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Impact of Thinning Intensity on the Harvesting Costs of First-Thinning Wood in Scots pine Stands

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Abstract

In the new forest management recommendations in Finland, one cultivation alternative for Scots pine (*Pinus sylvestris* L.) is intensive cultivation in which the quality of a poor or mediocre pine stand is improved by carrying out an intensive, quality first thinning. This type of thinning leaves ca. 700 trees per hectare. The research conducted by Metsäteho Oy investigated how harvesting conditions and costs change when the thinning intensity is increased and intensive, quality thinning is carried out in first-thinning Scots pine stands. The study showed that the harvesting conditions in intensive, quality thinning are superior, resulting in lower harvesting costs than for normal first thinning. One item of particular note was the drop in cutting costs. Intensive, quality thinning had less of an impact on the forest haulage costs. The reduction in harvesting costs, and especially in the cutting costs, was dependent on the extent to which the average stem size of the trees to be harvested increased throughout the marked stand. When the average stem size of the trees to be harvested increased by 25%, the harvesting costs in the typical harvesting conditions of first-thinning pine stands were 15–19% lower than in normal first thinning.

Keywords: Thinning intensity, Industrial roundwood, Pulpwood, First thinnings, Scots pine, Wood harvesting, Costs.

1. Introduction

During the 1970's and the beginning of the 1980's, the artificial regeneration area for Scots pine (*Pinus sylvestris* L.) in Finland annually totalled over 100,000 hectares, of which over two-thirds consisted of planting (Juntunen & Herrala-Ylinen 2007). Part of the area planted with pine included excessively fertile sites, resulting in poor quality, thick-branched pine stands. It is estimated that there are more than 0.5 million hectares of poor-quality Scots pine stands in Finland.

In the new forest management recommendations drawn up by Forestry Development Centre Tapio (Anon. 2006), one cultivation alternative for Scots pine is intensive cultivation in which the quality of a poor or mediocre pine stand is improved by carrying out an intensive, quality first thinning. This type of thinning leaves ca. 700 trees per hectare, whereas a normal first thinning leaves 900–1,000 trees per hectare (Anon. 2006). The research conducted by Metsäteho Oy investigated how harvesting conditions and costs change when the thinning intensity is increased and intensive, quality thinning is carried out in first-thinning Scots pine stands.

2. Material and methods

The impact of undergrowth on the productivity of harvesting work in first-thinning stands was clarified in the study conducted by Kärhä (2006). The thinning intensity (the removal density as a proportion of the initial growing stock density) in the study by Kärhä (2006) was relatively high, 51% on the average. The time consumption functions for industrial roundwood (i.e. pulpwood) cutting and forest haulage developed by Kärhä et al. (2006) were applied in the cost calculations of this research. It was assumed that there were 1,000 Norway spruce (*Picea abies* (L.) Karst.) undergrowth trees per hectare in a Scots pine first-thinning stand, and the average height of the spruce undergrowth trees was 2 m.

When calculating the wood harvesting costs, it was assumed that the removal density in an intensive, quality thinning is 250 industrial roundwood trees/ha greater than in a normal first thinning (Table 1). When the density of removal was very high (>1,600 roundwood trees/ha), the harvesting costs for this kind of site were not calculated in the research. Three different alternatives were developed for the cost comparisons between a intensive, quality thinning and a normal first thinning. The alternatives were:

1) Stem size of the trees to be harvested did not increase,
2) Stem size of the trees to be harvested increased by 25%, and
3) Stem size of the trees to be harvested increased by 50%.

When drawing up the cost calculations, it was assumed that cutting is carried out by a harvester for thinnings (weight: 13–15 tons) and forest haulage with a medium-duty forwarder (carrying capacity: 10–12 tons). The operating hour costs for the harvester were 79 €/E_{15}-hour, and for the forwarder 55 €/E_{15}-hour. The pulpwood load size in forest haulage was 10.0 m^3 in the calculations.

Table 1. Removal matrix used in the calculations for normal first thinning. In an intensive, quality thinning, the density of removal was 250 industrial roundwood trees/ha greater than in a normal first thinning.

Stem size, dm^3	Industrial roundwood removal, m^3/ha								
	20	30	40	50	60	70	80	90	100
	Density of removal, trees/ha								
40	500	750	1,000	1,250					
50	400	600	800	1,000	1,200				
60	333	500	667	833	1,000	1,167	1,333		
70	286	429	571	714	857	1,000	1,143	1,286	
80	250	375	500	625	750	875	1,000	1,125	1,250
90	222	333	444	556	667	778	889	1,000	1,111
100	200	300	400	500	600	700	800	900	1,000
110	182	273	364	455	545	636	727	818	909
120	167	250	333	417	500	583	667	750	833
130	154	231	308	385	462	538	615	692	769
140	143	214	286	357	429	500	571	643	714

Figure 1. Scots pine first-thinning stand after an intensive, quality thinning. There are 650 trees remaining per hectare in the stand. Photo: Metsäteho Oy / Kalle Kärhä.

3. Results

3.1. Harvesting conditions

When 250 trees per hectare more than in normal first thinning were harvested in a first-thinning Scots pine stand in intensive, quality thinning in typical harvesting conditions (i.e. stem size: 50–100 dm^3 and industrial roundwood removal: 20–60 m^3/ha (cf. Kärhä 2007)), the thinning intensity increased by 13–21 %-units. The increased removal density increased, in turn, the industrial roundwood removal of the marked first-thinning stand.

When the average stem size of the trees harvested in intensive, quality thinning was not increased, the industrial roundwood removal was 13–25 m^3/ha higher than in normal first thinning of a Scots pine stand in typical harvesting conditions (Table 2).

When the average stem size of the harvested trees was raised in an intensive, quality thinning, the industrial roundwood removal increased significantly compared to that in normal first thinning (Table 2). When the average harvested stem size was raised by 25%, the removal increased by 21–44 m^3/ha in typical harvesting conditions. When the average harvested stem size was increased by 50%, the removal increased by 29–64 m^3/ha compared to normal first thinning.

3.2. Harvesting costs

An increase in the average stem size of the trees harvested in intensive, quality thinning had a significant impact on the productivity and costs of cutting work. When the average stem size of the trees harvested in intensive, quality thinning was not raised, the cutting costs were 2–7% (0.4–1.0 €/m^3) lower than in normal first thinning in typical harvesting conditions. The relative forest haulage cost savings were similar to those of cutting. The overall harvesting costs were 0.5–1.5 €/m^3 lower than in normal first thinning in typical harvesting conditions in a Scots pine stand (Table 3).

When the average stem size was increased by one quarter, the cutting costs were over 20% (2.2–4.7 €/m^3) lower than in normal first thinning in typical harvesting conditions. The smaller the average stem size of the harvested first-thinning stand, the higher were the cost savings for cutting. The effect of average harvested stem size on the forest haulage costs was lower than the effect on the cutting costs. When the average stem size of the harvested trees was raised by 25%, the harvesting costs fell by 15–19% (2.6–5.3 €/m^3) compared to normal first thinning in typical harvesting conditions (Table 3).

When the average harvested stem size was raised by 50%, the cutting costs were more than 30% (3.4–7.0 €/m^3) lower and the forest haulage costs 6–12% (0.4–0.9 €/m^3) lower than in normal first thinning. The overall harvesting costs were 23–28% (3.9–7.7 €/m^3) lower than in normal first thinning in typical harvesting conditions in a pine stand (Table 3).

Table 2. Industrial roundwood removal matrices for three alternatives used in intensive, quality thinning: 1) Stem size of the trees to be harvested did not increase, 2) Stem size of the trees to be harvested increased by 25%, and 3) Stem size of the trees to be harvested increased by 50%. The table also gives the stem size and industrial roundwood removal in normal (N; light grey) first thinning.

1) Stem size of the trees to be harvested did not increase.

1	N	Industrial roundwood removal, m^3/ha								
Stem size, dm^3		20	30	40	50	60	70	80	90	100
40	40	30	40	50	60					
50	50	33	43	53	63	73				
60	60	35	45	55	65	75	85	95		
70	70	38	48	58	68	78	88	98	108	
80	80	40	50	60	70	80	90	100	110	120
90	90	43	53	63	73	83	93	103	113	123
100	100	45	55	65	75	85	95	105	115	125
110	110	48	58	68	78	88	98	108	118	128
120	120	50	60	70	80	90	100	110	120	130
130	130	53	63	73	83	93	103	113	123	133
140	140	55	65	75	85	95	105	115	125	135

2) Stem size of the trees to be harvested increased by 25%.

2	N	Industrial roundwood removal, m^3/ha								
Stem size, dm^3		20	30	40	50	60	70	80	90	100
50	40	38	50	63	75					
63	50	41	53	66	78	91				
75	60	44	56	69	81	94	106	119		
88	70	47	59	72	84	97	109	122	134	
100	80	50	63	75	88	100	113	125	138	150
113	90	53	66	78	91	103	116	128	141	153
125	100	56	69	81	94	106	119	131	144	156
138	110	59	72	84	97	109	122	134	147	159
150	120	63	75	88	100	113	125	138	150	163
163	130	66	78	91	103	116	128	141	153	166
175	140	69	81	94	106	119	131	144	156	169

3) Stem size of the trees to be harvested increased by 50%.

3	N	Industrial roundwood removal, m^3/ha								
Stem size, dm^3		20	30	40	50	60	70	80	90	100
60	40	45	60	75	90					
75	50	49	64	79	94	109				
90	60	53	68	83	98	113	128	143		
105	70	56	71	86	101	116	131	146	161	
120	80	60	75	90	105	120	135	150	165	180
135	90	64	79	94	109	124	139	154	169	184
150	100	68	83	98	113	128	143	158	173	188
165	110	71	86	101	116	131	146	161	176	191
180	120	75	90	105	120	135	150	165	180	195
195	130	79	94	109	124	139	154	169	184	199
210	140	83	98	113	128	143	158	173	188	203

Table 3. Reduction in Scots pine first-thi nning harvesting costs for three alternatives used in an intensive, quality thinning compared to a normal (N) first thinning: *1) Stem size of the trees to be harvested did not increase, 2) Stem size of the trees to be harvested increased by 25%, and 3) Stem size of the trees to be harvested increased by 50%.*

1) Stem size of the trees to be harvested did not increase.

		Industrial roundwood removal, m^3/ha								
		30–55	40–65	50–75	60–85	73–95	85–105	95–115	108–125	120–135
1	N	20	30	40	50	60	70	80	90	100
Stem size, dm^3		Savings in harvesting costs, €/m^3								
40	40	1.4	1.0	0.7	0.6					
50	50	1.4	1.0	0.8	0.6	0.5				
60	60	1.4	1.0	0.8	0.6	0.5	0.5	0.4		
70	70	1.4	1.0	0.8	0.7	0.6	0.5	0.4	0.4	
80	80	1.4	1.0	0.8	0.7	0.6	0.5	0.4	0.4	0.3
90	90	1.5	1.1	0.8	0.7	0.6	0.5	0.4	0.4	0.4
100	100	1.5	1.1	0.8	0.7	0.6	0.5	0.4	0.4	0.4
110	110	1.5	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4
120	120	1.5	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4
130	130	1.5	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4
140	140	1.5	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4

2) Stem size of the trees to be harvested increased by 25%.

1		Industrial roundwood removal, m^3/ha								
		38–69	50–81	63–94	75–106	91–119	106–131	119–144	134–156	150–169
	N	20	30	40	50	60	70	80	90	100
Stem size, dm^3		Savings in harvesting costs, €/m^3								
50	40	6.0	5.4	5.1	4.8					
63	50	5.3	4.7	4.4	4.2	4.0				
75	60	4.6	4.1	3.8	3.6	3.5	3.3	3.2		
88	70	4.3	3.8	3.5	3.3	3.2	3.0	3.0	2.9	
100	80	3.9	3.4	3.2	3.0	2.9	2.7	2.7	2.6	2.5
113	90	3.7	3.3	3.0	2.8	2.7	2.6	2.5	2.4	2.4
125	100	3.5	3.1	2.8	2.6	2.5	2.4	2.3	2.2	2.2
138	110	3.4	2.9	2.7	2.5	2.4	2.3	2.2	2.1	2.1
150	120	3.2	2.8	2.5	2.4	2.2	2.1	2.1	2.0	1.9
163	130	3.1	2.7	2.5	2.3	2.2	2.1	2.0	1.9	1.9
175	140	3.0	2.6	2.4	2.2	2.1	2.0	1.9	1.8	1.8

3) Stem size of the trees to be harvested increased by 50%.

		Industrial roundwood removal, m^3/ha								
		45–83	60–98	75–113	90–128	109–143	128–158	143–173	161–188	180–203
3	N	20	30	40	50	60	70	80	90	100
Stem size, dm^3		Savings in harvesting costs, €/m^3								
60	40	9.0	8.4	7.9	7.6					
75	50	7.7	7.1	6.7	6.4	6.2				
90	60	6.8	6.2	5.9	5.6	5.4	5.3	5.2		
105	70	6.1	5.6	5.2	5.0	4.8	4.7	4.6	4.5	
120	80	5.6	5.1	4.8	4.6	4.4	4.3	4.2	4.1	4.0
135	90	5.2	4.7	4.4	4.2	4.1	3.9	3.8	3.8	3.7
150	100	4.9	4.4	4.1	3.9	3.8	3.7	3.6	3.5	3.4
165	110	4.6	4.2	3.9	3.7	3.6	3.4	3.3	3.3	3.2
180	120	4.4	4.0	3.7	3.5	3.4	3.3	3.2	3.1	3.0
195	130	4.2	3.8	3.5	3.3	3.2	3.1	3.0	2.9	2.9
210	140	4.1	3.7	3.4	3.2	3.1	3.0	2.9	2.8	2.7

4. Discussion and conclusions

In terms of stumpage earnings and forestry profitability, it is essential to produce sawlogs in Scots pine cultivation. Intensive silvicultural treatments are applied in poor and mediocre Scots pine stands in order to achieve the best possible yields from the poorly growing trees. The main objective is to produce large-diameter, knot-free butt logs using a stand treatment programme that includes pruning, as well as intensive, quality thinning at a dominant stand height of 10–12 metres (Anon. 2006).

Instead of the standard three thinning operations, the intensive cultivation model employs just two thinnings (Anon. 2006). Due to the intensive first thinning and wider spacing, the trees have thicker growth rings. However, this has no known detrimental effect on the strength properties of the sawn timber.

According to the new national forest management recommendations, intensive cultivation should only be applied in the treatment of poor and mediocre quality Scots pine stands on moist or moderately dry upland forest sites in southern and central Finland (Anon. 2006). Intensive cultivation is not a general treatment alternative for all Scots pine stands. Nor is it always suitable, because intensive first thinning has been observed to cause considerable growth losses in Scots pine stands during the 10-year period following thinning, if fertilization is not carried out (e.g. Vuokila 1981, Mäkinen & Isomäki 2004). Growth losses are eliminated if fertilization is carried out a few years after the first thinning (Mäkinen et al. 2005).

Growth losses are compensated by the decrease in the rotation period, the transfer of growth to more valuable sawn wood, the smaller risk of harvesting damage, and the lower harvesting costs (cf. Mäkinen & Isomäki 2004, Mäkinen et al. 2005). The study showed that the harvesting conditions in intensive, quality thinning are superior, resulting in lower harvesting costs than for normal first thinning. One item of particular interest was the decrease in the cutting costs. Intensive, quality thinning has less of an impact on the forest haulage costs.

The reduction in harvesting costs, and especially in the cutting costs, is related to how much the average stem size of the trees to be harvested increases throughout the marked stand. The extent to which the average stem size harvested is increased in intensive, quality thinning depends on the spatial distribution and structure of the first-thinning stand. It can be assumed, however, that the average stem size harvested in intensive, quality thinning will be higher than that in normal first thinning.

When the average stem size of the trees to be harvested increased by 25%, which is a relatively realistic increase in the stem size harvested in the stand, the harvesting costs around 3 €/m^3 lower than in normal first thinning in the typical harvesting conditions in Scots pine stand in Finland. The cost savings were significant: in 2005, the average harvesting costs in mechanized pine first thinnings were 15.5 €/m^3 (cutting: 11.1 €/m^3 and forest haulage: 4.4 €/m^3) (Kariniemi 2006). The profitability of intensive management is dependent on timber prices, costs of management practices, and the applied discount rate (Mäkinen et al. 2005). Therefore, the profitability of intensive, quality thinning ultimately becomes clearly evident in the final cutting: at what stage are the timber assortment ratios and the stumpage price levels of the different timber assortments.

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