First Commercial Thinnings in Peatland Pine Stands: Effect of Timing on Fellings and Removals

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Abstract

The aim of this study was to examine the fellings and removals and their dimension distributions in first commercial thinnings in Scots pine (*Pinus sylvestris* L.) stands growing on drained peatlands, when the cuttings are carried out at different stages of thinning maturity. The reference for standard thinning maturity was defined as in the present guidelines for silviculture on upland sites in non-industrial, privately owned pine forests in Finland. Experimental and/or simulated thinnings were applied in altogether fifteen stands representing a wide range in site productivity, climate, and time elapsed since first ditching, and premature (7 cases), mature (11), and over-mature (15) stages for thinning. The average stemwood volumes of fellings were 51, 69, and 92 m^3ha^{-1} and those of harvest removals 36, 59, and 84 m^3ha^{-1} for premature, mature, and over-mature cases, respectively. The removals from stands mature and over-mature for thinning were large enough to enable a commercially profitable harvesting operation in most cases, unlike those from the premature stands where the fellings were barely harvestable and consisted of clearly smaller stems. Considering the obvious trends of increasing supply and simultaneously decreasing price competitiveness of pine pulpwood, our results do not support early thinning unless absolutely necessary from the silvicultural point-of-view. Retarding the thinning until the stage when thinning maturity criteria are actually met, i.e. till stand dominant height of ca. 15 m or even further, would result in markedly better harvesting profitability and hence enhance the implementation of thinnings as a part of the best management practices of peatland stands.

Key words: *Pinus sylvestris*, peatland forestry, silviculture, first thinning, intermediate cuttings, drainage

Introduction

In the boreal forests around the Baltic Sea, peatlands drained for forestry comprise a considerable land base: 4.7 million hectares in Finland (Hökkä *et al.* 2002), 1.6 Mha in the Baltic countries (Zalitis 1990, Kaunisto *et al.* 1991, Ruseckas 1991; cited by Paavilainen and Päivänen 1995), and 1.5 Mha in Sweden (Hånell 1990). Remarkable peatland areas have been drained for forestry also in North-West Russia (Medvedeva and Ionin 1983, Stolyarov *et al.* 1983, Vompersky 1991). Most of the peatland forest area consists of pine peatlands, i.e. sites fairly poor in nutrients (Westman and Laiho 2003) and typically dominated by Scots pine (*Pinus sylvestris* L.) with various admixtures of other tree species, mostly pubescent birch (*Betula pubescens* Ehrh.). As the bulk of these sites were drained during the 1950s to 1970's, they presently form a large potential supply of roundwood for forest industry. Furthermore, appropriate management of this resource for a sustainable supply of timber in the long-term may demand silvicultural operations on large areas in the very near future. In Finland alone, according to scenarios based on data from the 8[th] Finnish National Forest Inventory, the potential for annual cuttings in peatland forests may increase up to 15 - 20 million cubic meters in 20 years (Nuutinen *et al*. 2000). Particularly, thinnings in young peatland pine stands and, hence, the supply of pine pulpwood have a potential to increase markedly.

Apart from the silvicultural needs the implementation of the cuttings as well as the demand and the supply of roundwood depend on market conditions. Until recent times, the Finnish and Swedish pulp industries have largely utilized domestic pulpwood supplies, but recently expanded their wood-procurement also to Russia and the Baltic countries (Toppinen and Toropainen 2004). The demand for pine sawlogs is increasing, being higher than supply, in all the Baltic Sea countries, whereas the supply of pulpwood is abundant (Toppinen and Toropainen 2004). This may result in a more or less permanent decrease in the stumpage price of pine pulpwood, especially in relation to good quality saw logs, possibly leading to the situation where thinnings are neglected. Thus, the management applications that would enable profitable thinning harvests and simultaneously enhance the quality and value of the retained crop trees should draw the interest of forest owners in the Baltic region.

In the management of Scots pine, thinnings are widely used to control inter tree competition and to concentrate growth on fewer final crop trees of potentially high value as sawlogs. The basic concept for the present silviculture consists of early non-commercial thinnings in sapling stands followed by one or a few thinnings in more advanced stands with a potential for commercially profitable harvesting removals. Peatland pine stands, which are still mostly derived from naturally regenerated pre-drainage stands, generally differ from those on upland sites by their heterogeneous age and size structure and often clustered spatial distribution of trees (Hökkä and Laine 1988, Penner *et al*. 1995, Sarkkola *et al*. 2004). In such stands, the application of thinning operations and even the determination of thinning maturity is often more problematic than in homogenous stands. Despite the fairly intensive research and development of harvesting technology, the problematic harvesting conditions on peatlands, due to low bearing capacity of the ground and structural unevenness of the stands, often remain as unavoidable constraints to the harvesting operations (Sirén 2004, Väätäinen *et al*. 2004). Even though the structural differences between peatland and upland forests are widely recognized, there are very few studies on the applicability of different thinning regimes in peatland stands.

The profitability of thinning harvesting is known to markedly improve with increased harvesting removals and/or increased average stem size of the harvested trees (Ylimartimo 2001, Sirén and Aaltio 2003). Whole-tree harvesting has sometimes been used as a means of increasing thinning removals but, as this method removes considerably more nutrients from the site than conventional stem wood harvesting (Finér and Kaunisto 2000, Jacobson *et al*. 2000), it may not be a sustainable method on pine peatland sites. Silvicultural thinning guidelines or comparable regulations usually set a minimum limit to the stocking of the retained stand and thus inherently constrain the thinning removal. The timing of the thinning operation in relation to stand stocking or thinning maturity, remains, however, a potential but not much investigated tool in adjusting the harvestable removal. It should be noted that the growth losses and, ultimately, natural mortality potentially caused by delayed thinning may also be different in peatland vs. upland stands because of the differences in stand structure and inter-tree competition.

The aim of this study was to examine the fellings and removals and their dimension distributions in first commercial thinnings of peatland pine stands when the cuttings are carried out at different stages of thinning maturity. This study was part of the project "Quality and yield of pulpwood in drained peatland forests" within the Finnish forest cluster research program Wood Wisdom. Other parts of this project have focused on the variation in wood and fiber properties among peatland pine trees (Rissanen 2003), variation in pulpwood properties of the thinning removals among peatland pine stands (Varhimo *et al*. 2003), and the impacts of different thinning regimes on the post-thinning yields of the retained stands (Kojola *et al*. 2004). We used a set of experimental stands selected to represent a wide variation of drained pine peatland sites in Finland. In addition to experimental thinnings, we used a stand simulator to provide a wider selection of alternative thinning situations in some stands.

Material and methods

The study sites were selected from a set of stands initially meant to be treated with commercial thinnings by the forest owners (i.e. the Finnish Forest Research Institute [Metla], the Finnish Forest and Park Service, Stora Enso, and non-industrial private owners) and where Metla had earlier set up thinning experiments. Thus, the site and stand properties and their management histories (time and manner of stand establishment, timing of first and complementary ditching, pre-commercial thinnings, *etc.*) were well documented and could be used as a basis for site selection.

We selected Scots pine dominated stands that had been managed with pre-commercial thinning at an earlier stage of stand development. The stands represented i) a range as wide as possible of the potential variability in site productivity, climate, and the time elapsed since the first ditching (Table 1), and ii) a premature (dominant height 10-13 m), mature (13-16 m), or over-mature (16-19 m) stage of thinning maturity. Thinning maturity was defined according to the present guidelines for the first commercial thinnings in the forests of non-industrial private owners in Finland (Hyvän metsänhoidon... 2001) and as illustrated in Figure 1. Stand dominant height (H_{DOM}) was used as the primary criterion for thinning maturity but also the level of basal area was used for fine tuning the judgment. Consequently, one site (no 7164) was considered premature due to its low level of basal area despite the dominant height of 15.5 m.

The selected fifteen sites represented the range of peatland forest site types generally managed for pine and they were located on areas drained for forestry

Table 1. Study site properties

Stand id	Municipality	Location N	Location E	Temp. sum, dd[a]	Site type[b]	Peat depth, m	First ditched	V[c], $m^3 ha^{-1}$	SB-mix[d], %
5770	Kannus	63 60’	23 51’	1068	VT1	0.2	1954	205	35
5916	Viitasaari	63 16’	25 59’	1050	DsT	0.2-0.8	1958	163	1
5922	Pelkosenniemi	67 17’	27 44’	769	MT2	>1	1969	143	2
5923	Pelkosenniemi	67 17’	27 42’	761	MT2	>1	1969	147	5
5932	Rovaniemi	66 21’	26 38’	862	VT2	0.4	1934	100	0
5944	Simo	65 47’	25 19’	962	MT2	0.2	1961	143	40
5945	Kuivaniemi	65 34’	25 28’	982	VT2	0.2-0.5	1957	151	25
5949	Kittilä	67 22’	24 39’	776	MT2	0.9	1971	97	7
5953	Pudasjärvi	65 41’	27 19’	905	MT2	0.7-1.0	1937	153	19
5954	Yli-Ii	65 21’	25 51’	1020	VT2	0.3	1939	219	41
5955	Kuhmo	64 04’	29 20’	967	VT1	0.1	1963	181	34
5956	Puolanka	64 49’	27 22’	939	MT2	0.4-1.0	1967	176	2
5958	Pyhäjärvi	63 38’	25 42’	1039	VT2	0.6-1.0	1973	159	25
5960	Yli-Ii	65 25’	25 41’	1000	MT2	>1	1939	253	20
7164	Ruovesi	61 51’	24 16’	1127	DsT	>1	1967	130	3

[a] Cumulative annual temperature sum with +5°C threshold value
[b] Peatland forest site types according to Laine (1989):
MT2 = *Vaccinium myrtillus* type 2 [Mtkg(II) in the Finnish nomenclature]
VT1 = *Vaccinium vitis-idaea* type 1 [Ptkg(I)]
VT2 = *Vaccinium vitis-idaea* type 2 [Ptkg(II)]
DsT = Dwarf-shrub type [Vatkg].
[c] Total stand volume before thinning
[d] Combined proportion of spruce and birch of stand volume before thinning

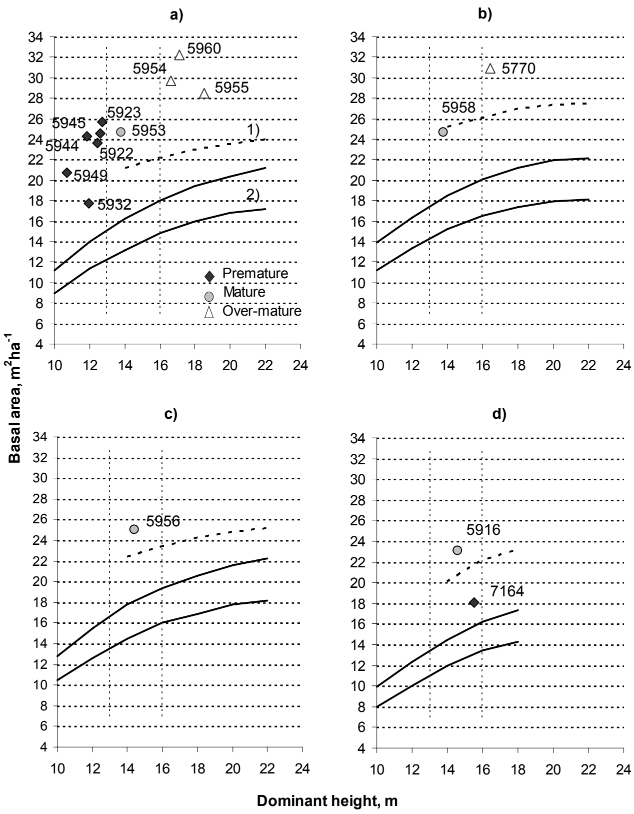

Figure 1. Dominant height and basal area of the stands before thinning, as related to the lines indicating 1) thinning maturity and 2) level of growing stock to be retained after thinning (basal area, minimum-maximum), on different site types (see Table 1) according to the present management guidelines in the forests of non-industrial private owners in Finland (Hyvän metsänhoidon... 2001):
a) VT2 and MT2, North Finland.
b) VT1 and VT2, South Finland
c) MT2, North Finland
d) DsT, South Finland.
Symbols depict thinning maturity; stand numbers refer to Table 1.

between 1934 and 1973 in different climatic regions from south boreal to mid boreal. The dominant height of the stands varied from 10.7 m to 18.5 m (Fig. 1), and total stand volume from ca. 95 up to 250 m^3ha^{-1} (Table 1). The stands contained varying proportions of birch and in some cases also spruce (*Picea abies* (L.) Karst.), mainly as understory mixtures (Table 1). The proportion of standing dead wood varied from 0.1 to 4.5 percent of the total stand volume.

The recently assessed (mapping of individual trees and measurement of tree DBH [diameter at 1.3 m]) control plots of the thinning experiments on the selected sites provided the tree stand framework for applying tree selection (i.e. trees to be retained vs. removed) for this study. This is termed as experimental thinning in the following. The selection of the retained trees was based on favoring externally good quality stems of pine, reducing the spatial inequality, and thinning from below when selecting among otherwise similar candidates. The plot-wise total basal area of the trees to be retained was recorded and adjusted according to the management guidelines (Hyvän metsänhoidon... 2001, Fig. 1).

The trees to be felled in the experimental thinnings were marked and tallied for DBH (minimum 7.5 cm) by tree species, separating dead trees from those alive. Standard stand and tree characteristics were computed for the fellings (total stemwood volume of trees to be cut), removals (merchantable part of stemwood), and retained growing stock using the KPL-software package by Metla (Heinonen 1994). The following minimum top diameters of logs were applied: sawlogs: pine 15 cm, spruce 17 cm, birch 18 cm; pulpwood: pine and birch 7 cm, spruce 8 cm. The technical quality of sawlogs was not taken into consideration. The length of the pulpwood logs was set at three metres. All results were calculated by tree species and by timber assortments.

As the empirical data set from the stands was biased towards the stands premature for thinning, we augmented the cases for mature and over-mature thinnings by applying simulations as follows. First the development of the initially premature non-thinned stands was simulated to meet the criterion of thinning maturity (defined as H_{DOM} = 14.5 m) and a simulated mature thinning was then applied. Secondly, the development of both initially premature and mature stands was simulated until they became over-mature for thinning (H_{DOM} > 16 m) and over-mature thinnings were then applied. For the predictions of stand development and thinnings we used the stand simulation software MOTTI (Salminen and Hynynen 2001) developed in Metla. For peatland stands, the MOTTI-simulator applies distance-independent, individual-tree basal area growth models, including growth responses to thinning, by Hökkä *et al*. (1997), height-diameter models by Hökkä (1997), and tree mortality models by Jutras *et al*. (2003). The need for the ditch network maintenance is predicted using the model by Hökkä *et al*. (2000), and growth responses to the ditch network maintenance are accounted for as in Hökkä and Kojola (2003). For more details about the functioning of the growth and mortality models included in MOTTI, see Hynynen *et al*. (2002). For all simulated thinnings, we applied the same criteria and procedures for log dimensions, tree selection, and calculations of fellings and retained growing stock as for the experimental thinnings described above. Finally, the material consisted of 7 cases of premature, 11 cases of mature, and 15 cases of over-mature thinnings, either experimental or simulated.

Results

The volumes of the fellings varied from 25 to 124 m^3ha^{-1}, and those of the removals from 19 to 115 m^3ha^{-1}, similarly for the experimental and simulated cases (Table 2, Fig. 2). In the stands premature, mature, and over-mature for thinning, the average volumes of fellings were 51, 69, and 92 m^3ha^{-1} and those of removals 36, 59, and 84 m^3ha^{-1}, respectively, when taking into account both experimental and simulated thinnings (Table 2). The fellings comprised 39, 40 and 42% of the initial stand volume in premature, mature and over-mature stands, respectively.

The fellings in premature stands contained smaller stems than in mature and over-mature stands (Fig. 3). The basal area weighed mean DBH of the fellings was 128 mm, 148 mm, and 148 mm in premature, mature, and over-mature stands, respectively. In all maturity classes, the biggest stems of the fellings were individual overstorey trees with a growth history dating back long before drainage. As an average of all cases, the sawlog removal was only 9 m^3ha^{-1}. The proportions of wastewood in the fellings varied between 4 to 47% and they showed a decreasing trend from premature to mature and to over-mature stands.

Table 2. The structure of the fellings and retained growing stock

		Fellings			Retained growing stock					
Stand id	Thinning mode[a]	Removal, m^3ha^{-1}	Wastewood, m^3ha^{-1}	All, m^3ha^{-1}	Basal area, m^2ha^{-1}	Sawlogs, m^3ha^{-1}	Pulpwood, m^3ha^{-1}	Wastewood, m^3ha^{-1}	All, m^3ha^{-1}	n
Stands premature for thinning										
5922	1	56.8	8.4	65.2	12.9	15.2	59.1	3.9	78.2	
5923	1	51.9	14.0	65.9	13.7	13.6	61.8	5.3	80.6	
5932	1	18.8	6.2	25.1	13.4	3.9	65.6	4.9	74.5	
5944	1	33.0	29.6	62.5	13.2	11.1	61.4	8.4	80.9	
5945	1	43.6	24.8	68.4	13.4	14.5	63.6	4.7	82.8	
5949	1	25.5	15.0	40.5	11.5	3.8	48.2	4.3	56.4	
7164	1	24.1	4.1	28.2	14.0	19.7	75.2	6.4	101.4	
Average1		***36.2***	***14.6***	***50.8***	***13.2***	***11.7***	***62.1***	***5.4***	***79.2***	***7***
Stands mature for thinning										
5916	1	55.5	6.4	61.9	14.3	29.3	68.7	3.0	101.0	
5953	1	50.3	9.2	59.5	14.8	28.1	60.0	5.5	93.5	
5956	1	54.4	6.6	61.1	16.7	54.7	56.6	3.2	114.5	
5958	1	37.6	15.7	53.3	17.7	18.0	81.4	6.8	106.1	
Average 1		*49.4*	*9.5*	*59.0*	*15.9*	*32.5*	*66.7*	*4.6*	*103.8*	*4*
5922	2	65.6	6.7	72.3	15.0	32.5	65.9	2.1	100.5	
5923	2	70.4	10.3	80.7	15.0	29.4	68.0	2.1	99.5	
5932	2	75.2	5.0	80.2	15.0	40.1	60.9	1.9	102.8	
5944	2	65.8	16.0	81.8	15.5	22.0	79.1	3.2	104.4	
5945	2	50.7	12.8	63.5	15.5	33.9	68.6	2.3	104.8	
5949	2	69.9	8.1	77.9	15.0	33.9	61.3	2.1	97.3	
7164	2	55.3	5.7	61.0	15.5	35.6	87.0	2.6	125.2	
Average 2		*64.7*	*9.2*	*73.9*	*15.2*	*32.5*	*70.1*	*2.3*	*104.9*	*7*
Average, all		***59.1***	***9.3***	***68.5***	***15.5***	***32.5***	***68.9***	***3.2***	***104.5***	***11***
Stands over-mature for thinning										
5954	1	82.6	12.6	95.3	16.9	32.0	87.1	4.2	123.2	
5955	1	60.9	7.9	68.8	18.1	49.0	59.0	4.4	112.5	
5960	1	114.8	9.5	124.3	16.9	57.8	66.4	4.3	128.6	
5770	1	49.8	23.5	73.3	18.7	47.1	75.3	9.0	131.5	
Average 1		*77.0*	*13.4*	*90.4*	*17.6*	*46.5*	*72.0*	*5.5*	*124.0*	*4*
5916	2	95.0	5.5	100.5	15.0	47.0	69.1	2.0	118.0	
5922	2	79.8	5.5	85.3	17.0	63.6	58.8	1.8	124.2	
5923	2	79.6	6.3	85.9	16.5	56.6	61.7	1.6	119.8	
5932	2	113.1	4.1	117.2	16.5	80.3	44.0	1.4	125.7	
5944	2	84.0	7.7	91.7	17.0	59.6	65.8	2.2	127.6	
5945	2	70.3	7.3	77.6	17.0	64.3	60.1	1.8	126.2	
5949	2	92.7	6.3	99.0	16.5	66.6	52.0	1.7	120.3	
5953	2	74.1	9.2	83.2	16.0	48.8	65.6	1.9	116.2	
5956	2	90.1	5.2	95.2	18.5	91.4	56.4	1.6	149.3	
5958	2	61.3	12.0	73.2	19.0	55.8	89.0	2.8	147.6	
7164	2	109.1	4.9	114.0	16.0	80.8	59.8	1.7	142.4	
Average 2		*86.3*	*6.7*	*93.0*	*16.8*	*65.0*	*62.0*	*1.8*	*128.9*	*11*
Average, all		***83.8***	***8.5***	***92.3***	***17.0***	***60.0***	***64.7***	***2.8***	***127.5***	***15***

[a] 1= experimental thinning, 2 = simulated thinning

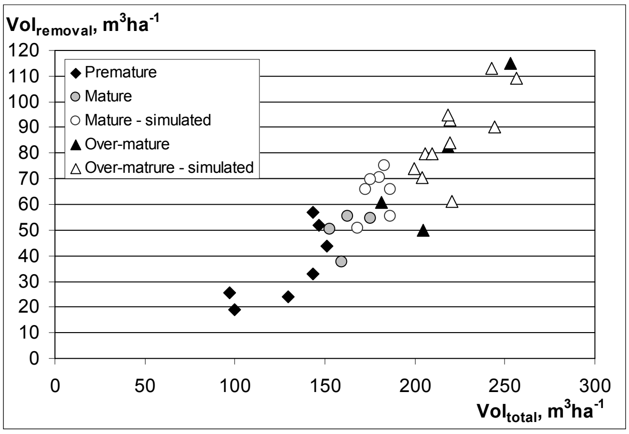

Figure 2. Removals (merchantable wood) in experimental and simulated thinnings relative to total stand volume before thinning

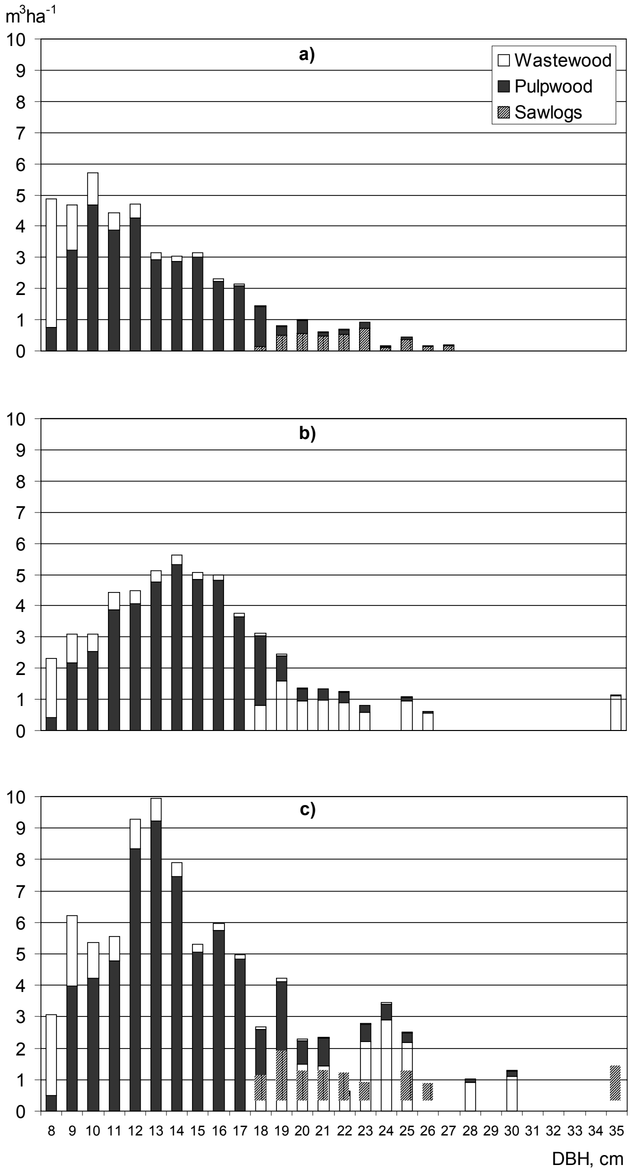

Figure 3. Mean volume (m^3ha^{-1}) of sawlogs, pulpwood and wastewood, by diameter class, in the fellings in a) premature, b) mature, and c) over-mature stages of thinning maturity

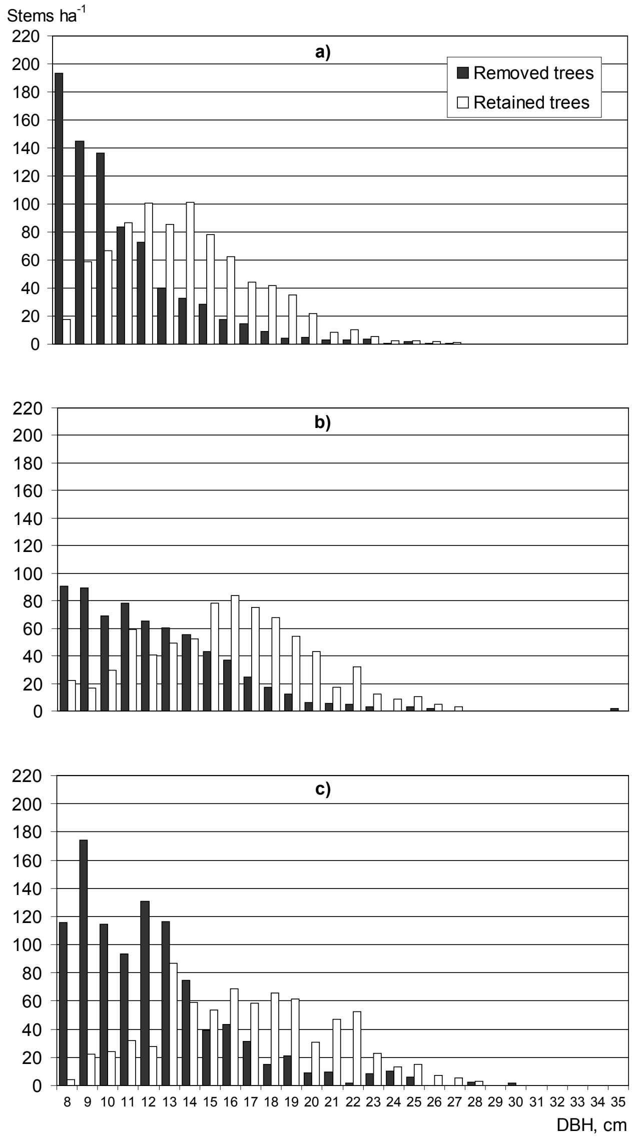

Figure 4. Diameter distribution of the fellings (black bars) and retained stand (white bars) in a) premature, b) mature, and c) over-mature stages of thinning maturity

Thinning decreased the number of trees in the growing stock (including trees with DBH≥7.5 cm) from the initial densities of 1430 - 1780 to 832, 761, and 762 retained stems per hectare in pre-mature, mature, and over-mature stands, respectively (Fig 4). The mean diameters weighed by basal area changed from 145, 167, and 171 to 156, 178, and 188 mm due to thinning in premature, mature, and over-mature stands, respectively. After thinning the retained stand basal area was 12 - 19 m^2ha^{-1} and stand volume 56 - 149 m^3ha^{-1}, depending on site type, location, and stage of thinning maturity (Table 2).

Discussion

The volume of the thinning removal depended firmly on the stage of thinning maturity, as expected. Thus, in the stands premature for thinning the removal was less than two thirds of that in mature stands. The differences in thinning removals among the maturity groups were due to both the number and volume of the removed trees. Smaller stand volumes, typical of premature thinnings, also contained a larger proportion of wastewood. Thereby, the average volume of wastewood decreased from the premature to the over-mature thinnings by 42%. In four of the seven premature stands the removals were very low, i.e. smaller than 35 m^3ha^{-1}, which is generally considered a limit of profitable harvesting in the first thinnings in Finnish forestry (Ylimartimo *et al*. 2001).

Fellings and removals from simulated thinnings on average were slightly larger than those from experimental thinnings. This was obviously due to somewhat greater stand volumes at the stage of the intended thinning maturity. Kojola *et al*. (2004) observed earlier that MOTTI-simulations underestimated the growth of these experimental peatland stands to some extent. Thus, the larger removals from the simulated thinnings were evidently not due to overestimation of simulated growth. More probably, the reason for the high levels of simulated stand volumes at the mature or over-mature stage of thinning maturity was that we used only dominant height as the criterion of thinning maturity. The increase in stand dominant heights to fully meet thinning maturity led to relatively large stand basal areas, which in turn resulted in large removals of basal area and, consequently, large removals of stand volume in the simulated thinnings.

Most of the removal was pulpwood at all maturity stages. The proportion of merchantable part of the stems is to some extent controlled by the minimum top diameters applied. Lowering the minimum top diameter of pulpwood logs from 7 cm to 5.5 cm would have increased the removal of merchantable wood by 6 - 7 m^3ha^{-1}. Thus, the relative impact of the minimum top diameter is clearly smaller than that of the stage of thinning maturity.

Our results showed larger removals from stands mature for thinning compared to some recent surveys of operational thinnings in peatland stands. For example, Sirén *et al*. (2002) and Sirén (2004) reported the average removal of 23 m^3ha^{-1} and 31 m^3ha^{-1} in northern Ostrobothnia and central Finland, respectively, in drained peatland stands that had been considered to be in need of thinning within the next five years. In eastern Finland, the corresponding average removal was 31 m^3ha^{-1} (Ylimartimo *et al*. 2001). On the other hand, the quantity of the thinning removals in our stands mature for thinning was of the same order as that reported in other studies concerning first commercial thinnings in stands of similar initial stockings. For example, the average volume of thinning removals on drained peatlands in southern Ostrobothnia was 52 m^3ha^{-1} (Tanttu *et al*. 2002).

Our interpretation of the results indicating very small removals in peatland thinnings is that those surveys have simply revealed a common feature of operational forestry, i.e. that the thinnings in drained peatlands tend to be applied relatively early in comparison to the maturity criteria of the present management guidelines (Hyvän metsänhoidon... 2001). This interpretation is supported by the observations in eastern Finland by Ojansuu *et al*. (2002) that first thinnings had regularly been suggested to premature pine stands, i.e. stands not fulfilling the criteria for thinning maturity. One reason for this may be that an urgent silvicultural need for thinning may occur in some but not all parts of the clustered and uneven stands, typical of drained peatlands. Pre-commercial thinnings would reduce such needs for premature first thinnings. Importantly, there is also evidence that delaying first commercial thinning by 2-3 metres in dominant height does not reduce the yield of merchantable wood over the whole rotation, if pre-commercial thinning has been applied (Kojola *et al*. 2004).

For corresponding upland stands, Hynynen and Arola (1999) have reported average removals of 35 m^3ha^{-1} and 64 m^3ha^{-1} in premature (dominant height 13 m) and over-mature (17.7 m) thinnings, respectively. Accordingly, Huuskonen and Ahtikoski (2005) have shown the benefits of delayed first thinnings in upland stands. These results are very similar to our results from peatlands. Thus, our results suggest that thinning removals from peatland stands would be similar to those from upland stands if the thinnings were done at the stage when the maturity criteria are actually met. Accordingly, thinnings in stands properly matured for first commercial thinning, resulting in the average removal of ca. 60 m^3ha^{-1} in our study, would probably enable a profitable harvesting operation in most cases unlike the barely harvestable average removal of 36 m^3ha^{-1} from the early thinnings.

In the management of Scots pine, the aims of the first thinnings are primarily silvicultural, i.e. to minimize self-thinning by reducing competition among the trees, and to allocate growth to the selected crop trees for the remaining part of the rotation. Therefore, the revenue from the removal should actually be a secondary criterion when assessing the benefits of first thinnings. The future development of the stand may be significantly affected by the early-rotation management, and thus, even an unprofitable first thinning may turn out to be profitable in the end. Considering the obvious trends of increasing supply and simultaneously decreasing price competitiveness of pine pulpwood, the managers of peatland pine forests should, however, pay attention to applying the necessary thinnings in a most profitable manner. This study, along with earlier findings on the impacts of thinnings on the yield of the retained stands (Kojola *et al*. 2004), suggests i) not to apply too early thinnings due to small and poorly profitable harvest removals unless absolutely necessary from the silvicultural point of view, and ii) to apply even rather heavy thinnings in stands properly meeting the criteria for thinning maturity.

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References

Finér, L. and Kaunisto, S. 2000. Variation in stemwood nutrient concentrations in Scots pine growing on peatland. Scandinavian Journal of Forest Research 15: 424-432.

Hånell, B. 1990. Present situation and future possibilities of peatland forestry in Sweden. In: Hånell, B. (ed.) Biomass production and element fluxes in forested peatland ecosystems. Swedish University of Agricultural Science, Department of Forest Site Research. pp. 45-48.

Heinonen, J. 1994. Koealojen puu- ja puustotunnusten laskentaohjelma KPL - käyttöohje (Summary: Computer programme package for computing stand and single tree characteristics from sample plot measurements). Metsäntutkimuslaitoksen tiedonantoja/Research reports of the Finnish Forest Research Institute 504. 80 pp. (in Finnish with English summary.)

Hökkä, H. 1997. Height-diameter curves with random intercepts and slopes for trees growing on drained peatlands. Forest Ecology and Management 97: 63-72.

Hökkä, H. and Laine, J. 1988. Suopuustojen rakenteen kehitys ojituksen jälkeen (Summary: Post-drainage development of structural characteristics in peatland forest stands). Silva Fennica 22: 45-65. (in Finnish with English summary.)

Hökkä, H. and Kojola, S. 2003. Suometsien kunnostusojitus – kasvureaktion tutkiminen ja kuvaus [Remedial ditching of peatland forests – exploring and describing the growth response]. In: Jortikka, S., Varmola, M. and Tapaninen, S. (eds.) Soilla ja kankailla – Metsien hoitoa ja kasvatusta Pohjois-Suomessa. Metsäntutkimuslaitoksen tiedonantoja/Research reports of the Finnish Forest Research Institute 903: 13-20. (in Finnish.)

Hökkä, H., Alenius, V. and Penttilä, T. 1997. Individual-tree basal area growth models for Scots pine, pubescent birch and Norway spruce on drained peatlands in Finland. Silva Fennica 31: 161-178.

Hökkä, H., Alenius, V. and Salminen H. 2000. Predicting the need for ditch network maintenance in drained peatland sites in Finland. Suo 51: 1-10.

Hökkä, H., Kaunisto, S., Korhonen, K. T., Päivänen, J., Reinikainen, A. and Tomppo, E. 2002. Suomen suometsät 1951-94 [Peatland forests in Finland in 1951-1994]. Metsätieteen aikakauskirja 2B/2002: 201-357. (in Finnish.)

Huuskonen, S. and Ahtikoski, A. 2005. Ensiharvennuksen ajoituksen ja voimakkuuden vaikutus kuivahkon kankaan männiköiden tuotokseen ja tuottoon. [Impacts of the timing and intensity of the first commercial thinning on the growth and yield of Scots pine stands in *Vaccinium vitis-idaea* type upland sites] Metsätieteen aikakauskirja 2/2005: 99-115. (in Finnish.)

Hynynen, J. and Arola, M. 1999. Ensiharvennusajankohdan vaikutus hoidetun männikön kehitykseen ja harvennuksen kannattavuuteen [Effects of the timing of first commercial thinning on stand development and profitability of the thinning operation in managed Scots pine stands]. Metsätieteen aikakauskirja 1/1999:5-23. (in Finnish.)

Hynynen, J., Ojansuu, R., Hökkä, H., Siipilehto, J., Salminen, H. and Haapala, P. 2002. Models for predicting stand development in MELA system. The Finnish Forest Research Institute, Research papers 835.

Hyvän metsänhoidon suositukset 2001 [Guidelines for best management practices in silviculture]. Tapio, Helsinki. 96 pp. (in Finnish.)

Jacobson, S., Kukkola, M., Mälkönen, E. and Tveite, B. 2000. Impact of whole-tree harvesting and compensatory fertilization on growth of coniferous thinning stands. Forest Ecology and Management 129: 41-51.

Jutras, S., Hökkä, H., Alenius, V. and Salminen, H. 2003. Modelling mortality of individual trees in drained peatland sites in Finland. Silva Fennica 37: 235-251.

Kaunisto, S., Ferm, A. and Kokkonen, J. 1991. Suometsät ja niiden tutkimus Virossa ja Latviassa (Summary: Peatland forestry research in Estonia and Latvia). Suo 42: 61-70. (in Finnish with English summary.)

Kojola, S., Penttilä, T. and Laiho, R. 2004. Impacts of different thinning regimes on the yield of uneven-structured Scots pine stands. Silva Fennica 38(4): 393-403.

Laine, J. 1989. Metsäojitettujen soiden luokittelu (Summary: Classification of peatlands drained for forestry). Suo 40: 37-51. (in Finnish with English summary.)

Medvedeva, V. M. and Ionin I.V. 1983. Experience in silvicultural mire management and tasks of forest reclamation in Karelia. In: Proceedings of the international symposium on forest drainage. International Peat Society Commission III, 19.-23. September, 1983. Tallinn, USSR. pp. 109-116.

Nuutinen, T., Hirvelä, H., Hynynen, J., Härkönen, K., Hökkä, H., Korhonen, K. T. and Salminen, O. 2000. The role of peatlands in Finnish wood production – an analysis based on large-scale forest scenario modelling. Silva Fennica 34: 131-153.

Ojansuu, R., Halinen, M. and Härkönen, K. 2002. Metsätalouden suunnittelujärjestelmän virhelähteet männyn ensiharvennuskypsyyden määrityksessä [Error sources related to the forest management planning system in defining thinning maturity of Scots pine stands]. Metsätieteen aikakauskirja 3/2002: 441-457. (in Finnish.)

Paavilainen, E. and Päivänen, J. 1995. Peatland forestry. Ecology and principles. Springer-Verlag, Berlin-Heidelberg-New York. 248 pp.

Penner, M., Penttilä, T. and Hökkä, H. 1995. A method for using random parameters in analyzing permanent sample plots. Silva Fennica 29: 287-296.

Rissanen, A. 2003. Männyn puuaineen ja –kuitujen ominaisuuksien vaihtelu ensiharvennusvaiheen ojitetuissa suometsissä [Variation in the wood and fiber properties of Scots pine trees in drained peatland forests at the stage of first commercial thinning]. Helsingin yliopiston metsävarojen käytön laitoksen julkaisuja 33. (in Finnish.)

Ruseckas, J. 1991. Theoretical background for forest hydromelioration. Leningrad Forestry Academy, Leningrad. 32 pp. (in Russian.)

Salminen, H. and Hynynen, J. 2001. MOTTI: A growth and yield simulation system. Abstract. In: LeMay, V., Marshall, P. (eds.) Forest Modelling for Ecosystem Management, Forest Certification, and Sustainable Management. Proceedings of the Conference held in Vancouver, BC, Canada. August 12 to 17, 2001, p. 488.

Sarkkola, S., Hökkä, H. and Penttilä, T. 2004. Natural development of stand structure in peatland Scots pine following drainage:

results based on long-term monitoring of permanent sample plots. Silva Fennica 38(4): 415-412.

Sirén, M. 2004. Harvesting on peatlands - a challenge. In: Päivänen, J. (ed.). Wise Use of Peatlands. Proceedings of the 12th International Peat Congress, Tampere, Finland, 6-11 June 2004. Vol. 1. Oral presentations. International Peat Society, Jyväskylä, pp. 514-520.

Sirén, M. and Aaltio, H. 2003. Productivity and costs of thinning harvesters and harvester-forwarders. International Journal of Forest Engineering 14(1): 39-48.

Sirén, M., Tanttu, V., Mäntynen, E., Aaltio, H. and Siipilehto, J. 2002. Ensiharvennusten korjuuolot [Harvesting conditions in first commercial thinnings]. In: Sirén, M. (ed.). Ensiharvennusten korjuuolot ja niiden parantamismahdollisuudet. Metsäntutkimuslaitoksen tiedonantoja/ Research reports of the Finnish Forest Research Institute 837, pp. 9-19. (in Finnish.)

Stolyarov, D. P., Popov, Yu. A., Rubtsov, V. G. and Knize, A. A. 1983. Reasons for forests cut in the drained pine stands in the North-West of the RSFSR. In: Proceedings of the international symposium on forest drainage. International Peat Society Commission III, 19.-23. September, 1983. Tallinn, USSR. pp. 88-94.

Tanttu, V., Sirén, M. and Aaltio, H. 2002. Harvennuskertymän rakenne ja energiapuun määrä ensiharvennusmänniköissä [Structure of the removal and the volume of energy wood in first commercial thinnings in pine stands]. In: Sirén, M. (ed.). Ensiharvennusten korjuuolot ja niiden parantamismahdollisuudet Metsäntutkimuslaitoksen tiedonantoja/ Research reports of the Finnish Forest Research Institute 837, pp. 27-36. (in Finnish.)

Toppinen, A. and Toropainen, M. (toim.) 2004. Puun tuonti Suomeen ja Itämeren alueen metsäsektorin kehitys (Abstract: Roundwood imports to Finland and forest sector development around the Baltic Sea). Metsäntutkimuslaitoksen tiedonantoja/Research reports of the Finnish Forest Research Institute 925. (in Finnish with English summary.)

Väätäinen, K., Sikanen, L. and Asikainen, A. 2004. Feasibility of excavator-based harvester in thinning of peatland forests. International Journal of Forest Engineering 15(2): 103-111.

Varhimo, A., Kojola, S., Penttilä, T. and Laiho, R. 2003. Quality and yield of pulpwood in drained peatland forests: Pulpwood properties of Scots pine in stands of first commercial thinnings. Silva Fennica 37: 343-357.

Vompersky, S. E. 1991. Current status of forest drainage in the USSR and problems in research. In: Jeglum, J. K. and Overend, R. P. (eds.). Peat and peatlands - Diversification and Innovation. Vol. 1. Canadian Society of Peat and Peatlands. pp. 13-18.

Westman, C. J. and Laiho, R. 2003. Nutrient dynamics of drained peatland forests. Biogeochemistry 63: 269-298.

Ylimartimo, M., Harstela, P., Korhonen, K.T. and Sirén, M. 2001. Ensiharvennuskohteiden korjuukelpoisuus ojitetuilla turvemailla [Harvesting potential of first commercial thinnings in drained peatland stands]. Metsätieteen aikakauskirja 2/2001: 253-263. (in Finnish.)

Zalitis, P. 1990. Yield capacity on drained forests sites in Latvia. In: Annual reports summarized. Research and Production Association "Silava", Latvian Forestry Research Institute, Salaspils, pp. 4-5.

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ВЛИЯНИЕ СРОКОВ ПЕРВОГО ПРОРЕЖИВАНИЯ НА ОБЪЁМ ЗАГОТОВЛЕННОЙ ДРЕВЕСИНЫ В БОЛОТНЫХ ЛЕСАХ С ПРЕОБЛАДАНИЕМ СОСНЫ

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Резюме

Настоящее исследование ставило своей целью определение объёма и структуры вырубленной и фактически заготовленной древесины при первых прореживаниях, проведенных на разных фазах созревания древостоя в осушенных болотных сосняках (*Pinus sylvestris* L). При определении спелости древостоя на обследованных участках леса в качестве рекомендованной нормы прореживания была принята действующая в Финляндии модель ухода за частными сосновыми лесами. Рубки прореживания на опытных участках и дополнительно смоделированные рубки были осуществлены на 15 участках лесных насаждений. Это – участки, широко представляющие разные места произрастания сосны на осушенных болотах, климатические зоны, разные сроки с первой прокладки осушительных канав, а также различные по фазам созревания древостоя участки: от слишком раннего прореживания (7 участков) до своевременного, соответствующего рекомендациям (11) и запоздалого прореживания (15). Средний объём вырубленной древесины составил при раннем прореживании 51 міга$^{-1}$, при рекомендованном – 69 міга$^{-1}$, а при запоздалом прореживании – 92 міга$^{-1}$. Соответственно, фактические объёмы заготовленной древесины составили при раннем прореживании 36, при своевременном – 59 и при запоздалом – 84 міга$^{-1}$. Выход древесины при рекомендованных и запоздалых рубках прореживания был достаточно высоким, что говорит о возможности рентабельной заготовки древесины при первом прореживании в отличие от ранних рубок ухода, при которых нельзя ожидать достаточной рентабельности из-за малых объёмов вырубляемой древесины и малого среднего объёма стволов. Учитывая явный рост поставок соснового баланса и одновременное снижение конкурентоспособности цен, результаты исследования не поддерживают проведения раннего прореживания, кроме необходимых для ухода за лесом случаев. Но с другой стороны, задержка с прореживанием до созревания древостоя и достижения им критериев спелости (например, преобладающая высота ствола около 15 м или выше) может повысить рентабельность рубок. Это в свою очередь будет способствовать проведению рубок прореживания в качестве положительной лесоводческой практики в болотных лесах.

Ключевые слова: *Pinus sylvestris,* болотные леса, лесоводство, первое прореживание, рубка прореживания, осушение.