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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 m³ ha⁻¹ and those of harvest removals 36, 59, and 84 m³ ha⁻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 8th 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 homogeneous 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 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 metsähoidon... 2001) and as illustrated in Figure 1. Stand dominant height (H\text{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

<table>
<thead>
<tr>
<th>Stand id</th>
<th>Municipality</th>
<th>Location</th>
<th>Temp. sum, d°</th>
<th>Site type</th>
<th>Peat depth, m</th>
<th>First thinned</th>
<th>V°</th>
<th>Sb</th>
<th>Sb %</th>
</tr>
</thead>
<tbody>
<tr>
<td>5779</td>
<td>Kammo</td>
<td>63'41'</td>
<td>23'11'</td>
<td>VT1</td>
<td>0.2</td>
<td>1954</td>
<td>205</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>5916</td>
<td>Viitna</td>
<td>63'16'</td>
<td>25'9'</td>
<td>DTx</td>
<td>0.2-0.8</td>
<td>1958</td>
<td>163</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5922</td>
<td>Pelkosenniemi</td>
<td>67'17'</td>
<td>23'44'</td>
<td>MT2</td>
<td>&gt;1</td>
<td>1969</td>
<td>143</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>5923</td>
<td>Pelkosenniemi</td>
<td>67'17'</td>
<td>23'42'</td>
<td>MT2</td>
<td>&gt;1</td>
<td>1969</td>
<td>147</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>5932</td>
<td>Rovaniemi</td>
<td>66'21'</td>
<td>26'38'</td>
<td>VT2</td>
<td>0.4</td>
<td>1934</td>
<td>100</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5944</td>
<td>Simo</td>
<td>65'47'</td>
<td>23'19'</td>
<td>MT2</td>
<td>0.2</td>
<td>1961</td>
<td>143</td>
<td>40</td>
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<tr>
<td>5945</td>
<td>Kuivaniemi</td>
<td>65'04'</td>
<td>23'28'</td>
<td>VT2</td>
<td>0.2-0.5</td>
<td>1957</td>
<td>151</td>
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<tr>
<td>5949</td>
<td>Kemiö</td>
<td>67'22'</td>
<td>24'39'</td>
<td>MT2</td>
<td>0.9</td>
<td>1971</td>
<td>97</td>
<td>7</td>
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<tr>
<td>5953</td>
<td>Puolansalmi</td>
<td>65'41'</td>
<td>27'19'</td>
<td>MT2</td>
<td>0.7-1.0</td>
<td>1937</td>
<td>153</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>5954</td>
<td>Utsjö</td>
<td>65'21'</td>
<td>23'51'</td>
<td>MT2</td>
<td>0.3</td>
<td>1939</td>
<td>219</td>
<td>41</td>
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<td>Kolmos</td>
<td>64'04'</td>
<td>29'30'</td>
<td>VT1</td>
<td>0.1</td>
<td>1963</td>
<td>181</td>
<td>34</td>
<td></td>
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<tr>
<td>5956</td>
<td>Puolanka</td>
<td>64'49'</td>
<td>27'22'</td>
<td>MT2</td>
<td>0.4-1.0</td>
<td>1967</td>
<td>176</td>
<td>2</td>
<td></td>
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<tr>
<td>5958</td>
<td>Puolanka</td>
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<td>23'42'</td>
<td>MT2</td>
<td>0.6-1.0</td>
<td>1973</td>
<td>159</td>
<td>25</td>
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<td>5960</td>
<td>Västång</td>
<td>65'25'</td>
<td>23'41'</td>
<td>MT2</td>
<td>&gt;1</td>
<td>1939</td>
<td>253</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>7164</td>
<td>Ruovesi</td>
<td>61'51'</td>
<td>24'16'</td>
<td>DTx</td>
<td>&gt;1</td>
<td>1967</td>
<td>130</td>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

* Cumulative annual temperature sum with +5°C threshold value
b) Peatland forest site types according to Laine (1989):
VT1 = Vaccinium vitis-idaea type 1 [Ptkg(I)]
VT2 = Vaccinium vitis-idaea type 2 [Ptkg(II)]
DTx = Dwarf-shrub type [Vatkg]

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 m³ ha⁻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 metsänhoito... 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 (merchandable 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. (2002). For all simulated thinnings, we applied the tree mortality models by Jutras 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$^3$ha$^{-1}$, and those of the removals from 19 to 115 m$^3$ha$^{-1}$, 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$^3$ha$^{-1}$ and those of removals 36, 59, and 84 m$^3$ha$^{-1}$, 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$^3$ha$^{-1}$. 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

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<tr>
<th>Stands for thinning</th>
<th>Fellings</th>
<th>Retained growing stock</th>
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<tbody>
<tr>
<td>Premature (5)</td>
<td></td>
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<td>Mature (3)</td>
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<tr>
<td>Over-mature (3)</td>
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<td>Over-mature (3)</td>
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<td></td>
</tr>
<tr>
<td>Over-mature (3)</td>
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</tr>
</tbody>
</table>

**Figure 2.** Removals (merchantable wood) in experimental and simulated thinnings relative to total stand volume before thinning.
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 m²ha⁻¹ and stand volume 56 - 149 m³ha⁻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 m³/ha⁻¹, which is generally consid-
ered a limit of profitable harvesting in the first thin-
nings in Finnish forestry (Ylimartimo et al. 2001).
Fellings and removals from simulated thinnings on
average were slightly larger than those from ex-
perimental thinnings. This was obviously due to
somewhat greater stand volumes at the stage of the
intended thinning maturity. Kojola et al. (2004) ob-
served earlier that MOTTI-simulations underestimat-
ed the growth of these experimental peatland stands to
some extent. Thus, the larger removals from the
simulated thinnings were evidently not due to over-
estimation of simulated growth. More probably, the
reason for the high levels of simulated stand volumes
at the mature or over-mature stage of thinning matur-
ity 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, conse-
sequently, large removals of stand volume in the simu-
lated thinnings.

Most of the removal was pulpwood at all matura-
ty stages. The proportion of merchantable part of
the stems is to some extent controlled by the mini-
um 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 m³/ha⁻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 ex-
ample, Sirén et al. (2002) and Sirén (2004) report-
ed the average removal of 23 m³/ha⁻¹ and 31 m³/ha⁻¹
in northern Ostrobothnia and central Finland, respecti-
vely, in drained peatland stands that had been consid-
ered to be in need of thinning within the next five
years. In eastern Finland, the corresponding average
removal was 31 m³/ha⁻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 in-
itial stockings. For example, the average volume of
thinning removals on drained peatlands in southern
Ostrobothnia was 52 m³/ha⁻¹ (Tanttu et al. 2002).

Our interpretation of the results indicating very
small removals in peatland thinnings is that those sur-
veys have simply revealed a common feature of op-
erational forestry, i.e. that the thinnings in drained
peatlands tend to be applied relatively early in compari-
son to the maturity criteria of the present management
guidelines (Hyvän Metsähoidon... 2001). This inter-
pretation 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 ma-
turity. One reason for this may be that an urgent si-
vicultural 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. Im-
portantly, 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
m³/ha⁻¹ and 64 m³/ha⁻¹ in premature (dominant height
13 m) and over-mature (17.7 m) thinnings, respec-
tively. 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 simi-
lar to those from upland stands if the thinnings were
done at the stage when the maturity criteria are ac-
tually met. Accordingly, thinnings in stands properly
matured for first commercial thinning, resulting in
the average removal of ca. 60 m³/ha⁻¹ in our study,
would probably enable a profitable harvesting oper-
ation in most cases unlike the barely harvestable av-
erage removal of 36 m³/ha⁻¹ from the early thinnings.

In the management of Scots pine, the aims of the
first thinnings are primarily silvicultural, i.e. to min-
imize self-thinning by reducing competition among
the trees, and to allocate growth to the selected crop
trees for the remaining part of the rotation. There-
fore, 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 thin-
ning may turn out to be profitable in the end. Con-
sidering 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 nec-
essary 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 thin-
nings due to small and poorly profitable harvest re-
movals unless absolutely necessary from the silvicul-
tural point of view, and ii) to apply even rather heavy
thinnings in stands properly meeting the criteria for thinning maturity.

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