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Stand structure of undrained and drained peatland forests in central Finland

Suometsien rakenne-erot keskisessä Suomessa

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The structure of peatland forests were compared between different site quality classes, drainage phases, and different forest ownership groups. The comparisons and statistical tests were made in terms of the number of tree species, range of diameter distribution and the estimated number of tree storeys, separately for spruce and pine mires. The statistical tests were performed with multivariate analysis of variance and covariance. Tree storeys were estimated with objective rule from the peaks of continuous diameter distribution smoothed by the non-parametric kernel-estimation. The data used was from the 8th National Forest Inventory of Finland. On average, the mean values of the chosen stand structure characteristics differed significantly between the site quality classes. The stands had a more diverse structure the more fertile the site was. When examining the differences between the post-drainage succession phases, a decrease of the stand structure diversity was observed in the recently drained peatlands. After this, the mean values of the stand structure characteristics increased and exceeded the values of undrained peatlands at latest in the transformed post-drainage succession stage. Statistically significant differences in the means of stand structure characteristics between the forest ownership groups were not observed. It seems that drainage and possible improvement cuttings have been made with the same intensity regardless of the particular forest ownership group. It is also possible that drainage causes so drastic a change in growth conditions that small differences in the intensity of improvement cuttings between forest ownership groups disappear. The results correspond to the results of previous studies which have examined different stand structure characteristics. The forest on drained peatlands maintains an uneven-sized structure for quite a long period after drainage. In order to preserve habitat diversity, this structure of the peatland forests should be maintained in subsequent forest management practices.

Key words: drainage, habitat diversity, peatland forest management, structure of forest stand

INTRODUCTION

Following the principles decided at 'the Ministerial Conference on the Protection of Forests in Europe', countries that signed the agreement have to create a set of indicators implementing sustainability in the use of natural resources. For Finnish forestry, a list of such indicators was published in 1995 (Suomen kestävän ... 1995). In relation to peatland forests, this set of indicators concentrate, to a large extent, upon the conservation of valuable key-biotopes (e.g. Soininen 1996). The same concentration on the management of the key-biotopes is also noticeable in the preliminary proposal for the new forest law as well as in the new guide lines for private forest management (Luonnonläheinen metsänhoito 1994).

Ensuring that the key-biotopes and their surroundings remain untouched is not necessarily enough to preserve the overall biodiversity of forests. Preserving the natural variation of boreal forests requires systematic actions in practical forestry. In drained peatland forests this could mean, for example, maintaining the structure of forests resembling natural peatland forests.

In a natural state, the structure of peatland forests is uneven-aged with a great range in tree diameters (Heikurainen 1971, Gustavsen & Päivänen 1986). In the uneven-aged stand, trees are concentrated in the small diameters and the shape of the diameter distribution is usually a reversed J-shape. The shape of dbh (diameter at 1.3 m)-distribution may remain unchanged up to 30–50 years after drainage (Keltikangas et al. 1986, Hökkä & Laine 1988), regardless of the improvement cuttings made after drainage (Paavilainen & Päivänen 1995). This has been explained by post-drainage regeneration of new seedlings and ingrowth, which, in turn, results from the drawdown of the water level and subsequent improvement of the growing conditions in soil (Hånell 1984, Hökkä & Laine 1988). However, if the stand structure is examined using other characteristics than the shape of the distribution, such as the proportions of tree species (c.f. Korpela & Reinikainen 1996, Uuttera et al. 1996a), it has been noticed that the drainage and possible improvement cuttings, have clearly affected the structure and dynamics of peatland forests.

Until today, only few forest management operations have been made in peatland forests after drainage and possible improvement cutting (Paavilainen & Päivänen 1995). If forest management operations have taken place, they have not noticeably affected the shape of the diameter distribution (Hökkä et al. 1991). However, even if the reversed J-shape of diameter distribution is maintained there can be changes in the other stand structure characteristics. This can be due, for example, to a different intensity of the forest management made by different forest ownership groups. In mineral soils, significant differences in stand structure between the forest ownership groups of private forest owners, forest enterprises and the state have been observed (Matti Maltamo, Janne Uuttera & Kullervo Kuusela, unpublished).

The aim of this study is to examine the effect of the drainage, site quality and forest ownership group on the structure of peatland forest stands. Examinations are made on the basis of data from the Finnish National Forest Inventory.

MATERIAL AND METHODS

The study area included the forestry districts of Etelä-Pohjanmaa, Keski-Pohjanmaa, Keski-Suomi, Pohjois-Savo and Pohjois-Karjala (Fig. 1). The chosen forestry districts follow the border of the southern and middle boreal vegetation zone (Fig. 1), and have relatively similar growth conditions (Kalela 1961). The equal proportions of forests owned by different forest ownership groups also affected the choice of the test areas, especially in the test areas of Keski-Suomi and Pohjois-Karjala, where the proportions of the forests owned by different ownership groups were equally divided (Aarne 1994, Matti Maltamo, Janne Uuttera & Kullervo Kuusela, unpublished).

The study material consists of the measurements made on the relascope sample plots in spruce and pine mires in the 8th National Forest Inventory of Finland (NFI) (Metsäntutkimuslaitos 1989). The relascope plots were located according to the NFI sampling framework on the sides of a half-square, each half-square including 21 sample plots (Metsäntutkimuslaitos 1989). The distance between sample plots is 200 m and the distance between the half-squares is 7 km in an east–west-direction and 8 km in a north–south-direction. The relascope factor by which the sampled trees were chosen was 2.

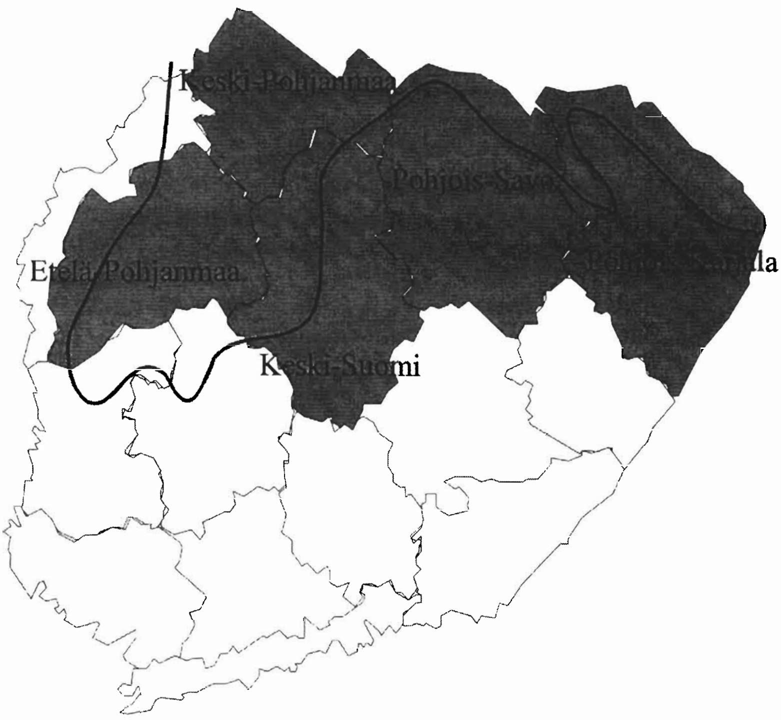

Fig. 1. The location of the study area. The border between the southern and middle boreal vegetation zones is also presented.

Kuva 1. Tutkimusalueen sijainti. Kuvaan on merkitty myös etelä- ja keskiboreaalisen kasvillisuusvyöhykkeen raja.

The sites were classified into spruce mires and pine mires (Norway spruce, *Picea abies*; Scots pine, *Pinus sylvestris*), and according to the site quality, the drainage phases, and the forest ownership groups used in NFI. The site quality classes were I = Eutrophic, II = Herb-rich (mesotrophic), III = *Vaccinium myrtillus* and tall-sedge (oligo-mesotrophic), IV = *Vaccinium vitis-idaea* and small-sedge (oligotrophic), V = Cottongrass and dwarf shrub (poor oligotrophic and ombrotrophic bogs), and VI = *Sphagnum fuscum* (ombrotrophic bogs) (Huikari 1952, 1974, Huikari et al. 1964, see also Paavilainen & Päivänen 1995). Site quality classes II, III and IV from the spruce mires and III, IV and V from the pine mires were chosen for final examination due to the adequate number of observations within these categories.

In the NFI routines the drainage phase is divided into four classes (numbered according to the NFI codes): (2) undrained peatlands, (3) recently drained peatlands, (4) the second phase of post-drainage vegetation succession (transforming phase) and (5) the third, final phase of post-drainage vegetation succession (transformed phase) (Sarasto 1961, Metsäntutkimuslaitos 1989).

Ownership groups are separated as follows: (1) private farmers, (2) other private forest owners, (3) forest enterprises, (4) state owned forests and (5) others. Because the 'others' category had relatively few observations and the group of forest owners within this category was very heterogenous, it was removed from the original data.

The study applied the same stand structure characteristics as the studies of Uuttera and Maltamo (1995) and Uuttera et al. (1996b). Information on the existing tree species and diameters of the sampled trees were used to describe the structure of the stand. The chosen stand structure characteristics were: (1) number of tree species, (2) estimated number of tree storeys, and (3) range of the diameter distribution.

To modify the sampled trees to represent better the whole stand, the diameter distribution was smoothed to a continuous form. First, the diameter distribution, weighted by the basal area, was modified to represent the number of stems per hectare (e.g. Kuusela 1966). Secondly, a non-parametric kernel-estimate was fitted to the modified diameter distribution. When using non-parametric methods in estimation there is no presumption of the form of the distribution, instead the form is determined from the original data itself (Silverman 1986). This fact makes the non-parametric estimation methods very flexible. The kernel-estimate is calculated with the formula:

$$f(x) = \frac{1}{nh} \sum_{i=1}^{n} K\left(\frac{x - X_i}{h}\right) \qquad (1)$$

where,

n = stem number per hectare
h = smoothing parameter
K = kernel function
x = sample from density function
X_i = observed diameter of sample tree i.

Normal distribution was chosen to be the form of the kernel function. The final kernel-estimate is the sum of these kernels. Based on the experiences of previous studies, the smoothing parameter h was determined to be 2 (Uuttera & Maltamo 1995, Uuttera et al. 1996a, b). From the smoothed kernel-estimate the number of tree storeys was determined using objective rule. If a peak in the smoothed diameter distribution was recognized, the peak was determined as a tree storey with the rule:

$$\frac{DIST}{D_{formerpeak}} \geq 0.5 \qquad (2)$$

where,

$DIST$ = $D_{peak} - D_{formerpeak}$,
D_{peak} = diameter class, in which the peak was found in the smoothed diameter distribution,
$D_{formerpeak}$ = diameter class, in which the former tree storey was determined.

Equation 2 states that the greater the diameter class, the greater must be the relative distance of the diameter distribution peaks in order to be defined as a new tree storey. The value of the window parameter h itself restricts the tree storeys from existing very close to one another.

The averages of the number of tree species, the number of tree storeys and the diameter range were statistically tested. The tests were performed with a multivariate analysis of variance and covariance using covariates and contrasts (SPSS-X User's Guide 1988). Firstly, the whole data was divided into two sub-populations (pine and spruce mires), and secondly, each stand structure variable were included separately in the same model with explanatory variables, e.g. forest ownership group, drainage phase and site quality class.

Because stands within different site quality classes and different drainage phases were in different stage of development, the mean values of the stand structure characteristics were adjusted to the stand development stage to enable feasible comparisons. The mean age of the stand was found to be the most usable covariate in the multivariate models. However, the observed means of stand structure characteristics are also presented to illustrate the actual situation.

RESULTS

Number of tree species

When investigating the number of tree species in pine mires, there were significant differences between site quality classes (Main effect $F = 204.38$, $p < 0.001$) and between different drainage phases ($F = 5.32$, $p < 0.001$). The poorer the site quality, the lower the number of tree species (Table 1). In spruce mires this kind of effect of site quality class on the number of tree species, at least statistically significant, was not observed ($F = 1.87$, $p = 0.154$). However, there were significant differences between the drainage phases also in spruce mires ($F = 5.37$, $p < 0.001$) (Table 2).

The number of tree species was at its lowest in recently drained peatlands, but exceeded the value of undrained peatlands at latest in the transformed phase of post-drainage succession (Tables 1 and 2). This phenomenon could also be seen between drainage phases within different site quality classes. The statistical differences between undrained peatlands and transformed phases of post-drainage succession were $F = 17.74$ ($p < 0.001$) in pine mires and $F = 9.48$ ($p < 0.01$) in spruce mires respectively.

The increment of the number of tree species after recently drained peatlands seemed to be slower in pine mires compared with spruce mires in every site quality class (Tables 1 and 2). Also the absolute values of tree species number were higher in spruce mires. The differences of tree species number between forest ownership groups were not significant in either of the main site types.

Estimated number of tree storeys

The means of the number of estimated tree storeys differed significantly from each other between the site quality classes in both main site types (Main effects: pine mires F = 33.29, p < 0.001; spruce mires F = 7.51, p < 0.001). The more nutrient rich the site, the more tree storeys existed (Tables 3 and 4). Also, in tree storeys number, spruce mires got higher absolute values compared with pine mires. Neither of the explanatory variables, drainage phase or forest ownership group, had a significant effect on the number of tree storeys. Without the age correction, the differences in the means of estimated tree storeys between drainage phases were statistically significant in pine mires (F = 4.87, p < 0.01), but after the age adjustment these differences vanished.

Range of the diameter distribution

The means of the range of diameter distributions behaved similarly with the number of tree spe-

Table 1. The observed (Obs. mean) and adjusted means (Adj. mean, mean age as a covariate) of the number of tree species in pine mires. The means are presented according to site quality classes of peatlands (e.g. Huikari 1974), by the drainage phases (e.g. Sarasto 1961), and also by drainage phases within site quality classes. The categories of the drainage phase are: 2 = no drainage, 3 = recently drained, 4 = transforming drained mires, 5 = transformed drained mires. The site quality classes are: II = Herb-rich (mesotrophic), III = *Vaccinium myrtillus* and tall-sedge (oligo-mesotrophic), IV = *Vaccinium vitis-idaea* and small-sedge (oligotrophic), V = Cottongrass and dwarf shrub (poor oligotrophic and ombrotrophic bogs). The statistically significant differences (F, p) are shown.

Taulukko 1. Puulajien lukumäärän havaitut (Obs. mean) ja sovitetut (Adj. mean, puuston keski-ikä kovariaattina) keskiarvot rämeillä ravinteisuusluokittain (Site quality) (Huikari 1974) ja ojitustilanteittain (Drainage) (Sarasto 1961), sekä ravinteisuusluokan sisällä ojitustilanteittain. Ravinteisuusluokat ovat: II = ruohoisuus, III = suursaraisuus, mustikkaisuus, IV = piensaraisuus, puolukkaisuus, V = tupasvillaisuus, isovarpuisuus. Ojitustilanne: 2 = ojittamaton suo, 3 = ojikko, 4 = muuttuma, 5 = turvekangas. Tilastollisesti merkitsevät erot (F, p) on esitetty.

Site quality	Drainage	n	Mean age	Age, s.d	Obs. mean	Adj. mean	F	p
III	all	370	45.1	31.8	1.91	1.89		
							81.37	< 0.001
IV	all	1843	44.4	27.8	1.60	1.57		
							264.38	< 0.001
V	all	1398	31.8	29.2	1.18	1.22		
all	2	515	33.5	40.7	1.44	1.46		
							8.53	0.004
	3	507	22.0	28.8	1.26	1.34		
							6.71	0.010
	4	2127	43.6	25.0	1.47	1.43		
							39.70	< 0.001
	5	462	47.2	25.3	1.69	1.63		
III	2	62	43.2	52.3	1.79	1.89		
	3	31	29.7	35.2	1.58	1.85		
	4	189	44.4	23.4	1.97	1.83		
	5	88	53.1	24.8	1.97	1.95		
IV	2	218	45.8	40.2	1.59	1.59		
	3	139	37.2	28.8	1.55	1.55		
	4	1195	44.5	25.4	1.56	1.53		
	5	291	46.6	24.9	1.76	1.65		
V	2	235	19.5	32.5	1.22	1.24		
	3	337	15.1	25.4	1.11	1.20		
	4	743	42.0	24.7	1.19	1.18		
	5	83	43.3	26.3	1.19	1.30		

cies between site quality classes and drainage phases. The mean of the range of diameter distribution differed significantly between site quality classes in both main site types (pine mires F = 89.58, $p < 0.001$, spruce mires F = 23.33, $p < 0.001$), having the lowest values in the poorest sites (Tables 5 and 6). Spruce mires had clearly greater absolute values of the range of diameter distribution compared with pine mires.

The differences of the diameter distribution range were very significant in pine mires (F = 14.15, $p < 0.001$) and minorly significant in spruce mires (F = 2.29, p = 0.077) between the different drainage phases. For spruce mires, the trend resembled that of pine mires (Table 6). Similarly, as with the number of tree species, also the range of the diameter distribution got its lowest values in the recently drained peatlands. After this, the mean values increased and exceeded the values of undrained peatlands in the transformed phase of post-drainage succession (Tables 5 and 6). The statistical difference between undrained peatland and transformed phase was very significant in pine mires (F = 25.51, $p < 0.001$) and minorly significant in spruce mires (F = 3.37, p = 0.066). The forest ownership group did not have a significant effect on the differences of diameter range.

DISCUSSION

When examining the differences of stand structure characteristics between different drainage phases, it seemed clear that drainage affects the diversity of stand structure by decreasing it. This change is, however, only temporary. The decrease in the number of tree species and the range of the diameter distribution may be due to the improve-

Table 2. The observed (Mean Obs.) and adjusted means (Mean Adj., mean age as a covariate) of the number of tree species in spruce mires. The means are presented according to the site quality classes of peatlands, by the drainage phases, and also by drainage phases within site quality classes. For explanations of the drainage phases and site quality classes, see Table 1. The statistically significant differences (F, p) are shown.

Taulukko 2. Puulajien lukumäärän havaitut (Mean Obs.) ja sovitetut (Mean Adj., puuston keski-ikä kovariaattina) keskiarvot korvilla ravinteisuusluokittain (Site quality) ja ojitustilanteittain (Drainage), sekä ravinteisuusluokan sisällä ojitustilanteittain. Ravinteisuusluokkien ja ojitustilanteen koodien selitykset, kts. Taulukko 1. Tilastollisesti merkitsevä erot (F, p) on esitetty.

Site quality	Drainage	n	Mean age	Age, s.d	Obs. mean	Adj. mean	F	p
II	all	659	38.7	26.5	2.15	2.20		
III	all	1220	53.6	30.5	2.20	2.17		
IV	all	160	51.6	35.5	2.06	2.05		
all	2	390	53.3	35.5	2.13	2.12	10.71	0.001
	3	120	56.8	32.3	2.06	2.03		
	4	809	48.3	30.2	2.13	2.14		
	5	720	45.1	26.9	2.26	2.29		
II	2	120	40.0	30.6	2.28	2.13		
	3	29	37.0	27.1	2.00	2.05		
	4	209	42.2	28.6	2.12	2.15		
	5	301	35.9	22.7	2.14	2.30		
III	2	237	58.8	33.7	2.04	2.12		
	3	73	63.0	31.6	2.10	2.04		
	4	529	51.5	30.5	2.16	2.15		
	5	381	51.6	27.5	2.37	2.29		
IV	2	33	62.5	49.7	2.24	2.01		
	3	18	63.9	30.8	2.00	1.93		
	4	71	43.0	28.9	1.96	2.04		
	5	38	52.3	30.7	2.13	2.18		

ment cuttings and ditch lines made concomitantly with the drainage. Newly drained peatlands typically regenerate easily (Kaunisto & Päivänen 1985 and references therein). After drainage and possible improvement cutting the regeneration of the new seedlings is quick within spruce mires, especially on fertile sites. This explains, to a great extent, the fact that recovery of the mean values of the stand structure characteristics is a little faster in spruce mires compared with those of pine mires. The growth effect of drainage is also different at different distances from the ditch (Päivänen 1990), which causes an increase in the stand structural diversity.

Surprisingly, the drainage together with possible improvement cutting seemed to have no significant effect on the number of tree storeys. This may be due to the tree sampling method of NFI,

Table 3. The observed (Mean Obs.) and adjusted means (Mean Adj., mean age as a covariate) of the number of estimated tree storeys in pine mires. The means are presented according to the site quality classes of peatlands, by drainage phases, and also by drainage phases within site quality classes. For number of observations, mean and standard deviation of ages, and explanations of drainage phases and site quality classes, see Table 1. The statistically significant differences (F, p) are shown.

Taulukko 3. Estimoitujen puujaksojen lukumäärän havaitut (Mean Obs.) ja sovitetut (Mean Adj., puuston keski-ikä kovariaattina) keskiarvot rämeillä ravinteisuusluokittain (Site quality) ja ojitustilanteittain (Drainage), sekä ravinteisuusluokan sisällä ojitustilanteittain. Havaintojen lukumäärät, iän keskiarvot ja hajonnat sekä ravinteisuusluokkien ja ojitustilanteen koodien selitykset, kts. Taulukko 1. Tilastollisesti merkitsevät erot (F, p) on esitetty.

Site quality	Drainage	Mean Obs.	Mean Adj.	F	p
III	all	1.61	1.59		
				21.42	< 0.001
IV	all	1.46	1.44		
				33.21	< 0.001
V	all	1.29	1.33		
all	2	1.39	1.40		
	3	1.28	1.36		
	4	1.42	1.39		
	5	1.52	1.46		
III	2	1.56	1.58		
	3	1.45	1.57		
	4	1.62	1.56		
	5	1.67	1.60		
IV	2	1.50	1.44		
	3	1.36	1.43		
	4	1.45	1.42		
	5	1.53	1.46		
V	2	1.23	1.33		
	3	1.24	1.31		
	4	1.33	1.31		
	5	1.30	1.35		

Table 4. The observed (Mean Obs.) and adjusted means (Mean Adj., mean age as a covariate) of the number of estimated tree storeys in spruce mires. The means are presented according to the site quality classes of peatlands, by drainage phases, and also by drainage phases within site quality classes. For number of observations, mean and standard deviation of ages, see Table 2, and for explanations of drainage phases and site quality classes, see Table 1. The statistically significant differences (F, p) are shown.

Taulukko 4. Estimoitujen puujaksojen lukumäärän havaitut (Mean Obs.) ja sovitetut (Mean Adj., puuston keski-ikä kovariaattina) keskiarvot korvilla ravinteisuusluokittain (Site quality) ja ojitustilanteittain (Drainage), sekä ravinteisuusluokan sisällä ojitustilanteittain. Havaintojen lukumäärät, iän keskiarvot ja hajonnat, kts. Taulukko 2, sekä ravinteisuusluokkien ja ojitustilanteen koodien selitykset, kts. Taulukko 1. Tilastollisesti merkitsevät erot (F, p) on esitetty.

Site quality	Drainage	Mean Obs.	Mean Adj.	F	p
II	all	1.71	1.79		
				9.38	0.002
III	all	1.73	1.68		
				5.02	0.025
IV	all	1.59	1.56		
all	2	1.73	1.71		
	3	1.74	1.70		
	4	1.70	1.72		
	5	1.71	1.75		
II	2	1.69	1.79		
	3	1.79	1.78		
	4	1.77	1.80		
	5	1.67	1.81		
III	2	1.78	1.69		
	3	1.73	1.68		
	4	1.71	1.70		
	5	1.72	1.71		
IV	2	1.58	1.56		
	3	1.72	1.56		
	4	1.45	1.58		
	5	1.79	1.58		

which is not very sensitive to the changes in the smallest diameter classes. This study was based on forest inventories in which the sampled trees were selected with the relascope method. Therefore, the calculated stem number diameter distribution is skewed and does not describe the structure of forest stock with the best possible accuracy. If these sampled trees are modified to the number of stems per hectare, the small diameter classes ($d < 9$ cm) clearly become skewed (Vuokila 1959). The stem number modification results in the distributions being, in almost in every case, a reversed J-shaped distribution and the examination of forest structure is not very reliable.

In the case of actual diameter distributions, where no weighting between different sized trees

Table 5. The observed (Mean Obs.) and adjusted means (Mean Adj., mean age as a covariate) of the range of diameter distribution in pine mires. The means are presented according to the site quality classes of peatlands, by the drainage phases, and also by drainage phases within site quality classes. For number of observations, mean and standard deviation of ages, and explanations of drainage phases and site quality classes, see Table 1. The statistically significant differences (F, p) are shown.

Taulukko 5. Läpimittajakauman vaihteluvälin havaitut (Mean Obs.) ja sovitetut (Mean Adj., puuston keski-ikä kovariaattina) keskiarvot rämeillä ravinteisuusluokittain (Site quality) ja ojitustilanteittain (Drainage), sekä ravinteisuusluokan sisällä ojitustilanteittain. Havaintojen lukumäärät, iän keskiarvot ja hajonnat sekä ravinteisuusluokkien ja ojitustilanteen koodien selitykset, kts. Taulukko 1. Tilastollisesti merkitsevät erot (F, p) on esitetty.

Site quality	Drainage	Mean Obs.	Mean Adj.	F	p
III	all	12.8	12.3		
				33.36	< 0.001
IV	all	10.7	10.3		
				138.85	< 0.001
V	all	6.9	7.7		
all	2	9.0	9.3		
				16.17	< 0.001
	3	6.3	7.8		
				13.78	< 0.001
	4	9.7	8.9		
				57.59	< 0.001
	5	12.5	11.4		
III	2	12.3	12.1		
	3	7.4	11.1		
	4	12.9	11.6		
	5	14.8	13.4		
IV	2	11.0	10.3		
	3	8.5	9.2		
	4	10.4	9.7		
	5	13.0	11.6		
V	2	6.3	7.9		
	3	5.2	6.8		
	4	7.7	7.3		
	5	8.1	9.2		

Table 6. The observed (Mean Obs.) and adjusted means (Mean Adj., mean age as a covariate) of the range of diameter distribution in spruce mires. The means are presented according to site quality classes of peatlands, and by drainage phases, and also by drainage phases within site quality classes. For number of observations, mean and standard deviation of ages, see Table 2, and for explanations of drainage phases and site quality classes, see Table 1. The statistically significant differences (F, p) are shown.

Taulukko 6. Läpimittajakauman vaihteluvälin havaitut (Mean Obs.) ja sovitetut (Mean Adj., puuston keski-ikä kovariaattina) keskiarvot korvilla ravinteisuusluokittain (Site quality) ja ojitustilanteittain (Drainage), sekä ravinteisuusluokan sisällä ojitustilanteittain. Havaintojen lukumäärät, iän keskiarvot ja hajonnat, kts. Taulukko 2, sekä ravinteisuusluokkien ja ojitustilanteen koodien selitykset, kts. Taulukko 1. Tilastollisesti merkitsevät erot (F, p) on esitetty.

Site quality	Drainage	Mean Obs.	Mean Adj.	F	p
II	all	15.7	17.1		
				24.10	< 0.001
III	all	16.1	15.2		
				20.09	< 0.001
IV	all	12.8	12.3		
all	2	16.3	15.9		
	3	15.4	14.5		
	4	15.2	15.6		
				8.83	0.003
	5	15.9	16.8		
II	2	16.0	17.2		
	3	16.8	16.1		
	4	16.6	17.0		
	5	14.8	17.8		
III	2	16.8	15.4		
	3	14.9	14.3		
	4	15.3	15.2		
	5	16.8	16.0		
IV	2	13.6	12.6		
	3	14.8	11.5		
	4	10.5	12.4		
	5	15.4	13.2		

is carried out, the interpretation of tree storeys would be easier. Furthermore, from the point of view of potential biological diversity of the stand, all trees are of equal importance, weighting between tree sizes should not be conducted (Uuttera & Maltamo 1995). Traditionally, when forest inventories, e.g. the NFI, have been carried out, stand characteristics, e.g. basal area, which most reliably depict the volume of the stand have been the most important. Also the costs of measuring basal area-weighted sample plots are much lower in comparison with equal-sized sample plots with a fixed radius. Thus, most of the large-scale data available has been weighted by basal area.

The impression that diversity of the stand structure in transformed phase exceeds the diversity of undrained peatland stand structure may be partly based on the fact that the undrained peatlands in Finland are not necessarily in a natural state. A part of the peatlands owned by the state have been under conservation programmes for a long time, and are, therefore, also in a natural state (for example in pine mires, in site quality class V, ~ 33% of undrained state owned peatlands in the study material were under conservation programmes). However, a proportion of the undrained peatlands have not been drained due to their small size, location, or due to a small amount of forest stock. It is possible that these peatland forests, especially on fertile sites and with a thin peat layer, have been managed with a selective cutting method at the same time that the surrounding mineral soil forests have been managed (Päivänen 1990). It can be presumed that partly because of this, the stand structure characteristics on undrained peatlands in this study had lower stand characteristic mean values compared with those of virgin peatland forests in the Ladenso forest inventory area, the Republic of Karelia, the Russian Federation, within the same site-quality class (Uuttera et al. 1996a). This fact may have had an effect on the observed differences in the structure of stands in different drainage phases.

The same kind of differences in stand structure characteristics between the forest ownership groups that were found in mineral soil forests (Matti Maltamo, Janne Uuttera & Kullervo Kuusela, unpublished), were not observed in peatland forests. It seems that drainage and improvement cutting have been made with the same intensity regardless of the particular forest ownership group. It is also possible that drainage causes so drastic a change in growing conditions that small differences in the intensity of improvement cuttings between forest ownership groups disappear. There also seems to be no significant differences between the management of peatland forests in subsequent drainage phases. However, the small differences in the values of stand structure characteristics between forest ownership groups in transforming and transformed drainage phases may also be due to the fact that, in general, the management of drained peatlands has been rather extensive (Paavilainen & Päivänen 1995).

In conclusion, one could state that regardless of the instant decrease in the structural diversity after drainage, peatland forests maintain their uneven-sized structure. However, in the transformed phase, the proportion of red-stemmed feather moss (*Pleurozium schreberi*) increases in the ground cover (Kaunisto & Päivänen 1985), and the competition of the growing space increases. This, in turn, decreases receptivity for regeneration and stand structure variation resembling natural peatland forests may be more difficult to maintain. Therefore, if the maintenance of the structural diversity of undrained peatland stands is set as a goal for management, the management of peatland forests will require careful consideration in the future.

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TIIVISTELMÄ:

Suometsien rakenne-erot keskisessä Suomessa

Tutkimuksen tavoitteena oli selvittää ravinteisuuden, ojituksen ja omistajaryhmien vaikutusta suopuuston rakenteeseen. Tutkimusalueen muodostivat Etelä-Pohjanmaan, Keski-Pohjanmaan, Keski-Suomen, Pohjois-Savon ja Pohjois-Karjalan metsälautakuntien alueet. Tutkimusaineistona oli Valtakunnan metsien 8. inventoinnin (VMI8) alaryhmältään korville ja rämeille osuneet puustoiset relaskooppikoealat. Korpiaineistosta mukaan otettiin ravinteisuustasot II (ruohoisuus), III (mustikkaisuus, suursaraisuus) ja IV (puolukkaisuus, piensaraisuus) ja rämeistä ravinteisuustasot III, IV ja V (tupasvillaisuus, isovarpuisuus).

Puuston rakenteen kuvaamiseen käytettiin

puulajien lukumäärää, läpimitan vaihteluväliä sekä VMI koealan ei-parametrisellä kernel-tasoituksella jatkuvaan muotoon tasoitetusta läpimittajakaumasta määritettyä puujaksojen lukumäärää. Puuston rakennetunnusten keskiarvojen eroja ravinteisuustasojen, kuivatusvaiheiden ja omistajaryhmien välillä testattiin tilastollisesti käyttäen moniulotteista varianssianalyysiä (Multivariate analysis of variance and covariance).

Puuston rakennetunnusten keskiarvot poikkesivat toisistaan merkitsevästi ravinteisuustasojen välillä sekä korvilla että rämeillä. Puuston rakenteen monimuotoisuus lisääntyi turpeen ravinteisuustason parantuessa. Ainoa poikkeus tähän oli puulajien lukumäärä korvilla, jossa ei havaittu tilastollisesti merkitseviä eroja ravinteisuustasojen välillä.

Ojituksen ja mahdollisen kunnostushakkuun vaikutus näkyi selvästi puulajien lukumäärässä ja läpimittajakauman vaihteluvälissä kummassakin päätyyppiryhmässä. Nämä tunnukset saivat pienimmät arvonsa ojikkovaiheen metsiköissä, jonka jälkeen keskiarvot nousivat ylittäen ojittamattomien soiden puuston arvot viimeistään turvekangas-sukkessiovaiheessa. Puujaksojen lukumäärässä ei havaittu tilastollisesti merkitseviä eroja ojitussukkessiovaiheiden välillä. Tämä johtunee osaltaan puustoaineiston keruussa käytetystä otantamenetelmästä. Relaskooppiotanta ei ole kovin herkkä menetelmä pienpuustossa tapahtuvan muutoksen kuvaamisessa.

Turvekankaiden ja ojittamattomien soiden puuston rakenne-eroihin vertailuun saattaa osaksi vaikuttaa se, että Suomessa ojittamattomat suot eivät välttämättä ole luonnontilassa. Ojittamattomillakin soilla puustoa on saatettu käsitellä harsintahakkuiden tapaisesti (Päivänen 1990). Tähän viittaa se seikka, että Suomen ojittamattomien soiden puusto sai pienempiä rakennetunnusten arvoja kuin vastaavilla ravinteisuustasoilla esiintyvät luonnontilaiset suot Venäjän Karjalassa (Uuttera ym. 1996a).

Omistajaryhmittäisiä eroja suopuuston rakenteessa ei havaittu ojittamattomilla soilla eikä missään kuivatusvaiheessa. Näyttäisi siltä, että ojitus ja sitä mahdollisesti seuraava kunnostushakkuu on tehty samalla intensiteetillä omistajaryhmästä riippumatta. Toisaalta ojitus voi aiheuttaa kasvuolosuhteissa niin suuren muutoksen, että mahdolliset omistajaryhmittäiset erot kunnostushakkuissa saattavat peittyä tämän kasvureaktion alle. Havaittuihin pieniin omistajaryhmittäisiin eroihin vaikuttanee myös se, että tähän päivään mennessä ojitetuilla soilla on tehty verrattain vähän metsänhoitotoimenpiteitä (Paavilainen & Päivänen 1995). Kivennäismaiden metsissä rakennevaihteluerot yksityisten ja valtion sekä metsäteollisuusyritysten omistamien metsien välillä ovat merkitsevät, rakennevaihtelun ollessa suurempaa yksityisten omistamissa metsissä (Matti Maltamo, Janne Uuttera & Kullervo Kuusela, julkaisematon).

Tutkimuksen tulokset suopuuston rakenteesta eri kuivatusvaiheissa myötäilevät edellisiä aiheesta tehtyjä tutkimuksia. Suopuusto säilyttää erikäisrakenteensa pitkään ojituksen ja siihen liittyvien metsänhoitotoimenpiteiden jälkeen. Tämä voidaan selittää sillä, että ojitetut suot taimettuvat helposti ojituksen jälkeen (Kaunisto & Päivänen 1985) ja toisaalta parantuneet kasvuolot nopeuttavat olemassa olevan pienpuuston kasvua (Hånell 1984, Hökkä & Laine 1988). Myöhemmissä ojituksen jälkeisissä sukkessiovaiheissa kuitenkin seinäsammalten osuus pohjakerroksessa lisääntyy (Kaunisto & Päivänen 1985) ja kilpailu kasvutilasta kovenee, mikä heikentää uuden taimiaineksen syntymistä. Tulevien metsänhoitotoimenpiteiden yhteydessä luonnontilaisen kaltainen puuston erikäisrakenne saattaakin olla vaikeaa säilyttää. Tämän vuoksi suopuustojen käsittely vaatii erityistä harkintaa.

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