ACTA FORESTALIA FENNICA

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LEENA FINÉR

BIOMASS AND NUTRIENT CYCLE IN FERTILIZED AND UNFERTILIZED PINE, MIXED BIRCH AND PINE AND SPRUCE STANDS ON A DRAINED MIRE

BIOMASSA JA RAVINTEIDEN KIERTO OJITUSALUEEN LANNOITETUSSA JA LANNOITTAMATTOMASSA MÄNNIKÖSSÄ, KOIVU-MÄNTYSEKAMETSIKÖSSÄ JA KUUSIKOSSA

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ACTA FORESTALIA FENNICA 208

BIOMASS AND NUTRIENT CYCLE IN FERTILIZED AND UNFERTILIZED PINE, MIXED BIRCH AND PINE AND SPRUCE STANDS ON A DRAINED MIRE

Biomassa ja ravinteiden kierto ojitusalueen lannoitetussa ja lannoittamattomassa männikössä, koivu-mäntysekametsikössä ja kuusikossa

Leena Finér

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At the beginning of the investigation period the total biomass of the pine stands on the ordinary sedge pine mire was 48 tn/ha. The biomass of the mixed stands on the herbrich sedge pine mire was 91 tn/ha, out of which about 60 % was from pine. The biomass of the spruce stands on the *Vaccinium myrtillus* spruce mire was 148 tn/ha. The average annual net increment of the stand biomass was 5.8 tn/ha in the unfertilized pine stand and 6.7 tn/ha in the NPK and micronutrient fertilized one during the six-year investigation period. The corresponding figures in the mixed stand were 7.2 tn/ha and 7.6 tn/ha. The net increment of the biomass in the unfertilized spruce stand was 6.9 tn/ha and in the fertilized one 8.4 tn/ha. A considerable proportion of the net increment was lost to the ground as litter in all stands.

The nitrogen, phosphorus, potassium, calcium, magnesium, iron, manganese, zinc, copper and boron cycles were investigated. The annual nitrogen uptake from the soil was 26–42 kg/ha, that of phosphorus 2.5–3.4 kg/ha, potassium 4.5–12 kg/ha, calcium 12–29 kg/ha, magnesium 2–4 kg/ha, iron 1.4–6.6 kg/ha, manganese less than 2 kg/ha and the other nutrients only some grammes. Only part of the fertilizer nutrients was fixed in the stand.

Varsinaisella nevarämemuuttumalla kasvavan männikön kokonaisbiomassa oli tarkastelujakson alussa 48 tn/ha. Ruohoisella nevarämemuuttumalla kasvavan sekametsikön biomassa oli 91 tn/ha, josta männyn osuus oli n. 60 %. Mustikkakorpimuuttuman kuusikon biomassa oli 148 tn/ha. Biomassan keskimääräinen vuotuinen nettokasvu kuuden vuoden tarkastelujakson aikana oli lannoittamattomassa männikössä 5,8 tn/ha ja NPK ja hivenlannoitetussa 6,7 tn/ha. Sekametsikössä vastaavat luvut olivat 7,2 tn/ha ja 7,6 tn/ha. Lannoittamattomassa kuusikossa biomassan nettokasvu oli 6,9 tn/ha ja lannoitetussa 8,4 tn/ha.

Tukimuksessa seurattiin typen, fosforin, kaliumin, kalsiumin, magnesiumin, raudan, mangaanin, sinkin, kuparin ja boorin kiertoa puustossa. Metsiköt ottivat maasta vuosittain typpeä 26–42 kg/ha, fosforia 2,5–3,4 kg/ha, kaliumia 4,5–12 kg/ha, kalsiumia 12–29 kg/ha, magnesiumia 2–4 kg/ha, rautaa 1,4–6,6 kg/ha, mangaania alle 2 kg/ha ja muita ravinteita vain muutamia grammoja. Lannoiteravinteista vain osa sitoutui puustoon.

Keywords: biomass allocation, fertilization, nutrient cycle, peatland, stand modelling, *Pinus sylvestris, Betula pubescens, Picea abies.*
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Mänttä 1989. Mäntän Kirjapaino Oy

PREFACE

The material was collected from the experiments of Ahvensalo in Ilomantsi, eastern Finland, set up for the nationwide project of LAVAME, "the Effect of Fertilization on the Forest Ecosystem". The experiments had been established as a collaboration between the Joensuu University, Enso Gutzeit Oy, Kemira Oy and the Finnish Forest Research Institute in 1979. The aim was to compare the effects of both slowly and easily soluble nitrogen, phosphorus and potassium fertilizers as well as those of a micronutrient mixture and ash fertilization.

The material for the peat nutrient characteristics was collected by researchers Juha Miettinen and Juha Paakkola under the supervision of Associate Professor Seppo Pasanen at the Joensuu University. The litter material was partly collected by researchers Jukka Välijoki and Heikki Aaltonen under the supervision of Dr Jouko Silvola at the Joensuu University.

The collection of the stand material was undertaken by the Finnish Forest Research Institute. The field work was supervised by Mr Jorma Issakainen, the forest engineer, in 1979 and Mr Markku Tiainen, the forest technician, in 1985. The extensive laboratory work was supervised by Ms Anna-Liisa Pesonen, the laboratory assistant and Mr Pekka Järviluoto, the research assistant. The technical finishing of the manuscript was done by Ms Leena Karvinen and Ms Päivi Mäkkeli. The text was translated into English by Ms Leena Kaunisto, M.A.

Professor Eero Paavilainen, Professor Juhani Päivänen, Dr Seppo Kaunisto, Dr Jukka Laine and Lic. Sc. Jussi Saramäki have read the manuscript and given valuable advice.

I wish to extend my best thanks to the above-mentioned persons and several others who have contributed to the completion of my work.

Joensuu, August 1989

Leena Finér

SYMBOLS – *MERKINNÄT*

r^2 = coefficient of determination – *selitysaste*
s_e = residual standard deviation – *jäännöshajonta*
$s_e\%$ = relative standard error – *suhteellinen keskivirhe* = $100 \times \sqrt{e^{s_e^2}-1}$
n = number of observations – *havaintojen lukumäärä*
$a_{1...n}$ = parameters – *parametrejä*
d = over-bark breast-height diameter, cm – *kuorellinen rinnankorkeusläpimitta, cm*
d_u = under-bark breast-height diameter, cm – *kuoreton rinnankorkeusläpimitta, cm*
h = *height, m – pituus, m*
cl = crown limit, m – *latvusraja, m*
cr = crown ratio – *latvussuhde*
b = bark thickness, mm – *kuoren paksuus, mm*
i = stem age, a – *rungon ikä, a*
i_o = branch age, a – *oksan ikä, a*
d_o = branch diameter at 3 cm distance from stem, mm – *oksan läpimitta 3 cm etäisyydeltä rungosta, mm*
h_o = branch length, cm – *oksan pituus, cm*
S = relative branch position in crown from top down: 5 %, 15 %, 25 %, 35 %, 45 %, 60 %, 85 % – *oksan suhteellinen sijainti latvuksessa latvasta lukien asteikolla: 5 %, 15 %, 25 %, 35 %, 45 %, 60 %, 85 %*
G = stand basal area, m^2/ha – *puuston pohjapinta-ala, m^2/ha*
V = over-bark stand volume, m^3/ha – *puuston tilavuus kuorineen, m^3/ha*
M_s = stemwood biomass, kg – *runkopuun biomassa, kg*
M_b = bark biomass of stem, kg – *rungon kuoren biomassa, kg*
M_{oo} = over-bark branch biomass without foliage, g – *oksan kuorellinen biomassa ilman lehtiä, g*
M_{no} = annual foliage biomass of branch, g – *oksan lehtivuosikerran biomassa, g*
M_o = over-bark branch biomass of live crown without foliage, g – *puun elävän latvuksen kuorellinen oksabiomassa ilman lehtiä, g*
M_n = annual foliage biomass of live crown, g – *puun elävän latvuksen lehtivuosikerran biomassa, g*
M_r = biomass of stump and coarse roots, kg – *puun kanto- ja paksujuurten biomassa, kg*
M_c = cone biomass, g – *puun käpyjen biomassa, g*
M_d = biomass of dead branches in crown, g – *puun latvuksen kuolleiden oksien biomassa, g*
I_s = biomass increment of stemwood after fertilization, kg/a – *runkopuun biomassan kasvu lannoituksen jälkeen, kg/a*
I_{oo} = over-bark biomass increment of live branch after fertilization, g/a – *elävän oksan oksabiomassan kuorellinen kasvu lannoituksen jälkeen, g/a*
I_o = biomass increment of live branches after fertilization, g/a – *puun elävien oksien oksabiomassan kasvu lannoituksen jälkeen, g/a*
I_d = biomass increment of dead branches after fertilization, g/a – *puun kuolleiden oksien biomassan kasvu lannoituksen jälkeen, g/a*
N_o = nutrient concentration of compartment, % of dry matter in 105 °C – *ositteen ravinnepitoisuus, % kuiva-aineesta 105 °C*

CONTENTS

1. INTRODUCTION

Knowledge of the biomass of different tree components and nutrient cycle is a basis for fertilization and essential for investigating the continuous and sustainable wood production capacity of drained peatlands. The most important components in the nutrient cycle of the peatland ecosystem are trees, understorey vegetation, peat and decomposing organisms. Vegetation fixes nutrients to its biomass from the substrate and returns them as litter back to the ground. Decomposing organisms release nutrients from the litter making them again available to plants. The most important nutrient stores in the peatland ecosystem are in peat and vegetation. Drained peatland receives additional nutrients from deposition and fertilizers. Shallow peat layers also receive nutrients from the underlying mineral soil. Nutrients are removed from the peatland ecosystem by leaching and harvesting. Continuous wood production on peatland may exhaust especially the potassium stores of the root layer (Holmen 1964, 1969, Braekke 1987, Kaunisto and Paavilainen 1988).

Only few investigations on biomass and nutrition have been carried out on peatland in Nordic countries. Holmen (1964) has investigated the above-ground biomass and nutrient cycle on a pine and spruce mire in Sweden. In Finland Paavilainen (1980) and in Sweden Schroeder and Svensson (1978) have investigated the nutrient conditions and biomass on a dwarf-shrub pine mire. Vasander (1981, 1982) has introduced results on biomass and nutrient cycle on a sparsely stocked raised pine mire in Finland. Albrektson (1980) collected material also from peatland for his investigation on pine biomass. Some investigations on biomass have also been carried out in conifer plantations (Braekke 1986) and in very dense young hardwood tree stands (Simola 1977, Björklund and Ferm 1982) on peatland. Furthermore, a number of investigations have focused only on root biomass (Heikurainen 1958, Hakkila 1972, Hakkila and Mäkelä 1973, Paavilainen 1967) and their nutrient concentrations (Paavilainen 1968, 1969).

The nutrient regime on peatlands can be improved by fertilization. The fertilization investigations have usually focused on the height, radial and volume growth of trees and changes in the foliar nutrient concentrations. Besides the increment of stems also the needle mass increases, which is known to lead to a higher photosynthetic capacity (Kellomäki 1978). It is not, however, yet fully known how the photosynthetic products brought on by fertilization are allocated to different compartments of trees: foliage, branches, stems and roots, and what proportion of the applied fertilizers eventually becomes available to trees.

The aim was to investigate the biomass, biomass increment and nutrient cycle in pine, mixed birch and pine, and spruce stands on drained mire. In addition, the effect of fertilization was studied.

2. MATERIAL AND METHODS

21. Research method

Sampling took place in both fertilized and unfertilized stands. The acquired material was used for formulating equations with the regression method. The equations were used for the simulation of stand biomass and nutrient cycle from the outset of fertilization till six years after the fertilization.

Measurements were carried out from different compartments of trees and the biomass equations were formulated according to the following table:

Tree compartment	Equations
Stem	Individual tree equations based on sample trees
Branches and leaves	Individual branch equations based on sample branches ——> individual tree equations based on sample trees
Stump and coarse roots	Individual tree equations based on sample trees
Fine roots	Single account of stands using systematic core sampling ——> individual tree equations

The following equations for trees of stands were formulated for estimating the increment of stand biomass:

Tree compartment	Increment equations
Stemwood	Individual tree equations based on sample trees
Branches	Individual branch equations based on sample branches ——> individual tree equations based on sample trees
Leaves	On the basis of individual tree biomass equations
Stump and coarse roots	On the basis of the ratio between stemwood biomass and its increment
Fine roots	On the basis of the biomass of fine roots and references
Litter fall	Collection of above-ground litter fall at the stand level ——> individual tree equations

Except litter fall the material was collected six years after fertilization.

22. Sampling

221. Experiments and treatments

The material was collected from three experiments at Ahvensalo in Ilomantsi, eastern Finland (62° 51′ N, 30° 53′ E, 155 m a.s.l.). The experiments were situated in the same drainage area each at a different site. All the sites were transforming mires where the effect of drainage is perceptible in the growing stock, but they have not yet reached the final stage of succession after drainage. One of the sites was an ordinary sedge pine mire (VNRmu), the other a herbrich sedge pine mire (RhNRmu) and the third a *Vaccinium myrtillus* spruce mire (MKmu) according to the classification by Heikurainen and Pakarinen (1982). A 40–50-year-old Scots pine stand (*Pinus sylvestris*) grew on the ordinary sedge pine mire. There were some birches (*Betula pubescens*) as well. Although the stand was rather aged, it had only recently passed the pole stage. The peat layer was over one metre thick. A 40–60-year-old mixed birch and pine stand with some Norway spruce grew on the herbrich sedge pine mire. Nearly all the birches belonged to the *Betula pubescens* species. The peat layer was over one metre thick at this site. The Norway spruce stand (*Picea abies*) on the spruce mire was a little over a hundred years old. Some birches and pines grew in the spruce stand. The average thickness of the peat layer was less than a metre.

The nutrient amounts in the root layer of peat (Table 1) were calculated according to Pasanen (1980, 1981) and Pasanen et al. (1983).

The experiments were set up in 1979, when 12–25 plots of 900–1 200 m^2 were chosen at each site (see Silvola et al. 1985). The experimental area had been drained for the first time in the 1930s. Supplementary drainage had been carried out in the 1960s. The old ditches were cleaned when the experiments were set up, and ditches were dug on all the borders of the plots at the turn of July and August in 1979. Fertilizers were spread in the autumn of 1979. There were seven fertilization treatments with an average of two replicates (see e.g. Silvola et al. 1985). This investigation focused on the unfertilized and the NPK and micronutrient treatments. This treatment involved the spreading of the following nutrients:

Nutrient	kg/ha
N	100
P	40
K	60
Ca	180
Mg	105
Mn	5.5
Fe	116
Zn	5.6
Cu	12.8
B	1.1

Nitrogen was given as urea, phosphorus as apatite, potassium as biotite and micronutrients as a commercial micronutrient mixture. Two fertilized and two unfertilized plots at each site were sampled. The most important stand characteristics of these plots are presented in Table 2.

Table 1. Nutrient reserves in the 0–20 cm peat layer at different sites (kg/ha).
Taulukko 1. Ravinnevarat 0–20 cm turvekerroksessa eri kasvupaikoilla (kg/ha).

Nutrient *Ravinne*	VNRmu	RhNRmu	MKmu
N	2570	5880	4970
P	125	380	310
K	90	220	235
Ca	830	1650	1800
Mg	140	200	250
Fe	340	1295	1110
Mn	9	19	55
Zn	17	16	23
Cu	1.0	2.5	1.9

222. Measurements

2221. Basic measurements

The breast-height diameter (with 1 cm precision) was measured from all the trees with over 5 cm at breast height before the growing season in 1980. In 1985 4–20 sample trees per each species were chosen from each plot by using the optimum allocation as regards the volume. Each sample tree was measured for the breast-height diameter (with 1 mm precision), the crown limit (with 0.1 m precision) and the bark thickness (with 1 mm precision). These measurements were carried out for formulating equations for the height, crown limit and bark thickness.

2222. Biomass sample trees

Sample tree characteristics

In 1985 3–5 biomass sample trees of the tree species in question were chosen from each plot by using stratified random sampling based on breast-height diameter.

Table 2. Stand characteristics of sample plots in 1985.
Taulukko 2. Koealojen puustotunnukset v. 1985.

Plot No. [*)] *Koealan n:o* [*)]	Fertilization *Lannoitus*	Tree species *Puulaji*	Stems *Runkoluku* –/ha	Mean diameter *Keskiläpimitta* cm	Mean height *Keskipituus* cm	Volume *Tilavuus* m^3/ha
				VNRmu		
8[1)3)]	0	pine –	990	14	11	68
23[1)2)]	0	*mänty*	1108	15	11	78
13[1)3)]	UABM	-"-	1020	15	12	97
24[1)2)]	-"-	-"-	1617	13	10	82
8[1)]	0	birch –	0	0	0	0
23[1)]	0	*koivu*	275	11	10	9
13[1)]	UABM	-"-	50	15	12	6
24[1)]	-"-	-"-	217	10	9	6
				RhNRmu		
2[1)]	0	pine –	1097	16	15	147
12[1)2)3)]	0	*mänty*	357	20	16	70
3[1)]	UABM	-"-	397	18	16	72
11[1)2)3)]	-"-	-"-	314	19	17	55
2[1)]	0	birch –	139	13	14	10
12[1)2)3)]	0	*koivu*	579	16	16	70
3[1)]	UABM	-"-	846	14	15	57
11[1)2)3)]	-"-	-"-	1100	17	16	94
				MKmu		
2[1)2)]	0	spruce –	731	22	18	164
5[1)3)]	0	*kuusi*	661	23	19	177
1[1)2)]	UABM	-"-	702	25	20	227
9[1)3)]	-"-	-"-	673	24	19	161
2[1)]	0	birch –	125	19	17	14
5[1)]	0	*koivu*	131	19	17	22
1[1)]	UABM	-"-	49	18	17	6
9[1)]	-"-	-"-	148	18	18	28

[1)] Plot for stand biomass – *Puuston biomassakoeala*
[2)] Plot for root biomass – *Juuriston biomassakoeala*
[3)] Litter collecting plot – *Karikkeenkeruukoeala*
[*)] see Silvola et al. 1985 – *Ks. Silvola ym. 1985*

Table 3. Characteristics of biomass sample trees.
Taulukko 3. Biomassakoepuutunnuksia.

Characteristic *Tunnus*	VNRmu Pine *Mänty* 0	UABM	RhNRmu Pine *Mänty* 0	UABM	RhNRmu Birch *Koivu* 0	UABM	MKmu Spruce *Kuusi* 0	UABM
d, cm								
x̄	13	13	17	17	13	13	19	19
std	6	7	6	5	5	6	10	10
min	6	5	9	10	8	6	6	6
max	22	25	24	25	21	23	37	37
h, m								
x̄	10.8	10.9	15.4	16.4	14	14.1	15.3	15.7
std	2.8	3.5	1.9	1.7	2.4	2.9	6.1	7.0
min	5.9	5.0	13.1	13.7	10.0	10.1	5.2	5.4
max	14.4	14.8	18.2	18.2	16.2	19.6	22.0	24.2
cl, m								
x̄	4.6	4.2	9.6	10.1	6.2	7.0	6.5	6.9
std	1.8	1.3	1.0	1.1	1.2	1.3	3.0	3.2
min	2.1	1.7	8.5	8.6	5.2	5.1	3.0	3.0
max	6.9	5.5	11.3	11.2	7.6	8.9	11.0	12.0
cr								
x̄	0.58	0.58	0.38	0.38	0.56	0.50	0.55	0.54
std	0.07	0.07	0.06	0.05	0.07	0.10	0.13	0.12
min	0.49	0.49	0.30	0.30	0.46	0.34	0.37	0.40
max	0.69	0.69	0.44	0.46	0.68	0.66	0.73	0.80
i, a								
x̄	51	45	50	48	50	51	140	82
std	16	5	2	2	3	6	81	28
min	42	39	46	45	47	45	48	46
max	87	53	54	51	53	65	307	121
n	8	8	8	8	7	8	9	9

Birches were measured before leaf fall in August and conifers in September-October. The most important tree characteristics are presented in Table 3.

Stem measurements

The sample trees were cut as close to the ground as possible, and the stem length (with 0.1 m precision) and breast-height diameter (with 1 mm precision) were measured. Discs were sawn from different relative heights (0 %, 10 %, 20 %, 30 %, 40 %, 50 %, 60 %, 70 %, 80 %, 90 %) of the stem and from the breast height. The under-bark and over-bark diameters were measured from the discs as well as the diameter increment in six postfertilization years from two opposite directions. The number of annual rings were counted as well.

The fresh volume of wood and bark was determined by immersing the discs in water. The dry mass was determined by weighing the wood and bark of discs after drying to a constant weight (a. 2 days at 60°C). The bark was ground and the powder of each sample tree was combined into one sample for nutrient determinations. The wood was treated in the same way.

All branches

The length of the live crown of the biomass sample trees was measured. The location of the live branches was defined using the following scale: at 0–30 %, 30–50 %, 50–60 %, 60–70 %, 70–80 %, 80–90 %, 90–100 % heights in the live crown measured from the lower limit of the living crown. The length of the main stem of the live branches was measured (with 1 cm precision) and the base diameter was measured from two opposite directions three centimetres from the stem (with 1 mm precision). All the dead branches and cones of at least one year old were detached, and their fresh mass weighed.

Sample branches

Seven live branches were chosen from each sample tree at the relative heights of 15 %, 40 %, 55 %, 65 %, 75 %, 85 % and 95 % from the lower limit of the live crown. Branches were carefully chosen from different directions. In addition to live branches, 10 dead sample branches were randomly chosen from each sample tree.

In the laboratory the live sample branches were divided into compartments according to species in the following way:

pine:
- the 1985 needles (c)
- the 1984 needles (c+1)
- the 1983 or older needles (c≥2)
- branchwood with bark
- cones

birch:
- leaves (c)
- branchwood with bark

spruce:
- the 1985 needles (c)
- the 1984 needles (c+1)
- the 1983 needles (c+2)
- the 1982 needles (c+3)
- the 1981 needles (c+4)
- the 1980 needles (c+5)
- the 1979 or older needles (c≥6)
- branchwood with bark
- cones

The dry mass of each compartment was weighed (with 0.1 g precision). The dead branches were dried and weighed. The age of live sample branches was determined from annual rings at the thick end of the branches and from those of the stem. The different branch compartments and dead branches were combined according to sample trees for nutrient determinations.

2223. Roots

In the spring of 1986 the stump of every other biomass sample tree and roots with diameter bigger than 10 mm were excavated (see Issakainen 1988).

In August 1985 core samples were taken from one fertilized and one unfertilized plot at each site for the determination of the dry mass of fine roots at the stand level (see Finér 1989, see also Table 2). Twenty core samples were taken systematically from each plot with a sampling device, whose cross-sectional area was 24 cm^2. The live moss layer was removed and the core samples were divided into subsamples from the surface down as follows: 0–10 cm, 10–20 cm, 20–40 cm. From the deepest layer a sample was taken only at every fifth sampling point.

The live tree roots were separated from each subsample by rinsing with water in the laboratory. The roots were divided into two diameter classes: ø < 1 mm and 1–10 mm. The roots of different species were separated. The roots were dried and weighed (with 0.001 g precision). For nutrient determinations the fine root samples were combined according to sites and species.

2224. Litter fall

Litter fall was collected from one fertilized and one unfertilized plot at each site since the spring of 1983 (Table 2). Five metal funnels (cross-sectional area 0.5 m^2) were systematically placed at 1.5 m sampling height and two wooden boxes (cross-sectional area a. 0.58 m^2) on the ground. The litter collectors were emptied at two weeks' intervals in the summertime. The wintertime litter fall was collected in May.

The litter of different tree species was separated from each other as well as leaf litter from the rest. Litter was dried and weighed. One-year litter fall was ground for nutrient determinations.

2225. Nutrient determinations

The total concentrations of the following nutrients were determined from the collected stemwood, bark, branch, leaf, root and litter: N, P, K, Ca, Mg, Fe, Mn, Zn, Cu and B. Nitrogen was determined with the Kjeldahl method, phosphorus photometrically with the molybdate-hydrazine method, cations from a hydrochloric acid extract on an atomic absorption spectrophotometer and boron with the azomethine method (Halonen et al. 1983).

23. Equations

231. Stem biomass and biomass increment

The under-bark biomass of stem before and the over-bark and under-bark biomasses after the fertilization of biomass sample trees were calculated by multiplying the corresponding volume by density. The under-bark volume before fertilization and the over-bark and under-bark volumes six years after fertilization were calculated with the Simpson formula (see Laasasenaho 1982). The density of wood and bark was obtained by calculating the mean, weighted with the dry mass, from the densities of the wood and bark of the discs.

The biomass increment of stemwood of the biomass sample trees was calculated as a difference between the prefertilization and postfertilization biomasses.

A regression equation was made between the stemwood and bark biomasses (Appendix 1).

Regression equations were made for the stemwood and bark biomasses as well as the increment of stemwood biomass. The breast-height diameter and height were used as independent variables (Appendices 2, 3). Appendix 4 presents the range of the material on which the equations are based as regards the available characteristics.

232. Crown biomass

Regression equations were formulated on the basis of the live branch material of the biomass sample trees so that the overbark biomass and unevenaged leaf biomasses were explained by the branch diameter and the relative location of the branch in the crown (Appendices 5, 6, 7).

The over-bark biomass of all the live branches of biomass sample trees and the biomass of unevenaged leaves were calculated with these equations. By adding the obtained biomasses the over-bark biomass of the live branches in the crown of each biomass sample tree and the biomass of unevenaged leaves were determined. Regression equations were formulated for the over-bark branch biomass and the biomass of unevenaged leaves. The independent variable was the breast-height diameter and in the case of spruce the crown ratio (Appendices 8, 9).

The biomasses of all the dead branches and over one-year-old cones of sample trees were calculated by using the the fresh mass and dry mass ratio of the dead sample branches and cone of live sample branches. Equations were formulated for the biomass of cones and dead branches (Appendices 10, 11). The range of the material for the crown biomass equations as regards the available characteristics is presented in Appendices 12 and 13.

233. Over-bark branch biomass increment

Equations were made between the over-bark branch biomass of the live sample branches and their age (see Whittaker 1965)(Appendix 14).

The derivative equations of these equations were used for calculating the increment of the over-bark branch biomass of each live sample branch during six postfertilization years.

The biomass increment of sample branches was explained by an equation where independent variables were the branch length and the relative location in the crown in the case of pine, the branch base diameter and the relative location in the crown in the case of birch and the branch base diameter and length in the case of spruce (Appendix 15).

The increment of the over-bark branch biomass of the entire crown in the biomass sample trees was calculated by summing up the branch increments, calculated by the increment equations for branch biomass. The increment of the branch biomass of the crown was explained by an equation where the breast-height diameter was the independent variable (Appendix 16).

Equations were made between the biomass of dead branches and the tree age (Appendix 17). These equations were used for calculating the biomass of the dead branches for each biomass sample tree before fertilization and six years after fertilization. The increment of the biomass of dead branches was obtained as a difference between the above-mentioned biomasses. There were no changes in the biomass of dead birch branches during the investigation period (see also Ovington and Madqwick 1959).

A regression equation was made between the increment of the biomass of dead branches and the breast-height diameter in pine and the tree height in spruce (Appendix 18).

234. Root biomass

Equations were made between the biomass of stump and coarse roots and breast-height diameter of biomass sample trees (Issakainen 1988), (Appendix 19).

The biomass of fine roots was determined at the stand level (Appendix 20). The mean stand characteristics (Table 2) were nearly the same in fertilized and unfertilized plot pairs. Thus the biomass of the fine roots of individual trees was obtained by dividing the stand biomass by the stem number.

235. Litter fall

The litter fall was determined at the stand level (Appendix 21). The annual litter fall of individual trees was calculated by dividing the litter fall by the stem number.

24. Nutrient concentrations of different tree compartments

There was a correlation between the concentrations of some nutrients in the stem and crown and the stem biomass. Regression equations were made between these nutrient concentrations and the stem biomass (Appendix 22). The nutrient concentrations of the stem, crown, cones, stump and thick roots of sample trees are presented in Appendices 23–26. The nutrient concentrations of fine roots and litter fall are in Appendices 27 and 28.

25. Stand simulation

251. Model stands

Two model stands were simulated for each site. One of them was unfertilized and the other fertilized with NPK and micronutrients. The starting point for simulation was the mean stem frequency distribution series of the plots (4 plots at each site) which had been sampled for biomass equations (Fig. 1). The simulation period was six years after fertilization.

The height and crown limit were calculated for the trees of the model stands by using the equations based on the sample tree material (Appendices 29–30). The volume was calculated with equations devised by Laasasenaho (1982), and the postfertilization mean radial increment was obtained from Finér's (1987) material collected from the same sites. The bark thickness was calculated with the equations on bark thickness (Appendix 31). The postfertilization volume increment was calculated as a difference between the postfertilization and prefertilization volumes. This information was used for calculating the most essential stand characteristics for the model stands (Table 4).

252. Biomass and biomass increment

The biomass of the model stands at the beginning of the investigation period was calculated with the equations based on the material collected from unfertilized sample plots (Appendices 2, 8, 9, 10, 11, 19, 20).

The mean annual net increment (net primary production) and increase of the stand biomass was calculated by summing up the net increments and increases of different tree compartments.

The net increment of stemwood and branch biomass in the stand was calculated with the equations of Appendices 3, 16, and 18. The annual increase in stemwood and branch biomass was estimated to be

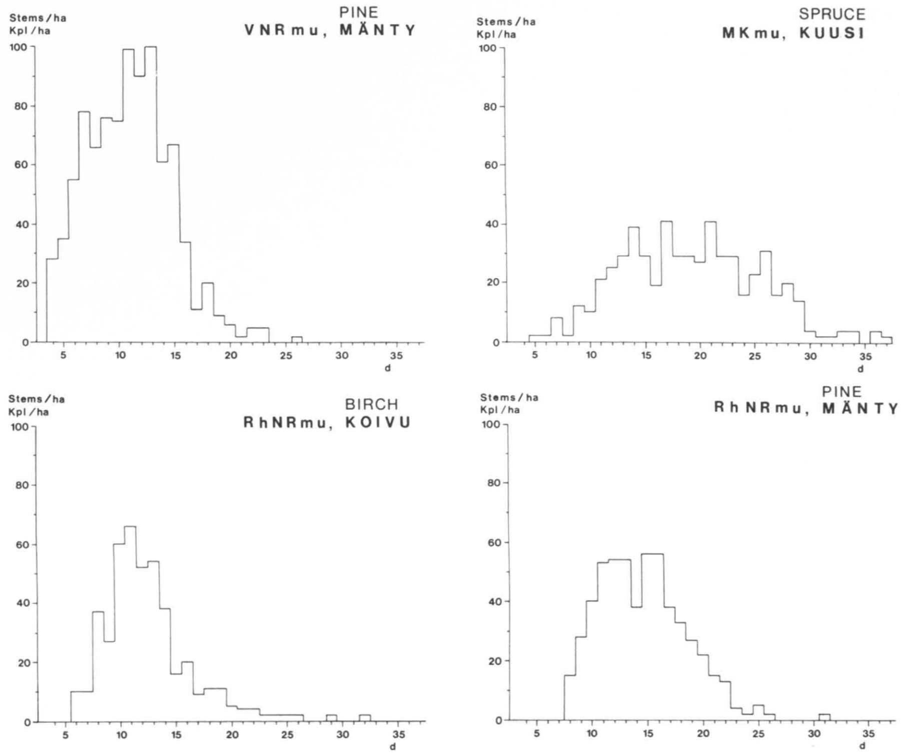

Figure 1. Stem frequency distribution series of model stands at each site and for each tree species.
Kuva 1. Mallimetsiköiden runkolukusarjat kasvupaikoittain ja puulajeittain.

Table 4. Stand characteristics of model stands before fertilization, volume increment after fertilization and volume six years after fertilization.
Taulukko 4. Mallimetsiköiden puustotunnukset ennen lannoitusta, tilavuuskasvu lannoituksen jälkeen ja tilavuus kuusi vuotta lannoituksen jälkeen.

Site *Kasvupaikka*	Tree species *Puulaji*	Stems *Runkoluku –/ha*	Mean diameter *Keskiläpimitta cm*	Mean height *Keskipituus m*	Basal area *Pohjapinta-ala* m²/ha	Volume before fert. *Tilavuus ennen lann.* m³/ha	Volume increment *Tilavuuskasvu* m³/ha/a 0	 UABM	Volume 6 years after fert. *Tilavuus 6 vuotta lann.jälk.* m³/ha 0	 UABM
VNRmu	pine – *mänty*	922	14	9	10	48	2.7	3.8	64	71
RhNRmu	pine – *mänty*	557	17	14	10	72	2.0	3.0	84	90
–"–	birch – *koivu*	443	15	14	6	39	2.0	1.2	51	46
MKmu	spruce – *kuusi*	565	23	19	18	162	4.0	4.5	186	189

equal to the net increment. The net increment and increase of the stem bark was calculated as a difference between the postfertilization and prefertilization bark biomasses. Equations in Appendix 1 were used for calculating the postfertilization bark biomass. The net increment of the foliar biomass was estimated as the mean of three needle sets in pine, as the mean of leaf biomass in birch and as the mean of six youngest needle sets in spruce. Equations in Appendix 9 were used for calculating the foliar biomass after fertilization. The increase in the foliar biomass was calculated as a difference between the postfertilization and prefertilization foliar biomasses.

A logarithmic transformation was used for the calculation of almost all the parameters. In order to correct the underestimate of the regression estimate caused by this transformation a condensed form (Madgwick and Satoo 1975) of the correction term (Finney 1941) was used for calculating the results:

$$k = e^{1/2 S_e^2}$$

k = correction term

s_e^2 = residual variance

The litter fall of the above-ground parts of the stand was estimated on the basis of stand measurements (see Appendix 21).

The annual cone production was estimated to be one half of the cone biomass. The cone biomass at the end of the investigation period was estimated to be the same as at the beginning.

The increment and increase of stump and coarse root biomass of the stands was estimated on the basis of the increment percentage of stems. In several investigations the biomass increment of fine roots has been calculated by using the increment percentage of the above-ground part of the stand (e.g. Mälkönen 1974, Paavilainen 1980). In most cases this leads to an underestimate (see Harris et al. 1977, Grier et al. 1981, Keyes and Grier 1981, Joslin and Henderson 1987, Santantonio and Santantonio 1987). The increment of fine roots, diameter < 1 mm was 0.18–3.5-fold, as compared to the fine root biomass (Gholz et al. 1986, Santantonio and Santantonio 1987). Correspondingly, the increment of fine roots, diameter < 2 mm was 0.5–7-fold and that of 2–5 mm fine roots was 0.6-fold as compared to their biomass (Keyes and Grier 1981, Persson 1979, 1980). Heikurainen (1955a) investigated the growth of fine roots in peat based on a small material. According to his findings < 1-mm-thick fine roots are renewed every third year, 1–2-mm-thick every fifth year and 2–5-mm-thick every tenth year.

The net increment of fine root biomass and litter fall could not be well estimated on the basis of the previous investigations and the collected material. It was estimated that < 1-mm-thick fine roots would be renewed annually and those 1–10 mm every fourth year. The litter production of fine roots was estimated to be the same as their net increment. Thus, no changes in the amount of biomass could be seen in unfertilized stands during the investigation period. The estimate is supported by the knowledge that the fine root biomass increases fast in the young stand stage and then gradually becomes level (Kalela 1949, Heikurainen 1955b).

253. Nutrients fixed in biomass and nutrient cycle

Nutrient amounts fixed in the stand before and after fertilization were calculated as a product of biomass and nutrient concentrations (Appendices 22–27). Nutrient amounts fixed in the biomass increase were calculated as the difference between the prefertilization and postfertilization nutrient amounts fixed in the stand. The nutrient concentration of litter fall was calculated with the values shown in Appendix 28. The nutrient concentration of fine root litter was estimated to be the same as that of live fine roots, which is probably an overestimate, because nutrients may be removed from dying fine roots.

The nutrient uptake of the stand from the soil (and from the air and precipitation) was estimated by adding the nutrient amounts fixed in the biomass increase and litter fall. The annual nutrient consumption of the stand was, however, larger than the nutrient uptake from the soil, because some nutrients have internal cycles in the trees (e.g. Viro 1955). The total annual nutrient consumption of the stand, which is used for the yearly biomass increment, was estimated by adding the nutrients taken from the soil to the amount of nutrients translocated annually from older leaves to the new ones. The nutrient amounts translocated in leaves were calculated by subtracting the nutrient amounts fixed in the average annual net increment of leaves from the nutrient amounts fixed in the net yearly increase of leaf biomass and the litter fall. In addition to leaves, nutrients are translocated also in branches and stem, but it is less significant than translocation in leaves (Lim and Cousens 1986b).

3. RESULTS

31. Biomass and biomass increment of model stands

At the beginning of the investigation period the biomass of the pine stands on the ordinary sedge pine mire was about 48 tn/ha, that of the mixed birch and pine stands on the herbrich sedge pine mire about 91 tn/ha, the proportion of birch being about 40 % (Fig. 2 and Appendix 32). The biomass of the spruce stands on the *Vaccinium myrtillus* spruce mire was about 148 tn/ha.

Before the fertilization the biomass was allocated to different tree compartments in nearly the same proportions in pine and spruce stands. Only the proportion of fine roots of the whole biomass was smaller by over half in the spruce than the pine stands. In the mixed birch and pine stands the proportion of live branches in the birch biomass was twice as much as that of pine. Also the proportion of birch fine roots was twice as large as that of pine. In the mixed birch and pine stands the stem accounted for a bigger and the underground parts, foliage and branches for a smaller part of the biomass than in the pine and spruce stands.

Six years later the biomass of the unfertilized pine stand was about 62 tn/ha, the annual biomass increase being about 2.4 tn/ha. Simultaneously, the biomass of the fertilized pine stand was about 5.2 tn /ha more than that of the unfertilized stand and the annual biomass increase was about 3.3 tn/ha. Thus the annual increase in the fertilized pine stand was about 38 % larger than in the unfertilized one. At the end of the investigation period the biomass of the unfertilized mixed birch and pine stand was about 113 tn/ha and that of the fertilized one about 3 tn/ha more. The biomass increase caused by fertilization was small. Correspondingly the biomass of the unfertilized spruce stand was about 165 tn/ha and that of the fertilized stand about 9.2 tn/ha larger at the end of the investigation period. The annual biomass increase in the unfertilized spruce stand was about 2.8 tn/ha and in the fertilized about 4.4 tn/ha, in other words about 57 % larger than in the unfertilized stand.

The biomass increase caused by fertilization in the pine stand had mainly been allocated to the stem and branches. Both absolutely and relatively the needle and fine root biomasses were smaller in the fertilized than unfertilized pine stand. Although fertilization did not much increase the biomass in

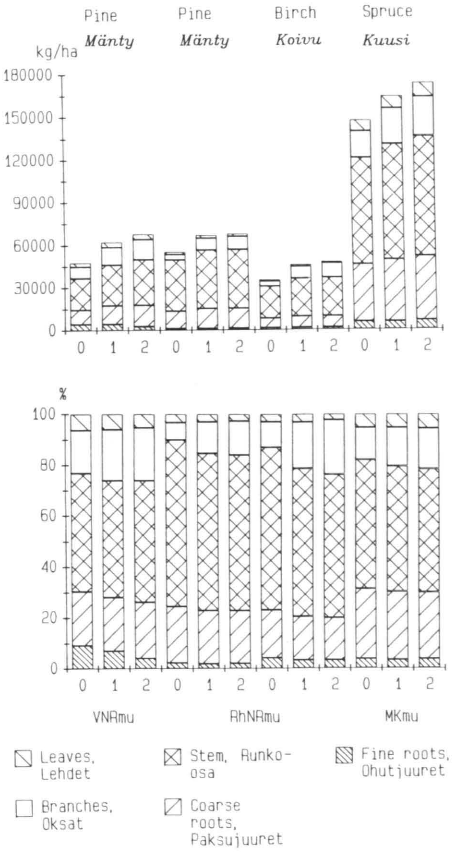

Figure 2. Biomass of model stands before (0) and after fertilization (1 = unfertilized, 2 = fertilized).
Kuva 2. Mallimetsiköiden biomassa ennen (0) ja jälkeen lannoituksen (1 = lannoittamaton, 2 = lannoitettu).

the mixed stand, the results imply that the biomass was allocated more to branches than leaves. In the fertilized spruce stand the biomass increase was quite evenly allocated to all tree compartments.

The annual net increment of biomass in the unfertilized pine stand was about 5.8 tn/ha and in the fertilized one about 6.7 tn/ha or about 14 % larger (Fig. 3 and Appendix 33). The net increments of the fertilized and unfertilized mixed birch and pine stands were almost equally large, namely 7.2 tn/ha and 7.6 tn/ha. The annual net increment of the unfertilized spruce stand was about 6.9 tn/ha and that of the fertilized one about 8.4 tn/ha or about 23 % larger.

A considerable proportion of the net increment was lost to the ground as litter in all stands (see Fig. 3 and Appendix 33). The proportion was clearly bigger in the underground than in the above-ground parts. In the fertilized pine and spruce stands a smaller proportion, a. 10 % of the net increment, was lost to the ground than in the unfertilized stands.

The proportion of stem of the total net increment was bigger in pine than in birch and spruce. Of the above-ground net increment the proportion of stem was smaller in birch than in pine and spruce. The proportion of both the leaves and branches of the total net increment was larger in birch than in pine and spruce. The proportion of fine roots of the net increment in the pine and spruce stands was larger than that of the stem and leaves, and 3–4-fold as compared to stump and coarse roots. In the mixed stands their proportion was of the same magnitude as the net increment of stem.

32. Nutrients fixed in model stands

Nitrogen was the most abundant nutrient fixed in the pine and mixed birch and pine stands (Figs. 4–6 and Appendices 34–35). It constituted nearly half the measured nutrient stores of the stand. Then came calcium with about one fourth of the nutrients. The next were potassium, magnesium and phosphorus. Iron and manganese were the only micronutrients, whose proportions exceeded 1 %. In the spruce stands calcium was the most plentiful nutrient besides nitrogen (Fig 7.). Also manganese was fixed in the spruce stands more than in the other stands. All the other nutrients were in nearly the same proportions as in the other stands.

In all the model stands 65–89 % of all the nutrients, except iron, had been accumulated in the above-ground compartments of trees. Iron was mostly in fine roots. In the

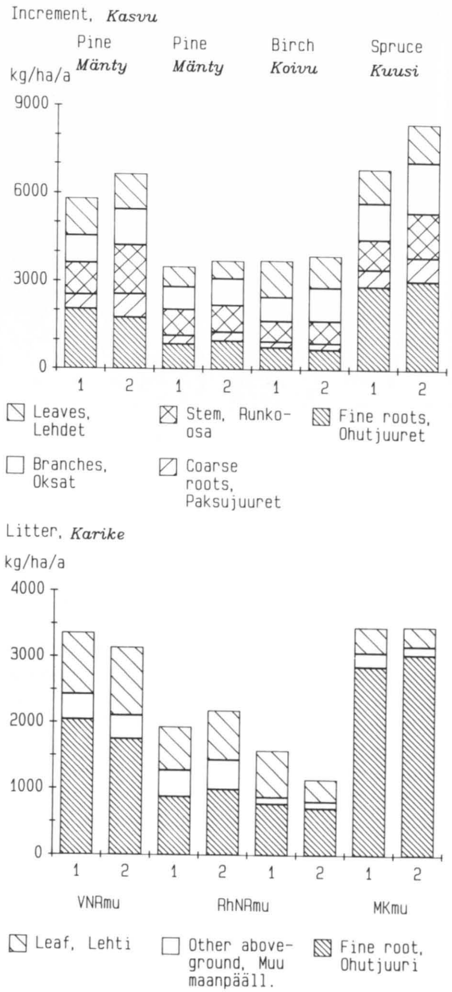

Figure 3. Annual net increment of the biomass and litter production of model stands (1 = unfertilized, 2 = fertilized).
Kuva 3. Mallimetsiköiden biomassan vuotuinen nettokasvu ja karikesato lannoituksen jälkeen (1 = lannoittamaton, 2 = lannoitettu).

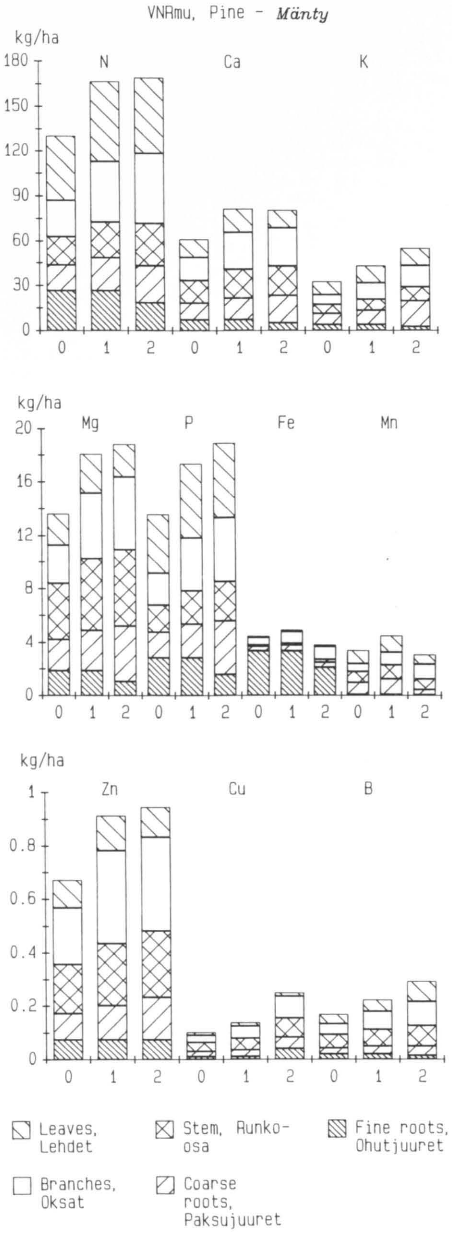

Figure 4. Nutrient amounts fixed in the pine stands before (0) and after fertilization (1 = unfertilized, 2 = fertilized).
Kuva 4. Männikköön ennen (0) ja jälkeen lannoituksen sitoutuneet ravinnemäärät (1 = lannoittamaton, 2 = lannoitettu).

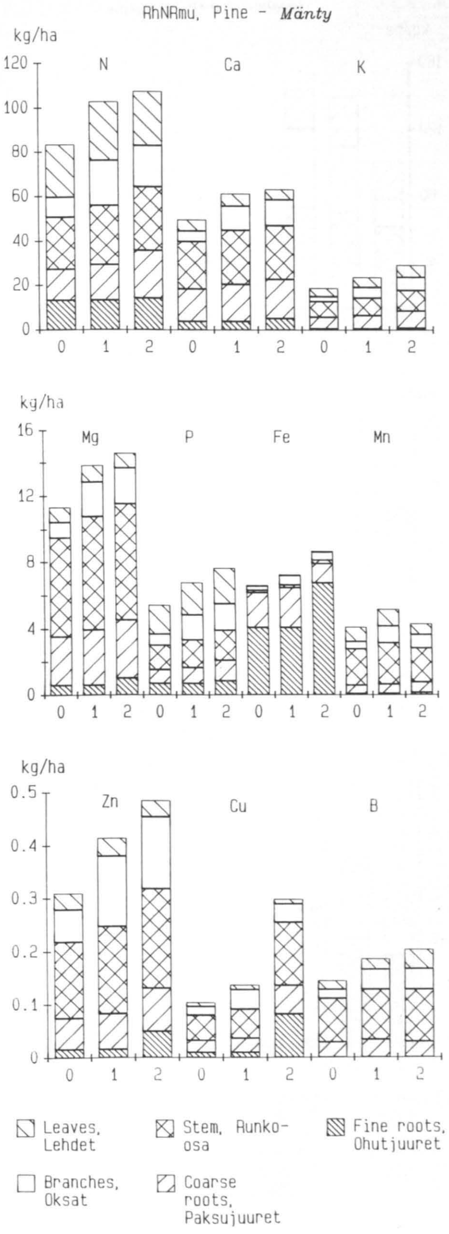

Figure 5. Nutrient amounts fixed in the pines in the mixed birch and pine stands before (0) and after fertilization (1 = unfertilized, 2 = fertilized).
Kuva 5. Sekametsikön mäntyihin ennen (0) ja jälkeen lannoituksen sitoutuneet ravinnemäärät (1 = lannoittamaton, 2 = lannoitettu).

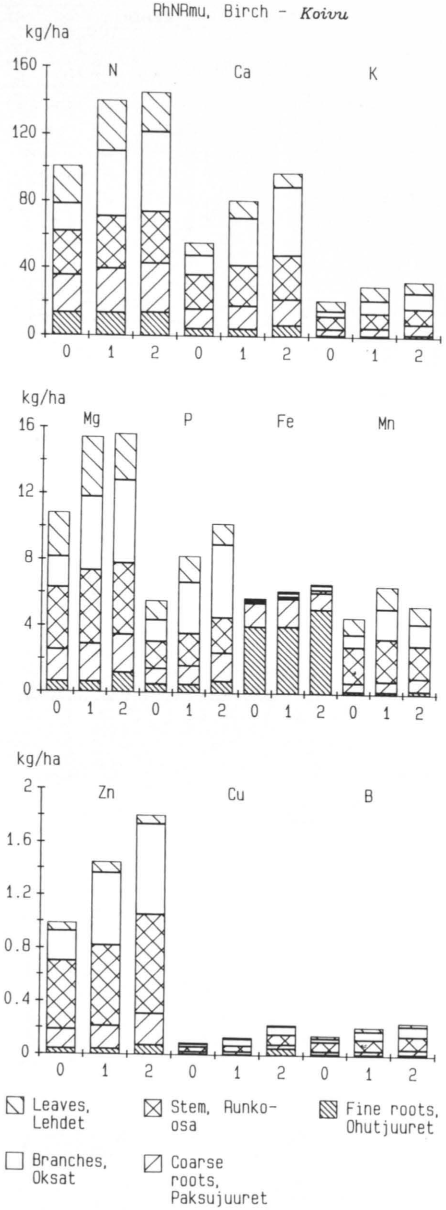

Figure 6. Nutrient amounts fixed in the birches in the mixed birch and pine stands before (0) and after fertilization (1 = unfertilized, 2 = fertilized).
Kuva 6. Sekametsikön koivuihin ennen (0) ja jälkeen lannoituksen sitoutuneet ravinnemäärät (1 = lannoittamaton, 2 = lannoitettu).

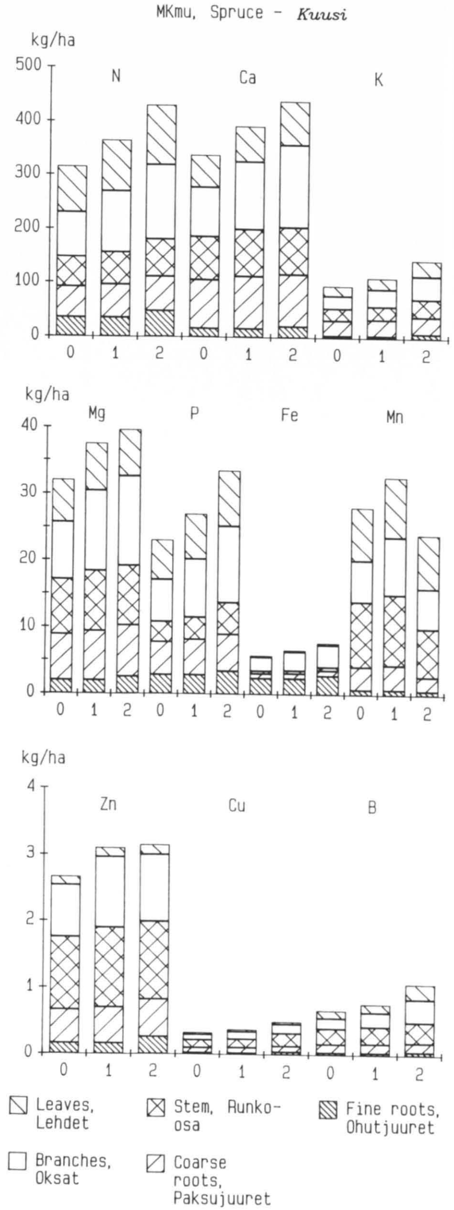

Figure 7. Nutrient amounts fixed in the spruce stands before (0) and after fertilization (1 = unfertilized, 2 = fertilized).
Kuva 7. Kuusikkoon ennen (0) ja jälkeen lannoituksen sitoutuneet ravinnemäärät (1 = lannoittamaton, 2 = lannoitettu).

pine stands the largest nitrogen, phosphorus, potassium and manganese stores were in the needles. The stems including bark were the largest magnesium, calcium, zinc, copper and boron store. The live branches contained the above-mentioned nutrients almost in equally large amounts as the stems. In addition to iron, the fine roots contained also considerable amounts of nitrogen and phosphorus.

In the mixed stands the pine stems contained nitrogen and phosphorus almost as much as the needles. The largest amounts of the other nutrients, excluding iron, were found in the stems. The birch branches, foliage and stems were large stores of nitrogen, potassium and magnesium. Large amounts of phosphorus, calcium and micronutrients were in the birch stems and branches. The fine roots of the mixed stands, as in the pine stands, contained very large amounts of iron.

There were plenty of nitrogen, phosphorus, potassium and calcium in the branches and needles of spruce. Calcium, potassium, magnesium and manganese were also abundant in the stems. The zinc, copper and boron stores were large in the stems. Iron was found in large amounts in the fine roots of spruce, and unlike the other stands, it was also found abundantly in live branches.

In the pine stands the pines had fixed to their total biomass a greater part of all the nutrients except iron, manganese and copper per biomass and volume units than the pines in the mixed birch and pine stands (Table 5). Birches had fixed more of all the nutrients than pines at the same stands. Spruces had fixed more potassium, calcium and manganese to their total biomass than birches and pines in the model stands. Compared to the pines in the mixed stands more of all the nutrients, except iron and copper, was fixed in spruces. Nearly equal amounts of phosphorus and boron were fixed in the total birch and spruce biomass, although birch contained more nitrogen, magnesium, iron, zinc and copper than spruce.

The average nutrient concentration in the stem was lower than that of the whole above-ground biomass in all the stands (Table 5). The average nutrient concentration in foliage was larger than in other compartments (see Appendices 23–27). Next came the live branches and stem bark, then fine roots and stump and coarse roots. The lowest nutrient concentration was in the stemwood.

At the end of the investigation period the total biomass of pines of the fertilized model pine stand contained more potassium and copper per biomass and volume units than the pines of the unfertilized one (Table 5), but there were clearly less manganese and iron. The total biomass of fertilized pines in the mixed stand contained more potassium, iron, zinc and copper and less manganese than the unfertilized ones. The fertilized birches contained more phosphorus, potassium, calcium, zinc, copper and boron and less manganese than the unfertilized ones. The biomass of fertilized spruces had fixed more of all the nutrients, except magnesium, zinc and manganese, per biomass and volume units than the unfertilized ones.

More of the applied fertilizers became fixed in the spruce stand than other stands, as can be seen in the table:

	Fertilizers fixed in the stands (% of applied doses)		
	VNRmu	RhNRmu	MKmu
N	<5	10	65
P	<5	7	16
K	20	14	54
Ca	<5	10	26
Mg	<5	<5	<5
Mn	<5	<5	<5
Fe	<5	<5	<5
Zn	<5	8	<5
Cu	<5	<5	<5
B	6	<5	28

33. Nutrient cycle in model stands

The annual uptake of nitrogen from the soil by the pine stands was about 26 kg/ha, that of phosphorus about 2.5 kg/ha, potassium 4.6–6.6 kg/ha, calcium about 12 kg/ha, magnesium about 2 kg/ha, iron less than 2 kg/ha and manganese less than 1 kg/ha (Table 7). The corresponding figures in the mixed stands were nitrogen 42, phosphorus 2.5, potassium 5.3–7.2, calcium 21, magnesium 4, iron 5.0–6.6 and manganese 1.3–2.1 kg/ha and in the spruce stands nitrogen 30–42, phosphorus 2.4–3.4, potassium 5–12, calcium 22–29, magnesium 2.5, iron 1.5 and manganese less than 2 kg/ha. The investiga-

Table 5. Nutrient amounts fixed in the stand biomass per biomass unit and volume unit of stem.
Taulukko 5. Puuston biomassaan sitoutuneiden ravinteiden määrät biomassayksikköä ja runko-osan tilavuusyksikköä kohti.

Fertilization *Lannoitus*	Unit *Yksikkö*	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
				VNRmu, pine – *VNRmu, mänty*							
0	[1]*10^{-4}	26.7	2.8	6.9	13.0	2.9	0.79	0.721	0.146	0.022	0.036
UABM	[1]*10^{-4}	25.0	2.8	8.1	11.9	2.8	0.56	0.452	0.140	0.037	0.043
0	[2]	2.61	0.271	0.670	1.27	0.283	0.077	0.071	0.014	0.002	0.004
UABM	[2]	2.38	0.267	0.773	1.13	0.265	0.054	0.043	0.013	0.004	0.004
0	[3]	1.85	0.187	0.464	0.935	0.206	0.018	0.051	0.011	0.002	0.003
UABM	[3]	1.78	0.188	0.498	0.805	0.192	0.019	0.037	0.010	0.002	0.003
0	[4]	0.378	0.039	0.116	0.299	0.083	0.002	0.016	0.004	0.001	0.001
UABM	[4]	0.404	0.041	0.132	0.275	0.080	0.003	0.011	0.004	0.001	0.001
				RhNRmu, pine – *RhNRmu, mänty*							
0	[1]*10^{-4}	15.4	1.0	3.5	9.2	2.1	1.08	0.773	0.062	0.020	0.028
UABM	[1]*10^{-4}	15.8	1.1	4.3	9.3	2.2	1.28	0.636	0.074	0.044	0.030
0	[2]	1.23	0.081	0.281	0.73	0.165	0.086	0.062	0.005	0.002	0.002
UABM	[2]	1.20	0.085	0.323	0.70	0.162	0.097	0.048	0.005	0.003	0.002
0	[3]	0.879	0.061	0.205	0.486	0.118	0.009	0.054	0.004	0.001	0.002
UABM	[3]	0.798	0.062	0.229	0.451	0.112	0.010	0.039	0.004	0.002	0.002
0	[4]	0.319	0.020	0.094	0.292	0.081	0.002	0.030	0.002	0.001	0.001
UABM	[4]	0.318	0.020	0.103	0.270	0.078	0.003	0.023	0.002	0.001	0.001
				RhNRmu, birch – *RhNRmu, koivu*							
0	[1]*10^{-4}	30.5	1.8	6.5	17.6	3.4	1.35	1.417	0.315	0.030	0.047
UABM	[1]*10^{-4}	30.2	2.1	6.8	20.2	3.2	1.38	1.109	0.374	0.048	0.052
0	[2]	2.75	0.162	0.591	1.59	0.303	0.122	0.128	0.028	0.003	0.004
UABM	[2]	3.16	0.223	0.717	2.11	0.340	0.144	0.116	0.039	0.005	0.005
0	[3]	1.98	0.130	0.489	1.233	0.246	0.009	0.113	0.024	0.002	0.004
UABM	[3]	2.23	0.170	0.549	1.637	0.264	0.012	0.095	0.033	0.003	0.004
0	[4]	0.617	0.039	0.169	0.470	0.087	0.003	0.051	0.012	0.001	0.002
UABM	[4]	0.672	0.046	0.199	0.573	0.093	0.004	0.043	0.016	0.002	0.002
				MKmu, spruce – *MKmu, kuusi*							
0	[1]*10^{-4}	22.2	1.6	7.2	23.8	2.3	0.40	1.988	0.189	0.023	0.047
UABM	[1]*10^{-4}	24.8	1.9	8.7	25.3	2.3	0.45	1.390	0.187	0.029	0.062
0	[2]	1.96	0.145	0.637	2.11	0.202	0.036	0.176	0.017	0.002	0.004
UABM	[2]	2.28	0.177	0.797	2.32	0.210	0.041	0.128	0.017	0.003	0.006
0	[3]	1.45	0.101	0.417	1.504	0.151	0.019	0.152	0.013	0.001	0.003
UABM	[3]	1.69	0.130	0.554	1.708	0.155	0.022	0.113	0.008	0.002	0.005
0	[4]	0.323	0.018	0.128	0.473	0.048	0.002	0.057	0.006	0.001	0.001
UABM	[4]	0.370	0.025	0.174	0.466	0.047	0.003	0.039	0.006	0.001	0.002

[1] Nutrient content in the total biomass (=above-ground parts+underground parts)/total biomass, kg/ha. – *Ravinnetta koko biomassassa (=maanpäällisissä osissa + maanalaisissa osissa)/koko biomassa, kg/kg.*
[2] Nutrient content in the total biomass/stem volume, kg/m^3. – *Ravinnetta koko biomassassa/runko-osan tilavuus, kg/m^3.*
[3] Nutrient content in the above-ground biomass/stem volume, kg/m^3. – *Ravinnetta maanpäällisissä osissa/runko-osan tilavuus, kg/m^3.*
[4] Nutrient content in stem/stem volume, kg/m^3. – *Ravinnetta runko-osassa/runko-osan tilavuus, kg/m^3.*

tion focused on the main nutrients and only on manganese and iron of the micronutrients, as the annual cycle of the other micronutrients was very small, only some tens of grams.

Over half of the nutrient amount taken from the soil by the tree stands returned as litter to the ground. The returning proportion was clearly higher from the underground than above-ground parts. The fertilized stands fixed more nutrients on average than the unfertilized ones.

The nutrients were arranged according to the intensity of their internal cycle. The order in the unfertilized pines on the pure pine stand was as follows: K > P > N > Mg > Ca > Fe > Mn (Table 7). The corresponding order in the pines in the mixed stand was K > P > N > Fe > Mg > Ca > Mn and in birches K > N = P > Mg > Ca > Mn > Fe. The following order was in spruces: K > N = P > Mn = Mg > Ca > Fe. Nitrogen, phosphorus and potassium were clearly mobile (see also Viro 1955,

Table 6. Nutrient amounts annually taken from soil by the stand per postfertilization net increment of stand total biomass and volume increment of stem.
Taulukko 6. Puuston vuosittain maasta ottamat ravinnemäärät lannoituksen jälkeistä puuston kokonaisbiomassan nettokasvua ja runko-osan tilavuuskasvua kohti.

Fertilization *Lannoitus*	Unit *Yksikkö*	N	P	K	Ca	Mg	Fe	Mn	Cu	B
				VNRmu, pine – *VNRmu, mänty*						
0	[1]*10^{-4}	45.1	4.4	7.8	20.5	3.8	3.2	1.2	0.029	0.046
UABM	[1]*10^{-4}	39.2	4.0	9.9	18.5	3.4	2.1	0.70	0.044	0.077
0	[2]	9.7	0.94	1.7	4.4	0.83	0.69	0.27	0.006	0.010
UABM	[2]	6.9	0.70	1.7	3.2	0.60	0.36	0.12	0.008	0.013
				RhNRmu, pine – *RhNRmu, mänty*						
0	[1]*10^{-4}	54.8	3.0	5.7	22.9	3.8	8.0	2.0	0.046	
UABM	[1]*10^{-4}	61.0	4.2	10.1	24.8	4.5	11.6	1.6	0.195	
0	[2]	9.6	0.53	1.0	4.0	0.66	1.4	0.36	0.008	
UABM	[2]	7.6	0.52	1.3	3.1	0.56	1.5	0.20	0.024	
				RhNRmu, birch – *RhNRmu, koivu*						
0	[1]*10^{-4}	63.2	3.4	8.9	34.8	8.0	6.0	3.8	0.040	0.075
UABM	[1]*10^{-4}	46.8	3.4	8.8	33.5	5.3	5.7	1.7	0.100	0.084
0	[2]	11.8	0.63	1.7	6.5	1.5	1.1	0.70	0.008	0.014
UABM	[2]	15.2	1.1	2.9	10.9	1.7	1.9	0.55	0.032	0.027
				MKmu, spruce – *MKmu, kuusi*						
0	[1]*10^{-4}	44.9	3.5	7.7	32.7	3.3	2.2	2.5	0.032	0.063
UABM	[1]*10^{-4}	49.9	4.1	13.7	34.5	3.1	1.9	0.0	0.056	0.115
0	[2]	7.7	0.60	1.3	5.6	0.57	0.37	0.44	0.006	0.011
UABM	[2]	9.4	0.76	2.6	6.5	0.57	0.36	0.0	0.010	0.022

[1] Nutrient taken from soil by the stand/net increment of biomass, kg/kg. – *Puuston maasta ottama ravinne/biomassan nettokasvu, kg/kg.*
[2] Nutrient taken from soil by the stand/stem volume increment, kg/m^3. – *Puuston maasta ottama ravinne/runko-osan tilavuuskasvu, kg/m^3.*

Mälkönen 1974). The mobility of manganese was poorest in pine. They even accumulated in needles before needle fall (see also Paavilainen 1980). The mobility of manganese was clearer in spruce than in other tree species. The mobility of calcium and magnesium was intermediate.

For the production of the same amount of biomass, the pines in the pure pine stands took up less nitrogen, calcium and micronutrients than the pines in the mixed stands, but for the production of stem only less micronutrients (Table 6). Birches took up more of all the nutrients from the soil for the biomass and stem production than the pines in the same stands. Spruces consumed the nutrient stores, except calcium, manganese and boron, of the soil almost to the same extent as pines in the pine stands. Spruces consumed calcium, manganese and boron more than pines, but not more than birches.

Table 7. Annual nutrient amounts taken by the stand from the soil and circulating in leaves as well as the total annual nutrient consumption, (kg/ha). (1 = Total amount returned to soil as percentage taken from soil, 2 = Returned from the above-ground parts as percentage taken from soil, 3 = Internal cycle % out of total consumption).

Taulukko 7. Puuston vuosittain maasta ottamat ja lehdissä kiertävät ravinnemäärät sekä puuston vuotuinen ravinteiden kokonaiskäyttö, (kg/ha). (1 = Palautui maahan maasta otetusta %, 2 = Palautui maahan maanpäällisiin osiin maasta otetuista %, 3 = Sisäinen kierto kokonaiskäytöstä %).

a) VNRmu, pine – *mänty,*

Compartment *Osite*	N		P		K		Ca		Mg		Fe		Mn	
	0	UABM	0	UABM	0	UABM	0	UABM	0	UABM	0	UABM	0	UABM
Stemwood – *Runkopuu*	0.446	0.943	0.040	0.082	0.131	0.361	0.514	0.627	0.147	0.186	0.002	0.006	0.032	0.0
Stem bark – *Rungon kuori*	0.339	0.595	0.040	0.076	0.106	0.204	0.135	0.091	0.042	0.065	0.002	0.012	0.005	-0.001
Live branches – *Elävät oksat*	2.306	3.363	0.254	0.375	0.727	1.173	1.452	1.640	0.327	0.406	0.043	0.056	0.060	0.085
Dead branches – *Kuolleet oksat*	0.363	0.368	0.013	0.022	0.021	0.035	0.198	0.144	0.013	0.026	0.011	0.014	0.004	0.003
Leaves – *Lehdet*	1.762	1.224	0.180	0.195	0.372	0.498	0.505	–0.138	0.098	0.021	0.005	0.007	0.041	-0.050
Cones – *Kävyt*	0.0	0.035	0.0	0.007	0.0	0.037	0.0	–0.003	0.0	-0.005	0.0	0.0	0.0	0.0
Above-ground parts in all – *Maanp. yht.*	5.216	6.528	0.527	0.757	1.357	2.308	2.804	2.361	0.627	0.699	0.063	0.095	0.142	0.037
Stump and thick roots – *Kanto- ja paksujuuret*	0.834	1.287	0.097	0.344	0.354	1.632	0.548	1.172	0.116	0.302	0.017	0.003	0.045	-0.087
Fine roots – *Ohutjuuret*	0.0	–1.370	0.0	–0.207	0.0	–0.230	0.0	–0.340	0.0	-0.133	0.0	-0.206	0.0	-0.004
Underground parts in all – *Maanal. yht.*	0.834	–0.083	0.097	0.137	0.354	1.402	0.548	0.832	0.116	0.169	0.017	-0.203	0.045	-0.091
Total – *Yhteensä*	6.050	6.445	0.624	0.894	1.711	3.710	3.352	3.193	0.743	0.868	0.080	-0.108	0.187	-0.054
Leaf litter – *Lehtikarike*	5.428	6.790	0.447	0.553	0.841	1.116	4.465	5.432	0.525	0.621	0.081	0.087	0.463	0.467
Other above – ground litter – *Muu maanpääll. karike*	2.464	1.777	0.164	0.126	0.175	0.155	0.821	0.711	0.082	0.084	0.160	0.067	0.031	0.022
Fine-root litter – *Ohutj.karike*	12.315	11.036	1.309	1.082	1.828	1.600	3.291	2.986	0.886	0.720	1.547	1.337	0.037	0.033
Litter production – *Karikesato*	20.207	19.603	1.920	1.761	2.844	2.871	8.577	9.129	1.493	1.425	1.788	1.491	0.531	0.522
Total taken from soil – *Yhteensä maasta otettu*	26.257	26.048	2.544	2.655	4.555	6.581	11.927	12.322	2.236	2.293	1.868	1.383	0.718	0.468
Internal cycle – *Sisäinen kierto*	10.840	8.939	1.210	1.119	2.524	2.376	0.220	–1.391	0.354	0.181	-0.039	-0.043	-0.083	-0.178
Total nutrient consumption – *Ravinteiden kokonaiskäyttö*	37.097	34.987	3.754	3.774	7.079	8.957	12.149	10.931	2.590	2.474	1.829	1.340	0.635	0.290
1	77	75	75	66	62	44	72	74	67	62	96	108	74	112
2	60	57	54	47	43	36	65	72	49	50	79	62	78	93
3	29	26	32	30	36	27	2	–13	14	7	–2	–3	–13	–61

Table 7. Continued.
Taulukko 7. Jatkoa.

b) RhNRmu, pine — *mänty,*

Compartment *Osite*	N 0	N UABM	P 0	P UABM	K 0	K UABM	Ca 0	Ca UABM	Mg 0	Mg UABM	Fe 0	Fe UABM	Mn 0	Mn UABM
Stemwood — *Runkopuu*	0.310	0.454	0.015	0.046	0.084	0.281	0.405	0.420	0.112	0.176	0.002	0.003	0.045	–0.013
Stem bark — *Rungon kuori*	0.211	0.369	0.018	0.014	0.066	0.103	0.095	0.041	0.028	–0.005	0.002	0.010	0.007	–0.011
Live branches — *Elävät oksat*	1.270	1.252	0.110	0.132	0.410	0.579	0.781	0.902	0.173	0.192	0.030	0.030	0.085	0.057
Dead branches — *Kuolleet oksat*	0.591	0.375	0.028	0.018	0.037	0.031	0.215	0.235	0.019	0.016	0.021	0.010	0.008	0.006
Leaves — *Lehdet*	0.503	0.111	0.037	0.070	0.085	0.242	0.105	–0.052	0.019	0.003	0.001	0.001	0.018	–0.037
Cones — *Kävyt*	0.0	–0.013	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.002	0.0	0.0	0.0	0.0
Above-ground parts in all — *Maanp. yht.*	2.885	2.548	0.208	0.280	0.682	1.239	1.591	1.546	0.351	0.384	0.056	0.054	0.163	0.002
Stump and thick roots — *Kanto- ja paksujuuret*	0.333	1.292	0.020	0.066	0.121	0.419	0.350	0.499	0.070	0.096	0.050	–0.155	0.012	0.022
Fine roots — *Ohutjuuret*	0.0	0.148	0.0	0.027	0.0	0.045	0.0	0.222	0.0	0.070	0.0	0.445	0.0	0.012
Underground parts in all — *Maanal. yht.*	0.333	1.440	0.020	0.093	0.121	0.464	0.350	0.721	0.070	0.166	0.050	0.290	0.012	0.034
Total — *Yhteensä*	3.218	3.988	0.228	0.373	0.803	1.703	1.941	2.267	0.421	0.550	0.106	0.344	0.175	0.036
Leaf litter — *Lehtikarike*	5.175	6.937	0.265	0.472	0.665	1.283	2.588	2.706	0.419	0.409	0.047	0.062	0.448	0.434
Other above ground litter — *Muu maanpääll. karike*	2.402	2.094	0.118	0.148	0.163	0.263	1.109	1.109	0.100	0.148	0.053	0.070	0.043	0.060
Fine-root litter — *Ohutj.karike*	8.352	9.765	0.440	0.557	0.372	0.519	2.377	3.163	0.380	0.578	2.580	3.871	0.047	0.078
Litter production — *Karikesato*	15.929	18.796	0.823	1.177	1.200	2.065	6.074	6.978	0.899	1.135	2.680	4.003	0.538	0.572
Total taken from soil — *Yhteensä maasta otettu*	19.147	22.784	1.051	1.550	2.003	3.768	8.015	9.245	1.320	1.685	2.786	4.347	0.713	0.608
Internal cycle — *Sisäinen kierto*	3.299	1.145	0.351	0.178	0.747	0.288	–0.810	–1.084	–0.105	–0.112	–0.026	–0.041	–0.134	–0.177
Total nutrient consumption — *Ravinteiden kokonaiskäyttö*	22.446	23.929	1.402	1.728	2.750	4.056	7.205	8.161	1.215	1.573	2.760	4.306	0.579	0.431
1	83	82	78	76	60	55	76	75	68	67	96	92	75	94
2	72	78	65	69	55	56	70	71	60	59	64	71	75	100
3	15	5	25	10	27	7	–11	–13	–9	–7	–1	–1	–23	–41

Table 7. Continued.
Taulukko 7. Jatkoa.

b) RhNRmu, birch – *koivu,*

Compartment *Osite*	N 0	N UABM	P 0	P UABM	K 0	K UABM	Ca 0	Ca UABM	Mg 0	Mg UABM	Fe 0	Fe UABM	Mn 0	Mn UABM
Stemwood – *Runkopuu*	0.606	0.617	0.036	0.050	0.157	0.170	0.315	0.302	0.087	0.056	0.002	0.004	0.040	0.026
Stem bark – *Rungon kuori*	0.186	0.083	0.015	0.026	0.064	0.139	0.298	0.707	0.026	0.033	0.002	0.005	0.027	–0.007
Live branches – *Elävät oksat*	3.803	5.256	0.298	0.527	0.756	1.035	2.757	4.813	0.435	0.525	0.022	0.031	0.176	0.093
Dead branches – *Kuolleet oksat*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leaves – *Lehdet*	1.343	0.238	0.071	0.013	0.378	0.067	0.470	0.083	0.161	0.029	0.005	0.001	0.061	0.011
Above-ground parts in all – *Maanp. yht.*	5.938	6.194	0.420	0.616	1.355	1.411	3.840	5.905	0.709	0.643	0.031	0.041	0.304	0.123
Stump and thick roots – *Kanto- ja paksujuuret*	0.687	1.184	0.029	0.132	0.113	0.422	0.357	0.644	0.060	0.064	0.044	–0.066	0.016	0.040
Fine roots – *Ohutjuuret*	0.0	0.060	0.0	0.035	0.0	0.108	0.0	0.365	0.0	0.092	0.0	0.173	0.0	0.011
Underground parts in all – *Maanal. yht.*	0.687	1.244	0.029	0.167	0.113	0.530	0.357	1.009	0.060	0.156	0.044	0.107	0.016	0.051
Total – *Yhteensä*	6.625	7.438	0.449	0.783	1.468	1.941	4.197	6.914	0.769	0.799	0.075	0.148	0.320	0.174
Leaf litter – *Lehtikarike*	8.801	3.960	0.469	0.203	1.284	0.773	6.063	3.305	1.800	0.789	0.073	0.038	0.945	0.362
Other above ground litter – *Muu maanpääll. karike*	1.292	0.866	0.091	0.056	0.106	0.189	0.500	0.451	0.082	0.084	0.020	0.009	0.059	0.044
Fine-root litter – *Ohutj.karike*	6.870	6.018	0.258	0.272	0.453	0.539	2.251	2.435	0.319	0.398	2.082	2.030	0.077	0.081
Litter production – *Karikesato*	16.963	10.844	0.818	0.531	1.843	1.501	8.814	6.191	2.201	1.271	2.175	2.077	1.081	0.487
Total taken from soil – *Yhteensä maasta otettu*	23.588	18.282	1.267	1.314	3.311	3.442	13.011	13.105	2.970	2.070	2.250	2.225	1.401	0.661
Internal cycle – *Sisäinen kierto*	20.166	19.482	1.060	1.034	6.878	5.830	4.077	4.902	1.679	2.022	0.033	0.048	0.361	–0.266
Total nutrient consumption – *Ravinteiden kokonaiskäyttö*	43.754	37.764	2.327	2.348	10.189	9.272	17.088	18.007	4.649	4.092	2.283	2.273	1.762	0.395
1	72	59	65	40	56	44	68	47	74	61	97	93	77	74
2	63	44	57	30	51	41	63	39	73	58	75	53	77	77
3	46	52	46	44	68	63	24	27	36	49	1	2	20	–67

Table 7. Continued.
Taulukko 7. Jatkoa.

b) MKmu, spruce – *kuusi,*

Compartment *Osite*	N 0	N UABM	P 0	P UABM	K 0	K UABM	Ca 0	Ca UABM	Mg 0	Mg UABM	Fe 0	Fe UABM	Mn 0	Mn UABM
Stemwood – *Runkopuu*	0.498	1.330	0.015	0.140	0.180	1.098	0.483	0.422	0.046	0.009	0.003	0.010	0.077	–0.290
Stem bark – *Rungon kuori*	0.290	1.109	0.031	0.145	0.142	0.749	0.687	0.760	0.077	0.101	0.003	0.008	0.067	–0.121
Live branches – *Elävät oksat*	5.111	8.773	0.406	0.829	1.532	3.070	5.504	10.456	0.575	0.813	0.123	0.182	0.416	0.0
Dead branches – *Kuolleet oksat*	0.021	0.319	0.001	0.042	0.002	0.072	0.032	–0.111	0.001	–0.008	0.001	0.035	0.001	–0.035
Leaves – *Lehdet*	1.718	4.511	0.123	0.373	0.369	1.755	1.246	3.613	0.132	0.120	0.005	0.015	0.163	0.028
Cones – *Kävyt*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Above-ground parts in all – *Maanp. yht.*	7.638	16.042	0.576	1.529	2.225	6.744	7.952	15.140	0.831	1.035	0.135	0.250	0.724	–0.418
Stump and thick roots – *Kanto- ja paksujuuret*	0.743	1.144	0.065	0.100	0.359	0.553	1.162	1.072	0.090	0.138	0.009	0.014	0.044	–0.212
Fine roots – *Ohutjuuret*	0.0	2.050	0.0	0.097	0.0	0.723	0.0	0.740	0.0	0.093	0.0	0.072	0.0	–0.027
Underground parts in all – *Maanal. yht.*	0.743	3.194	0.065	0.197	0.359	1.276	1.162	1.812	0.090	0.231	0.009	0.086	0.044	–0.239
Total – *Yhteensä*	8.381	19.236	0.641	1.726	2.584	8.020	9.114	16.952	0.921	1.266	0.144	0.336	0.768	–0.657
Leaf litter – *Lehtikarike*	3.261	2.441	0.194	0.158	0.374	0.377	4.141	3.107	0.279	0.191	0.029	0.021	0.504	0.268
Other above – ground litter – *Muu maanpääll. karike*	1.188	1.051	0.117	0.079	0.168	0.154	0.891	0.425	0.054	0.048	0.078	0.043	0.056	0.028
Fine-root litter – *Ohutj.karike*	18.002	19.401	1.462	1.477	2.166	3.010	8.283	8.637	1.028	1.076	1.240	1.237	0.414	0.341
Litter production – *Karikesato*	22.451	22.893	1.773	1.714	2.708	3.541	13.315	12.169	1.361	1.315	1.347	1.301	0.974	0.637
Total taken from soil – *Yhteensä maasta otettu*	30.832	42.129	2.414	3.440	5.292	11.561	22.429	29.121	2.282	2.581	1.491	1.637	1.742	–0.020
Internal cycle – *Sisäinen kierto*	8.086	8.496	0.650	0.661	3.256	3.007	1.730	2.396	0.455	0.552	0.002	0.009	0.390	0.729
Total nutrient consumption – *Ravinteiden kokonaiskäyttö*	38.918	50.625	3.064	4.101	8.548	14.568	24.159	31.517	2.737	3.133	1.493	1.646	2.132	0.709
1	73	54	73	50	51	31	59	42	60	51	90	79	56	
2	37	18	35	13	20	7	39	19	29	19	44	20	44	
3	21	17	21	16	38	21	7	8	17	18	0	1	18	103

4. DISCUSSION

41. Reliability of the results

Because several possibilities of error are involved in this kind of investigations, certain reserve is advisable when evaluating the results. The material was mainly collected after fertilization, and part of the differences may have existed already before fertilization. The collected sample tree material for biomass was small without any control material.

The coefficient of determination of the biomass equations was in most cases high, but the relative standard error rose, particularly in the case of the stemwood and branch increment equations. The biomass equations for different crown compartments and the branch increment equations were made on the basis of the material used for branch equations. Therefore the risk for error was greater than in the case of stem equations. The equations cannot be generalized outside the material.

The litter fall was collected during a. 2 years. The period was apparently short, as the largest litter fall in pines was 2.0-fold as compared to the smallest litter fall (Appendix 21), (see also Bray and Gorham 1964, Flower-Ellis 1985, Paavilainen 1987). Pine litter fall should be collected for at least 3–4 years in an unfertilized stand (Flower-Ellis and Olsson 1978), and as the age of spruce needles is 3–4 years longer than that of pine, spruce litter should correspondingly be collected for a longer period of time.

The increment models for fine roots were perhaps the weakest part in the investigation. Only some investigations in the world have dealt with fine root increment. According to these investigations the annual net increment of fine roots has been 5–75 % of the net increment of the stand biomass (Harris et al. 1977, Grier et al. 1981, Keyes and Grier 1981, Joslin and Henderson 1987, Santantonio and Santantonio 1987). Possibly in the present study a remarkable proportion of the net increment of biomass was not under detailed enough study.

The nutrient amounts fixed in the stand were calculated as a product of nutrient concentrations and biomass. The result was most affected by the accuracy of the biomass estimate. The nutrient amounts annually consumed by the stand were expected to originate from the soil and the internal nutrient cycle of trees. The trees are, however, able to take nutrients also directly from the air and the rain water retained by the above-ground parts of trees (Miller et al. 1976, Lim and Cousens 1986b, Helmisaari and Mälkönen 1989). The trees are known to receive for instance nitrogen in that way, although only small amounts (Miller et al. 1976, Lim and Cousens 1986b, Helmisaari and Mälkönen 1989), so that the omission of this factor has hardly affected the results.

Precipitation is known to leach nutrients from the crown, potassium and calcium in particular, but also magnesium and manganese (Mälkönen 1974, Päivänen 1974, Miller et al. 1976, Lim and Cousens 1986b, Helmisaari and Mälkönen 1989). The nutrient amounts leached from the crown are some tens of per cent out of the annual nutrient requirements of the stand (Mälkönen 1974, Lim and Cousens 1986b). This investigation did not involve the nutrient amounts leached by precipitation, so in this respect the quoted values are underestimates.

42. Biomass and biomass increment

The volume of the model stands was smaller than that of the drained sites of the same age and peatland site type in South Finland on average (Keltikangas et al. 1986). The model pine stands as regards their tree characteristics were quite similar to one of the three pine stands studied by Mälkönen (1974). Also the total biomass was almost equal, although the proportion of the underground parts was larger in this investigation. Albrektson (1980) and Hakkila and Mäkelä (1973) have discovered that pines on peat soil have larger root systems than on mineral soil.

In the mixed stands the branch biomass of birch was proportionately larger than in pine. This observation is confirmed by Satoo and Madgwick (1982), who pointed out that the branch biomass of broadleaved species is relatively larger than that of conifers. In the pine stands the proportion of stemwood out of the entire biomass was larger than in the mixed stands, and that of branches and leaves smaller. This is known to occur as the stand ages (Albrektson 1980) and the stand density increases (Viherä and Kellomäki 1983).

The above-ground biomass of the model spruce stands was allocated to different tree compartments nearly in the same way as in an old spruce stand investigated by Holmen (1964).

The volume increment of model stands was small compared to stands in the drainage areas of the same age and peatland site types in South Finland (Keltikangas et al. 1986). Reasons for this can be considered. The material was collected on a mire that had been drained for the first time as early as the 1930s, although the drainage had been insufficient before the outset of the investigation (see Silvola et al. 1985). In addition, the mixed stand on the herbrich sedge pine mire was dense before the outset of the investigation. A great number of birches mixed in the stand is known to disturb the development of pine (Mielikäinen 1980). The spruce stand was old, past the prime of growth.

The net increment of biomass in the model stands was greatly affected by the increment estimate of fine root biomass, which was 18–42 % out of the whole net increment. If the increment of the fine root biomass had been calculated on the basis of the increment percentage of the above-ground parts of the stand, the net increment of fine roots would have been 430–540 kg/ha/a in the pine stand, 220–240 kg/ha/a in the mixed birch and pine stand and only 190–250 kg/ha/a in the spruce stand. Such an estimate would clearly have been lower than the values in the employed calculations, for example less than 10 % of the values used for the spruce stand.

Only about a fifth of the net increment was fixed in the stemwood. This proportion was largest in pine. Out of the total net increment 40–70 % was fixed in the standing biomass, the rest was lost as litter. The litter production of the spruce stand used as a basis for calculations was low as compared to that of the spruce stands on mineral soil (Viro 1974). The litter production of birch and pine was of about the same magnitude as in the peatland stands investigated by Paavilainen (1980, 1987).

The material was collected from the sites that should have been fertilized with PK according to the recommendations (e.g. Paavilainen 1979). Nitrogen application increases considerably growth only at sites less fertile than an ordinary sedge pine mire (see also Finér 1987). Fertilization increased biomass in the pine and spruce stands. In the mixed stand the effect of fertilization was hardly noticeable in the total biomass. Fertilization has not increased the growth of birch according to several other investigations (Viro 1974, Oikarinen and Pyykkönen 1981, Puro 1982, Moilanen 1985, Paarlahti and Paavilainen 1985), while pine apparently suffered from the birches in the mixed stand.

The material was collected six years after fertilization. Thus all the birch leaves and pine needles developed in the fertilization year had fallen as litter onto the ground, while the spruce crown still carried needles developed in the fertilization and prefertilization years. For this reason the fertilization effect was at different stages in different species. In the pine stand the effect of fertilization was seen in stems and branches (see also Saramäki and Silander 1982). In spruce it was quite evenly distributed to the various tree compartments. Although fertilization did not affect the total biomass in the mixed stand, more biomass was allocated to branches and less to foliage in the fertilized stand than in the unfertilized one. Surprisingly the fertilized pines had a smaller needle biomass than the unfertilized ones (cf. Brix and Ebell 1969, Brix 1972, Miller and Miller 1976, Lim and Cousens 1986a). In fact, fertilization is known to increase the needle biomass. However, in the former studies the situation had been studied only for 1–4 postfertilization years. The fertility of the site is known to increase branchiness in pine (Kellomäki and Väisänen 1986). The present findings agree in this respect.

43. Nutrient cycle

The nutrient amounts fixed in the trees of the model stands were small except for potassium and manganese as compared to the nutrient stores in the root layer. The whole-tree harvesting consumes the nutrient stores, especially those of nitrogen, phosphorus and potassium, considerably more than the traditional stem harvesting (see also Mälkönen 1976, Paavilainen 1980, Kaunisto and Paavilainen 1988). The younger the stand, the larger the proportion of biomass fixed in the crown, and the more damaging the whole-tree harvesting is to the nutrient conditions of the stand (see also Mälkönen and Saarsalmi 1982). There are also differences between tree species. The wood production of birch consumes more nutrients than that of pine (see also Mälkönen 1977), and compared to spruce more of all the nutrients except calcium and manganese. On the other hand, the wood production of spruce consumes more potassium, calcium and manganese and zinc than that of pine.

The potassium stores, especially in the root layer, were small compared to the nutrient amounts fixed by the stands. Thus also this investigation supports the notion that there is a shortage of potassium when considering the continuous wood production on deep-peat soils (Holmen 1964, 1969, Kaunisto and Paavilainen 1988). The situation can be helped by potassium fertilization and by avoiding whole-tree harvesting (Kaunisto and Paavilainen 1988). The investigation of the nutrient stores in the present root layer alone does not adequately explain the effects of growing trees on the nutrient regime of peatlands. It is likely that the peat layer gradually becomes thinner as a result of decomposition and tree harvesting, and tree roots penetrate into deeper peat layers or even down to the subsoil for nutrients. On deep-peat mires this, however, does not increase the available potassium reserves, as they are mainly in the surface peat (e.g. Westman 1981, Braekke 1987, Kaunisto and Paavilainen 1988). The peatland ecosystem receives additional nutrients from the deposition, but simultaneously nutrients are leached away from the ecosystem. When comparing the deposition (Järvinen 1986) to leaching (Ahti 1983, Ahtiainen 1988) only the nitrogen balance is clearly positive. Phosphorus and potassium are nearly in balance. The concern for the sufficiency of potassium is probably real on deep-peat mires.

In the investigations of Mälkönen (1974) and Paavilainen (1980) the pine stands were estimated to use annually 19–44 kg/ha of nitrogen, 2.5–4.5 kg/ha of phosphorus, 8–18 kg/ha of potassium and 11–23 kg/ha of calcium. The annual nutrient consumption in the model stands of this investigation was of the same magnitude. Exceptions were calcium and nitrogen, whose consumption was bigger in spruce and mixed birch and pine stands. Particularly nitrogen, phosphorus and potassium circulated in trees (see also Viro 1955, Mälkönen 1974), so that the uptake from the soil was clearly smaller than the total consumption. A remarkable amount of nutrients compared to the amount taken up from the soil was returned as litter. Birches were not observed to consume the soil nutrients more extravagantly than pines. Some previous investigations indicate that birch returns a larger proportion of the nutrients taken from the soil than pine (Paavilainen 1979). These calculations include, however, the internal cycle. If the effect of the internal cycle is stronger as a supplier of the annual nutrients in birch than in pine, it may provide one explanation to the difference. This explanation is not, however, supported by Viro (1955) whose investigation showed that the internal cycle in birch is not as large as in conifers. The present results were also affected by the ratio between the birch leaf biomass and litter fall. The litter fall of the model stands was small compared to the leaf biomass, even if considering the change in dry weight of yellowing leaves (see Viro 1955).

In six years only part of the consumed fertilizer nutrients had become fixed in the biomass of the model stands, and proportionally less from micronutrients than macronutrients. The proportion was the largest in the spruce stand. The result was connected with the magnitude of the biomass increment, its allocation to the various compartments of trees and changes in the nutrient concentrations. In the pine and mixed stands fertilization had decreased the leaf biomass, which is one the most important nutrient stores in the stand. Surprisingly, manganese uptake decreased as a result of fertilization, although it had been applied.

Except for nitrogen the applied amount of nutrients to the soil was high as compared to the nutrient stores in surface peat and manifold as compared to the annual need of trees. Therefore, the stand could only fix a small part of the applied nutrients. Fertilizer nutrients should therefore be stored in surface peat for later use. Part of the easily soluble nutrients, particularly potassium, may, however, leach away from the peatland ecosystem (e.g. Ahti 1983) and part of them are consumed by soil organisms and understorey vegetation.

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Total of 77 references

SELOSTE

Biomassa ja ravinteiden kierto ojitusalueen lannoitetussa ja lannoittamattomassa männikössä, koivu-mäntysekametsikössä ja kuusikossa

Johdanto

Puuston ravinteiden kierron tuntemus luo perustan lannoitustoiminnalle ja on tarpeen tarkasteltaessa ojitettujen turvemaiden jatkuvaa kestävää puuntuotoskykyä. Paksuturpeiset ojitetut turvemaat elävät turpeessa olevien ja sadeveden mukanaan tuomien ravinteiden varassa. Ohutturpeiset turvemaat saavat ravinnelisää myös alla olevasta kivennäismaasta. Puunkorjuu kuluttaa turvemaan ravinnevaroja, ja on tuonut esille huolen erityisesti turpeen kaliumvarojen riittävyydestä.

Tämän tutkimuksen tarkoituksena oli selvittää ojitetulla turvemaalla kasvavan männikön, koivu-mäntysekametsikön ja kuusikon biomassaa ja ravinteiden kiertoa. Lisäksi pyrittiin tutkimaan lannoituksen vaikutusta.

Aineisto ja menetelmät

Tutkimuksessa kerättiin aineisto Ilmomantsissa ojitusalueen varsinaisella nevarämemuuttumalla (VNRmu), ruohoisella nevarämemuuttumalla (RhNRmu) ja mustikkakorpimuuttumalla (MKmu) kasvavista lannoittamattomista (0) ja NPK sekä hivenlannoitetuista (UAMB) metsiköistä (ks. Silvola ym. 1985). Aineiston perusteella laadittiin puuston eri osien biomassayhtälöt (liitetaulukot 2, 8, 9, 10, 11, 19, 20, 21) ja biomassan kasvuyhtälöt (liitetaulukot 3, 16, 18) sekä määritettiin puuston eri osien ravinnepitoisuus (liitetaulukot 23–28). Näillä yhtälöillä simuloitiin lannoittamattomien ja NPK sekä hivenlannoitettujen mallimetsiköiden (taulukko 4, kuva 1) biomassa ja ravinteiden kierto lannoitushetkestä aikaan kuusi vuotta jälkeen lannoituksen.

Tulokset

Biomassa ja biomassan kasvu

Varsinaisella nevarämemuuttumalla kasvavan männikön biomassa oli tarkastelujakson alussa 48 tn/ha, ruohoisella nevarämemuuttumalla kasvavan koivu-mäntysekametsikön 91 tn/ha, josta koivun osuus oli n. 40 % (kuva 2 ja liitetaulukko 32). Mustikkakorvella kasvavan kuusikon biomassa oli 148 tn/ha.

Ennen lannoitusta männikön ja kuusikon biomassa jakaantui puuston eri osiin lähes samoissa suhteissa. Ohutjuurten osuus biomassasta oli kuitenkin kuusikossa yli puolta pienempi kuin männikössä. Sekametsikössä koivujen oksien ja ohutjuurten osuus biomassasta oli kaksinkertainen mäntyihin verrattuna. Sekametsikössä rungon osuus biomassasta oli suurempi ja maanalaisten osien, lehtien ja oksien osuus pienempi kuin männikössä ja kuusikossa.

Mallimetsiköiden tilavuuskasvu oli alhainen verrattuna Etelä-Suomen samoilla suotyypeillä kasvaviin saman kehitysluokan metsiköihin (Keltikangas ym. 1986). Puuston biomassan vuotuinen nettokasvu tarkastelujakson aikana oli lannoittamattomassa männikössä 5,8 tn/ha ja lannoittamattomassa koivu-mäntysekametsikössä 7,2 tn/ha sekä kuusikossa 6,9 tn/ha (kuva 3 ja liitetaulukko 33). Nettokasvun suuruuteen vaikutti suuresti ohutjuurten nettokasvu, jonka osuus oli 18–42 % koko nettokasvusta. Ohutjuurten kasvun laskenta ei kuitenkaan perustunut kasvumittauksiin, vaan aikaisempien tutkimustulosten perusteella tehtyihin päätelmiin ja tässä tutkimuksessa mitattuihin ohutjuuribiomassoihin. Rungon osuus maanpäällisten osien nettokasvusta oli kuusilla ja männyillä 30–40 % ja koivuilla alhaisempi n. 25 %. Lehtien ja oksien osuus oli koivuilla suurempi kuin havupuilla.

Huomattava osuus nettokasvusta joutui karikkeiden mukana maahan, ja selvästi enemmän maanalaisista osista kuin maanpäällisistä osista. Lannoitetussa männikössä ja kuusikossa menetettiin karikkeiden mukana nettokasvusta n. 10 % vähemmän kuin lannoittamattomassa.

Lannoitus lisäsi biomassaa ja biomassan nettokasvua selvimmin männikössä ja kuusikossa. Lisäys oli kuusikossa männikköä suurempi. Biomassan lisäys allokoitui männikössä runkoon ja oksiin ja kuusikossa melko tasaisesti puuston eri osiin. Vaikka lannoitus tuskin lisäsi kokonaisbiomassaa sekametsikössä, allokoitui biomassaa lannoituksen vaikutuksesta oksiin osin lehtien kustannuksella.

Puustoon sitoutuneet ravinteet ja ravinteiden kierto

Kaikissa mallimetsiköissä 65–89 % kaikista ravinteista, rautaa lukuunottamatta oli sitoutunut puiden maanpäällisiin osiin (kuvat 4–7 ja liitetaulukot 34–35). Suurimmat maanpäälliset ravinnevarastot olivat rungossa, oksissa ja lehdissä. Männikön koko biomassaan oli sitoutunut biomassayksikköä ja puuston tilavuusyksikköä kohti rautaa, kuparia ja mangaania lukuunottamatta kaikkia ravinteita enemmän kuin sekametsikön mäntyihin (taulukko 5). Koivujen biomassaan oli sitoutunut kaikkia ravinteita enemmän kuin samalla kasvupaikalla kasvaviin mäntyihin. Kuusten biomassaan oli sitoutunut kaliumia, kalsiumia ja mangaania runsaammin kuin mallimetsiköiden mäntyihin ja koivuihin. Sekametsikön mäntyihin verrattuna, rautaa ja kuparia lukuunottamatta, kuusiin oli sitoutunut enemmän kaikkia ravinteita. Fosforia ja booria oli koivujen ja kuusten biomassassa lähes yhtä paljon, mutta typpeä, magnesiumia, rautaa, sinkkiä ja kuparia koivuissa oli enemmän kuin kuusissa.

Mallimännikköön oli sitoutunut tarkastelujakson lopussa n. 20 % lannoitekaliumista, n. 6 % lannoiteboorista ja muista ravinteista alle 5 %. Sekametsikköön oli sitoutunut vastaavasti 14 % lannoitekaliumista, 7–10 % lannoitetypestä, -kalsiumista, -fosforista ja -sinkistä. Muista ravinteista se sitoi alle 5 %. Kuusikko sitoi lannoitetypestä peräti 65 %, -kaliumista n. 54 %, -kalsiumista n. 26 %, -boorista n. 28 % ja -fosforista n. 16 %. Muista lannoiteravinteista se sitoi alle 5 %.

Mallimetsiköt ottivat vuosittain maasta typpeä 26–43 kg/ha, fosforia 2,5–3,4 kg/ha, kaliumia 4,5–12 kg/ha, kalsiumia 12–29 kg/ha, magnesiumia 2–4 kg/ha, rautaa 1,4–6,6 kg/ha ja mangaania keskimäärin alle 2 kg/ha (taulukko 7). Sinkkiä, kuparia ja booria puusto otti vuodessa vain muutamia kymmeniä grammoja. Yli puolet maasta otetuista ravinteista palasi karikkeiden mukana takaisin maahan. Maanalaisiin osiin, lähinnä ohutjuuriin otetuista ravinteista palasi vuosittain takaisin maahan selvästi suurempi osa kuin maanpäällisiin osiin otetuista. Koivujen ei voitu todeta käyttävän ravinteitaan tuhlailevammin kuin mäntyjen samalla kasvupaikalla kasvaessaan.

Puuston sisäistä ravinteiden kiertoa tarkasteltiin lehdissä kiertävien ravinnemäärien osalta. Typpi, fosfori ja kalium todettiin lehdissä kiertäviksi ravinteiksi.

Mallimänniköiden männyt ottivat vuosittain maasta vain typpeä, kalsiumia ja hivenravinteita vähemmän kuin sekametsiköiden männyt saman biomassamäärän tuottamiseen (taulukko 6). Runko-osan tuottamiseen taas mallimänniköiden männyt ottivat vuosittain hivenravinteita lukuunottamatta kaikkia ravinteita enemmän kuin sekametsiköiden männyt. Koivut ottivat maasta kaikkia ravinteita enemmän sekä kokonaisbiomassan että runko-osan tuottamiseen kuin samoissa metsiköissä kasvavat männyt. Kuuset käyttivät vuosittain kalsiumia, mangaania ja booria lukuunottamatta maan ravinnevaroja lähes kuten mallimänniköiden männyt. Kalsiumia, mangaania ja booria kuuset ottivat enemmän kuin männyt, mutta eivät kuitenkaan enempää kuin koivut.

Päätelmiä

Mallimetsiköiden puustoon sitoutuneet ravinnemäärät olivat kaliumia ja mangaania lukuunottamatta vähäiset verrattuna juuristokerroksen ravinnevaroihin (taulukko 1, kuvat 4–7). Kokopuukorjuun pääteltiin kuluttavan erityisesti typen, fosforin ja kaliumin varastoja perinteistä runkopuukorjuuta enemmän (taulukko 5). Myös puuston kehitysvaihe vaikuttaa kokopuukorjuun ja runkopuukorjuun välisiin ravinnemenetyksiin. Mitä pienemmästä puustosta kokopuukorjuu tehdään, sitä suurempi on latvuksen osuus biomassasta ja sitä enemmän ravinteita menetetään. Myös puulajien välillä on eroja. Koivun kasvatus kuluttaa kasvualustan ravinnevaroja männyn kasvatusta enemmän, ja myös kuuseen verrattuna enemmän kaikkia muita ravinteita paitsi kalsiumia ja mangaania. Kuusen kasvatus puolestaan kuluttaa männyn kasvatusta enemmän kasvualustan kaliumin, mangaanin, sinkin ja kalsiumin varastoja.

Pintaturpeen kaliumravinnevarat olivat alhaiset verrattuna puuston kuluttamiin määriin. Tämä aiheuttaa huolen turpeen kaliumvarojen riittävyydestä puuston jatkuvaa kasvatusta silmällä pitäen (ks. Holmen 1964, 1969, Kaunisto ja Paavilainen 1988). Tilannetta voidaan helpottaa kaliumlannoituksella sekä välttämällä kokopuukorjuuta. Pelkästään tämänhetkisen juuristokerroksen ravinnevarojen tarkastelu ei kuitenkaan riitä selittämään puunkasvatuksen vaikutuksia turvemaiden ravinnetalouteen. On todennäköistä, että turvekerros vähitellen hajotustoiminnan (Braekke 1987) ja puunkorjuun seurauksena ohenee, ja puiden juuret tavoittavat syvempien turvekerrosten ja jopa alla olevan kivennäismaan ravinnevarat. Paksuturpeisilla soilla tämä ei kuitenkaan paljon lisää puuston käytössä olevia kaliumvaroja, sillä ne ovat suurimmalta osin pintaturpeessa (Westman 1981, Braekke 1987, Kaunisto ja Paavilainen 1988). Suoekosysteemiin tulee ravinnelisää myös laskeuman mukana, mutta samanaikaisesti ravinteita huuhtoutuu ekosysteemin ulkopuolelle. Verrattaessa laskeumia (Järvinen 1986) huuhtoutumiin (Ahti 1983, Ahtiainen 1988) voidaan todeta, että vain typen tase on selvästi positiivinen. Fosforin ja kaliumin tase lienee lähellä tasapainotilaa. Huoli kaliumin riittävyydestä on todellinen paksuturpeisilla soilla.

Lannoituksessa lisätyt ravinnemäärät olivat moninkertaisia puuston vuotuiseen tarpeeseen verrattuna, ja typpeä lukuunottamatta suuret myös pintaturpeen ravinnevaroihin verrattuna. Tämän vuoksi on selvää, ettei puusto pystynyt sitomaan kuin pienen osan lannoiteravinteista. Lannoiteravinteista osa on mukana puiden ja maan välisessä ravinteiden kierrossa, ja osan toivotaan varastoituvan pintaturpeeseen myöhempää käyttöä varten. Mutta osa ravinteista, etenkin helppoliukoisesta kaliumista voi huuhtoutua suoekosysteemin ulkopuolelle (esim. Ahti 1983), ja osansa ottaa myös pintakasvillisuus ja maaperäeliöstö.

Appendix 1. Equations for bark and stemwood,
Liitetaulukko 1. *Kuori-runkopuuyhtälöt,*

$$M_b = a_1 M_s^{a_2} \rightarrow \ln M_b = \ln a_1 + a_2 \ln M_s.$$

Site Kasvupaikka	Tree species Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	pine-mänty	-1.6756	0.8030	0.977	0.151	15.2	16
RhNRmu	pine-mänty	-2.0429	0.8926	0.917	0.196	19.8	16
RhNRmu	birch-koivu	-2.2896	1.0242	0.969	0.186	18.8	14
MKmu	spruce-kuusi	-2.3319	0.9934	0.984	0.199	20.1	17

Appendix 2. Biomass equations for stemwood and bark (unfertilized material),
Liitetaulukko 2. *Runkopuun ja kuoren biomassayhtälöt (lannoittamaton aineisto),*

a) Stemwood - Runkopuu

$$M_s = a_1 d^{a_2} * (h-1,3)^{a_3} \rightarrow \ln M_s = \ln a_1 + a_2 \ln d + a_3 \ln(h-1,3).$$

Site Kasvu- paikka	Tree species Puulaji	$\ln a_1$	a_2	a_3	r^2	s_e	s_e%	n
VNRmu	pine-	-3.2875	1.8136	0.9317	0.996	0.094	9.4	7
-"-	mänty	-2.6905	1.9167	0.5642	0.998	0.065	6.5	8
RhNRmu	pine-	-1.6475	2.1064		0.962	0.160	16.1	8
-"-	mänty	-1.5957	2.0793		0.968	0.133	13.4	8
RhNRmu	birch-	-2.3362	2.3811		0.986	0.109	10.9	7
-"-	koivu	-2.0240	2.2886		0.991	0.100	10.0	7
MKmu	spruce-	-2.8414	1.5541	1.0560	0.998	0.082	8.2	8
-"-	kuusi	-2.4762	1.4797	0.9969	0.997	0.101	10.1	9

b) Bark - Kuori

$$M_b = a_1 d^{a_2} \rightarrow \ln M_b = \ln a_1 + a_2 d.$$

Site Kasvu- paikka	Tree species Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	pine-	-4.0168	2.0023	0.972	0.175	17.6	8
-"-	mänty	-3.6609	1.8650	0.985	0.131	13.2	8
RhNRmu	pine-	-2.9847	1.6874	0.906	0.208	21.0	8
-"-	mänty	-4.1947	2.1158	0.915	0.227	23.0	8
RhNRmu	birch-	-5.5507	2.7731	0.962	0.213	21.5	7
-"-	koivu	-3.5391	1.9958	0.936	0.244	24.8	7
MKmu	spruce-	-5.9120	2.7644	0.988	0.191	19.3	8
-"-	kuusi	-4.9328	2.4221	0.976	0.252	25.6	9

Appendix 3. Increment equations for stemwood biomass,
Liitetaulukko 3. *Runkopuun biomassan kasvuyhtälöt,*

$$I_s = a_1(d^2)^{a_2} \rightarrow \ln I_s = \ln a_1 + a_2 \ln d^2.$$

Site Kasvu- paikka	Fertilization Lannoitus	Tree species Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	0	pine-	-4.2197	0.8593	0.803	0.454	47.8	8
-"-	UABM	mänty	-4.3133	0.9719	0.900	0.389	40.4	8
RhNRmu	0	-"-	-5.6311	1.0921	0.882	0.319	32.7	8
-"-	UABM	-"-	-6.7911	1.3012	0.838	0.381	39.5	8
-"-	0	birch-	-2.4549	0.5384	0.624	0.396	41.2	7
-"-	UABM	koivu	-6.1527	1.2449	0.879	0.485	51.4	8
MKmu	0	spruce-	-6.5675	1.1496	0.910	0.462	48.8	8
-"-	UABM	kuusi	-5.5391	1.0451	0.891	0.496	52.8	9

Appendix 4. Range of biomass and increment characteristics in sample tree material on which stem biomass and increment equations were based.
Liitetaulukko 4. *Rungon biomassa ja kasvuyhtälöiden perustana olevien koepuuaineistojen vaihtelualue biomassa- ja kasvutunnusten suhteen.*

Characteristics Tunnus	VNRmu		RhNRmu				MKmu	
	Pine- Mänty		Pine- Mänty		Birch- Koivu		Spruce- Kuusi	
	0	UABM	0	UABM	0	UABM	0	UABM
Stemwood- Runkopuu, kg								
$\bar{x}$	42.2	49.8	82.0	83.7	55.2	62.9	101.3	138.5
min	4.1	3.2	22.2	21.2	13.7	7.9	3.6	5.0
max	108.3	148.2	208.7	161.0	131.8	213.0	268.3	418.9
Stem bark- Rungon kuori, kg								
$\bar{x}$	3.7	4.0	6.2	7.0	6.5	7.3	9.8	13.6
min	0.6	0.5	1.7	1.8	1.1	1.1	0.4	0.5
max	8.2	9.6	11.5	14.6	16.5	27.6	32.3	41.1
Increment of stemwood biomass after fertilization- Runkopuun biomassan kasvu lann. jälkeen, kg/a								
$\bar{x}$	1.06	1.71	1.38	1.45	1.04	0.97	1.06	1.92
min	0.14	0.14	0.37	0.23	0.36	0.05	0.05	0.06
max	2.41	3.59	3.50	2.84	2.08	3.20	2.68	5.79

Appendix 5. Equations for over-bark branch biomass (unfertilized material),
***Liitetaulukko** 5. Oksien kuorelliset oksabiomassayhtälöt (lannoittamaton aineisto),*

a) $M_{oo} = a_1 d_o^{a_2} * e^{a_3 S} * e^{a_4 S^2} \rightarrow \ln M_{oo} = \ln a_1 + a_2 \ln d_o + a_3 S + a_4 S^2$.

Site Kasvu-paikka	Tree species Puu-laji	$\ln a_1$	a_2	a_3	a_4	r^2	s_e	s_e%	n
VNRmu	pine-mänty	-4.6983	2.8545	0.0353	$-2.354*10^{-4}$	0.980	0.221	22.4	55
RhNRmu	-"-	-4.2071	2.7126	0.0368	$-2.456*10^{-4}$	0.976	0.235	23.8	52
-"-	birch-koivu	-3.1322	2.6750	0.0186	$-1.387*10^{-4}$	0.960	0.326	33.6	39
MKmu	spruce-kuusi	-3.0550	2.6029	0.0372	$-3.153*10^{-4}$	0.953	0.321	32.9	60

Appendix 6. Equations for the annual leaf biomass of branches,
***Liitetaulukko** 6. Oksien lehtibiomassayhtälöt vuosikerroittain,*

$M_{no} = a_1 d_o^{a_2} * e^{a_3 S} * e^{a_4 S^2}$ 1) $\rightarrow \ln M_{no} = \ln a_1 + a_2 \ln d_o + a_3 S + a_4 S^2$.

Fertili-zation Lannoi-tus	Age of leaf biomass Vuosi-kerta	$\ln a_1$	a_2	a_3	a_4	r^2	s_e	s_e%	n
				VNRmu, pine - VNRmu, mänty					
0	C	-2.4155	2.1968	-0.0169		0.862	0.342	35.2	55
UABM	C	-1.6059	1.7739	-0.0078		0.830	0.341	35.1	55
0	C+1	-4.1258	1.8881	0.0948	$-9.266*10^{-4}$	0.887	0.465	49.1	55
UABM	C+1	-4.1734	2.0950	0.0635	$-6.339*10^{-4}$	0.846	0.556	60.2	55
0	C≥2	-5.0688	1.9736	0.1027	$-8.837*10^{-4}$	0.933	0.406	42.3	55
UABM	C≥2	-5.5773	2.4444	0.0606	$-5.197*10^{-4}$	0.813	0.742	85.7	55
				RhNRmu, pine - RhNRmu, mänty					
0	C	-1.8387	1.9148	-0.0145		0.868	0.329	33.8	56
UABM	C	-2.0785	2.0225	-0.0166		0.819	0.421	44.0	56
0	C+1	-2.5904	1.7356	0.0476	$-5.091*10^{-4}$	0.874	0.433	45.4	56
UABM	C+1	-3.1577	1.8825	0.0570	$-6.250*10^{-4}$	0.917	0.386	40.1	56
0	C≥2	-3.3672	1.7120	0.0783	$-6.977*10^{-4}$	0.898	0.482	51.1	56
UABM	C≥2	-3.5305	1.7224	0.0710	$-6.361*10^{-4}$	0.907	0.459	48.4	56
				RhNRmu, birch - RhNRmu, koivu					
0	C	-2.1040	2.1471			0.948	0.277	28.2	39
UABM	C	-2.4953	2.2421			0.915	0.376	39.0	48
				MKmu, spruce - MKmu, kuusi					
0	C	-2.3719	2.0412	-0.0145		0.757	0.554	59.9	63
UABM	C	-2.0056	1.8754	-0.0165		0.713	0.601	66.0	63
0	C+1	-2.0437	1.7318			0.783	0.493	52.4	63
UABM	C+1	-2.2460	1.7710			0.733	0.586	64.0	63
0	C+2	-2.0139	1.6551			0.776	0.480	50.9	63
UABM	C+2	-2.0080	1.6218			0.709	0.569	61.8	63
0	C+3	-2.5968	1.8504	0.0131	$-1.664*10^{-4}$	0.810	0.494	52.6	63
UABM	C+3	-2.9536	1.8712	0.0303	$-3.211*10^{-4}$	0.831	0.515	55.1	63
0	C+4	-2.5785	1.7370	0.0123	$-1.578*10^{-4}$	0.780	0.509	54.4	63
UABM	C+4	-2.7947	1.6184	0.0451	$-4.468*10^{-4}$	0.775	0.586	64.0	63
0	C+5	-3.2076	1.9157	0.0224	$-3.416*10^{-4}$	0.761	0.580	63.2	63
UABM	C+5	-3.4920	1.8963	0.0403	$-4.764*10^{-4}$	0.775	0.631	69.9	63
0	C≥6	-4.5501	2.4902	0.0545	$-7.387*10^{-4}$	0.793	0.730	83.9	63
UABM	C≥6	-4.2584	2.1365	0.0744	$-8.345*10^{-4}$	0.732	0.882	108.5	63

1) At the linearization stage constant +1 added to M_{no} - linearisointivaiheessa lisät M_{no}:hon vakio +1.

Appendix 7. Range of different characteristics in sample branch material on which branch biomass and increment equations were based.
***Liitetaulukko** 7. Elävien oksien biomassa- ja kasvuyhtälöiden perustana olevien koeoksa-aineistojen vaihtelualue eri tunnusten suhteen.*

Characteristics Tunnus	VNRmu Pine-Mänty 0	 UABM	RhNRmu Pine-Mänty 0	 UABM	 Birch-Koivu 0	 UABM	MKmu Spruce-Kuusi 0	 UABM
n	55	55	53	56	44	52	61	61
d_o, mm								
$\bar{x}$	15	15	13	15	13	13	15	15
min	5	5	3	5	3	3	4	4
max	31	37	32	45	28	48	31	34
h_o, cm								
$\bar{x}$	107	107	89	101	134	150	123	108
min	23	20	14	15	25	21	19	17
max	245	248	231	291	281	489	291	235
Age-Ikä, a								
$\bar{x}$	7	7	8	9	13	14	23	17
min	1	1	1	1	1	1	2	1
max	30	26	21	21	31	33	93	52
Branch biomass (without foliage),-Oksabiomassa (ilman neulasia), g								
$\bar{x}$	102	126	79	134	125	226	186	153
min	2	1	1	1	1	1	1	2
max	552	841	442	1476	651	4427	948	669
Leaf biomass-Lehtibiomassa, C, g								
$\bar{x}$	21.2	20.9	13.9	18.0	43	42	15.6	13.7
min	1.4	0.0	0.8	0.6	1	1	0.4	0.2
max	133.1	100.9	61.9	108.9	238	353	72.4	56.0
C+1, g								
$\bar{x}$	23.2	22.8	18.8	24.4			15.8	14.8
min	0.0	0.0	0.0	0.0			0.6	0.0
max	107.5	103.7	72.0	175.7			60.4	55.3
C+2, g								
$\bar{x}$	20.6	25.9	22.5	23.2			12.8	11.8
min	0.0	0.0	0.0	0.0			0.0	0.0
max	111.3	153.7	97.2	220.5			55.4	45.9
C+3, g								
$\bar{x}$							14.8	16.3
min							0.0	0.0
max							58.2	67.7
C+4, g								
$\bar{x}$							10.8	13.3
min							0.0	0.0
max							47.9	41.3
C+5, g								
$\bar{x}$							10.2	12.1
min							0.0	0.0
max							50.0	59.1
C≥6, g								
$\bar{x}$							26.4	28.5
min							0.0	0.0
max							153.9	163.8
Branch biomass increment (without foliage),-Oksien biomassan kasvu (ilman lehtiä), g/a								
$\bar{x}$	12	14	12	14	14	20	11	11
min	1	0.9	0.0	0.2	0.1	0.1	0.0	0.3
max	33	46	30	39	48	73	25	24

Appendix 8. Equations for the over-bark branch biomass of crown (unfertilized material).
Liitetaulukko 8. *Latvuksen kuorelliset oksabiomassayhtälöt (lannoittamaton aineisto),*

$M_o = a_1 d^{a_2} \rightarrow \ln M_o = \ln a_1 + a_2 \ln d$ (pine - mänty, birch - koivu)

$M_o = a_1 d^{a_2} * cr^{a_3} \rightarrow \ln M_o = \ln a_1 + a_2 \ln d + a_3 \ln cr$ (spruce -kuusi).

Site Kasvupaikka	Tree species Puulaji	$\ln a_1$	a_2	a_3	r^2	s_e	s_e%	n
VNRmu	pine-mänty	3.2988	2.2387		0.980	0.165	16.6	8
RhNRmu	-"-		3.0560		0.999	0.344	35.4	8
-"-	birch-koivu		3.3891		0.999	0.252	25.6	7
MKmu	spruce-kuusi	4.1857	2.0822	0.6252	0.987	0.180	18.1	9

Appendix 9. Equations for the annual leaf biomass of crown,
Liitetaulukko 9. *Latvuksen lehtibiomassayhtälöt vuosikerroittain,*

$M_n = a_1 d^{a_2} * cr^{a_3} \rightarrow \ln M_n = \ln a_1 + a_2 \ln d + a_3 \ln cr.$

Fertilization Lannoitus	Age of leaf biomass Vuosikerta	$\ln a_1$	a_2	a_3	r^2	s_e	s_e%	n
		VNRmu, pine - VNRmu, mänty						
0	C	2.3958	1.8121		0.962	0.184	18.6	8
UABM	C	2.5991	1.7392		0.993	0.085	8.5	8
0	C+1	3.0319	1.6660		0.973	0.143	14.4	8
UABM	C+1	1.9569	2.0124		0.987	0.132	13.3	8
0	C≥2	2.8450	1.7205		0.975	0.140	14.1	8
UABM	C≥2	1.2005	2.2679		0.984	0.169	17.0	8
		RhNRmu, pine - VNRmu, mänty						
0	C	1.1906	2.0091		0.994	0.188	19.0	8
UABM	C	0.4024	2.2576		0.929	0.220	22.3	8
0	C+1	1.8862	1.8809		0.950	0.166	16.7	8
UABM	C+1	1.0657	2.1495		0.917	0.229	23.2	8
0	C≥2	2.1337	1.8666		0.945	0.173	17.4	8
UABM	C≥2	1.3715	2.0078		0.915	0.216	21.8	8
		RhNRmu, birch - RhNRmu, koivu						
0	C		2.9749		0.999	0.270	27.5	7
UABM	C		2.9289		0.999	0.300	30.7	8
		MKmu, spruce - MKmu, kuusi						
0	C	2.2939	1.8981	0.8337	0.994	0.117	11.7	9
UABM	C	2.9811	1.6941	1.0797	0.990	0.135	13.6	9
0	C+1	2.8349	1.7137	0.5291	0.990	0.128	12.8	9
UABM	C+1	3.3744	1.6309	1.0209	0.989	0.136	13.7	9
0	C≥2	2.7760	1.6714	0.5235	0.990	0.127	12.7	9
UABM	C≥2	3.4362	1.5502	1.0070	0.990	0.123	12.3	9
0	C+3	2.5818	1.7820	0.6142	0.990	0.137	13.8	9
UABM	C+3	3.3586	1.6784	1.0969	0.987	0.157	15.8	9
0	C+4	2.4523	1.7122	0.5289	0.990	0.127	12.7	9
UABM	C+4	3.5843	1.5383	1.0849	0.986	0.146	14.7	9
0	C+5	2.1302	1.8232	0.7358	0.989	0.144	14.5	9
UABM	C+5	2.9251	1.6882	1.1494	0.986	0.164	16.5	9
0	C≥6	1.9123	2.1511	0.9628	0.986	0.195	19.7	9
UABM	C≥6	3.1615	1.8118	1.2274	0.981	0.203	20.5	9

Appendix 10. Equations for cone biomass,
Liitetaulukko 10. *Käpybiomassayhtälöt,*

$M_c = a_1 d^{a_2} * cr^{a_3} \rightarrow \ln M_c = \ln a_1 + a_2 \ln d + a_3 \ln cr.$

Site Kasvupaikka	Tree species Puulaji	$\ln a_1$	a_2	a_3	r^2	s_e	s_e%	n
VNRmu	pine-mänty		2.4638		0.969	1.153 1)	166.7	16
RhNRmu	-"-		1.8038		0.790	2.689 1)	3715.1	16
MKmu	spruce-kuusi		1.2358	-4.7864	0.985	0.844	101.9	18

1) Without the correction term - ilman korjaustermiä.

Appendix 11. Biomass equations for the dead branches of crown,
Liitetaulukko 11. *Latvuksen kuolleiden oksien biomassayhtälöt,*

$M_d = a_1 d^{a_2} \rightarrow \ln M_d = \ln a_1 + a_2 \ln d$ (pine - mänty)

$M_d = a_1 d^{a_2} * cr^{a_3} \rightarrow \ln M_d = \ln a_1 + a_2 \ln d + a_3 \ln cr$ (birch - koivu)

$M_d = a_1 e^{a_2 d} \rightarrow \ln M_d = \ln a_1 + a_2 d$ (spruce - kuusi).

Site Kasvupaikka	Fertilization Lannoitus	Tree species Puulaji	$\ln a_1$	a_2	a_3	r^2	s_e	s_e%	n
VNRmu	0	pine-mänty	2.9225	1.7067		0.665	0.620	68.5	8
RhNRmu	0	-"-		2.7189		0.997	0.424	44.4	8
-"-	0+UABM	birch-koivu	-19.7244	5.9290	-10.9833	0.529	1.901	600.9	14
MKmu	0	spruce-kuusi	5.5372	0.1328		0.828	0.665	74.6	9

Appendix 12. Range of the measured characteristics in live branch material of sample trees on which crown biomass and increment equations were based.
Liitetaulukko 12. *Latvuksen biomassa- ja kasvuyhtälöiden perustana olevien koepuiden oksa-aineistojen vaihtelu mitattujen tunnusten suhteen.*

Characteristics Tunnus	VNRmu		RhNRmu				MKmu	
	Pine - Mänty		Pine - Mänty		Birch - Koivu		Spruce - Kuusi	
	0	UABM	0	UABM	0	UABM	0	UABM
No/tree- kpl/puu								
$\bar{x}$	75	70	66	69	64	66	190	218
min	53	33	43	59	58	26	68	69
max	109	119	71	92	91	72	320	453
d_o, mm								
$\bar{x}$	15	16	15	15	11	12	12	12
min	3	2	2	2	1	1	1	1
max	39	50	43	57	65	72	54	50
h_o, cm								
$\bar{x}$	107	115	100	99	123	132	94	93
min	3	3	2	2	1	1	2	2
max	290	365	330	331	462	616	356	324

Appendix 13. Range of biomass and increment characteristics of sample tree material on which crown biomass and increment equations were based.
Liitetaulukko 13. *Latvuksen biomassa- ja kasvuyhtälöiden perustana olevien koepuuaineistojen biomassa- ja kasvutunnusten vaihtelualue.*

Biomass characteristics- Biomassatunnus	VNRmu		RhNRmu				MKmu	
	Pine - Mänty 0	UABM	Pine - Mänty 0	UABM	Birch - Koivu 0	UABM	Spruce - Kuusi 0	UABM
Live branches (without foliage)- Elävät oksat (ilman lehtiä), g								
$\bar{x}$	10439	11736	7298	8724	9295	11225	27453	30265
min	1365	699	1232	854	1748	433	1614	2089
max	21684	39191	21864	28744	31933	43719	69777	98081
Leaves- Lehdet, C, g								
$\bar{x}$	1300	1483	1052	1080			1968	1914
min	250	242	308	253			138	189
max	2658	4088	2495	2668			4765	4772
C+1, g								
$\bar{x}$	1648	1734	1441	1519			2245	2418
min	394	219	469	380			241	273
max	3276	5310	3224	3701			5076	6271
C+2, g								
$\bar{x}$	1586	1716	1771	1346			1853	1985
min	372	165	596	356			211	251
max	3135	5530	3932	3118			4157	4872
C+3, g								
$\bar{x}$							2065	2671
min							195	278
max							4780	6913
C+4, g								
$\bar{x}$							1524	2125
min							164	268
max							3445	5061
C+5, g								
$\bar{x}$							1396	1732
min							118	175
max							3312	4316
Lehdet $C \geq 6$, g								
$\bar{x}$							2852	3180
min							135	268
max							7146	8308
Cones- Kävyt, g								
$\bar{x}$	844	1157	1381	453			1170	872
min	97	27	0	0			140	74
max	3103	3212	5334	1913			3654	2215
Dead branches- Kuolleet oksat, g								
$\bar{x}$	2016	2718	2996	2541	35	390	7016	5285
min	455	208	272	359	1	1	413	549
max	6635	10077	7905	6482	169	2671	27307	16812
Increment of live branches- Elävien oksien kasvu, g/a								
$\bar{x}$	838	1263	997	1235	1697	2316	1693	2395
min	506	440	652	867	843	1065	604	666
max	1363	2301	1392	1607	3041	4663	2693	5499
Increment of dead branches- Kuolleiden oksien biomassan muutos, g/a								
$\bar{x}$	82	82	419	419	0	0	58	110
min	67	67	109	109	0	0	30	68
max	141	141	1197	1197	0	0	114	162

Appendix 14. Branch biomass (without foliage) as explained by age,
Liitetaulukko 14. *Oksabiomassa (ilman lehtiä) iän funktiona,*

$$M_{oo} = a_1 i_o^{a_2} \rightarrow \ln M_{oo} = \ln a_1 + a_2 \ln i_o.$$

Site Kasvupaikka	Fertilization Lannoitus	Tree species Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	0	pine-	1.4319	1.4114	0.686	0.862	105.0	55
-"-	UABM	mänty	1.2491	1.5583	0.719	0.880	108.1	55
RhNRmu	0	-"-		1.8060	0.936	0.974	125.8	55
-"-	UABM	-"-		1.9249	0.957	0.823	98.4	56
-"-	0	birch-	-1.4696	2.1611	0.783	1.191	176.9	49
-"-	UABM	koivu	-2.2716	2.3682	0.662	1.449	267.6	56
MKmu	0	spruce-		1.5018	0.948	1.054	142.7	62
-"-	UABM	kuusi		1.5744	0.949	0.994	129.8	63

Appendix 15. Increment equations for branch biomass (without foliage),
Liitetaulukko 15. *Oksien biomassan kasvuyhtälöt (ilman lehtiä),*

$$I_o = a_1 h_o^{a_2} * e^{a_3 S} * e^{a_4 S^2} \rightarrow \ln I_o = \ln a_1 + a_2 \ln h_o + a_3 S + a_4 S^2 \text{ (pine - mänty)}$$

$$I_o = a_1 d_o^{a_2} * e^{a_3 S} * e^{a_4 S^2} \rightarrow \ln I_o = \ln a_1 + a_2 \ln d_o + a_3 S + a_4 S^2 \text{ (birch - koivu)}$$

$$I_o = a_1 d_o^{a_2} * h^{a_3} \rightarrow \ln I_o = \ln a_1 + a_2 \ln d_o + a_3 \ln h_o \text{ (spruce- kuusi).}$$

Site Kasvupaikka	Fertilization Lannoitus	Tree species Puulaji	$\ln a_1$	a_2	a_3	a_4	r^2	s_e	s_e%	n
VNRmu	0	pine-	-2.1168	0.5438	0.0736	$-5.767*10^{-4}$	0.940	0.271	27.6	55
-"-	UABM	mänty	-2.4096	0.6098	0.0726	$-4.749*10^{-4}$	0.909	0.378	39.2	55
RhNRmu	0	-"-	-2.4514	0.4894	0.0995	$-7.501*10^{-4}$	0.877	0.488	51.8	55
-"-	UABM	-"-	-2.6631	0.4147	0.1261	$-9.614*10^{-4}$	0.927	0.432	45.3	56
-"-	0	birch-	-3.2294	0.7243	0.1440	-0.0011	0.912	0.611	67.3	49
-"-	UABM	koivu	-2.1965	0.5747	0.1404	-0.0011	0.848	0.717	82.0	56
MKmu	0	spruce-	-1.5587	-0.4586	1.0795		0.872	0.234	23.7	63
-"-	UABM	kuusi	-3.0065	-0.6637	1.5310		0.820	0.409	42.7	63

Appendix 16. Increment equations for the over-bark branch biomass of crown (without foliage),
Liitetaulukko 16. *Latvuksen kuorellisen oksabiomassan kasvuyhtälöt (ilman lehtiä),*

$$I_o = a_1 d^{a_2} \rightarrow \ln I_o = \ln a_1 + a_2 \ln d.$$

Site Kasvupaikka	Fertilization Lannoitus	Tree species Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	0	pine-	5.0826	0.6874	0.869	0.142	14.3	8
-"-	UABM	mänty	4.8224	0.9623	0.974	0.094	9.4	8
RhNRmu	0	-"-	4.8422	0.7626	0.911	0.095	9.5	8
-"-	UABM	-"-	5.7037	0.5200	0.645	0.129	12.9	8
-"-	0	birch-	5.4602	0.8068	0.670	0.269	27.4	7
-"-	UABM	koivu	5.1117	1.0687	0.779	0.299	30.6	8
MKmu	0	spruce-	5.1045	0.8214	0.907	0.177	17.8	9
-"-	UABM	kuusi	5.1085	0.9172	0.730	0.379	39.3	9

Appendix 17. Biomass of dead branches as a function of tree age,
Liitetaulukko 17. Kuolleiden oksien biomassa puun iän funktiona,

$M_d = a_1 i^{a_2} \rightarrow \ln M_d = \ln a_1 + a_2 \ln i.$

Site Kasvu-paikka	Fertili-zation Lannoi-tus	Tree species Puu-laji	$\ln a_1$	a_2	r^2	s_e	$s_e\%$	n
VNRmu	0+UABM	pine-mänty		1.8748	0.984	0.943	119.7	16
RhNRmu	0+UABM	-"-	-45.279	13.5466	0.380	0.834	100.2	16
MKmu	0	spruce-		1.6923	0.993	0.703	79.9	9
-"-	UABM	kuusi		1.8587	0.990	0.861	104.8	9

Appendix 18. Increment in the biomass of dead branches,
Liitetaulukko 18. Kuolleiden oksien biomassan muutos,

$I_d = a_1 d^{a_2} \rightarrow \ln I_d = \ln a_1 + a_2 \ln d$ (pine - mänty)

$I_d = a_1 h^{a_2} \rightarrow \ln I_d = \ln a_1 + a_2 \ln h_o$ (spruce - kuusi).

Site Kasvu-paikka	Fertili-zation Lannoi-tus	Tree species Puu-laji	$\ln a_1$	a_2	r^2	s_e	$s_e\%$	n
VNRmu	0+UABM	pine-mänty	3.9118	0.1894	0.258	0.162	16.3	16
RhNRmu	0+UABM	-"-	2.7218	1.1286	0.370	0.504	53.8	16
MKmu	0	spruce-	0.4395	0.7359	0.830	0.194	19.6	9
-"-	UABM	kuusi	2.6425	0.4161	0.524	0.239	24.2	9

Appendix 19. Biomass equations for stump and thick roots,
Liitetaulukko 19. Kanto- ja paksujuurten biomassayhtälöt (Issakainen 1988),

$M_r = a_1 d^{a_2} \rightarrow \ln Mr = \ln a_1 + a_2 d$.

Tree species Puulaji	$\ln a_1$	a_2	r^2	n
Pine - Mänty	-4.5698	2.7929	0.989	16
Birch - Koivu	-5.3806	3.0861	0.991	8
Spruce - Kuusi	-4.9853	3.0333	0.982	8

Appendix 20. Biomass of fine foots per size classes.
Liitetaulukko 20. Ohutjuurten biomassa kokoluokittain.

Site Kasvu-paikka	Tree species Puu-laji	Fertili-zation Lannoi-tus	Ø<1mm kg/ha	1mm<Ø≤10mm kg/ha	Ø≤10mm kg/ha	Ø≤10mm kg/ha/ tree-puu
VNRmu	pine-	0	1488	3784	5272	4.8
-"-	mänty	UABM	1525	3247	4772	3.0
RhNRmu	-"-	0	447	436	883	2.5
-"-	-"-	UABM	479	294	773	2.5
-"-	birch-	0	624	1372	1996	3.4
-"-	koivu	UABM	1029	2910	3939	3.6
MKmu	spruce-	0	2565	4614	7179	9.8
-"-	kuusi	UABM	2392	5609	8001	11.4

Appendix 21. Annual litter fall.
Liitetaulukko 21. Vuotuinen karikesato karikelajeittain.

Period of time Ajan-jakso	Fertili-zation Lannoi-tus	Leaf Lehti kg/ha	kg/ha/ tree-puu	Other Muu kg/ha	kg/ha/ tree-puu	All Kaikki kg/ha
		VNRmu, pine - VNRmu, mänty				
21.05.1983-	0	1109		635		1744
30.05.1984	UABM	1198		747		1945
19.10.1983-	0	904		198		1102
09.10.1984	UABM	1114		442		1556
21.05.1983-	0	1007	1.02	417	0.42	1605
09.10.1984	UABM	1156	1.13	595	0.38	1744
		RhNRmu, pine/birch - RhNRmu, mänty/koivu				
21.05.1983	0	527		398		925
30.05.1984	0	1121		138		1259
21.05.1983-	UABM	542		291		833
30.05.1984	-"-	1018		281		1299
19.10.1983-	0	324		119		443
09.10.1984	0	746		130		876
19.10.1983-	UABM	301		213		514
09.10.1984	-"-	678		210		888
21.05.1983-	0	426	1.19	258	0.72	684
09.10.1984	0	934	1.61	134	0.23	1068
21.05.1983	UABM	422	1.34	252	0.80	674
09.10.1984	-"-	848	0.77	246	0.22	1094
		MKmu, spruce - MKmu, kuusi				
21.05.1983-	0	374		349		723
30.05.1984	UABM	394		264		658
19.10.1983-	0	557		155		712
09.10.1984	UABM	322		54		376
21.05.1983	0	466	0.70	252	0.38	718
09.10.1984	UABM	358	0.53	159	0.24	517

Appendix 22. Regression equations between the nutrient concentrations of different stem and crown compartments and stem biomass.
Liitetaulukko 22. *Rungon ja latvuksen eri ositteiden ravinnepitoisuuksien ja rungon biomassan väliset regressioyhtälöt.*

$N_o = M_s^{a_1}$ -> $\ln N_o = a_1 M_s$

Nutrient Ravinne	Tree species Puulaji	Compartment Osite	a_1	r^2	S_e
N	pine-mänty	stemwood-runkopuu	-0.0664	0.33	0.40
	birch-koivu	bark-kuori	-0.1302	0.42	0.38
	spruce-kuusi	-"-	-0.0776	0.58	0.27
	pine-mänty	branches-oksat	-0.1846	0.74	0.36
	birch-koivu	-"-	-0.0919	0.41	0.16
P	pine-mänty	branches-oksat	-0.1780	0.50	0.99
	spruce-kuusi	needle year class-neulaskerta			
	-"-	C+1	-0.0439	0.46	0.25
	-"-	C+2	-0.0551	0.44	0.23
	-"-	C+3	-0.0519	0.36	0.28
	-"-	C+4	-0.0654	0.54	0.22
	-"-	C+5	-0.0678	0.50	0.25
	-"-	C≥6	-0.0654	0.51	0.21
	-"-	branches-oksat	-0.0330	0.53	0.14
K	pine-mänty	stemwood-runkopuu	-0.0981	0.34	1.49
	-"-	needle year class-neulaskerta			
	-"-	C	-0.1224	0.43	0.89
	-"-	C+1	-0.0878	0.46	1.24
	-"-	branches-oksat	-0.1654	0.42	1.30
Ca	spruce-kuusi	stemwood-runkopuu	-0.0382	0.35	0.13
	pine-mänty	bark-kuori	-0.1402	0.18	2.62
	pine-mänty	branches-oksat	-0.1054	0.31	0.83
	spruce-kuusi	needle year class-neulaskerta			
	-"-	C+1	-0.0912	0.38	0.69
	-"-	C+2	-0.0834	0.29	0.71
Mg	spruce-kuusi	stemwood-runkopuu	-0.0692	0.28	0.53
	pine-mänty	needle year class-neulaskerta			
	-"-	C	-0.1099	0.59	0.30
	-"-	C+1	-0.0845	0.35	0.99
	-"-	C≥2	-0.1311	0.40	1.24
	-"-	branches-oksat	-0.1362	0.50	0.46
	spruce-kuusi	needle year class-neulaskerta			
	-"-	C+1	-0.0725	0.40	0.37
	-"-	C+2	-0.0791	0.36	0.58
	-"-	C+3	-0.0796	0.35	0.62
	-"-	C+4	-0.1145	0.49	0.74
	-"-	C+5	-0.1155	0.46	0.86
Fe	pine-mänty	needle year class-neulaskerta			
	-"-	C+1	+0.1675	0.56	2.49
	-"-	C≥2	+0.1258	0.49	0.56
Zn	pine-mänty	needle year class-neulaskerta			
	-"-	C≥2	-0.1303	0.76	1.47
Cu	birch-koivu	branches-oksat	-0.1286	0.42	0.32
	spruce-kuusi	-"-	-0.0511	0.33	0.16
B	pine-mänty	branches-oksat	-0.1043	0.48	0.49

Appendix 23. Mean nutrient concentrations of the stem and crown of sample trees, (DM %, 105 °C). Standard deviation in brackets.
Liitetaulukko 23. *Koepuiden rungon ja latvuksen ravinnepitoisuuksien keskiarvot, % kuiva-aineesta (105 °C). Suluissa keskihajonta.*

Site Kasvupaikka	Tree species Puulaji	Fertilization Lannoitus	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Zn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
			Stemwood - Runkopuu									
VNRmu	pine-	0	0.065	0.0044	0.022	0.056	0.016	2.5	35	6.5	1.4	1.6
			(0.008)	(0.0009)	(0.0050)	(0.0038)	(0.0025)	(1.6)	(12)	(1.4)	(0.2)	(0.5)
-"-	mänty	UABM	0.072	0.0048	0.027	0.052	0.015	3.1	24	6.3	1.6	1.7
			(0.011)	(0.0014)	(0.0080)	(0.0040)	(0.0016)	(1.4)	(14)	(1.2)	(0.5)	(0.3)
RhNRmu	pine-	0	0.059	0.0021	0.019	0.034	0.015	2.1	60	3.3	1.2	1.9
			(0.009)	(0.0006)	(0.0073)	(0.0068)	(0.0023)	(0.4)	(11)	(0.7)	(0.2)	(0.5)
-"-	mänty	UABM	0.062	0.0026	0.024	0.054	0.016	2.4	50	3.9	1.6	2.0
			(0.008)	(0.0007)	(0.0030)	(0.0035)	(0.0018)	(0.7)	(18)	(1.3)	(0.3)	(0.6)
RhNRmu	birch-	0	0.104	0.0061	0.027	0.054	0.015	3.7	68	12.5	1.4	1.9
			(0.009)	(0.0012)	(0.0054)	(0.015)	(0.0028)	(1.7)	(15)	(2.8)	(0.3)	(0.3)
-"-	koivu	UABM	0.103	0.0064	0.027	0.053	0.014	4.1	50	15.0	1.7	2.1
			(0.009)	(0.0014)	(0.0054)	(0.011)	(0.0036)	(1.9)	(24)	(3.7)	(0.5)	(0.4)
MKmu	spruce-	0	0.058	0.0017	0.021	0.071	0.0081	3.3	90	6.6	1.4	2.2
			(0.003)	(0.0005)	(0.0038)	(0.0072)	(0.0025)	(1.3)	(23)	(1.2)	(0.3)	(0.5)
-"-	kuusi	UABM	0.063	0.0027	0.028	0.068	0.0074	3.8	56	5.9	1.5	2.5
			(0.010)	(0.0015)	(0.0044)	(0.0080)	(0.0012)	(1.9)	(23)	(1.4)	(0.4)	(0.5)
			Bark - Kuori									
VNRmu	pine-	0	0.462	0.055	0.144	0.361	0.058	29	73	30	3.8	9.7
			(0.060)	(0.011)	(0.038)	(0.113)	(0.013)	(4.7)	(18)	(7.5)	(0.6)	(1.7)
-"-	mänty	UABM	0.478	0.058	0.153	0.321	0.058	48	53	28	10	11
			(0.038)	(0.0060)	(0.028)	(0.090)	(0.0074)	(11)	(31)	(4.2)	(5.8)	(1.3)
RhNRmu	pine-	0	0.377	0.032	0.119	0.326	0.050	31	124	16	3.7	8.9
			(0.071)	(0.0042)	(0.024)	(0.153)	(0.0072)	(5.9)	(33)	(2.1)	(0.4)	(1.4)
-"-	mänty	UABM	0.408	0.031	0.126	0.309	0.043	47	87	16	21	8.6
			(0.056)	(0.0049)	(0.025)	(0.073)	(0.0049)	(16)	(31)	(5.5)	(25)	(0.8)
RhNRmu	birch-	0	0.513	0.029	0.093	0.433	0.038	22	386	120	4.7	16
			(0.058)	(0.0031)	(0.018)	(0.071)	(0.0034)	(5.6)	(168)	(14)	(0.8)	(2.5)
-"-	koivu	UABM	0.471	0.032	0.108	0.516	0.039	30	308	146	13	19
			(0.112)	(0.0030)	(0.012)	(0.215)	(0.0067)	(9.8)	(144)	(71)	(14)	(2.4)
MKmu	spruce-	0	0.417	0.041	0.129	0.997	0.070	29	615	104	4.9	15
			(0.068)	(0.0067)	(0.019)	(0.166)	(0.013)	(7.6)	(187)	(17)	(0.4)	(1.8)
-"-	kuusi	UABM	0.498	0.052	0.172	0.966	0.069	32	439	100	12	18
			(0.092)	(0.011)	(0.028)	(0.254)	(0.013)	(6.0)	(122)	(13)	(11)	(2.8)
			Live branches - Elävät oksat									
VNRmu	pine-	0	0.559	0.062	0.167	0.281	0.069	61	86	30	4.0	7.8
			(0.147)	(0.018)	(0.056)	(0.057)	(0.014)	(11)	(57)	(5.9)	(0.8)	(1.4)
-"-	mänty	UABM	0.555	0.062	0.175	0.245	0.063	57	83	25	4.9	8.8
			(0.137)	(0.022)	(0.068)	(0.041)	(0.014)	(8.2)	(77)	(5.5)	(1.8)	(1.9)
RhNRmu	pine-	0	0.524	0.046	0.157	0.235	0.059	59	168	19	5.4	8.7
			(0.082)	(0.0062)	(0.042)	(0.058)	(0.0055)	(8.4)	(31)	(4.2)	(1.1)	(1.3)
-"-	mänty	UABM	0.457	0.045	0.170	0.225	0.055	52	121	19	4.7	8.1
			(0.089)	(0.0085)	(0.027)	(0.037)	(0.012)	(13)	(45)	(8.3)	(0.8)	(0.9)
RhNRmu	birch-	0	0.498	0.039	0.099	0.361	0.057	29	230	69	6.5	7.9
			(0.028)	(0.069)	(0.033)	(0.093)	(0.0097)	(7.2)	(99)	(15)	(1.3)	(0.8)
-"-	koivu	UABM	0.496	0.046	0.098	0.422	0.052	29	136	71	6.4	7.9
			(0.087)	(0.0067)	(0.012)	(0.106)	(0.0088)	(6.2)	(45)	(13)	(1.5)	(1.5)
MKmu	spruce-	0	0.507	0.047	0.152	0.546	0.057	122	413	47	6.2	9.5
			(0.026)	(0.0056)	(0.038)	(0.069)	(0.0095)	(13)	(96)	(11)	(0.7)	(1.4)
-"-	kuusi	UABM	0.548	0.055	0.176	0.617	0.057	124	256	45	6.4	14.4
			(0.053)	(0.051)	(0.035)	(0.089)	(0.013)	(14)	(56)	(10)	(1.0)	(11)
			Dead branches - Kuolleet oksat									
VNRmu	pine-	0	0.387	0.020	0.032	0.296	0.019	157	56	25	2.8	4.4
			(0.037)	(0.013)	(0.0095)	(0.078)	(0.0083)	(44)	(24)	(7.9)	(0.7)	(1.0)
-"-	mänty	UABM	0.426	0.023	0.037	0.276	0.024	169	53	26	12	4.6
			(0.060)	(0.0040)	(0.0070)	(0.075)	(0.010)	(37)	(28)	(7.1)	(15)	(1.3)
RhNRmu	pine-	0	0.316	0.015	0.020	0.115	0.010	113	44	13	3.6	3.3
			(0.060)	(0.0054)	(0.0073)	(0.052)	(0.0062)	(37)	(24)	(4.3)	(1.2)	(1.1)
-"-	mänty	UABM	0.252	0.012	0.018	0.121	0.0093	81	36	8.1	2.6	3.1
			(0.12)	(0.0032)	(0.0060)	(0.042)	(0.0036)	(42)	(17)	(1.4)	(0.6)	(0.7)
RhNRmu	birch-	0 1)	0.452	0.021	0.039	0.320	0.033	13	180	56	7.7	4.9
-"-	koivu	UABM	0.379	0.013	0.031	0.331	0.027	11	110	29	5.6	4.5
MKmu	spruce-	0 1)	0.315	0.016	0.024	0.482	0.013	110	130	36	3.9	5.1
-"-	kuusi	UABM	0.359	0.023	0.036	0.440	0.011	168	60	25	7.0	4.0

1) The nutrient concentrations of dead birch and pine branches as calculated from the combined material-
koivun ja kuusen kuolleitten oksien ravinnepitoisuudet laskettu yhdistetystä aineistosta.

Appendix 24. Annual mean nutrient concentrations of leaf year classes of sample trees, (DM %, 105 °C). Standard deviation in brackets.
Liitetaulukko 24. *Koepuiden eri lehtivuosikertojen ravinnepitoisuuksien keskiarvot, % kuiva-aineesta (105 °C). Suluissa keskihajonta.*

Site Kasvu-paikka	Tree species Puu-laji	Fertili-zation Lannoi-tus	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Zn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
						C						
VNRmu	pine-	0	1.54	0.174	0.455	0.258	0.119	41	215	38	4.4	14
			(0.11)	(0.017)	(0.14)	(0.063)	(0.011)	(5.8)	(59)	(7.5)	(1.1)	(6.6)
-"-	mänty	UABM	1.56	0.185	0.517	0.213	0.111	45	124	36	4.5	23
			(0.14)	(0.033)	(0.10)	(0.040)	(0.025)	(4.0)	(48)	(9.4)	(0.8)	(4.1)
RhNRmu	pine-	0	1.39	0.121	0.386	0.170	0.093	36	301	26	4.8	13
			(0.12)	(0.018)	(0.068)	(0.049)	(0.011)	(9.5)	(96)	(3.9)	(0.9)	(4.2)
-"-	mänty	UABM	1.39	0.138	0.464	0.165	0.092	42	219	26	5.2	22
			(0.12)	(0.020)	(0.082)	(0.040)	(0.012)	(10)	(68)	(3.5)	(0.9)	(4.0)
-"-	birch-	0	2.29	0.121	0.645	0.802	0.275	84	1033	64	10	23
			(0.20)	(0.013)	(0.12)	(0.12)	(0.051)	(7.1)	(176)	(11)	(1.7)	(5.8)
-"-	koivu	UABM	2.36	0.151	0.708	0.948	0.281	90	719	94	9.9	31
			(0.18)	(0.021)	(0.131)	(0.12)	(0.052)	(13)	(346)	(27)	(1.2)	(8.8)
MKmu	spruce-	0	1.38	0.148	0.578	0.341	0.111	27	516	24	5.6	21
			(0.085)	(0.011)	(0.085)	(0.068)	(0.018)	(5.4)	(294)	(6.6)	(0.8)	(6.9)
-"-	kuusi	UABM	1.43	0.156	0.571	0.425	0.102	33	425	26	5.7	26
			(0.10)	(0.030)	(0.16)	(0.13)	(0.014)	(9.4)	(133)	(9.9)	(1.9)	(6.8)
						C+1						
VNRmu	pine-	0	1.56	0.151	0.384	0.437	0.122	55	349	41	3.6	12
			(0.12)	(0.0066)	(0.12)	(0.019)	(0.007)	(12)	(114)	(10)	(0.9)	(6.6)
-"-	mänty	UABM	1.50	0.162	0.435	0.348	0.108	69	215	38	3.8	23
			(0.11)	(0.022)	(0.059)	(0.069)	(0.030)	(15)	(106)	(9.3)	(0.7)	(7.3)
RhNRmu	pine-	0	1.43	0.096	0.281	0.294	0.087	52	519	21	4.8	10
			(0.082)	(0.022)	(0.083)	(0.065)	(0.015)	(5.5)	(130)	(6.8)	(1.7)	(5.0)
-"-	mänty	UABM	1.44	0.121	0.418	0.274	0.084	59	403	21	4.9	22
			(0.094)	(0.021)	(0.076)	(0.067)	(0.014)	(11)	(183)	(12.5)	(1.0)	(4.7)
MKmu	spruce-	0	1.21	0.108	0.398	0.586	0.115	29	779	25	4.6	19
			(0.11)	(0.013)	(0.061)	(0.12)	(0.020)	(5.4)	(603)	(20)	(1.0)	(6.4)
-"-	kuusi	UABM	1.27	0.129	0.492	0.693	0.105	33	702	19	5.0	27
			(0.11)	(0.022)	(0.151)	(0.20)	(0.024)	(8.4)	(287)	(8.2)	(1.0)	(6.6)
						C+2						
VNRmu	pine-	0	1.45	0.142	0.341	0.581	0.103	69	473	47	3.5	11
			(0.11)	(0.015)	(0.087)	(0.094)	(0.019)	(14)	(119)	(10)	(0.8)	(5.0)
-"-	mänty	UABM	1.43	0.148	0.376	0.467	0.086	75	291	36	3.8	21
			(0.11)	(0.019)	(0.050)	(0.092)	(0.028)	(15)	(158)	(10.5)	(0.6)	(5.4)
RhNRmu	pine-	0	1.39	0.096	0.268	0.368	0.071	69	646	19	4.5	9.1
			(0.058)	(0.021)	(0.085)	(0.069)	(0.017)	(10)	(156)	(6.3)	(1.5)	(3.5)
-"-	mänty	UABM	1.44	0.120	0.375	0.357	0.071	77	490	15	5.5	21
			(0.14)	(0.017)	(0.062)	(0.120)	(0.011)	(14)	(223)	(2.6)	(0.9)	(5.8)
MKmu	spruce-	0	1.16	0.101	0.328	0.761	0.111	33	1099	16	4.3	15
			(0.11)	(0.016)	(0.068)	(0.12)	(0.022)	(5.7)	(611)	(6.4)	(9.6)	(5.2)
-"-	kuusi	UABM	1.17	0.112	0.393	0.833	0.099	36	847	16	4.6	27
			(0.14)	(0.016)	(0.067)	(0.31)	(0.026)	(9.1)	(428)	(7.5)	(0.7)	(7.4)
						C+3						
MKmu	spruce-	0	1.13	0.095	0.287	0.825	0.104	36	1122	13	3.9	14
			(0.12)	(0.016)	(0.052)	(0.14)	(0.018)	(8.1)	(648)	(6.8)	(6.8)	(6.0)
-"-	kuusi	UABM	1.18	0.105	0.360	0.924	0.093	38	961	16	3.9	24
			(0.15)	(0.017)	(0.073)	(0.39)	(0.026)	(11)	(482)	(11)	(9.0)	(7.2)
						C+4						
MKmu	spruce-	0	1.11	0.090	0.275	0.972	0.110	36	1220	12	3.8	14
			(0.12)	(0.015)	(0.054)	(0.29)	(0.022)	(4.8)	(694)	(6.1)	(0.5)	(5.7)
-"-	kuusi	UABM	1.15	0.103	0.333	0.992	0.093	36	990	14	3.7	25
			(0.12)	(0.010)	(0.083)	(0.38)	(0.030)	(8.6)	(526)	(8.5)	(1.2)	(8.0)
						C+5						
MKmu	spruce-	0	1.06	0.086	0.252	1.06	0.109	34	1162	12	3.9	12
			(0.12)	(0.015)	(0.048)	(0.34)	(0.023)	(4.4)	(644)	(5.6)	(0.9)	(4.5)
-"-	kuusi	UABM	1.17	0.096	0.295	0.992	0.093	39	912	12	3.2	25
			(0.19)	(0.016)	(0.071)	(0.34)	(0.031)	(13)	(436)	(7.0)	(1.4)	(8.5)
						C≥6						
MKmu	spruce-	0	0.98	0.078	0.214	1.40	0.111	37	1503	16	3.6	12
			(0.12)	(0.012)	(0.047)	(0.38)	(0.024)	(9.0)	(676)	(11)	(0.7)	(4.4)
-"-	kuusi	UABM	1.05	0.084	0.255	1.43	0.101	37	1074	13	2.7	23
			(0.18)	(0.014)	(0.075)	(0.30)	(0.033)	(8.9)	(476)	(9.6)	(0.7)	(62)

Appendix 25. Nutrient concentration of cones, (DM %, 105 °C).
Liitetaulukko 25. *Käpyjen ravinnepitoisuudet, (% kuiva-aineesta, 105 °C).*

Site Kasvu-paikka	Tree species Puu-laji	Fertili-zation Lannoi-tus	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Zn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
VNRmu	pine-	0	0.34	0.042	0.112	0.034	0.021	32	18	14	2.3	5.9
-"-	mänty	UABM	0.35	0.046	0.142	0.027	0.015	25	15	13	3.0	8.2
RhNRmu	pine-	0	0.45	0.048	0.179	0.021	0.038	37	33	15	3.7	7.2
-"-	mänty	UABM	0.36	0.040	0.207	0.015	0.035	25	24	16	3.7	11.3
MKmu	spruce- kuusi	0+UABM	0.57	0.062	0.518	0.009	0.070	18	43	18	5.6	14.7

Appendix 26. Mean nutrient concentrations of stump and thick roots of sample trees, (DM %, 105 °C), (Issakainen 1988). Standard deviation in brackets.
Liitetaulukko 26. *Koepuiden kanto- ja paksujuurten ravinnepitoisuuksien keskiarvot % kuiva-aineesta, 105 °C, (Issakainen 1988). Suluissa keskihajonta.*

Site Kasvu-paikka	Tree species Puu-laji	Fertili-zation Lannoi-tus	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Zn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
VNRmu	pine-	0	0.172	0.020	0.073	0.113	0.024	35	93	10	2	2.5
			(0.051)	(0.008)	(0.025)	(0.032)	(0.009)	(16)	(93)	(3)		(1.4)
-"-	mänty	UABM	0.171	0.028	0.118	0.126	0.029	25	27	11	3	2.4
			(0.043)	(0.008)	(0.027)	(0.017)	(0.005)	(5)	(41)	(4)		(0.2)
RhNRmu	pine-	0	0.118	0.007	0.043	0.124	0.025	177	43	5	2	2.5
			(0.013)	(0.002)	(0.004)	(0.026)	(0.005)	(215)	(19)	(1)	(1)	(0.4)
-"-	mänty	UABM	0.160	0.009	0.056	0.130	0.026	85	47	6	4	2.2
			(0.020)	(0.001)	(0.006)	(0.022)	(0.005)	(70)	(10)		(4)	(1.4)
RhNRmu	birch-	O	0.352	0.015	0.058	0.183	0.031	225	83	23	3	3.7
			(0.133)	(0.009)	(0.016)	(0.079)	(0.009)	(308)	(29)	(16)	(1)	(1.2)
-"-	koivu	UABM	0.388	0.023	0.082	0.204	0.031	135	101	31	4	4.4
			(0.046)	(0.005)	(0.024)	(0.046)	(0.005)	(36)	(5)	(6)		(1.2)
MKmu	spruce-	0	0.149	0.013	0.072	0.233	0.018	18	88	13	2	3.3
			(0.022)	(0.001)	(0.034)	(0.056)	(0.003)	(5)	(39)	(1)	(1)	(0.1)
-"-	kuusi	UABM	0.149	0.013	0.072	0.233	0.018	18	49	13	2	3.2
			(0.011)	(0.004)	(0.013)	(0.072)	(0.004)	(5)	(28)	(5)	(1)	(0.3)

Appendix 27. Nutrient concentrations of fine roots (ø ≤10 mm) (DM %, 105 °C).
Liitetaulukko 27. *Ohutjuurten (ø ≤10 mm) ravinnepitoisuudet (% kuiva-aineesta 105 °C).*

Site Kasvu-paikka	Tree species Puu-laji	Fertili-zation Lannoi-tus	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Zn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
VNRmu	pine-	0	0.640	0.068	0.095	0.171	0.045	804	19	18	2.7	4.8
-"-	mänty	UABM	0.708	0.061	0.099	0.195	0.041	812	21	29	15.8	5.5
RhNRmu	pine-	0	1.100	0.058	0.049	0.313	0.050	3398	62	13	8.3	
-"-	mänty	UABM	1.080	0.066	0.066	0.390	0.078	5170	110	38	62.7	
-"-	birch-	0	0.941	0.035	0.062	0.308	0.044	2851	105	30	4.2	7.3
-"-	koivu	UABM	0.913	0.047	0.102	0.437	0.078	3383	141	49	36.3	9.4
MKmu	spruce-	0	0.665	0.054	0.080	0.306	0.038	458	153	31	4.0	6.8
-"-	kuusi	UABM	0.774	0.056	0.140	0.336	0.042	464	105	43	7.0	8.7

Appendix 28. Nutrient concentrations of litter from Oct. 20, 1983 to Oct. 9, 1984 (DM %, 105 °C).
Liitetaulukko 28. *Karikkeiden ravinnepitoisuudet 20.10.1983–9.10.1984 (% kuiva-aineesta, 105 °C).*

Fertilization / Lannoitus	Litter / Karikelaji	N	P	K	Ca	Mg	Fe $*10^{-4}$	Mn $*10^{-4}$	Cu $*10^{-4}$	B $*10^{-4}$
				VNRmu, pine		- VNRmu, mänty				
0	needle-	0.62	0.051	0.096	0.51	0.060	93	529	4.0	6.4
UABM	neulas	0.70	0.057	0.115	0.56	0.064	90	481	3.5	23.3
0	other-	0.69	0.046	0.049	0.23	0.023	447	88	8.1	9.3
UABM	muu	0.55	0.039	0.048	0.22	0.026	206	68	5.5	8.1
				RhNRmu, pine		- RhNRmu, mänty				
0	needle-	0.84	0.043	0.108	0.42	0.068	76	727	2.6	3.3
UABM	neulas	1.00	0.068	0.185	0.39	0.059	89	626	3.6	21.5
0	other-	0.65	0.032	0.044	0.30	0.027	143	117	4.1	8.8
UABM	muu	0.51	0.036	0.064	0.27	0.036	170	145	11.6	9.3
				RhNRmu, birch		- RhNRmu, koivu				
0	leaf-	1.35	0.072	0.197	0.93	0.276	112	1451	6.6	20.7
UABM	lehti	1.27	0.065	0.248	1.06	0.253	123	1161	7.5	34.9
0	other-	1.37	0.096	0.112	0.53	0.087	216	623	10.4	13.3
UABM	muu	0.96	0.062	0.209	0.50	0.093	98	486	9.7	10.0
				MKmu, spruce		- MKmu, kuusi				
0	needle-	0.89	0.053	0.102	1.13	0.076	79	1374	3.3	10.6
UABM	neulas	0.88	0.057	0.136	1.12	0.069	75	966	2.1	22.2
0	other-	0.60	0.059	0.085	0.45	0.027	392	284	6.1	11.5
UABM	muu	0.84	0.063	0.123	0.34	0.038	345	223	7.3	11.2

Appendix 29. Height equations,
Liitetaulukko 29. *Pituusyhtälöt,*

$$h = 1,3 + \frac{d^2}{(a_1+a_2d)^2} .$$

Site / Kasvupaikka	Tree species / Puulaji	a_1	a_2	r^2	s_e	s_e%	n
VNRmu	pine-mänty	1.1888	0.2611	0.942	0.294	30.0	77
RhNRmu	pine-mänty	0.9226	0.2180	0.978	0.141	14.2	37
RhNRmu	birch-koivu	0.9066	0.2120	0.979	0.162	16.3	27
MKmu	spruce-kuusi	1.8137	0.1584	0.944	0.228	23.1	57

Appendix 30. Equations for crown limit,
Liitetaulukko 30. *Latvusrajayhtälöt,*

$$cl = h^{a_1}*e^{a_3d} \rightarrow \ln cl = a_1h+a_3d.$$

Site / Kasvupaikka	Tree species / Puulaji	a_1	r^2	s_e	s_e%	n
RhNRmu	birch-koivu	0.7543	0.997	0.113	11.3	30
MKmu	spruce-kuusi	0.6532	0.973	0.315	32.3	74

Appendix 31. Equations for bark thickness,
Liitetaulukko 31. *Kuorenpaksuusyhtälöt,*

$$2*b = a_1*d_u^{a_2} \rightarrow \ln 2*b = \ln a_1+a_2\ln d_u.$$

Site / Kasvupaikka	Tree species / Puulaji	$\ln a_1$	a_2	r^2	s_e	s_e%	n
VNRmu	pine-mänty	0.0090	0.9096	0.742	0.260	26.4	16
RhNRmu	pine-mänty	-0.1462	0.9920	0.704	0.225	22.8	16
RhNRmu	birch-koivu	-0.7247	1.0117	0.929	0.116	11.6	14
MKmu	spruce-kuusi	0.1109	0.6981	0.831	0.194	19.6	18

Appendix 32. Biomass of model stands before and after fertilization.
Liitetaulukko 32. *Mallimetsiköiden biomassa ennen ja jälkeen lannoituksen.*

a) VNRmu

Compartment Osite	Before fertilization Ennen lannoitusta Pine - Mänty		After fertilization Lannoituksen jälkeen 0		UABM	
	kg/ha	%	kg/ha	%	kg/ha	%
Stemwood- Runkopuu	19940	41.6	25890	41.4	29285	43.2
Bark- Kuori	2290	4.8	2760	4.4	3020	4.5
Live branches- Elävät oksat	6320	13.2	10340	16.6	11900	17.6
Dead branches- Kuolleet oksat	1330	2.8	1780	2.8	1780	2.6
Leaves- Lehdet	3035	6.3	3780	6.0	3600	5.3
Cones- Kävyt	410	0.9	410	0.7	410	0.6
Above-ground parts in all- Maanpääll. yht.	33325	69.6	44960	71.9	49995	73.8
Stump and thick roots- Kanto- ja paksujuuret	10110	21.1	13110	21.0	14970	22.1
Fine roots- Ohutjuuret	4420	9.3	4425	7.1	2765	4.1
Underground parts in all- Maanal. yht.	14530	30.4	17535	28.1	17735	26.2
Total- Kaikki yht.	47855	100.0	62495	100.0	67730	100.0

b) RhNRmu

Compartment Osite	Before fertilization Ennen lannoitusta Pine - Mänty		Birch - Koivu		After fertilization Lannoituksen jälkeen Pine - Mänty 0		UABM		Birch - Koivu 0		UABM	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Stemwood- Runkopuu	33480	60.6	20270	57.3	38310	57.2	38490	56.7	23990	52.1	24290	50.4
Bark- Kuori	2770	5.0	2415	6.8	3130	4.7	3140	4.6	2840	6.2	2885	6.0
Live branches- Elävät oksat	2655	4.8	3490	9.8	5925	8.9	6705	9.9	8380	18.2	10300	21.4
Dead branches- Kuolleet oksat	960	1.7	0	0.0	2160	3.2	2160	3.2	0	0.0	0	0.0
Leaves- Lehdet	1805	3.3	1060	3.0	2035	3.0	1825	2.7	1445	3.1	1130	2.3
Cones- Kävyt	75	0.1			75	0.1	75	0.1				
Above-ground parts in all- Maanpääll. yht.	41745	75.5	27235	76.9	51635	77.1	52395	77.2	36655	79.6	38605	80.1
Stump and thick roots- Kanto- ja paksujuuret	12275	22.2	6655	18.8	14045	21.0	14105	20.8	7885	17.1	7975	16.6
Fine roots- Ohutjuuret	1280	2.3	1505	4.3	1280	1.9	1395	2.0	1505	3.3	1595	3.3
Underground parts in all- Maanal. yht.	13555	24.5	8160	23.1	15325	22.9	15500	22.8	9390	20.4	9570	19.9
Total- Kaikki yht.	55300	100.0	35395	100.0	66960	100.0	67895	100.0	46045	100.0	48175	100.0

c) MKmu

Compartment Osite	Before fertilization Ennen lannoitusta Spruce - Kuusi		After fertilization Lannoituksen jälkeen 0		UABM	
	kg/ha	%	kg/ha	%	kg/ha	%
Stemwood- Runkopuu	68205	46.2	73730	44.8	76370	44.0
Bark- Kuori	6975	4.7	7675	4.7	8015	4.6
Live branches- Elävät oksat	14750	10.0	21135	12.8	23790	13.7
Dead branches- Kuolleet oksat	3300	2.3	3340	2.0	3455	2.0
Leaves- Lehdet	7870	5.3	8825	5.4	9945	5.7
Cones- Kävyt	355	0.3	355	0.2	355	0.2
Above-ground parts in all- Maanpääll. yht.	101455	68.8	115060	69.9	121930	70.2
Stump and thick roots- Kanto- ja paksujuuret	40565	27.5	43975	26.7	45425	26.1
Fine roots- Ohutjuuret	5535	3.7	5535	3.4	6435	3.7
Underground- parts in all- Maanal. yht.	46100	31.2	49510	30.1	51860	29.8
Total- Kaikki yht.	147555	100.0	164570	100.0	173790	100.0

Appendix 33. Annual net increment of the biomass and litter production of model stands.
Liitetaulukko 33. *Mallimetsiköiden biomassan vuotuinen nettokasvu ja karikesato lannoituksen jälkeen.*

a) VNRmu

Compartment Osite	Pine - Mänty 0 kg/ha/a	%	UABM kg/ha/a	%
Stemwood- Runkopuu	990	17.0	1555	23.4
Bark- Kuori	80	1.4	120	1.8
Live branches- Elävät oksat	670	11.5	930	14.0
Dead branches- Kuolleet oksat	70	1.2	70	1.1
Leaves- Lehdet	1260	21.7	1200	18.0
Cones- Kävyt	205	3.5	205	3.1
Above-ground parts in all- Maanpääll. yht.	3275	56.3	4080	61.4
Stump and thick roots- Kanto- ja paksu-juuret	500	8.6	810	12.2
Fine roots- Ohutjuuret	2045	35.1	1760	26.4
Underground parts in all- Maanal. yht.	2545	43.7	2570	38.6
Total net increment- Nettokasvu yht.	5820	100.0	6650	100.0
Leaf litter- Lehtikarike	940	27.9	1040	33.0
Other above-ground litter- Muu maanpääll. karike	385	11.4	350	11.1
Fine root litter- Ohutjuurikarike	2045	60.7	1760	55.9
Total litter- Karike yht.	3370	100.0	3150	100.0
Biomass fixed in stand- Puustoon sitoutu-nut biomassa	2450	42.1	3500	52.6
Biomass fixed in above-ground parts- Maanpääll. osiin sitout. biomassa	1950	59.5	2690	65.9

b) MKmu

Compartment Osite	Spruce - Kuusi 0 kg/ha/a	%	UABM kg/ha/a	%
Stemwood- Runkopuu	920	13.4	1360	16.1
Bark- Kuori	115	1.7	175	2.1
Live branches- Elävät oksat	1065	15.5	1505	17.8
Dead branches- Kuolleet oksat	5	0.1	25	0.3
Leaves- Lehdet	1145	16.7	1330	15.8
Cones- Kävyt	180	2.6	180	2.1
Above ground parts in all- Maanpääll. yht.	3430	50.0	4575	54.2
Stump and thick roots- Kanto- ja paksu-juuret	570	8.3	810	9.6
Fine roots- Ohutjuuret	2865	41.7	3050	36.2
Underground parts in all Maanal. yht.	3435	50.0	3860	45.8
Total net increment- Nettokasvu yht.	6865	100.0	8435	100.0
Leaf litter- Lehtikarike	395	11.4	300	8.6
Other above-ground litter- Muu maanpääll. karike	215	6.2	135	3.9
Fine root litter- Ohutjuurikarike	2865	82.4	3050	87.5
Total litter- Karike yht.	3475	100.0	3485	100.0
Biomass fixed in stand- Puustoon sitoutu-nut biomassa	3390	49.4	4950	58.7
Biomass fixed in above-ground parts- Maanpääll. osiin sitout. biomassa	2820	82.2	4140	90.5

c) RhNRmu

Compartment Osite	Pine - Mänty 0 kg/ha/a	%	UABM kg/ha/a	%	Birch - Koivu 0 kg/ha/a	%	UABM kg/ha/a	%
Stemwood- Runkopuu	805	23.0	835	22.5	620	16.6	670	17.1
Bark- Kuori	60	1.7	60	1.6	70	1.9	80	2.1
Live branches- Elävät oksat	545	15.6	675	18.2	815	21.8	1135	29.0
Dead branches- Kuolleet oksat	200	5.8	200	5.4	0	0.0	0	0.0
Leaves- Lehdet	675	19.3	610	16.4	1250	33.5	1095	28.0
Cones- Kävyt	35	1.0	35	0.9				
Above-ground parts in all- Maanpääll. yht.	2320	66.4	2415	65.0	2755	73.8	2980	76.2
Stump and thick roots- Kanto- ja paksu-juuret	295	8.4	305	8.2	205	5.5	220	5.6
Fine roots- Ohutjuuret	880	25.2	995	26.8	775	20.7	710	18.2
Underground parts in all- Maanal. yht.	1175	33.6	1300	35.0	980	26.2	930	23.8
Total net increment- Nettokasvu yht.	3495	100.0	3715	100.0	3735	100.0	3910	100.0
Leaf litter- Lehtikarike	665	34.2	750	34.2	715	45.0	340	29.6
Other above-ground litter- Muu maanpääll. karike	400	20.6	445	20.3	100	6.3	100	8.7
Fine root litter- Ohutjuurikarike	880	45.2	995	45.5	775	48.7	710	61.7
Total litter- Karike yht.	1945	100.0	2190	100.0	1590	100.0	1150	100.0
Biomass fixed in stand- Puustoon sitoutu-nut biomassa	1550	44.3	1525	41.0	2145	57.4	2760	70.6
Biomass fixed in above-ground parts- Maanpääll. osiin sitout. biomassa	1255	54.1	1220	50.5	1940	70.4	2540	85.2

Appendix 34. Nutrient amounts (kg/ha) fixed in the stand before fertilization.
Liitetaulukko 34. *Puustoon ennen lannoitusta sitoutuneiden ravinteiden määrät (kg/ha).*

a) VNRmu, pine - mänty

Compartment Osite	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Stemwood- Runkopuu	9.62	0.81	2.93	10.34	2.95	0.046	0.650	0.120	0.026	0.030
Bark- Kuori	9.87	1.18	3.08	4.89	1.24	0.062	0.160	0.064	0.008	0.021
Live branches- Elävät oksat	17.58	1.94	5.59	11.44	2.54	0.352	0.496	0.173	0.023	0.032
Dead branches- Kuolleet oksat	4.74	0.24	0.39	3.62	0.23	0.192	0.069	0.031	0.003	0.005
Leaves- Lehdet	43.52	4.43	8.98	12.54	2.34	0.114	1.018	0.105	0.011	0.035
Cones- Kävyt	1.73	0.21	0.57	0.17	0.11	0.016	0.009	0.007	0.001	0.003
Above-ground parts in all- Maanp. yht.	87.06	8.81	21.54	43.00	9.41	0.782	2.402	0.500	0.072	0.126
Stump and thick roots- Kanto- ja paksujuuret	16.81	1.95	7.13	11.04	2.35	0.342	0.909	0.098	0.020	0.023
Fine roots- Ohutjuuret	26.65	2.83	3.96	7.12	1.87	3.348	0.079	0.075	0.011	0.020
Underground parts in all- Maanal. yht.	43.46	4.78	11.09	18.16	4.22	3.690	0.988	0.173	0.031	0.043
Total- Kaikki yht.	130.52	13.59	32.63	61.16	13.63	4.472	3.390	0.673	0.103	0.169

b) RhNRmu, pine - mänty

Compartment Osite	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Stemwood- Runkopuu	13.89	0.66	3.91	16.85	4.68	0.066	1.870	0.103	0.037	0.059
Bark- Kuori	9.77	0.83	3.08	4.71	1.30	0.080	0.321	0.041	0.010	0.023
Live branches- Elävät oksat	5.82	0.51	1.90	3.68	0.81	0.146	0.416	0.047	0.013	0.014
Dead branches- Kuolleet oksat	2.84	0.14	0.18	1.04	0.09	0.102	0.040	0.012	0.003	0.003
Leaves- Lehdet	23.92	1.73	3.98	5.02	0.89	0.059	0.890	0.031	0.008	0.017
Cones- Kävyt	0.31	0.03	0.12	0.01	0.03	0.003	0.002	0.001	0.0	0.0
Above-ground parts in all- Maanp. yht.	56.55	3.90	13.17	31.31	7.80	0.456	3.539	0.235	0.071	0.116
Stump and thick roots- Kanto- ja paksujuuret	13.87	0.82	5.05	14.57	2.94	2.080	0.505	0.059	0.023	0.029
Fine roots- Ohutjuuret	13.24	0.70	0.59	3.77	0.60	4.090	0.075	0.016	0.010	
Underground parts in all- Maanal. yht.	27.11	1.52	5.64	18.34	3.54	6.170	0.580	0.075	0.033	
Total- Kaikki yht.	83.66	5.42	18.81	49.65	11.34	6.626	4.119	0.310	0.104	

c) RhNRmu, birch - koivu

Compartment Osite	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Stemwood- Runkopuu	19.82	1.16	5.15	10.29	2.86	0.071	1.300	0.238	0.027	0.036
Bark- Kuori	6.88	0.51	2.15	10.00	0.88	0.051	0.890	0.277	0.011	0.037
Live branches- Elävät oksat	16.24	1.27	3.23	11.77	1.86	0.095	0.750	0.225	0.021	0.026
Dead branches- Kuolleet oksat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leaves- Lehdet	22.25	1.18	6.27	7.79	2.67	0.082	1.000	0.062	0.010	0.022
Cones- Kävyt										
Above-ground parts in all- Maanp. yht.	65.19	4.12	16.80	39.85	8.27	0.299	3.940	0.802	0.069	0.121
Stump and thick roots- Kanto- ja paksujuuret	22.16	0.94	3.65	11.52	1.95	1.416	0.522	0.145	0.019	0.023
Fine roots- Ohutjuuret	13.34	0.50	0.88	4.37	0.62	4.042	0.149	0.043	0.006	0.010
Underground parts in all- Maanal. yht.	35.50	1.44	4.53	15.89	2.57	5.458	0.671	0.188	0.025	0.033
Total- Kaikki yht.	100.69	5.56	21.33	55.74	10.84	5.757	4.611	0.990	0.094	0.154

d) MKmu, kuusi

Compartment Osite	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Stemwood- Runkopuu	36.91	1.08	13.36	37.28	3.64	0.210	5.730	0.420	0.089	0.140
Bark- Kuori	18.41	1.94	8.46	43.68	4.59	0.190	4.030	0.680	0.032	0.098
Live branches- Elävät oksat	70.82	5.57	21.23	76.27	7.96	1.704	5.769	0.656	0.067	0.133
Dead branches- Kuolleet oksat	9.90	0.50	0.75	15.14	0.41	0.346	0.410	0.113	0.012	0.016
Leaves- Lehdet	85.11	6.04	18.59	59.56	6.33	0.247	7.974	0.129	0.032	0.114
Cones- Kävyt	1.97	0.21	1.79	0.03	0.24	0.006	0.015	0.006	0.002	0.006
Above-ground parts in all- Maanp. yht.	223.12	15.34	64.18	231.96	23.17	2.703	23.928	2.004	0.234	0.507
Stump and thick roots- Kanto- ja paksujuuret	57.18	4.99	27.63	89.42	6.91	0.690	3.380	0.499	0.077	0.127
Fine roots- Ohutjuuret	34.78	2.83	4.18	16.00	1.99	2.390	0.800	0.162	0.021	0.036
Underground parts in all- Maanal. yht.	91.96	7.82	31.81	105.42	8.90	3.080	4.180	0.661	0.098	0.163
Total- Kaikki yht.	315.08	23.16	95.99	337.38	32.07	5.783	28.108	2.665	0.332	0.670

Appendix 35. Nutrient amounts (kg/ha) fixed in the stand six years after fertilization.
Liitetaulukko 35. *Puustoon sitoutuneiden ravinteiden määrät (kg/ha) kuusi vuotta lannoituksen jälkeen.*

a) VNRmu, pine - mänty

Compartment Osite	N 0	N UABM	P 0	P UABM	K 0	K UABM	Ca 0	Ca UABM	Mg 0	Mg UABM	Fe 0	Fe UABM	Mn 0	Mn UABM	Zn 0	Zn UABM	Cu 0	Cu UABM	B 0	B UABM
Stemwood- Runkopuu	12.29	15.27	1.05	1.30	3.72	5.10	13.42	14.10	3.84	4.07	0.060	0.084	0.840	0.651	0.156	0.171	0.034	0.043	0.038	0.046
Bark- Kuori	11.90	13.44	1.42	1.63	3.71	4.30	5.70	5.44	1.49	1.63	0.075	0.135	0.188	0.149	0.077	0.079	0.010	0.028	0.025	0.031
Live branches- Elävät oksat	31.42	37.76	3.46	4.19	9.95	12.63	20.16	21.28	4.50	4.97	0.609	0.690	0.859	1.004	0.300	0.302	0.040	0.059	0.056	0.077
Dead branches- Kuolleet oksat	6.92	6.94	0.33	0.37	0.52	0.60	4.81	4.49	0.31	0.39	0.255	0.275	0.091	0.086	0.041	0.042	0.005	0.020	0.007	0.007
Leaves- Lehdet	54.09	50.86	5.51	5.60	11.21	11.97	15.57	11.71	2.93	2.47	0.142	0.153	1.264	0.718	0.131	0.111	0.014	0.014	0.044	0.076
Cones- Kävyt	1.73	1.94	0.21	0.25	0.57	0.79	0.17	0.15	0.11	0.08	0.016	0.014	0.009	0.008	0.007	0.007	0.001	0.002	0.003	0.005
Above-ground parts in all- Maanp. yht.	118.35	126.21	11.98	13.34	29.68	35.39	59.83	57.17	13.18	13.61	1.157	1.351	3.251	2.616	0.712	0.712	0.104	0.166	0.173	0.242
Stump and thick roots- Kanto- ja paksujuuret	21.81	24.53	2.54	4.02	9.26	16.93	14.33	18.07	3.04	4.16	0.444	0.359	1.179	0.388	0.127	0.158	0.025	0.043	0.030	0.036
Fine roots- Ohutjuuret	26.65	18.43	2.83	1.59	3.96	2.58	7.12	5.08	1.87	1.07	3.348	2.113	0.079	0.055	0.075	0.075	0.011	0.041	0.020	0.014
Underground parts in all- Maanal. yht.	48.46	42.96	5.37	5.61	13.22	19.51	21.45	23.15	4.91	5.23	3.792	2.472	1.258	0.443	0.202	0.233	0.036	0.084	0.050	0.050
Total Kaikki yht.	166.81	169.17	17.35	18.95	42.90	54.90	81.28	80.32	18.09	18.84	4.949	3.823	4.509	3.059	0.914	0.945	0.140	0.250	0.223	0.292

b) RhNRmu, pine - mänty

Compartment Osite	N 0	N UABM	P 0	P UABM	K 0	K UABM	Ca 0	Ca UABM	Mg 0	Mg UABM	Fe 0	Fe UABM	Mn 0	Mn UABM	Zn 0	Zn UABM	Cu 0	Cu UABM	B 0	B UABM
Stemwoood- Runkopuu	15.75	16.61	0.75	0.93	4.41	5.60	19.28	19.37	5.36	5.74	0.075	0.086	2.142	1.793	0.118	0.140	0.043	0.057	0.068	0.072
Bark- Kuori	11.06	11.99	0.94	0.91	3.48	3.70	5.22	4.96	1.46	1.26	0.091	0.138	0.363	0.256	0.047	0.047	0.011	0.062	0.026	0.026
Live branches- Elävät oksat	13.43	13.33	1.17	1.30	4.36	5.37	8.37	9.09	1.85	1.96	0.326	0.325	0.929	0.756	0.105	0.119	0.030	0.029	0.031	0.033
Dead branches- Kuolleet oksat	6.39	5.10	0.30	0.24	0.40	0.36	2.33	2.45	0.20	0.19	0.229	0.164	0.089	0.073	0.026	0.016	0.007	0.005	0.007	0.006
Leaves- Lehdet	26.93	24.58	1.96	2.16	4.49	5.44	5.65	4.71	1.00	0.90	0.066	0.066	0.996	0.661	0.035	0.031	0.009	0.009	0.020	0.037
Cones- Kävyt	0.31	0.23	0.03	0.03	0.12	0.14	0.01	0.01	0.03	0.02	0.003	0.002	0.002	0.002	0.001	0.001	0.0	0.0	0.0	0.0
Above-ground parts in all- Maanp. yht.	73.87	71.84	5.15	5.57	17.26	20.61	40.86	40.59	9.90	10.07	0.790	0.781	4.521	3.541	0.332	0.354	0.100	0.162	0.152	0.174
Stump and thick roots- Kanto- ja paksujuuret	15.86	21.62	0.94	1.22	5.78	7.57	16.67	17.56	3.36	3.51	2.379	1.148	0.578	0.635	0.067	0.081	0.027	0.054	0.034	0.030
Fine roots- Ohutjuuret	13.24	14.13	0.70	0.86	0.59	0.86	3.77	5.10	0.60	1.02	4.090	6.760	0.075	0.144	0.016	0.050	0.010	0.082		
Underground parts in all- Maanal. yht.	29.10	35.75	1.64	2.08	6.37	8.43	20.44	22.66	3.96	4.53	6.469	7.908	0.653	0.779	0.083	0.131	0.037	0.136		
Total- Kaikki yht.	102.97	107.59	6.79	7.65	23.63	29.04	61.30	63.25	13.86	14.60	7.259	8.689	5.174	4.320	0.415	0.485	0.137	0.298		

c) RhNRmu, birch - koivu

Compartment Osite	N 0	 UABM	P 0	 UABM	K 0	 UABM	Ca 0	 UABM	Mg 0	 UABM	Fe 0	 UABM	Mn 0	 UABM	Zn 0	 UABM	Cu 0	 UABM	B 0	 UABM
Stemwood- Runkopuu	23.45	23.52	1.38	1.46	6.09	6.17	12.18	12.10	3.38	3.20	0.083	0.094	1.533	1.142	0.282	0.343	0.032	0.039	0.043	0.048
Bark- Kuori	8.00	7.38	0.60	0.66	2.53	2.98	11.79	14.24	1.03	1.08	0.060	0.083	1.051	0.850	0.327	0.403	0.013	0.036	0.044	0.052
Live branches- Elävät oksat	39.06	47.78	3.06	4.43	7.76	9.44	28.31	40.65	4.47	5.01	0.227	0.279	1.800	1.310	0.541	0.684	0.051	0.062	0.062	0.076
Dead branches- Kuolleet oksat	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Leaves- Lehdet	30.31	23.68	1.60	1.25	8.54	6.67	10.61	8.29	3.64	2.84	0.111	0.087	1.367	1.070	0.085	0.066	0.013	0.010	0.030	0.024
Cones- Kävyt																				
Above-ground parts in all- Maanp. yht.	100.82	102.36	6.64	7.80	24.92	25.26	62.89	75.28	12.52	12.13	0.481	0.543	5.751	4.372	1.235	1.496	0.109	0.147	0.179	0.200
Stump and thick roots- Kanto- ja paksujuuret	26.28	29.26	1.12	1.73	4.33	6.18	13.66	15.38	2.31	2.34	1.680	1.018	0.620	0.762	0.172	0.234	0.023	0.030	0.028	0.036
Fine roots- Ohutjuuret	13.34	13.70	0.50	0.71	0.88	1.53	4.37	6.56	0.62	1.17	4.042	5.078	0.149	0.212	0.043	0.074	0.006	0.054	0.010	0.014
Underground parts in all- Maanal. yht.	39.62	42.96	1.62	2.44	5.21	7.71	18.03	21.94	2.93	3.51	5.722	6.096	0.769	0.974	0.215	0.308	0.029	0.084	0.038	0.050
Total Kaikki yht.	140.44	145.32	8.26	10.24	30.13	32.97	80.92	97.22	15.45	15.64	6.203	6.639	6.520	5.346	1.450	1.804	0.138	0.231	0.217	0.250

d) MKmu, spruce - kuusi

Compartment Osite	N 0	 UABM	P 0	 UABM	K 0	 UABM	Ca 0	 UABM	Mg 0	 UABM	Fe 0	 UABM	Mn 0	 UABM	Zn 0	 UABM	Cu 0	 UABM	B 0	 UABM
Stemwood- Runkopuu	39.90	44.89	1.17	1.92	14.45	19.95	40.18	39.81	3.92	3.70	0.227	0.271	6.191	3.990	0.454	0.420	0.096	0.107	0.151	0.178
Bark- Kuori	20.15	25.07	2.12	2.80	9.30	12.95	47.81	48.24	5.05	5.19	0.209	0.241	4.436	3.305	0.750	0.753	0.035	0.090	0.108	0.136
Live branches- Elävät oksat	101.48	123.45	8.00	10.54	30.42	39.65	109.29	139.00	11.41	12.84	2.442	2.793	8.267	5.767	0.941	1.010	0.097	0.112	0.190	0.324
Dead branches- Kuolleet oksat	10.02	11.81	0.51	0.76	0.76	1.18	15.34	14.48	0.41	0.36	0.350	0.553	0.414	0.197	0.115	0.082	0.012	0.023	0.016	0.013
Leaves- Lehdet	95.42	112.18	6.78	8.28	20.81	29.13	67.03	81.24	7.13	7.05	0.277	0.339	8.955	8.142	0.144	0.153	0.035	0.038	0.128	0.236
Cones- Kävyt	1.97	1.97	0.21	0.21	1.79	1.79	0.03	0.03	0.24	0.24	0.006	0.006	0.015	0.015	0.006	0.006	0.002	0.002	0.005	0.005
Above-ground parts in all- Maanp. yht.	268.94	319.37	18.79	24.51	77.53	104.65	279.68	322.80	28.16	29.38	3.511	4.203	28.278	21.416	2.410	2.424	0.277	0.372	0.598	0.892
Stump and thick roots- Kanto- ja paksujuuret	61.64	64.04	5.38	5.59	29.79	30.95	96.39	95.85	7.45	7.74	0.745	0.774	3.641	2.106	0.538	0.559	0.083	0.086	0.137	0.138
Fine roots- Ohutjuuret	34.78	47.08	2.83	3.41	4.18	8.52	16.00	20.44	1.99	2.55	2.390	2.823	0.800	0.639	0.162	0.262	0.021	0.043	0.036	0.053
Underground parts in all Maanal. yht.	96.42	111.12	8.21	9.00	33.97	39.47	112.39	116.29	9.44	10.29	3.135	3.597	4.441	2.745	0.700	0.821	0.104	0.129	0.173	0.191
Total Kaikki yht.	365.36	430.49	27.00	33.51	111.50	144.12	392.07	439.09	37.60	39.67	6.646	7.800	32.719	24.161	3.110	3.245	0.381	0.501	0.771	1.083

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