 the European Union and the ICP Forests organisation together initiated a new intensive monitoring program (level II) for investigating the causal relations between forest vitality and air pollution. The Finnish programme for the intensive monitoring of forest ecosystems started in 1995. In Finland, 31 intensive monitoring plots have been established in different parts of the country, 18 of them in 1995. The four plots of the Integrated Monitoring program were integrated into the level II monitoring program and two new plots established in 1996. Seven new plots were established in 1997.

The aim of this report is to evaluate at the national level the data collected on the intensive monitoring plots during the year 1996.

2. The observation plot network in Finland in 1996

In Finland, there were 24 monitoring plots in different parts of the country in 1996 (Fig. 1). All the plots are on mineral soil sites; 13 have stands comprising Scots pine (*Pinus sylvestris* L.) and 11 Norway spruce (*Picea abies* (Karst.) L.). All the plots, except the four Integrated Monitoring (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.

The stands on the plots represent the main tree species and prevailing growing conditions in Finland. The stand age ranges from 40 to 230 years old. Information has been obtained about the previous history of the site and tree stand. In addition to the main tree species, the stands also contain scattered individuals of other tree species.

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

The observation plots proper consists of three sub-plots and a surrounding mantle. The sub-plots are square in shape (30 x 30 m); if the stand density is low, the area of the sub-plots is greater (Fig. 2). Plot No. 1 is an exception: there are 2 subplots proper, and the mantle represents the third subplot. A 5 - 10 m wide strip has been

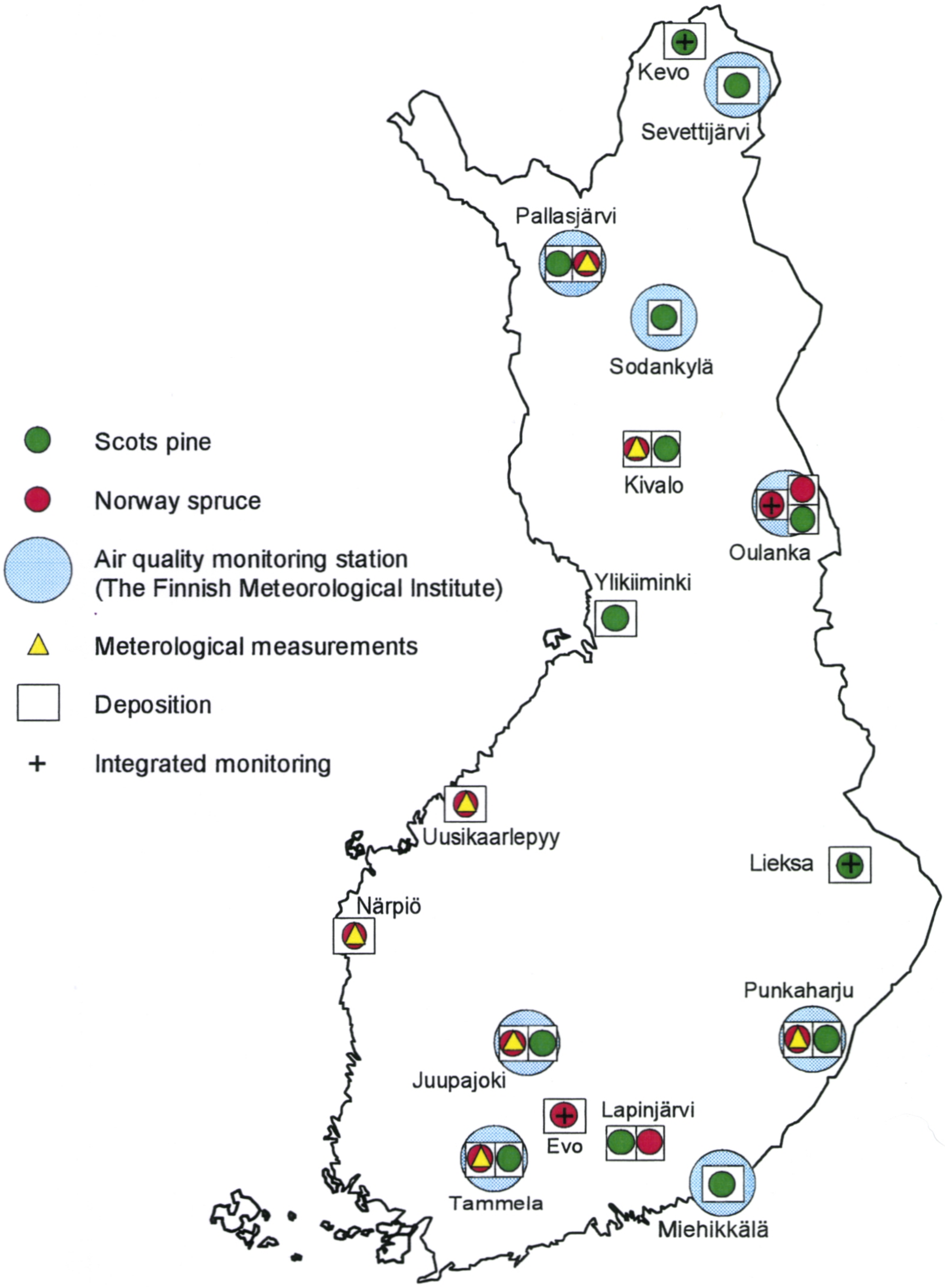


Fig. 1. The intensive monitoring network of forest ecosystems in Finland in 1996.

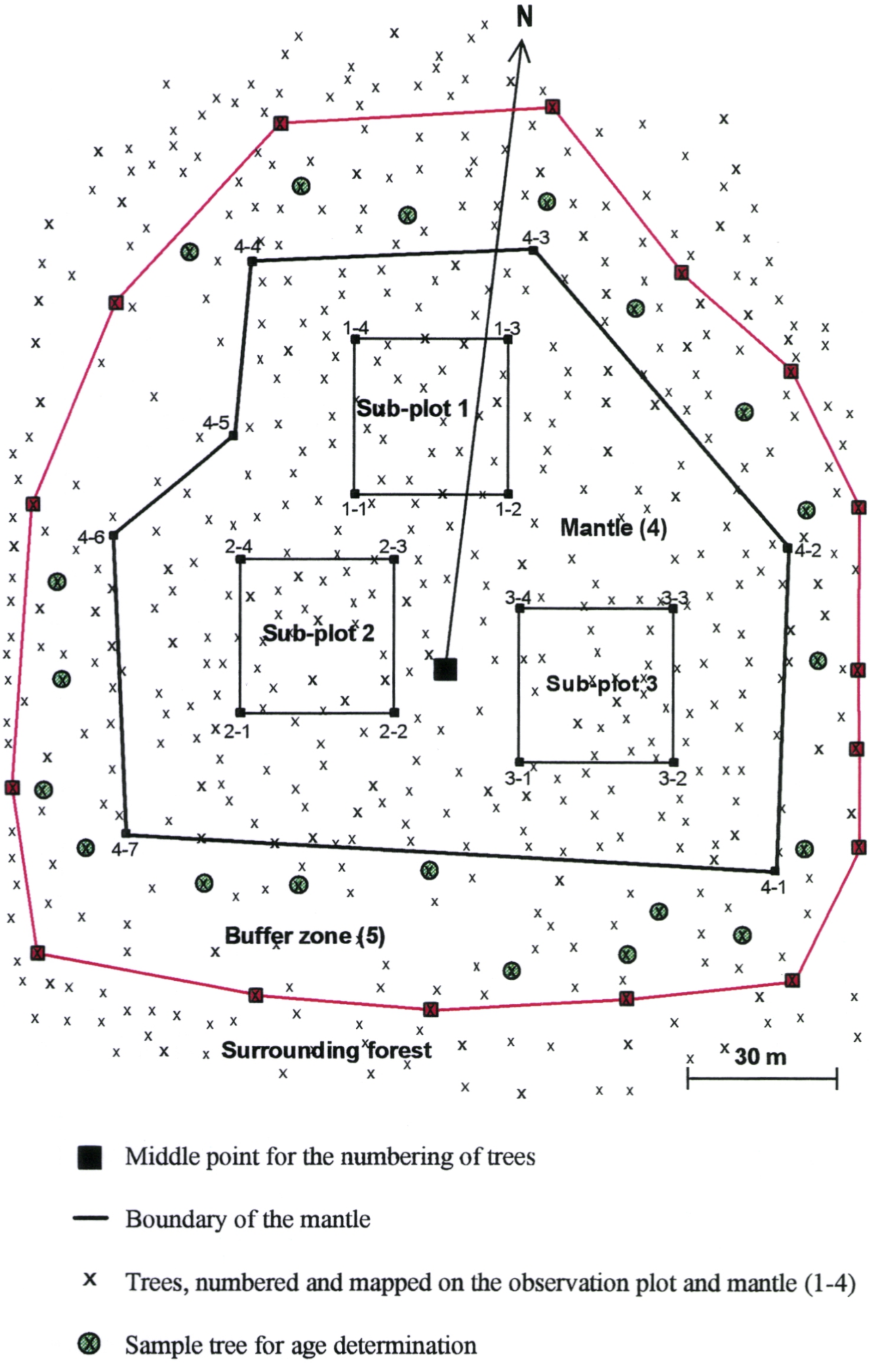


Fig. 2. The design of the observation plot and location of the subplots.

left between the sub-plots for possible future use in special studies and for additional sampling. Sampling methods that may have a detrimental, long-term effect on the soil or stand, e.g. soil sampling, deposition and soil water collection, needle and litter sampling etc., are concentrated on one sub-plot. One of the other two sub-plots is reserved for vegetation studies, and the other for tree growth measurements.

The centre point of the observation plot, the corners of the sub-plots and the outer edge of the mantle area (sub-plot 4) have been marked with wooden posts. The mantle is surrounded by a buffer zone (sub-plot 5). The width of the mantle and buffer zones varies from 10 - 30 m. All the sub-plots are at least 30 m away from the outer edge of the stand. The minimum distance between the sub-plots, as well as the minimum width of the buffer zone, is 5 m.

4. 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 each 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 of the observation plot 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.

5. Mandatory monitoring

5.1 Crown condition

The results presented in the following concern the annual crown condition assessment made on the 13 Scots pine (*Pinus sylvestris*) and 11 Norway spruce (*Picea abies*) plots by three observers. During the summer 1996 six new sample plots were added to the sample. Defoliation, needle discoloration and easily identifiable causes of damage were assessed on 20 trees from each sub-plot, as well as on the 20 needle sampling trees, totalling 760 pines and 700 spruces. However, the trees used for needle sampling (40 pines and 80 spruces) are not included in the following results. The number of common sample trees (cst) 1995/1996 was 640 pines and 420 spruces.

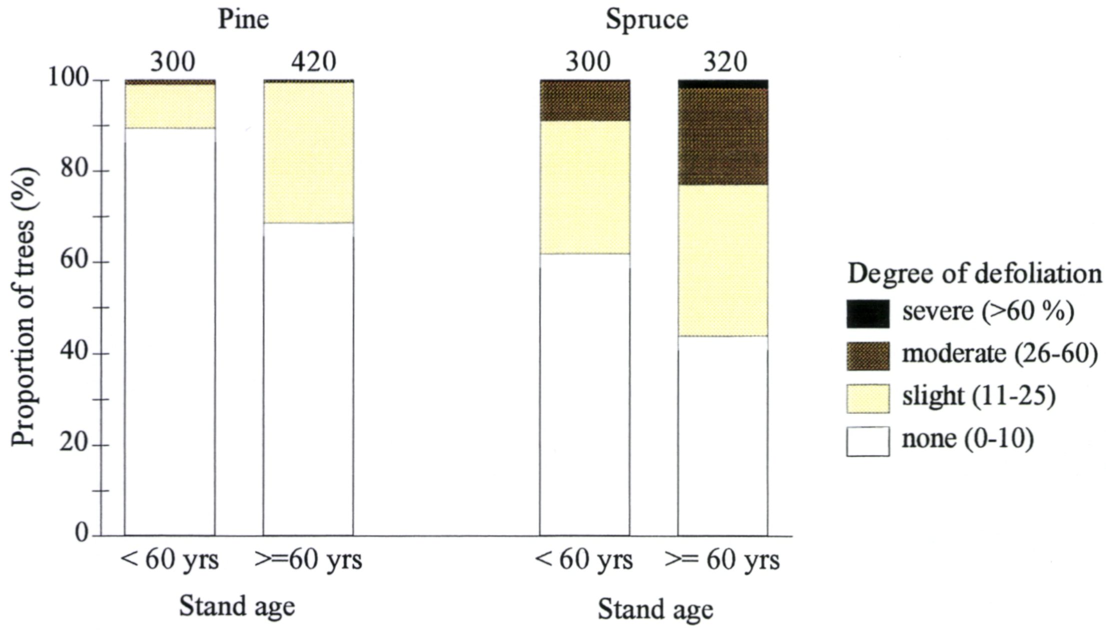


Figure 3. Defoliation frequency distribution for pine and spruce in two stand age classes in 1996. The number of trees is given above the column.

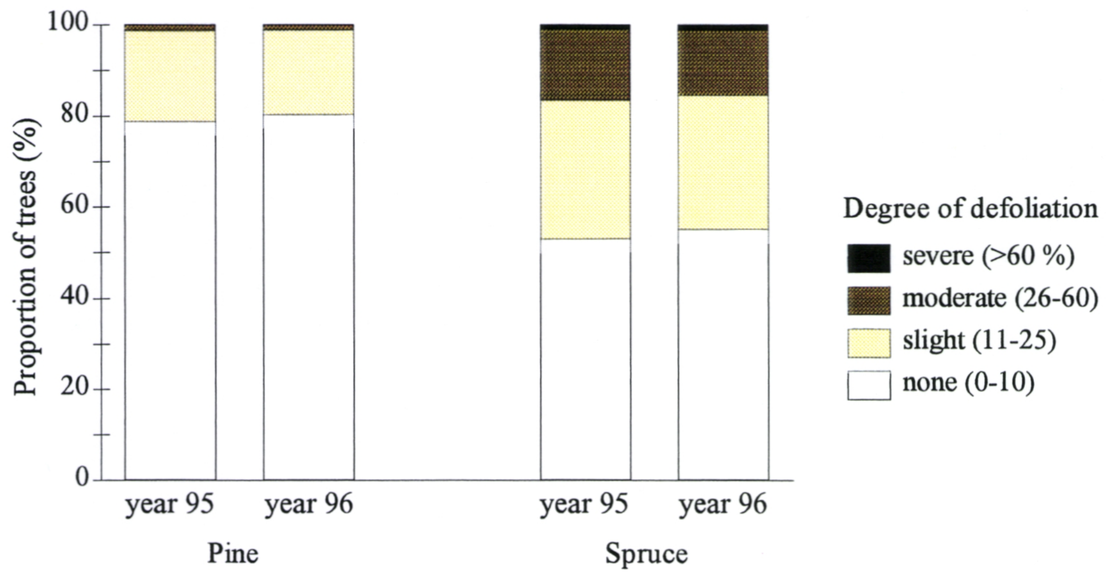


Figure 4. Defoliation frequency distribution for common sample trees in 1995 and 1996. The number of pines are 640 and spruces 420.

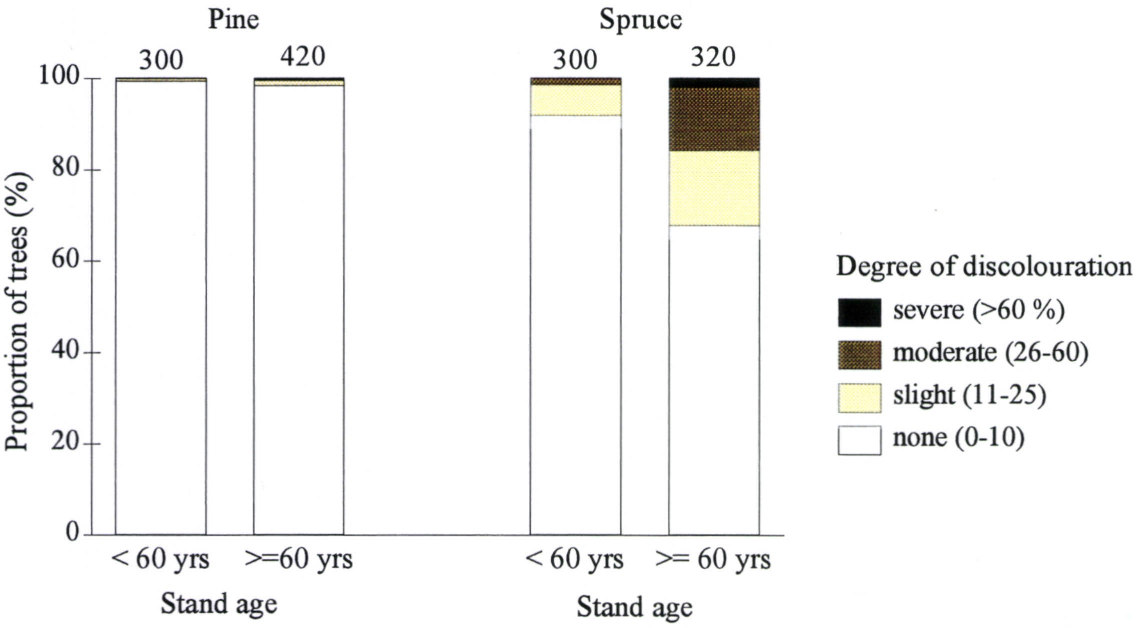


Figure 5. Discoloration frequency distribution for pine and spruce in two stand age classes in 1996. The number of trees is given above the column.

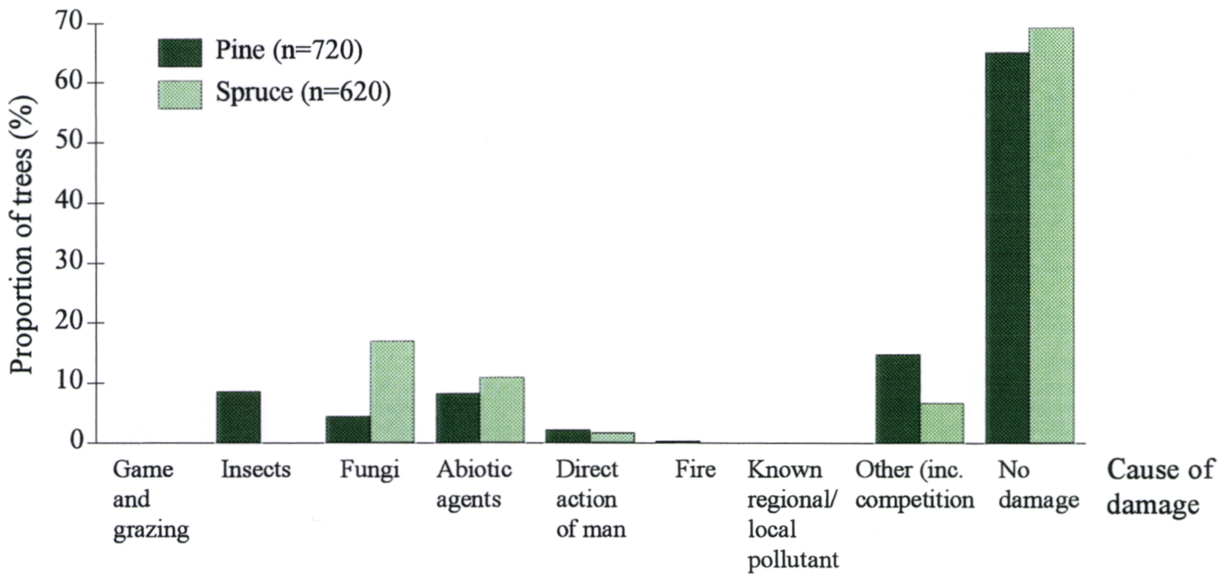


Figure 6. The proportion of pine and spruce in easily identifiable damage classes in 1996.

In 1996, 75% of the pines and 52% of the spruces on growing on the level II plots were not suffering from any defoliation (needle loss 0-10%). The corresponding proportions for level I were 73% and 41%, respectively. The proportion of slightly defoliated pines (11 - 25%) was 21% (level I, 22%), moderately defoliated (26 - 60%) 4% (level I, 5%) and severely defoliated (over 60%) 0.3 (level I, 1%). For the spruces the corresponding proportions were 31% (level I, 31%), 15% (level I, 26%) and 1 % (level I, 2%) respectively. In both species, over 60-year-old trees were more defoliated than trees under 60 years (Fig. 1). No changes in the defoliation level were observed either on pine or spruce between the years 1995 and 1996 (common sample trees) (Fig 2).

Needle discoloration was rare in pine in 1996. In contrast, 19% of the spruces were discoloured (Fig. 3). The most abundant discoloration symptoms were needle yellowing and needle-tip yellowing.

Altogether 35% of the pines and 31% of the spruces had some kind of damage symptom. The distribution of easily identifiable causes of damage is presented in Figure 4. The most common biotic agents on pine were *Tomicus spp.* (24%) and on spruce fungal pathogens (*Chrysomyza sp.*, 12%). Abiotic or mechanical damage was detected on 7% of the pines and 5% of the spruces.

5.2 Needle chemistry

Sampling

Two sets of 10 sample trees have been selected for needle chemistry determination on each observation plot. Sample branches are taken from 10 of these trees every second year. The two tree sets are sampled in rotation, i.e. each set is sampled every 4 years. This arrangement is being employed in order to minimise damage to the trees as a result of branch removal.

The sample branches with the current (C) and the previous year's needles have been collected from the uppermost third of the living crown with a pruning device during October and November each year.

Transport, storage and preparation

The branches were transported in paper bags to the laboratory as soon as possible and then stored in a freezer (-20 °C) in polyethylene bags until pretreatment. Before chemical analysis the dry mass of 50 needles was determined. During the pretreatment, current and previous-year shoots were separated and dried (10 days, 60 °C) and, after drying, the needles were separated from the stems. The dry, unwashed needles were ground using a Retsch ultracentrifugal mill type (Zm 1). The mesh size of the sieve was 1 mm. The dry needle powder was stored in polyethylene bags in cartons at room temperature. The composite samples for chemical analysis were prepared by mixing an equal amount of needle powder from each of the 10 trees.

Analyses

Total nitrogen concentration was determined on a CHN analyser (LECO CHN-600). The concentrations of P, K, Ca, Mg, Fe, Cu, Zn, Mn and Al were determined, following wet digestion by nitric acid-hydrogen peroxide, by inductively coupled plasma atomic emission spectroscopy (ICP/AES). Total boron concentration was determined specrophotometrically using azomethine H. Duplicate analyses were not carried out. The concentrations are given on a dry mass basis (105°C)

Each of the sample batches for wet digestion comprised 45 actual samples, 1-3 zero samples, and one non-certified control sample. The non-certified control sample was used to monitor the repeatability of the wet digestion procedure. The reliability of the wet digestion method was controlled by analysing three certified samples during 1995 and 1996; the results of these analyses are presented in Table 1. In addition, our laboratory has participated in inter-laboratory comparison, e.g. the ICP Forests 2nd Needle/Leaf Interlaboratory Test 95/96; our laboratory no. 7/Bartels 1996.

Table 1. Results of the analysis of certified reference materials.

		mg/g					mg/kg						
		N	P	K	Ca	Mg	B	Mn	Fe	Al	Cu	Zn	S
1995	Own result		1.27	4.36	3.97			644	172	484	5.38		
	NIST 1575		1.20	3.70	4.10			675	200	545	3.00		
1995	Own result	17.1	1.83		4.10	0.66		869		129		32.1	1842
1996	Own result	16.9	1.76		4.31	0.61		893		124		32.0	1759
	CRM 101	18.9	1.69		4.28	0.62		915		173		35.3	1700
1996	Own result						28.3						
	Nist 1547						29.0						

The analysis result has been corrected if the mean value of the zero sample exceeds the detection limit of the ICP/AES instrument. The corrected result has been obtained by subtracting the result of the zero analysis from the analysis result. This procedure had to be employed mainly for sulphur and iron, and less frequently with the other elements.

Discoloration and defoliation of trees selected for foliar analysis in 1996

In 1996, more than 75 % of the pines and spruces selected for needle chemistry determination were not suffering from defoliation or were only slightly (11-25 %) defoliated. There were no severely defoliated trees in 1996. No changes in defoliation level were observed either on pine or spruce between the years 1995 and 1996. The spruces were slightly more defoliated than the pines, and trees more than 60 years old were slightly more defoliated than those under 60.

Figure 7 shows the discoloration (A) and the defoliation (B) of the pines (13 plots) and spuces (11 plots) in two different age classes selected for foliar analysis in 1996. The proportion of trees with easily identifiable causes of damage are presented in Fig. 8.

Nutrient status of the trees

A deficiency of plant-available nitrogen and phosphorus are the most common factors limiting growth within the boreal coniferous zone, and hence forest condition. Deficiencies of potasium, magnesium or calcium, especially on mineral soil sites, are much less common. Micronutrient deficiencies, e.g. of boron and copper, are rather common on peatland sites in Finland. Foliar boron and copper concentrations on mineral soil sites are also often very low. This is also supported by regional Finnish surveys and long-term monitoring studies carried out in Finland. The results of the level II studies are also in agreement with this.

Table 2 shows the average, minimum and maximum concentrations of elements in current-year and previous-year needles of pine (n = 13) and spruce (n = 11) on the observation plots in 1995. Table 3 shows the average concentrations of spruce needles in Uusikaarlepyy (Plot No. 23) and Närpiö (Plot No. 24) in 1996. Figures 9 and 10 show the average element concentrations of pine and spruce needles on the different observation plots in 1995 and 1996.

Table 2. Average, minimum and maximum element concentrations in the current-year (C) and the previous-year (C+1) needles of Scots pine and Norway spruce on the level II observation plots in Finland in 1995.

		Scots pine						Norway spruce					
		C			C+1			C			C+1		
		$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max	$\bar{x}$	min	max
N	mg/g	10.6	9.1	12.7	10.7	9.1	12.7	9.9	7.7	12.3	9.5	7.6	11.8
P	-"-	1.50	1.29	1.80	1.40	1.21	1.64	1.71	1.44	1.98	1.52	1.10	1.88
K	-"-	5.10	4.59	5.65	4.76	4.28	5.56	7.06	5.59	8.08	5.63	4.80	6.32
Ca	-"-	1.79	1.20	2.37	3.03	1.95	3.78	3.90	2.91	5.40	5.81	4.98	7.32
Mg	-"-	1.04	0.92	1.33	0.93	0.68	1.37	1.25	1.04	1.71	1.15	0.93	1.42
S	mg/kg	903	744	1052	929	747	1100	870	786	1029	846	727	1002
Fe	-"-	29.3	20.3	44.6	46.3	29.6	72.2	22.4	16.0	33.4	26.7	17.9	38.2
B	-"-	10.6	4.6	16.5	9.7	4.4	18.6	11.5	7.9	16.1	9.6	6.0	15.6
Cu	-"-	2.42	1.66	4.06	2.00	1.47	3.18	1.77	1.31	2.27	1.50	1.03	1.94
Zn	-"-	40.4	33.4	46.5	51.8	43.3	62.3	36.3	25.4	54.6	37.4	16.8	57.4
Mn	-"-	394	234	618	662	401	947	748	445	1159	1027	572	1305
Al	-"-	246	154	318	342	246	447	41.0	21.0	71.0	48.0	25.0	81.0

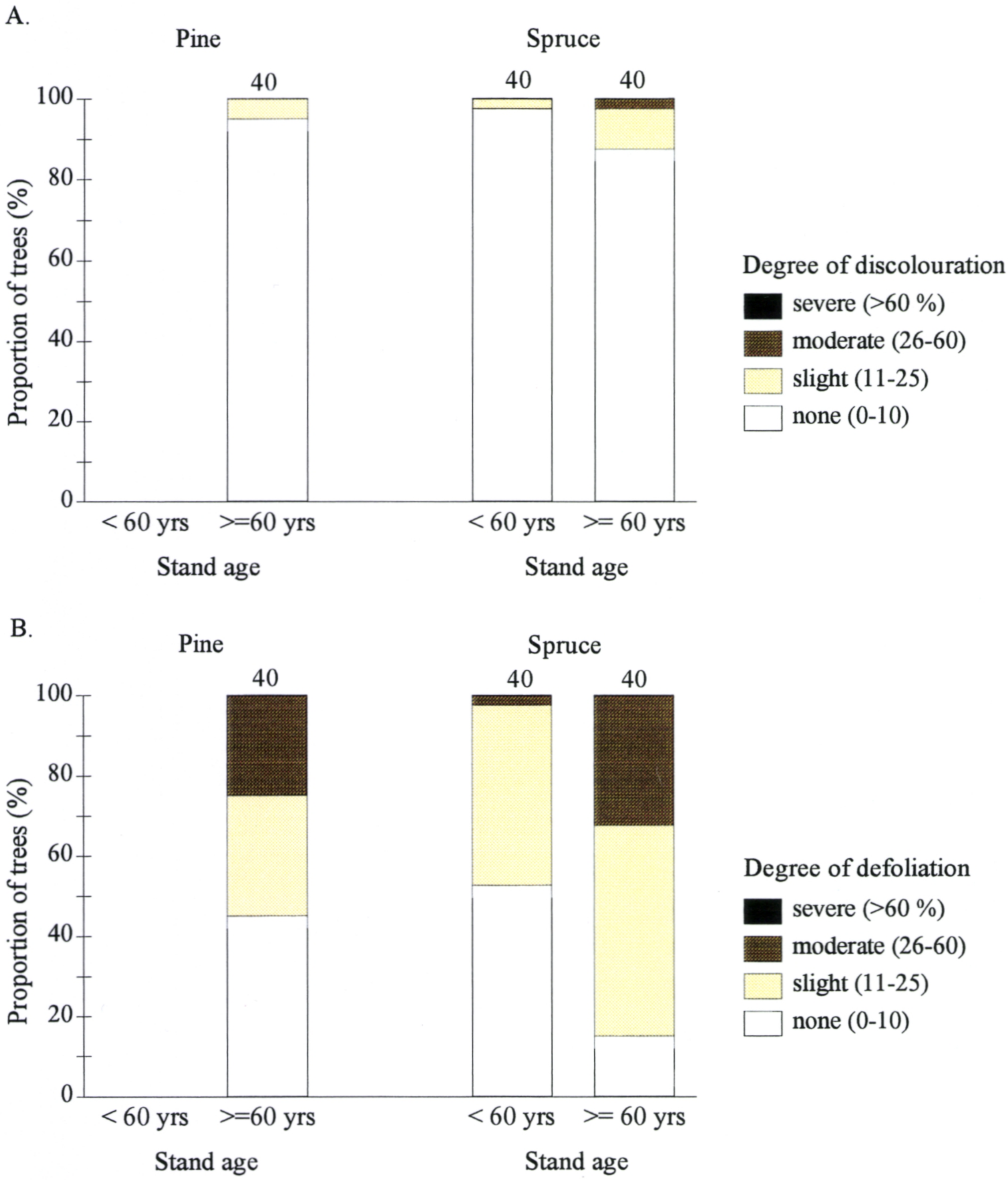


Fig. 7. Discoloration (a) and defoliation (b) of trees selected for foliar analyses in 1996.

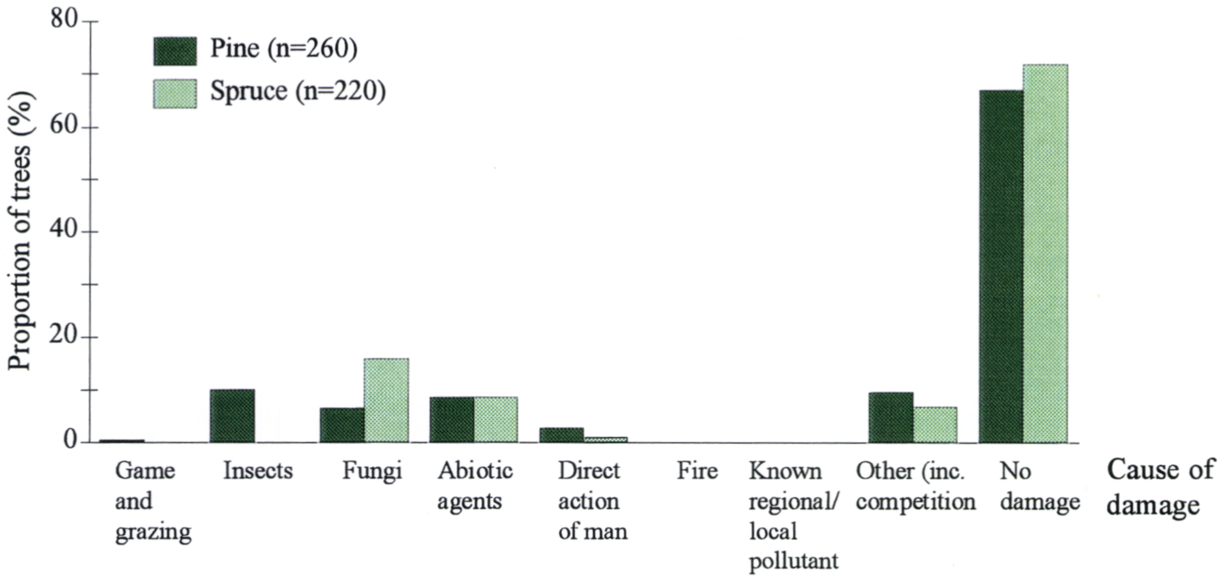


Fig. 8. The proportion of pine and spruce selected for foliar analyses in easily identifiable damage classes in 1996.

Table 3. Average element concentrations in Norway spruce needles from Uusikaarlepyy and Närpiö in 1996.

	Uusikaarlepyy Plot No. 23		Närpiö Plot No. 24	
	C	C+1	C	C+1
N mg/g	12.8	10.9	13.5	11.5
P -"-	1.75	1.31	1.60	1.07
K -"-	6.69	5.71	7.26	4.76
Ca -"-	2.78	4.97	4.36	6.70
Mg -"-	1.41	1.30	1.20	1.17
S mg/kg	1066	1010	1118	953
Fe -"-	29.6	32.7	23.7	26.6
B -"-	13.3	16.0	19.8	20.7
Cu -"-	1.48	1.33	1.95	1.32
Zn -"-	27.8	24.0	33.7	25.8
Mn -"-	351	556	557	820
Al -"-	55.9	82.2	33.7	45.9

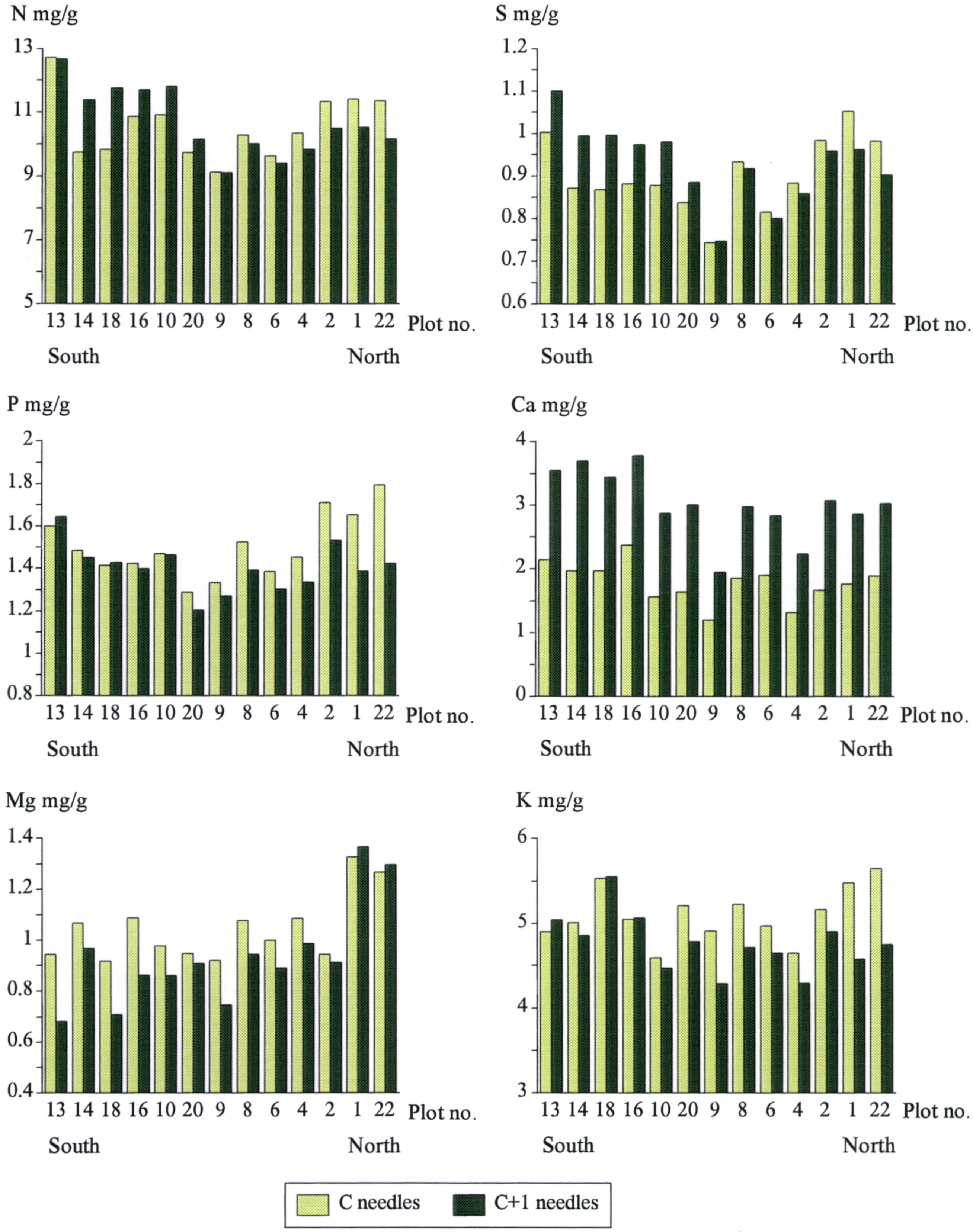


Fig. 9. Average element concentrations of Scots pine needles on the observation plots in 1995.

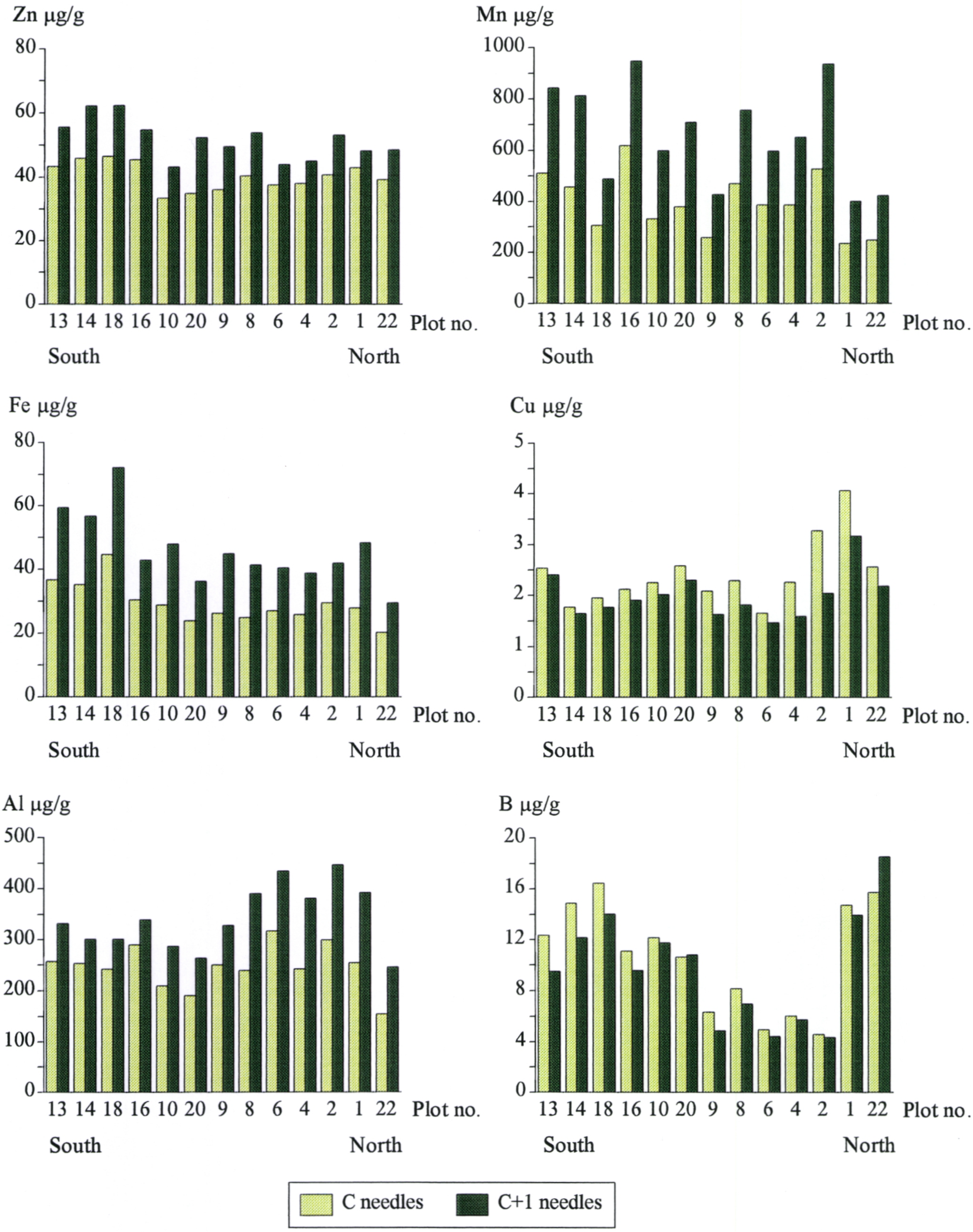


Fig. 9. Continues

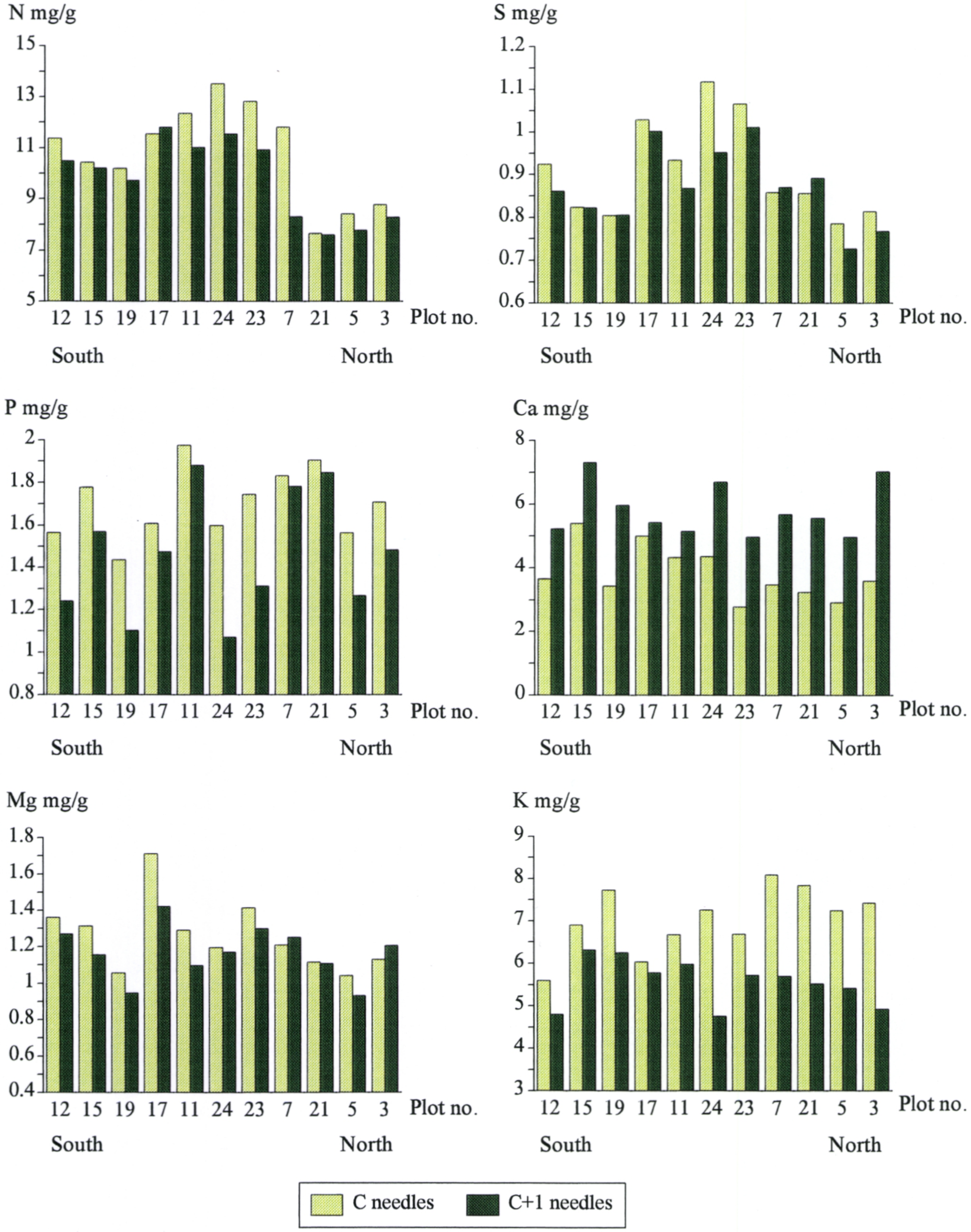
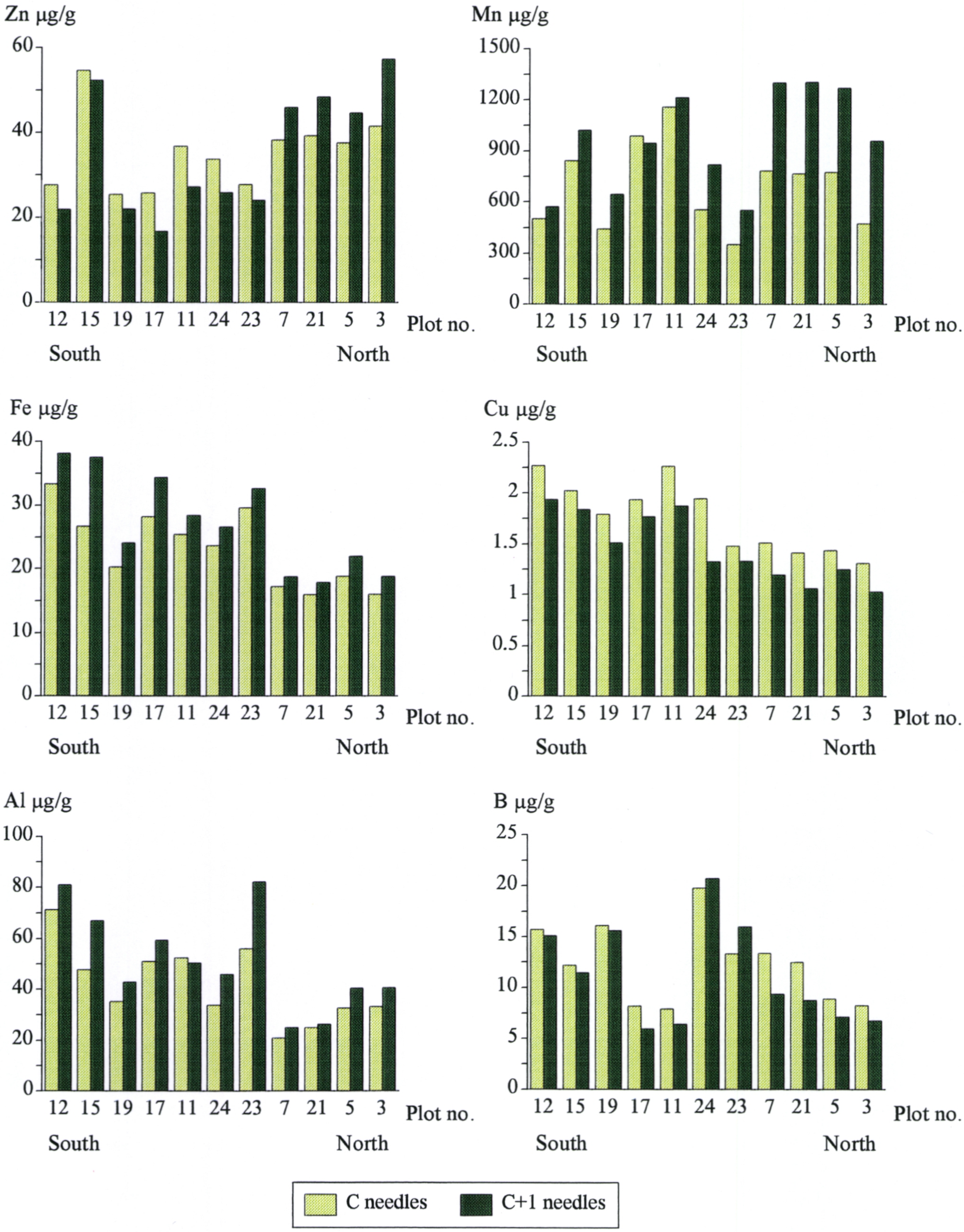


Fig. 10. Average element concentrations of Norway spruce needles on the observation plots in 1995. (Samples of plot No. 23 and No. 24 have been collected in 1996).



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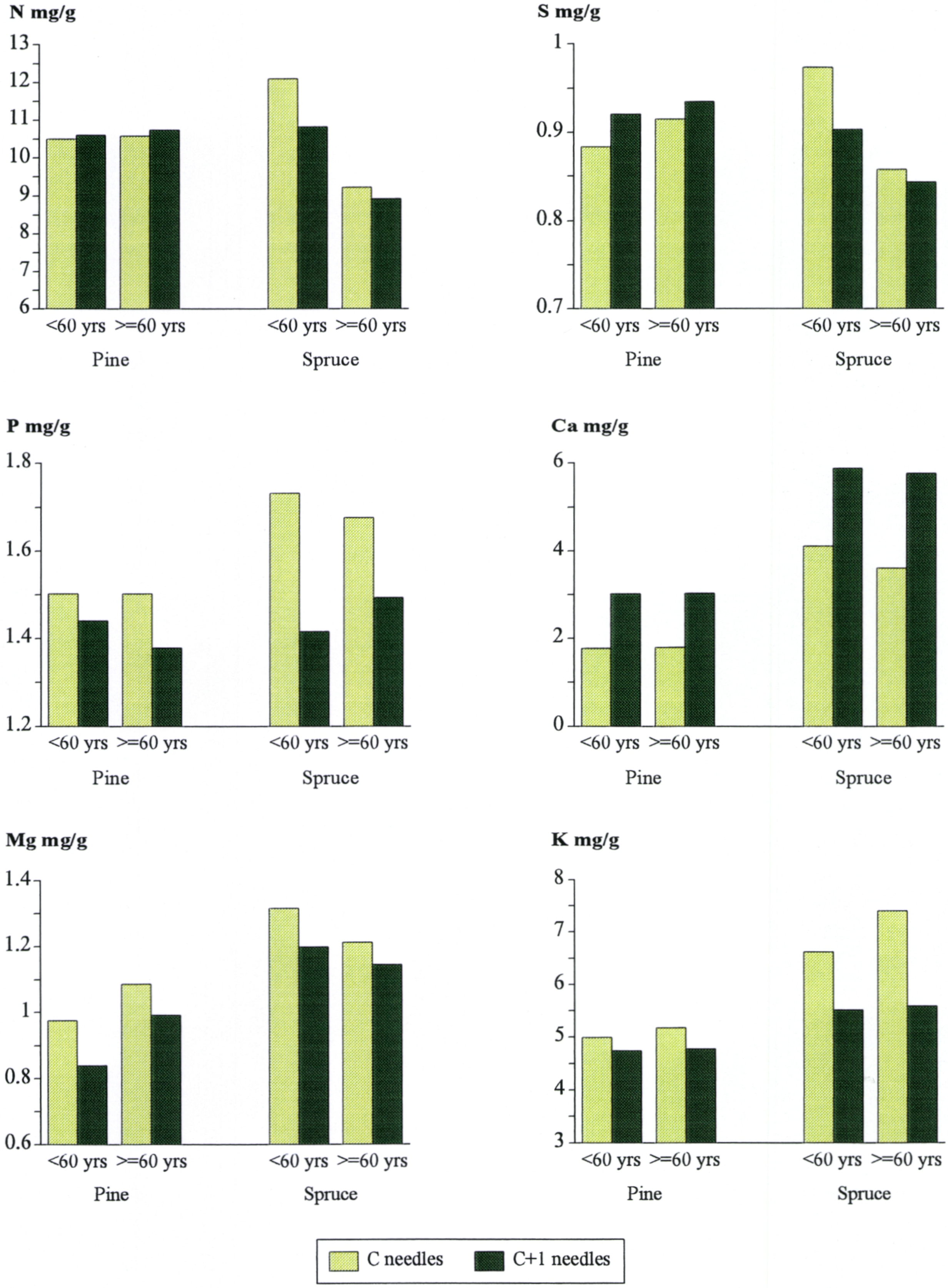

Fig. 11. Average element concentrations of pine and spruce needles in two stand age classes.

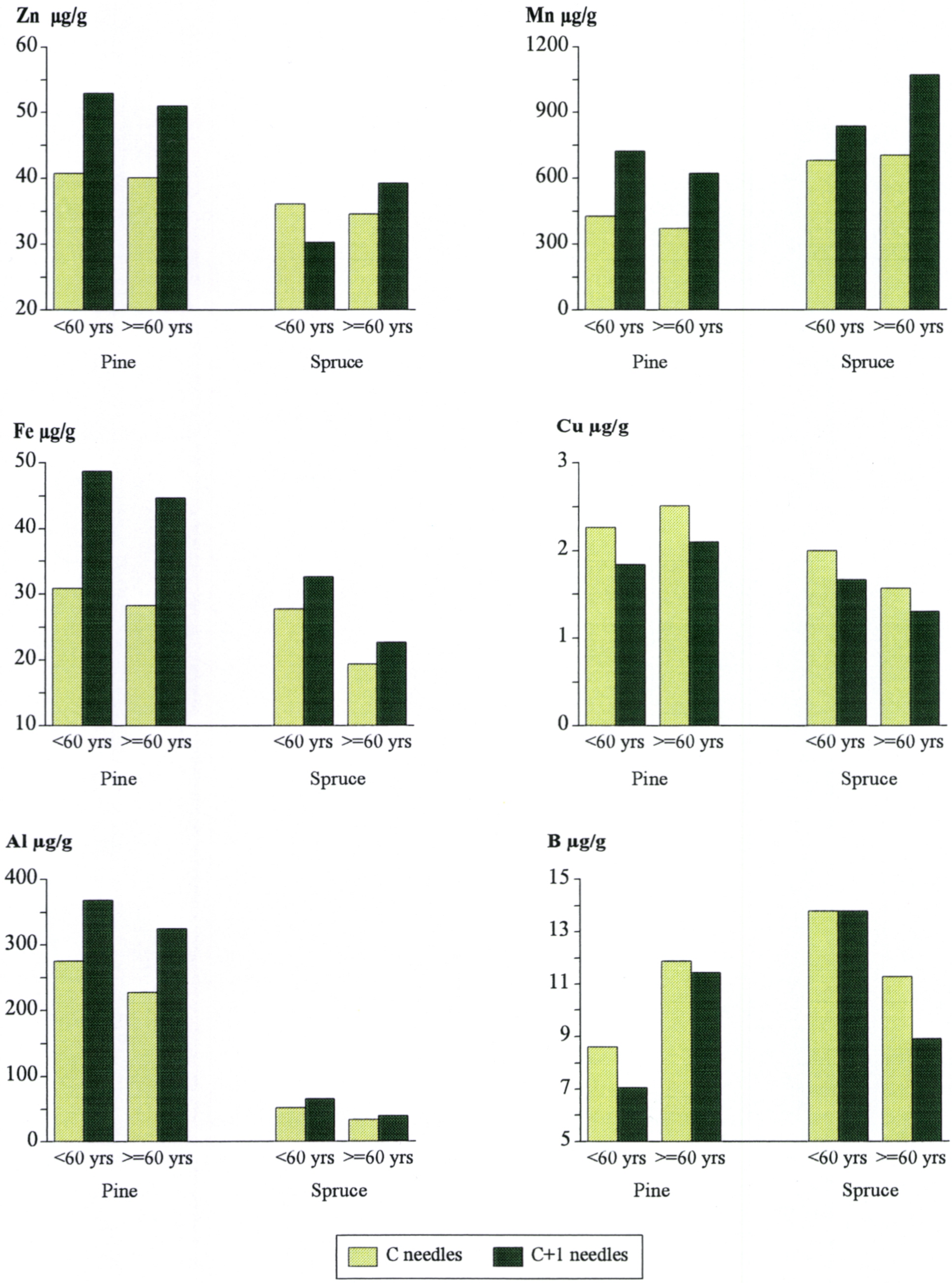

Fig. 11. Continues

A large number of factors affect the concentration of elements in needles e.g. age of trees and needles (Raitio 1995). The results of the level II studies are also in agreement with this. The N, S, Cu, B, Fe, Al, Ca and Mg concentrations in the current-year spruce needles and the N, S, Cu, B, Fe and Al concentrations in the previous-year spruce needles were statistically higher, and the K concentrations in the current-year needles and the Zn concentrations in the previous-year needles lower in trees under 60 years old than in those over 60 (Fig. 11). The B and Mg concentrations of the current-year pine needles, and the B, Mg and Cu concentrations of the previous-year pine needles were statistically lower, and the Fe, Al and Mn concentrations of the current-year pine needles and the Mn concentration of the previous-year pine needles were higher in trees under 60 years old than in those over 60 (Fig. 11).

5.3 Soil condition

Soil samples were taken and analysed from the two new plots established and the 4 IM plots incorporated into the soil condition survey in 1996. The network of plots can now be considered to be rather representative of the forest site types occurring in Finland (Fig. 12). The two site types most important from the point of view of commercial forestry, i.e. MT (the Myrtillus forest site type) and VT (Vaccinium site type), account for over 70% of the plots. 12% of the plots represent the poorest site types (CT = Calluna site type, ClT = Cladonia site type), which are generally assumed to be the most sensitive to the adverse effects of acidic deposition. There is a clear division between tree species as regards the site types; Norway spruce occurs only on the OMT and MT site types, and Scots pine only on the VT, CT and ClT site types. However, the tree stand on two of the IM plots (Nos. 19 and 21) is mixed (Norway spruce, Scots pine, birch) but dominated by spruce.

Soil texture and water availability

The soil on 5 of the plots is very coarse textured, with a clay+silt (<63 µm) content of over 80%. As is to be expected, there is rather close correlation between the proportion of fine fractions and the site type. Four of the more fertile plots are somewhat paludified, especially during the spring after snowmelt and after heavy rainfall episodes.

Site fertility

The bedrock in Finland primarily consists of granitic species and forest soils are therefore relatively poor in macronutrients such as Mg and Ca. Under normal conditions, however, there are no deficiencies of these elements on mineral soil sites in Finland, the main nutrient limiting tree growth being nitrogen. Magnesium deficiency has been reported in a number of countries subjected to excessive levels of acidic deposition. Total Mg concentrations in the organic layer of the 24 plots varied from 323 - 1139 mg/kg, with the Mg concentrations on the majority of the plots ranging from 400 - 700 mg/kg (Fig. 13). The lowest value (323 mg/kg) occurred on plot No. 18, located in the SE corner of the country where sulphur deposition is at its highest. At this site, however, there is also a considerable input of Ca and Mg from the oil shale-fired power stations in NE Estonia, as well as from fly ash originating from power stations in the St. Petersburg area.

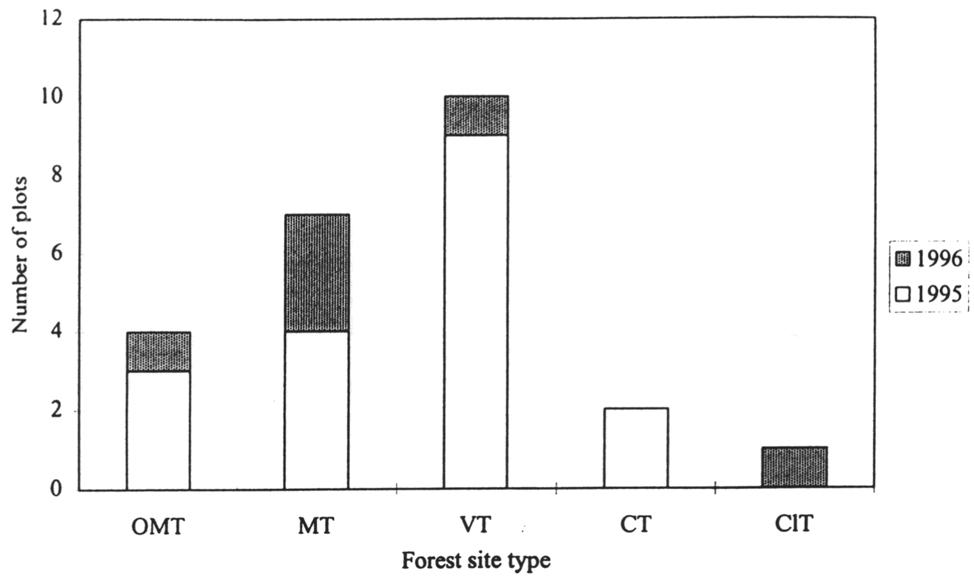

Fig. 12. Distribution of the 24 ICP level II monitoring plots according to forest site type. OMT = Oxalis-Myrtillus type, MT = Myrtillus type, VT = Vaccinium type, CT = Calluna, ClT = Cladonia type

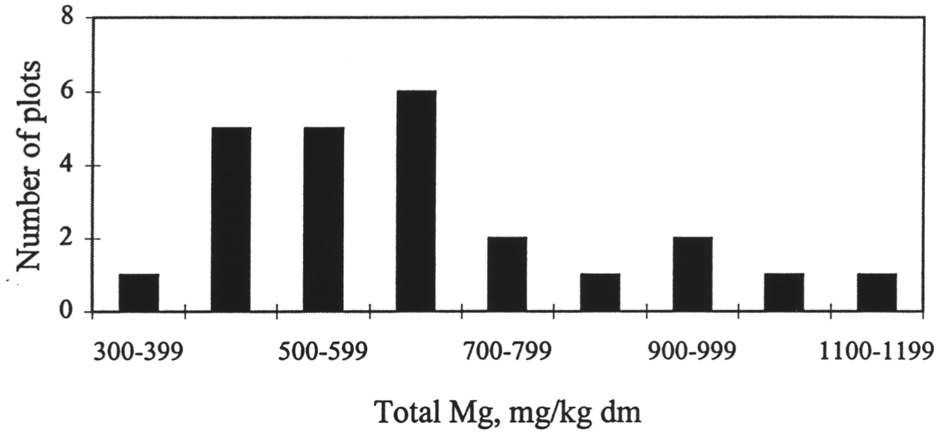

Fig. 13. Distribution of the 24 ICP level II monitoring plots according to the total Mg concentrations in the organic layer.

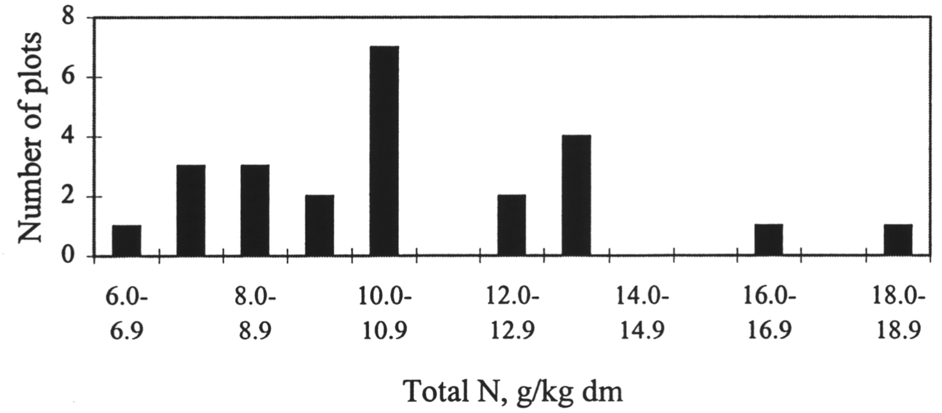

Fig. 14. Distribution of the 24 ICP level II monitoring plots according to the total N concentration in the organic layer.

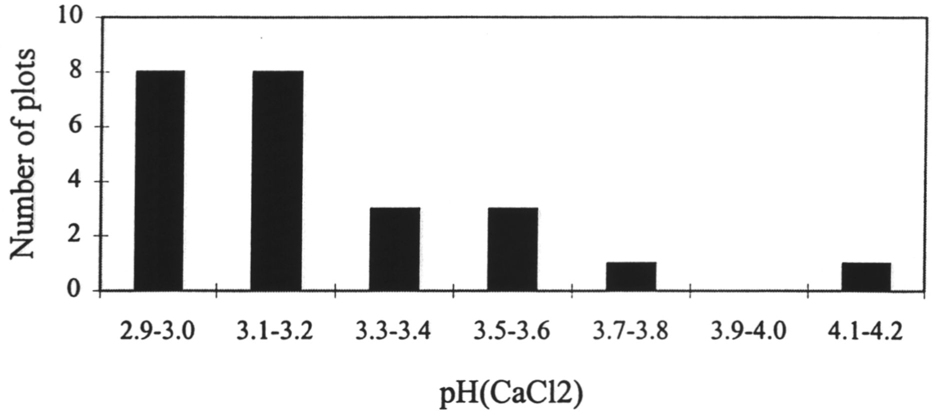

Fig. 15. Distribution of the 24 ICP level II monitoring plots according to the pH($CaCl_2$) of the organic layer.

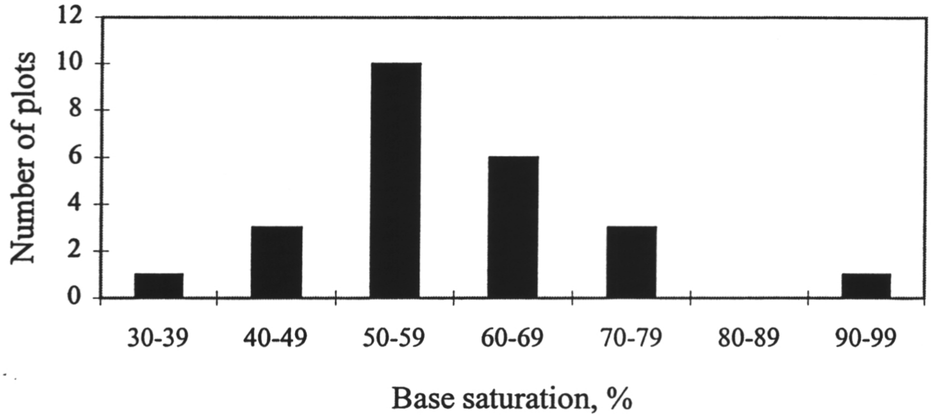

Fig. 16. Distribution of the 24 ICP level II monitoring plots according to the base saturation of the organic layer.

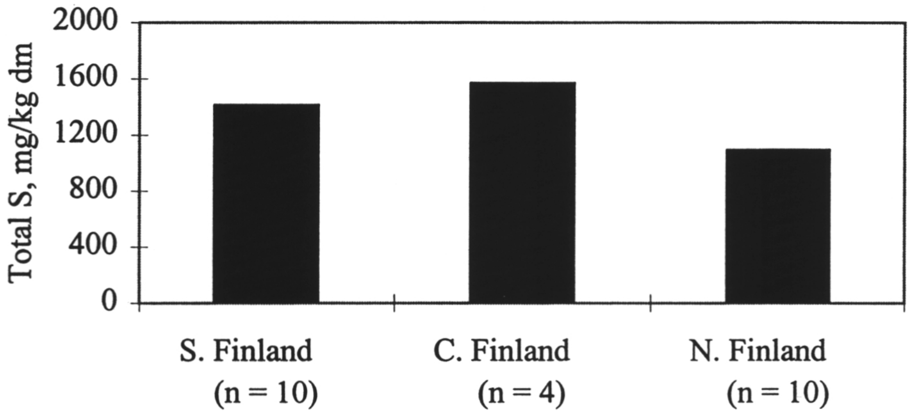

Fig. 17. Total sulphur concentrations in the organic layer of the 24 ICP level II monitoring plots grouped according to their location Finland.

The distribution of total N concentrations in the organic layer was rather broad, on 90% of the plots ranging from 6.3 to 13.6 g/kg (Fig. 14). Although these values are relatively low, they are rather normal for sites with a coniferous tree cover in northern Europe. A high proportion of the nitrogen is in a form that is not available for tree growth. The two plots with a total N concentration above 14 g/kg (plots No 23 and 24) are located in spruce stands on the western coast of Finland.

Soil acidity

The organic layer that forms under conifers in the cool, moist climate of northern Europe is naturally rather acidic. The pH($CaCl_2$) of the organic layer on 2/3 of the plots was <3.2 (Fig. 15). The one plot with a relatively high pH (plot No. 15) is in a spruce stand located on the southern coast of Finland. Although this area receives the highest deposition load of both S and N, the soil naturally has a very high Ca content. The base saturation levels in the organic layer was above 50% on 5/6 of the plots (Fig. 16), thus indicating that although the organic layer is rather acidic it does have a relatively high capacity to counteract acidic deposition.

Sulphur

In Finland there is a clear decreasing N-S gradient in sulphur deposition. Although a relatively strong decreasing N-S gradient has also been reported for sulphur concentrations in the organic layer, it would appear that this is to a great extent due to the climatic gradient, which affects biomass production, running in the same direction. There was a clear difference between total S concentrations in southern and northern Finland (Fig. 17). The higher total S concentrations in central Finland are due to the fact that two of the plots (Nos. 23 and 24) had total S concentrations above 2000 mg/kg. The plots are located right on the western coast in an area subjected to rather rapid (ca. 1 m/100 year) land uplift, and the sulphur concentration in the soil is naturally high owing to the fact that a few centuries ago the sites were covered by the Baltic Sea. The two plots in the northernmost part of the country (Nos. 1 and 22) also have relatively high sulphur concentrations owing to their proximity to the Arctic Ocean (marine-derived sulphate) and possibly also to emissions from the Cu-Ni smelter at Nikel, NW Russia.

5.4 Tree growth

The six plots added to the level II observation network in 1996 represent rather different management regimes. The four IM plots (Evo No. 19, Lieksa No. 20, Oulanka No. 21 and Kevo No. 22) are located in nature conservation areas, which means that forest management has had minimal effect on these stands: for instance, no intermediate cuttings have been conducted in these stands for decades. On plot Nos. 19 and 22 trees have almost certainly not been removed during the lifetime of the current tree generation. Plot Nos. 23 and 24 are have been subjected to normal forest management regimes. Generally speaking all the stands, with the possible exception of plot No. 24, have a high cubic volume compared to stands of similar age and site type growing in the same geographical area.

Plot No. 19, located in Southern Finland, is extremely dense compared to the normal stand density in Finland. The tree stand is old and has suffered from high tree mortality, evidently due to competition between trees. Stands of this type are normally regenerated before reaching this state and, if not, they have been subjected to several intermediate cuttings.

Plot No. 20 is a mature pine stand. The cubic volume is not especially high for a stand that has not been thinned. Nevertheless, natural mortality has been rather high. This suggests that the site is of relatively low fertility.

Plot No. 21 is located in the northern part of the country, in an area where the annual temperature sum is rather low and the growing conditions therefore less favourable for trees. In the light of this, the density of the stand is very high.

Plot No. 22 is located in northernmost Finland, very close to the northern timber line of Scots pine. In this region pine is able to grow only at low altitudes, and tree growth is therefore extremely slow. The stand density is very low, but very few pine stands with markedly higher cubic volume are to be found in the area.

Plot No. 23 has been managed intensively although, according to the silvicultural norms, an intermediate cutting would be necessary in the near future. While many spruce stands in the same region have shown various symptoms of reduced vitality, this stand appears to be in excellent condition.

Plot No. 24 is situated on a more heterogeneous site that is suffering in places from excessive moisture. As a result, the stand structure is also heterogeneous. The cuttings performed in the stand do not represent the best tradition of silviculture; large individual trees have presumably been removed without properly considering the silvicultural status of the remaining stand.

5.5 Deposition

During 1996 deposition samples were collected within 24 forest stands and in adjacent open areas. The collection period for 19 of the intensive monitoring plots was 1.1.-31.12.1996. The collection did not necessarily start on 1.1.1996 or stop on 31.12.1996, but the amount of precipitation reported has been calculated to correspond to these dates. The deposition measurements started on two of the plots (Nos. 23 and 24) in July 1996, and on three of the plots (Nos. 20-22) in September 1996. The deposition samples were collected monthly throughout the year. However, during the winter months the collection periods were in some cases longer due to the fact that access to the plots has been difficult.

In general there have been no problems in collecting the samples; the number of corrected deposition values has therefore been low and there was no loss of deposition data. In a couple of cases the bulk deposition values have been used as substitutes for missing within-stand values during the snow collection period. A number of missing values during the rainwater collection period were generated using site-specific regression equations based on paired bulk deposition and stand throughfall values. Punctured plastic bags in the collectors were the main reason for the missing values.

The results presented here are for the 19 intensive sample plots that were in operation throughout the year. The bulk deposition values have been compared to the long-term average values (1971-1988) recorded by the National Board of Waters and the Environment (Järvinen & Vänni 1990). This long-term series was chosen for comparison since sulphur deposition in Finland was at its highest during the 1970s and 1980s.

Precipitation

Annual precipitation in the open varied between 500 - 650 mm in southern Finland during 1996. The corresponding values in the northern parts of the country were 450 - 550 mm. Annual precipitation was relatively close to the long-term mean values; during 1971-1988 annual precipitation in southern Finland was about 650 mm, in central Finland 600 mm and in northern Finland 450 mm.

The tree canopies intercepted 15 - 30% of the bulk precipitation in the pine stands in southern Finland, and about 20% in the three pine stands located in the southern parts of northern Finland. On the three northernmost plots the pine stands intercepted only a small proportion of the precipitation as the rain water passed through the canopy layer (Fig. 18). The density of the stands is usually lower in the north, which undoubtedly has an effect on the interception values. The fact that a higher proportion of precipitation falls as snow in the north also affects the interception value.

The interception was 20 - 40% of the bulk precipitation in the spruce stands located in the southern parts of Finland, but somewhat lower on the plots in the north. In one of the northern spruce stands the amount of stand throughfall was similar to that measured in the open, and interception was only 10% on one of the other plots (Fig.18).

The interception values were slightly lower in the pine than the spruce stands, although the difference was rather small. In other studies it has been reported that interception is generally higher in spruce stands due to the shape of the spruce canopies and the higher stand density (e.g. Hyvärinen 1990).

pH and H^+ deposition

The mean pH of the bulk deposition varied between 4.5 - 4.8 in southern Finland and the values were very similar to the long-term means (1971-1988). The pH values were generally lower within the stand. The stand throughfall pH was somewhat higher in the spruce than in the pine stands (Fig. 19).

In northern Finland the bulk deposition pH values varied between 4.9 - 5.0 and were close to the means for 1971-1988. The pH was in most cases lower within the stand, which is a well-documented phenomenon in coniferous stands (Derome et al. 1995, Lindroos et al. 1997) (Fig.19).

There was a clear decreasing gradient in the H^+ deposition in the bulk deposition and stand throughfall running from the south to the north. The bulk deposition values were close to the long-term means in southern Finland especially (Fig. 20).

Sulphate

The bulk SO_4-S deposition was clearly lower in 1996 on the intensive monitoring plot network than the corresponding long term means (Fig. 21). This is undoubtedly due to the reduction in S emissions during the past decade. Despite the relatively low S deposition values on the sample plots, the pH and H^+ loads were close to the long-term mean values. This

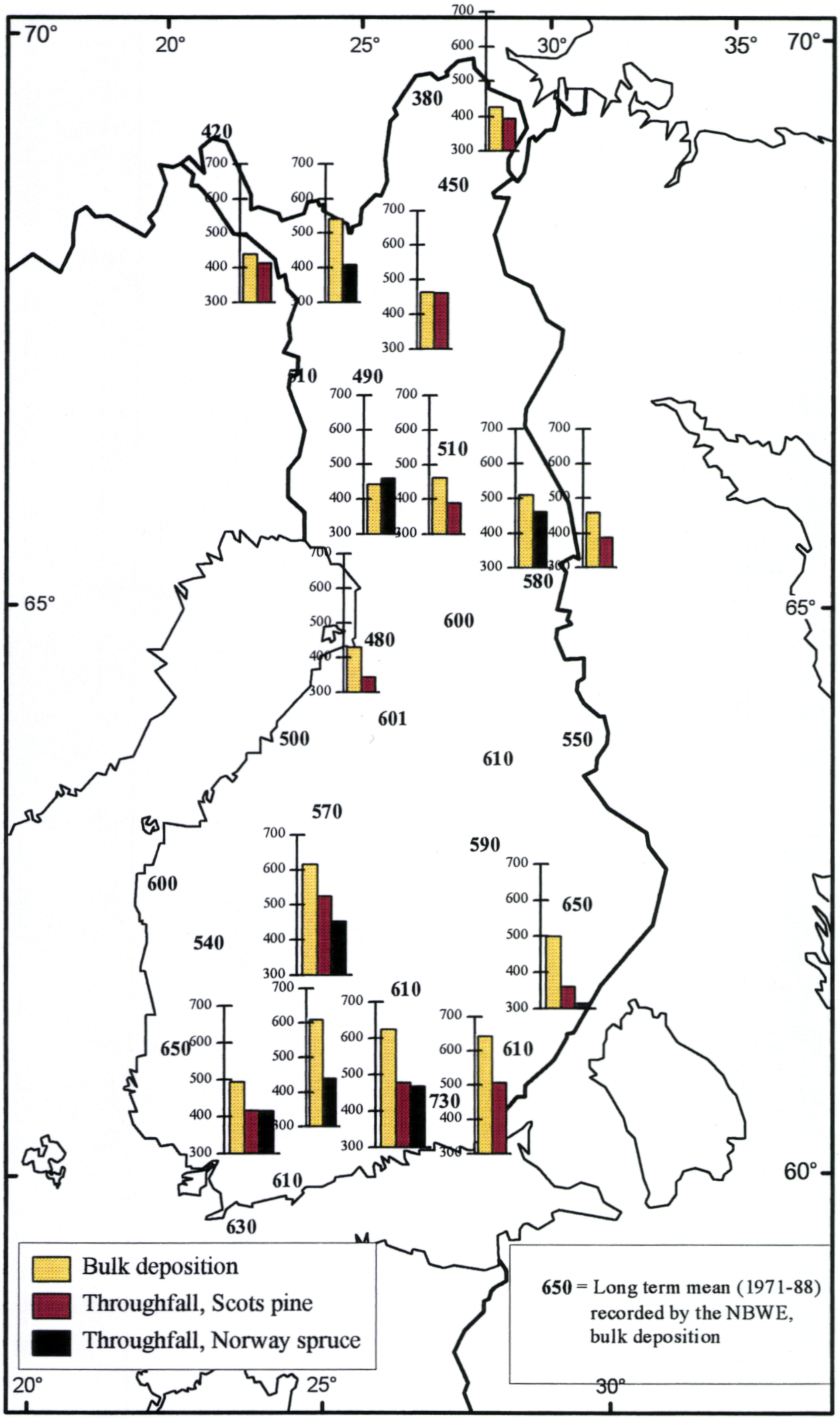

Fig. 18. Annual precipitation (mm) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

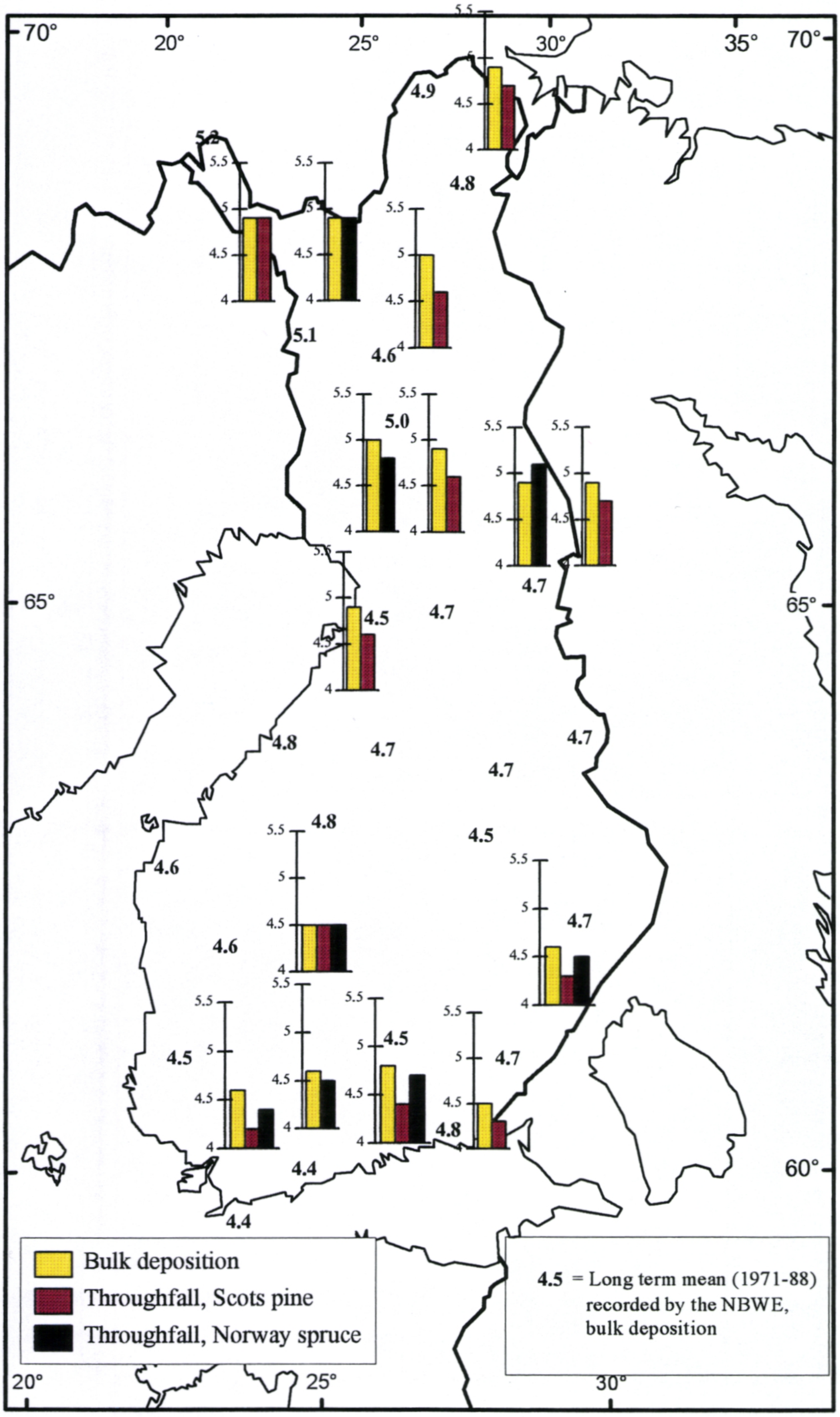

Fig. 19. Mean deposition pH during 1.1.-31.12.1997. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

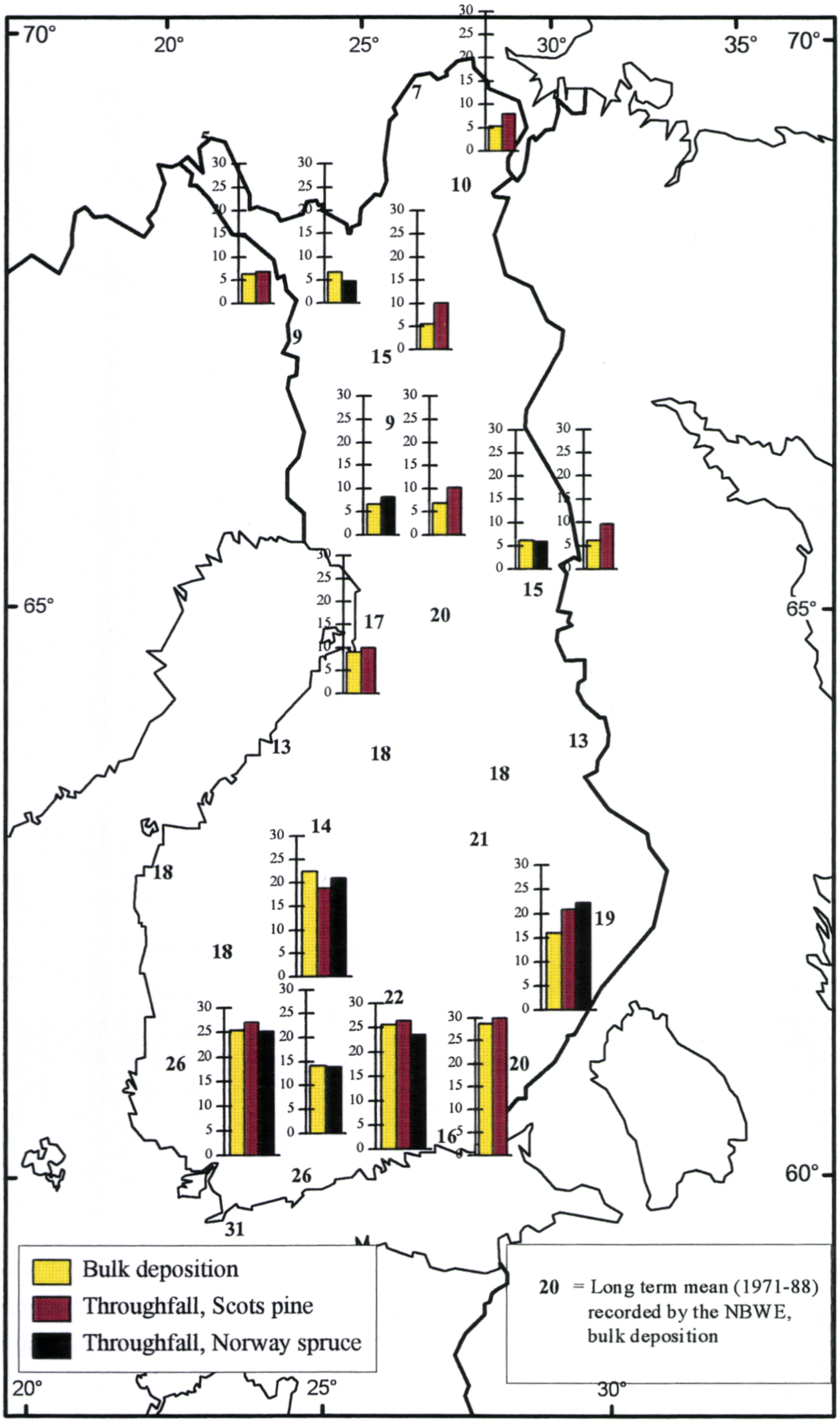

Fig. 20. H+ deposition (mmol/m^2/a) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

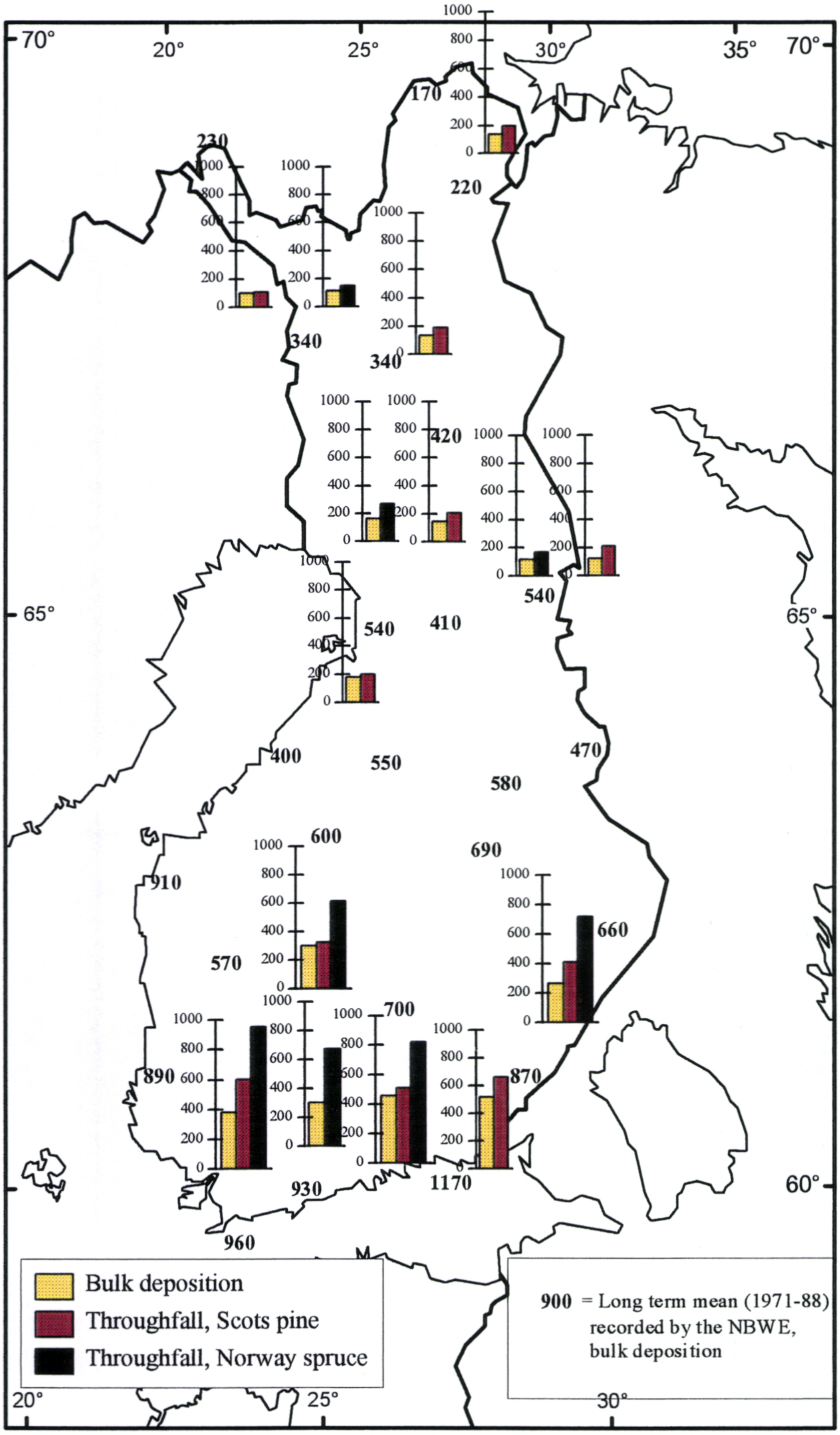

Fig. 21. SO_4-S deposition (mg/m^2/a) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

finding is supported by the general conclusion that the concentration of hydrogen ions in precipitation in Europe and North America has not decreased in proportion to the decrease in sulphur dioxide emissions (Rodhe et al. 1995).

The sulphur load increased as the rainwater passed through the tree canopies. The increase was higher in the spruce than in the pine stands. The higher S loads in stand throughfall compared to the corresponding values for bulk deposition are due to the effects of dry deposition interception and within-stand nutrient cycling on stand throughfall deposition.

Nitrogen

There was a clear decreasing N deposition gradient running from south to north in bulk deposition and stand throughfall. The bulk deposition values were somewhat lower than the long-term mean values (Fig. 22).

The throughfall N load was generally lower than the corresponding value in the open, indicating uptake processes in the tree canopies. Nitrogen uptake in the canopy layer was evident in all the spruce stands. Net N accumulation in the canopies also occurred in the pine stands, apart from the three sample plots where there was an increase in the N load. Canopy uptake is an important process in areas with low to medium N loads (100-500 $mg/m^2/a$) (Starr & Ukonmaanaho 1995, Hallgren Larsson et al. 1995).

Base cations and chloride

The base cation and chloride loads were generally higher in stand throughfall than in bulk deposition (Figs 23-27). The increase in these ions was much stronger in the spruce than in the pine stands. The bulk Ca and Mg deposition in 1996 was clearly lower than the long-term mean values. A decreasing trend in Ca and Mg deposition over the past decades has also been reported in other studies (e.g. Derome et al. 1991, Järvinen & Vänni 1990).

The Mg, Na and Cl loads in bulk deposition and stand throughfall were considerably higher on the sample plot located at a distance of only 60 km from the Arctic Ocean compared to those measured on the other plots in northern Finland.

6. Optional monitoring

6.1 Meteorological measurements

During 1996 meteorological measurements were carried out throughout the year on 3 of the Level II monitoring plots: Pallasjärvi (plot No. 3), Juupajoki (No. 11) and Tammela (No. 12). In addition, four new weather stations were established in autumn 1996 and data from those stations are also being submitted: Kivalo (plot No. 5), Punkaharju (No. 17), Uusikaarlepyy (No. 23), Närpiö (No. 24).

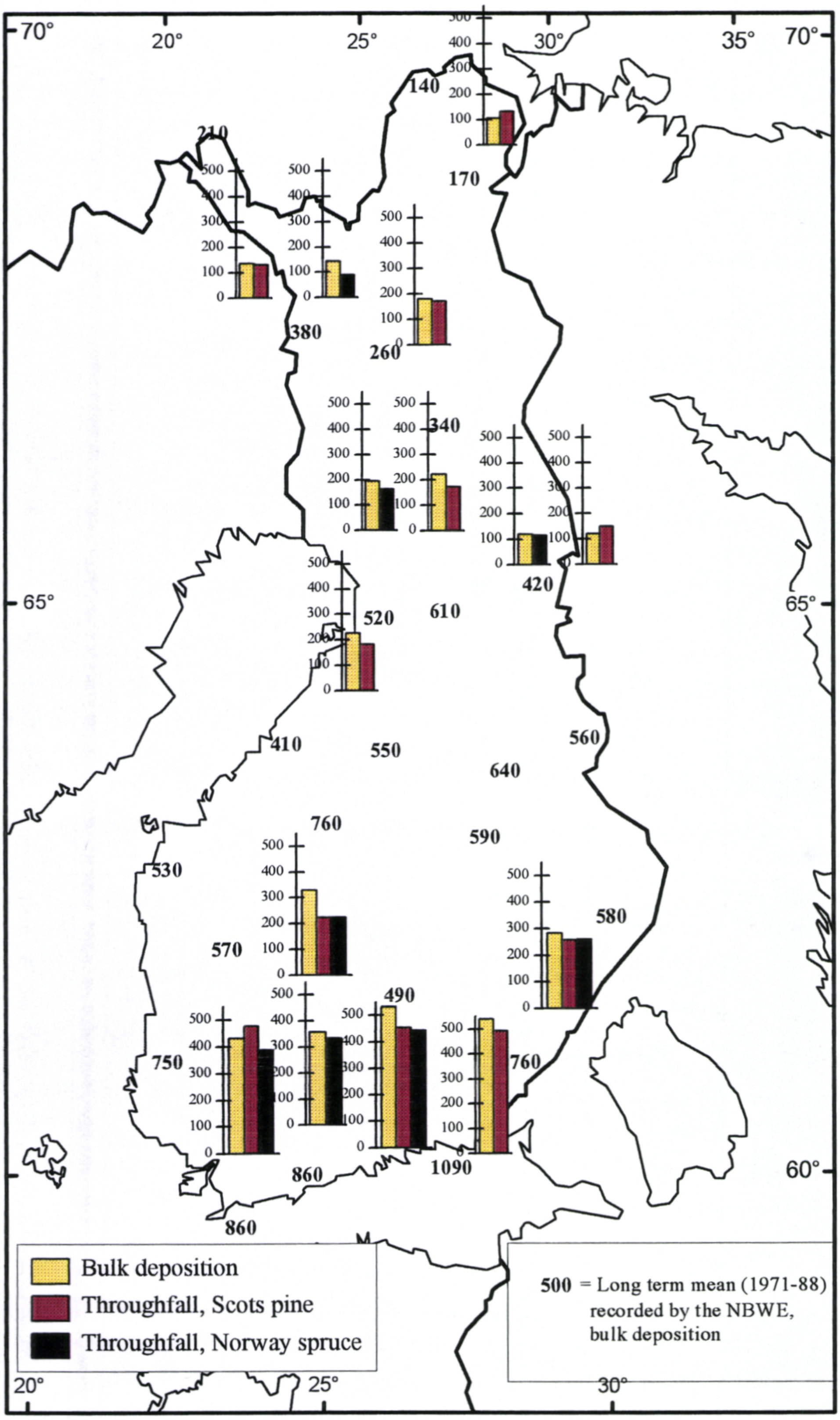

Fig. 22. N-tot deposition (mg/m^2/a) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

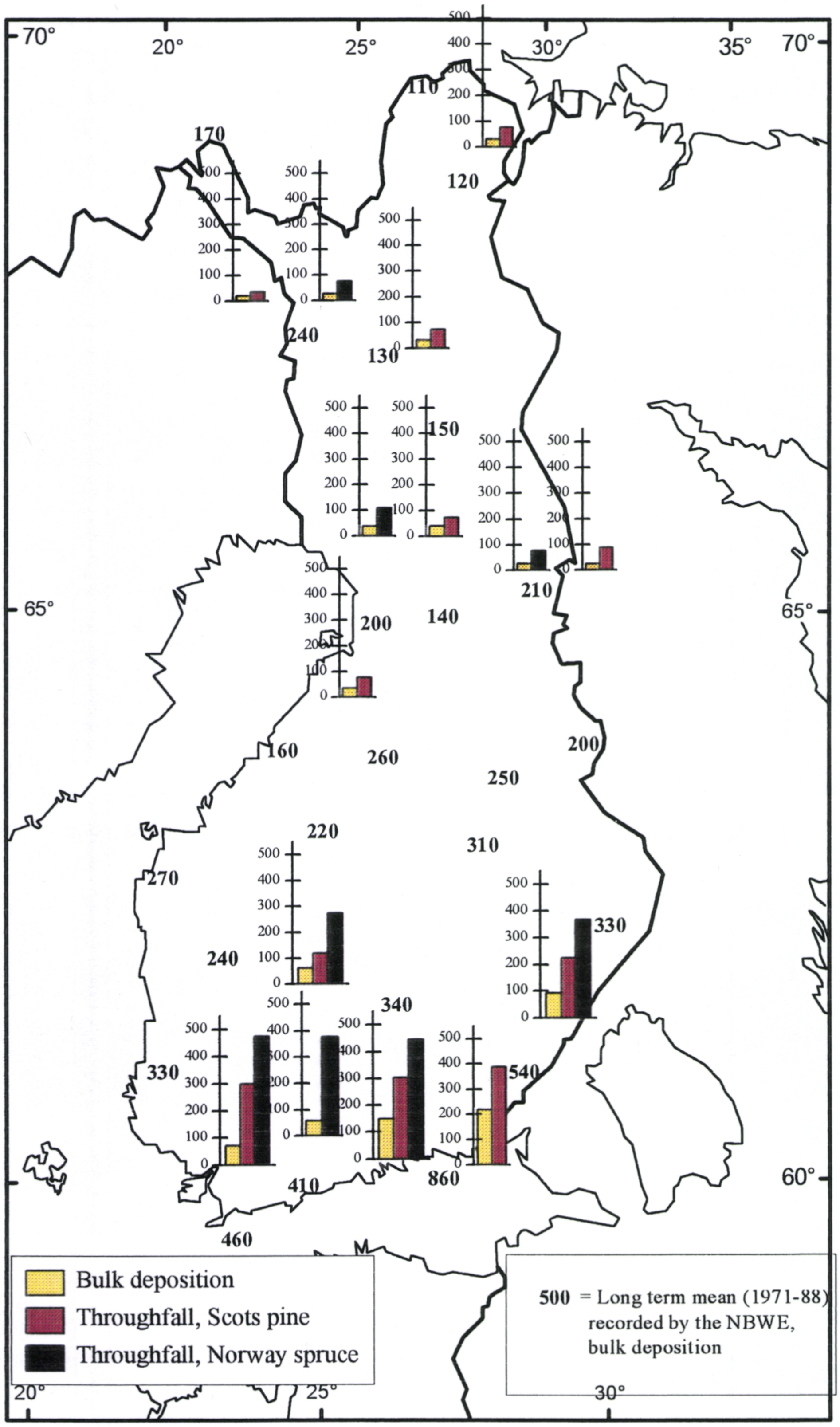

Fig. 23. Ca deposition (mg/m^2/a) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

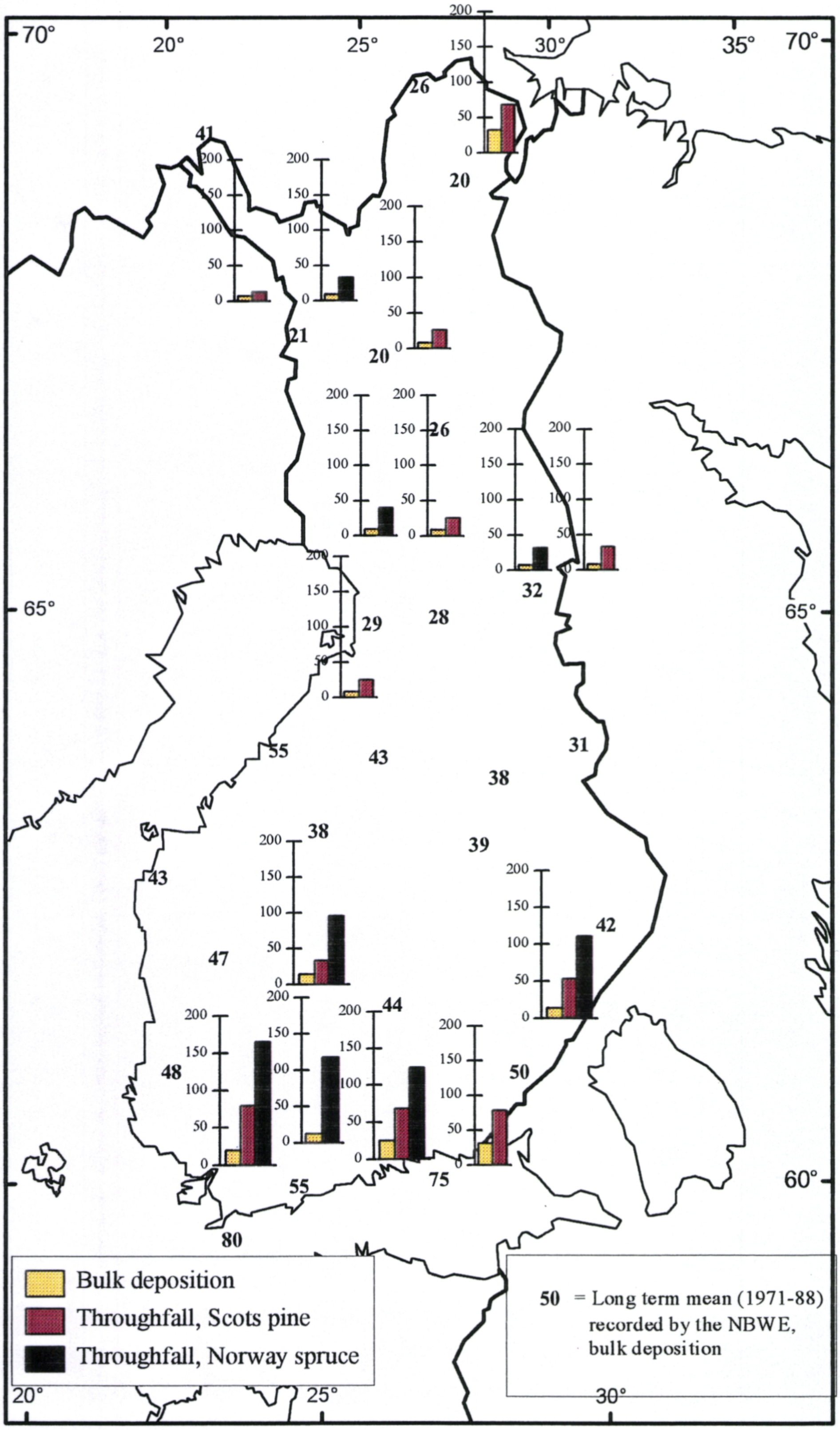

Fig. 24. Mg deposition ($mg/m^2/a$) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

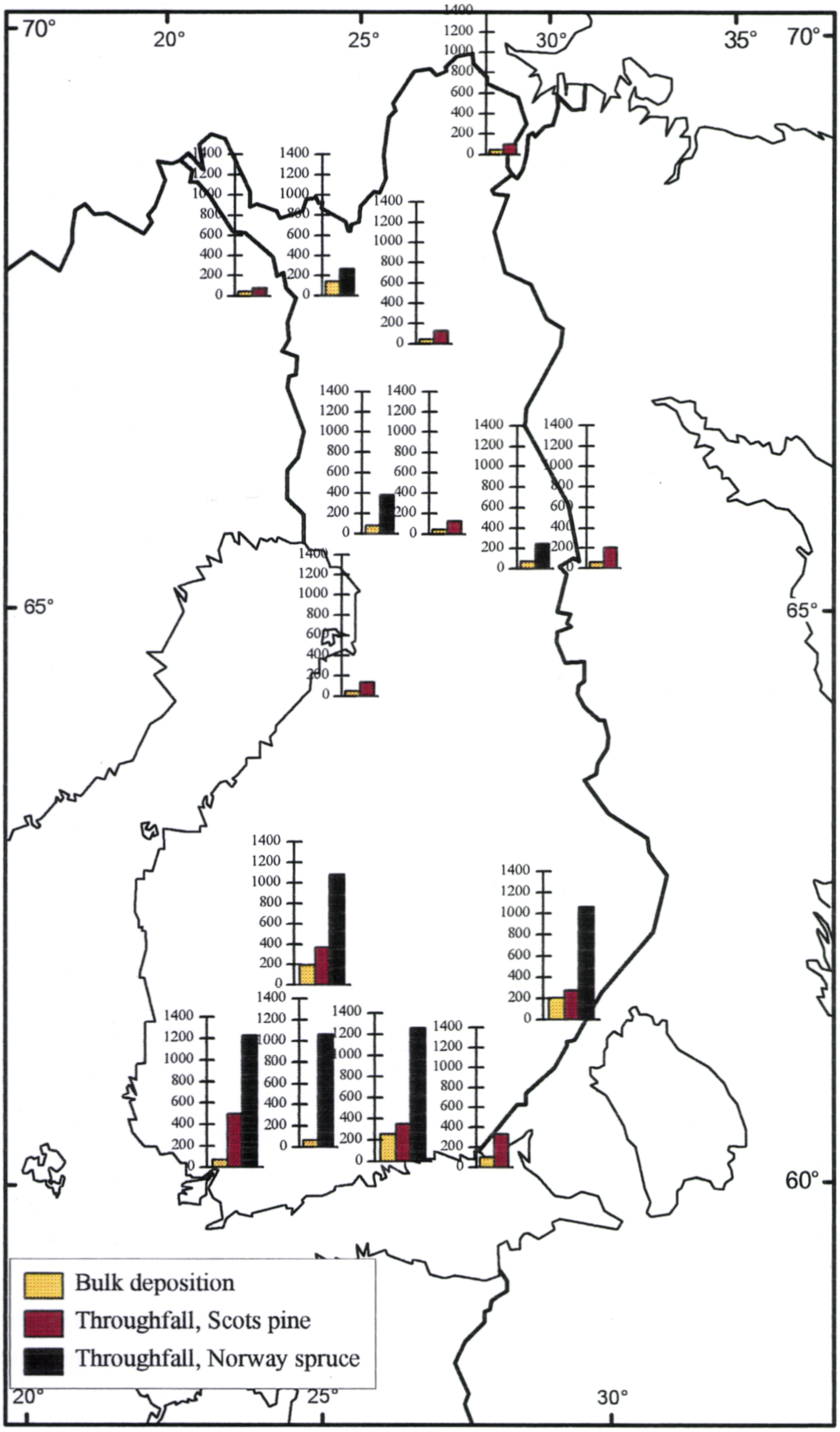

Fig. 25. K deposition (mg/m^2/a) during 1.1.-31.12.1996.

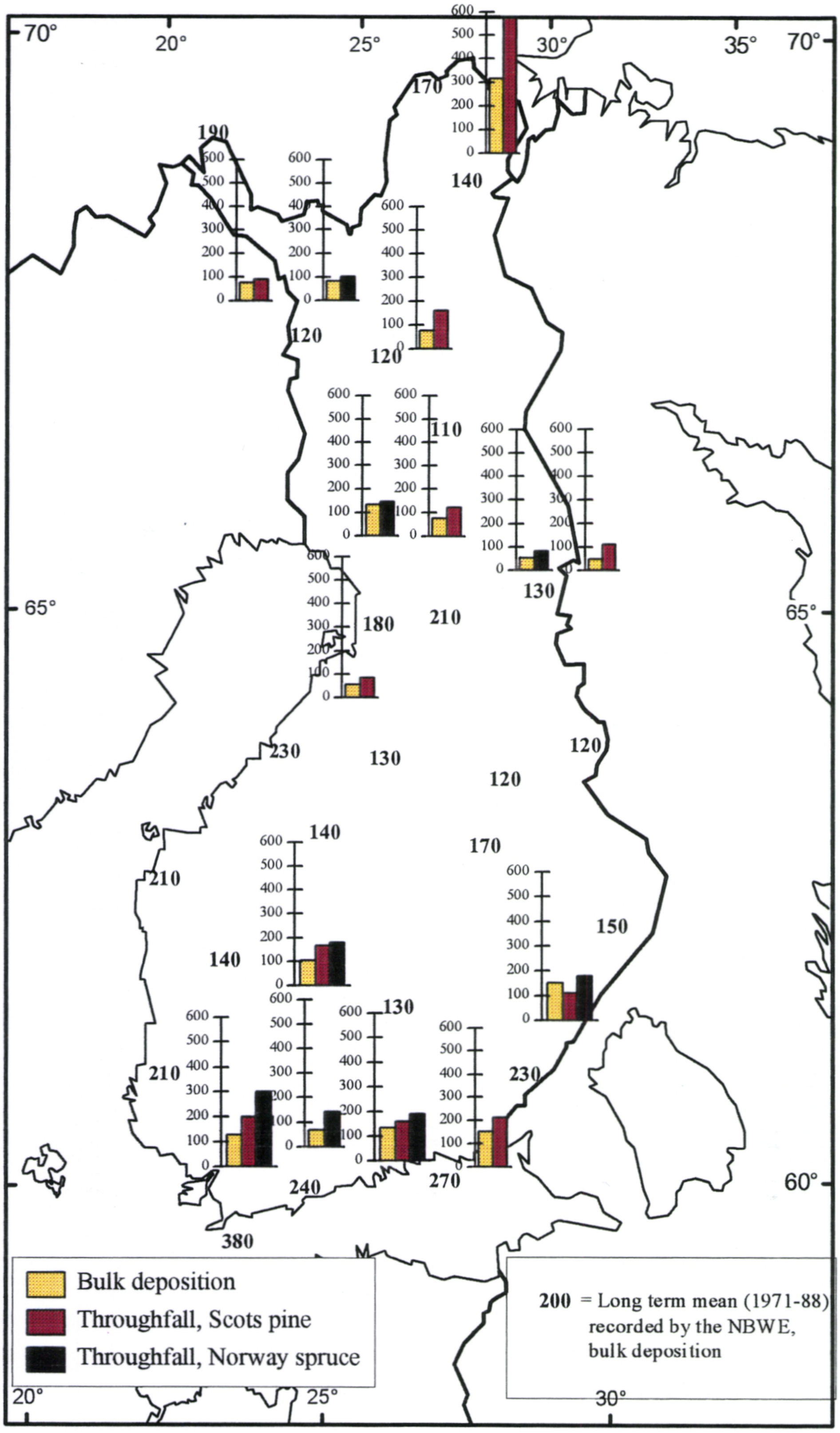

Fig. 26. Na deposition (mg/m^2/a) during 1.1.-31.12.1996. Long term mean values (bulk deposition) are recorded by the National Board of Waters and the Environment (NBWE).

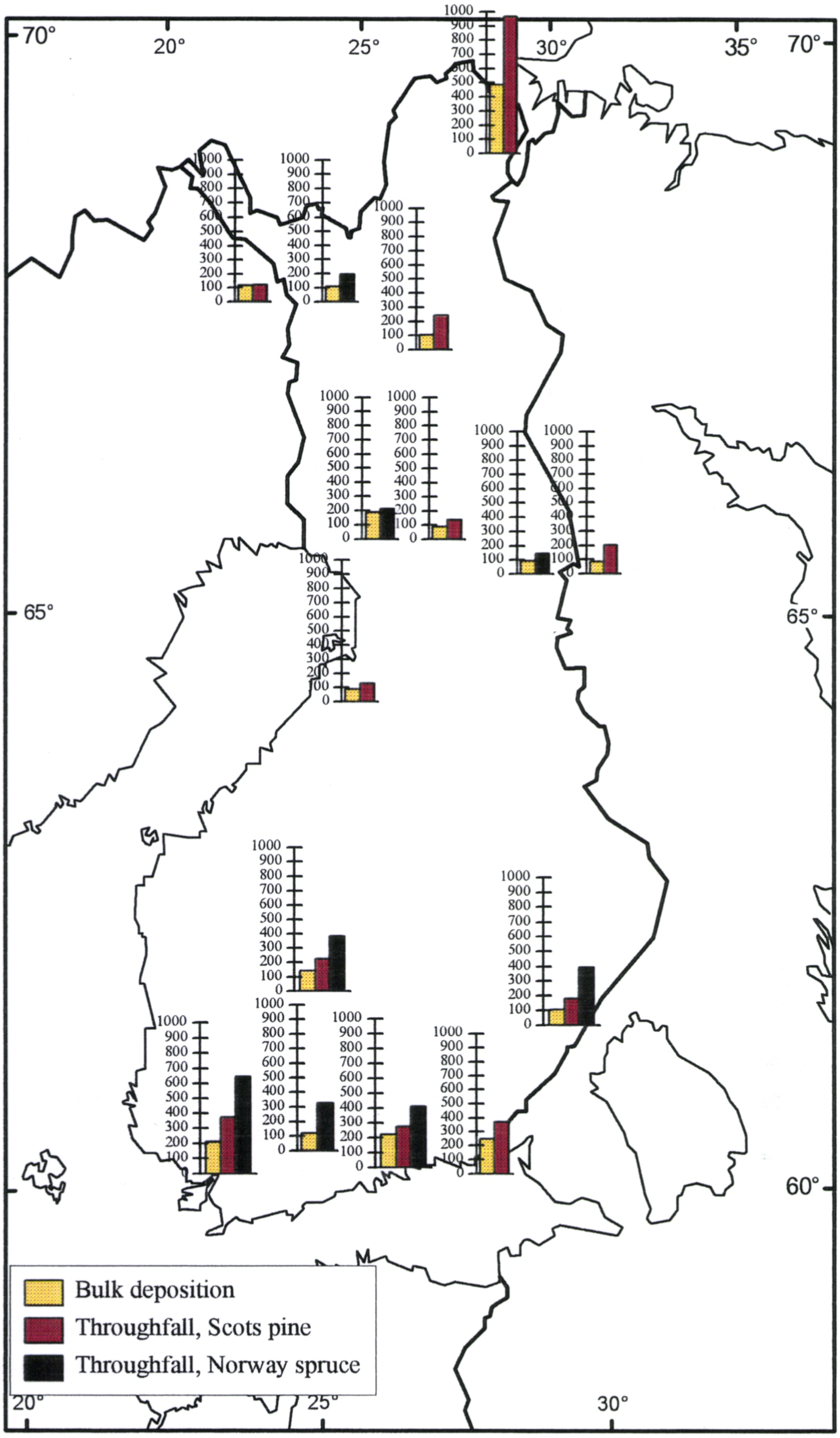

Fig. 27. CL deposition (mg/m^2/a) during 1.1.-31.12.1996.

The following meteorological parameters have been monitored within or above the tree stand:

1. Air temperature above the tree canopy
2. Air temperature within the crown canopy
3. Relative humidity within the crown canopy
4. Wind speed above the tree canopy
5. Wind direction above the tree canopy
6. Photosynthetically active radiation (PAR) above the tree canopy
7. Precipitation under the canopy
8. Soil temperature
9. Soil frost

The meteorological data submitted consist of observations of air temperature, relative humidity, wind speed and wind direction on all the seven, above-mentioned Level II plots with the exception of Juupajoki (No. 11) where wind monitoring was not begun until autumn 1997. Daily sums of precipitation and throughfall have not been monitored. The rain gauge installed on each plot measures precipitation at only one point under the canopy and cannot therefore be used as a measure of throughfall of the stand. However, monthly sums of precipitation and throughfall are included in the datafile with deposition measurements. The photosynthetically active radiation was measured ($\mu molm^{-2}s^{-1}$) instead of total solar radiation (Wm^{-2}). Soil temperature data have not been submitted.

Technical remarks

The most serious problems in the meteorological observations were caused by a thunderstorm on the 3rd of July, 1996 near the Tammela (Plot No. 12) weather station. This damaged the datalogger hardware and resulted in the loss of data for the period 5.6.-22.8.1996. There have also been problems with the functioning of the wind monitor and PAR sensor at this station resulting in incomplete series of wind observations during 14.4.-6.5. 1996.

There were some problems with the power supply during the winter at all the three weather stations established in 1995. This was rectified by installing solar panels and car batteries as an auxiliary power supply. The most serious problems at Pallasjärvi (Plot No. 3) were associated with the lap-top computer, which did not function at temperatures down to -30°C.

Weather conditions in 1996 in Finland

Compared to the long-term statistics, the weather conditions in Finland in 1996 were not exceptional (Finnish Meteorological Institute 1997). However, the weather during the summer months June-August was somewhat anomalous: a period of cool, rainy weather started in the middle of June and continued up until almost the end of July. In contrast, August was exceptionally warm: as warm an August as that in 1996 occurs only once a decade (Finnish Meteorological Institute 1997). Hence, August 1996 was more than 2°C warmer than July (Fig. 28) although statistically July is the warmest month of the year. The rainy period in midsummer 1996 may have provided favourable conditions for infection by fungal diseases, e.g. *Gremmeniella abietina*. It will be interesting to see whether these conditions promote an increase in biotic damage in forest stands in 1997.

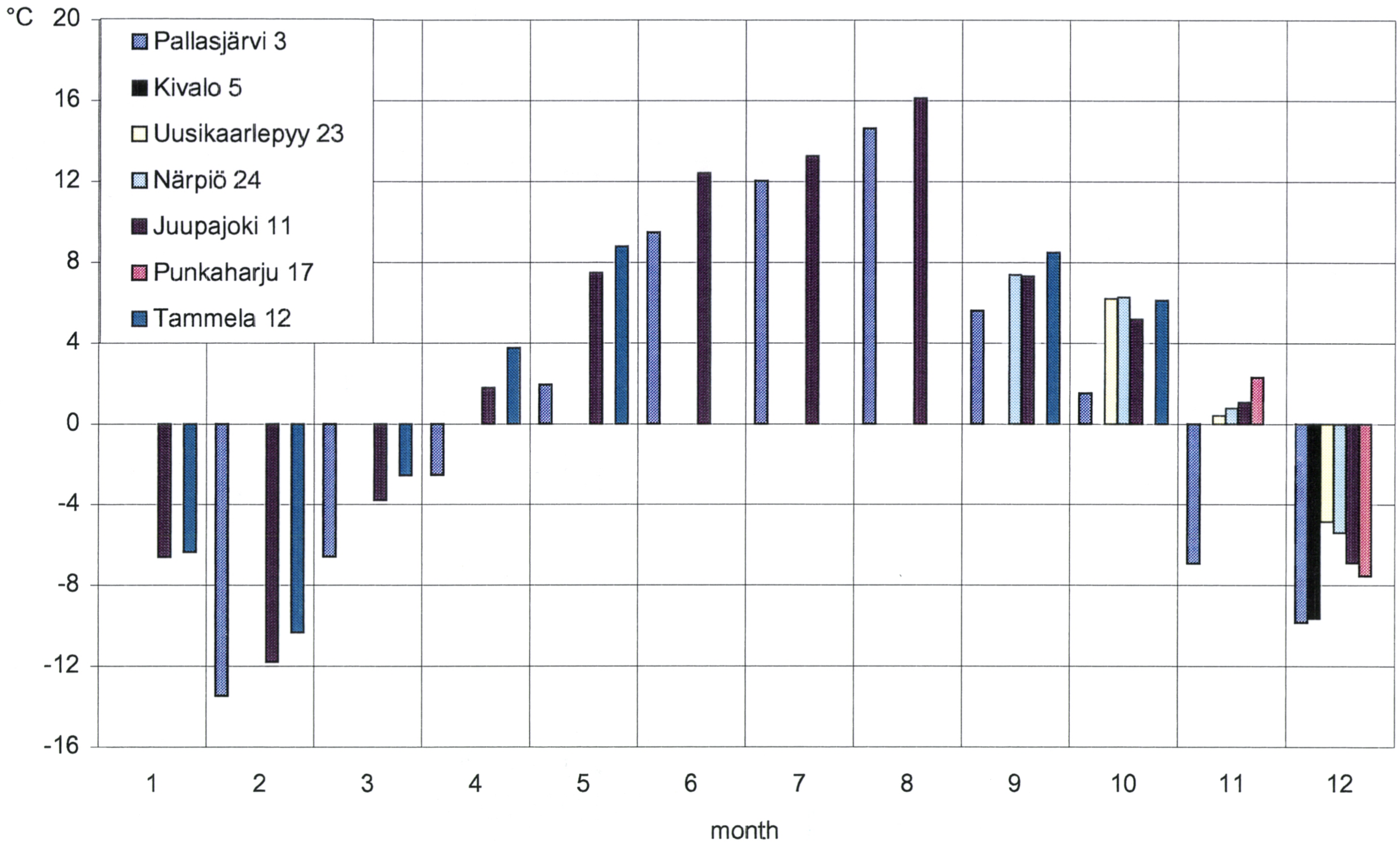

Fig. 28. Mean monthly temperatures on Level II plots (from north to south) with meteorological measurements in 1996.

7. The relationship between tree vitality and deposition

The amount and quality of phytomass are important indicators of tree condition, because changes in the assimilation surface affect stem growth (Dong & Kramer 1987), root functioning (Eichorn et al. 1988) and nutrient allocation. However there are many factors which cause defoliation and discoloration, including tree age, needle senescence, soil type, nutrient status, pathogens, insects, competition for light, air pollution etc. During the past decades air pollutants have become a serious threat to forest health. Long-term changes in the nutrient status caused by acidifying deposition might play an important role in determining the state of health of forest ecosystems (Ulrich et al 1979).

The relationships between tree vitality (defoliation and discoloration) and deposition were studied on 19 observation plots. Despite the limited amount of data, this part of the report deals with the covariation between deposition (bulk deposition and throughfall), including H^+, sulphate and nitrogen deposition, and tree age and tree vitality. The estimation of defoliation and discoloration are generally accepted methods for assessing the vitality of trees. The standwise average defoliation degree of spruce and pine correlated significantly with tree age (Table 4), i.e increasing defoliation with increasing age. Although in this case the correlation was stronger in pine, results based on larger datasets have shown stronger correlation in spruce (EC-UN/ECE 1997). In general, the degree of defoliation varies between 10 to 20% on pine plots, and 2 to 60% on spruce plots, in most cases being below 20%. The degree of discoloration averaged less than 10% on the plots and there was no correlation with age (Table 5).

Table 4. Correlation between defoliation (5% defoliation classes, plot average) and age and deposition (BD = bulk deposition and TF = stand throughfall)

	Pine n = 11		Spruce n = 8	
	r	p	r	p
Age	0.89	0.000	0.69	0.059
BD:				
H^+	0.02	0.637	0.57	0.141
SO_4-S	0.07	0.837	0.56	0.151
N-Tot	0.21	0.544	0.58	0.132
TF:				
H^+	0.17	0.617	0.55	0.173
SO_4-S	0.11	0.752	0.51	0.205
N-Tot	0.23	0.500	0.46	0.257

Correlation between deposition (H^+, sulphate, nitrogen) and defoliation/discoloration was studied separately for the two tree species. There was no significant correlation between deposition (H^+, SO_4-S, N) and defoliation (Table 4). Although the correlations were not statistically significant, the correlation coefficient (r) was mainly higher in spruce. There was weak linear correlation between discoloration and deposition on the spruce plots (Table 5), primarily due to the two northernmost spruce plots (Nos. 3 and 21) where discoloration was the strongest. Pine did not show any significant correlation between deposition and discoloration, probably because the degree of discoloration was low.

Table 5. Correlation between discoloration (discoloration >10 % in the share of trees) and age and deposition (BD = bulk deposition TF = throughfall)

	Pine n = 11		Spruce n = 8	
	r	p	r	p
age	0.070	0.847	0.343	0.405
BD:				
H^+	0.185	0.585	0.576	0.135
SO_4-S	0.148	0.663	0.674	0.067
N-Tot	0.119	0.728	0.680	0.063
TF:				
H^+	0.235	0.487	0.663	0.073
SO_4-S	0.223	0.510	0.686	0.060
N-Tot	0.176	0.604	0.653	0.079

The results indicate that there may be weak relationships between deposition and defoliation/discoloration, but it is clear that age and geographical location are the main factors causing defoliation and discoloration under Finnish conditions. Similar conclusions have been drawn by the Finnish part of the Programme for the Crown Condition of European Forests (level I), which is based on 10 years' monitoring of a systematic grid of sample plots (EC-UN/ECE 1997). However, the primary purpose of this study is to provide a starting point for the temporal and spatial analysis of the relationship between deposition and tree vitality.

8. Pilot studies

8.1 Girth band for determining tree-diameter changes during the growing period.

Kari Mielikäinen and Erkki Pesonen

The prototype of a simple girth band for the automatic measuring of short-term changes in stem diameter was developed and tested in 1993-1995. The testing of about fifty bands showed that these bands can be used to measure diameter changes of the magnitude of 0.03 mm, thus permiting diameter changes to be monitored on a daily basis. The formation of individual cell layers within the annual rings can also be determined as long as the swelling and shrinkage of the stem and the real growth can be separated from each other. The durability and low price of the equipment and the capacity to collect data automatically make the band suitable for obtaining answers to practical issues in the field of forest science. On-line transfer of data from the field (the bands attached to trees) to the office can soon be done via telemetry.

Key-words: annual ring, daily growth, girth band, growth variation.

9. Cooperation

In 1993, five international organizations - FAO, ICSU, UNEP, UNESCO and WMO - decided to co-sponsor the planning process for a Global Terrestrial Observing System (GTOS). GTOS is intended to provide the data basis and observational framework needed to understand and address the impacts of global change on terrestrial, including freshwater, ecosystems. The Terrestrial Ecosystem Monitoring Sites (TEMS) database, which is an international directory of meta-data about monitoring stations and their activities, has been established to document existing long-term monitoring sites that may be suitable for inclusion in the GTOS network once it has been established. The Finnish ICP level II monitoring plots are included in the TEMS database.

The data collected on the monitoring plots in northern Finland will be regularly submitted for inclusion in the database of the Arctic Monitoring and Assessment Programme (AMAP).

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