Productivity and Costs of Thinning Harvesters and Harvester-Forwarders

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ABSTRACT

Machines with lower investment and operating costs can be one solution in solving the harvesting costs problem of first thinnings. The long-term productivity of thinning harvesters and harvester-forwarders was investigated in a joint project between Finnish research institutions. In the follow-up study, three harvester-forwarders and five thinning harvesters were studied. The total harvested volume was almost 30000 m^3.

The work performed by harvester-forwarders includes both cutting and forwarding. The average productivity of a harvester-forwarder varied from 3.81 m^3/E_{15} hours in first thinnings to 7.87 m^3/E_{15} hours in regeneration cuttings. The productivity was calculated for a 250 m forwarding distance. Average stem size of the stand, removal per hectare, and number of timber assortments were the factors affecting productivity when the forwarding distance was standardized. The productivity of thinning harvesters varied from an average of 6.92 m^3/E_{15} hours in first thinnings to 16.18 m^3/E_{15} hours in clear cuttings. Some of the harvesters were well capable in small dimensioned clear cuttings, the smallest machines being solely designed for thinnings.

Harvesting costs were compared at the harvesting system level. The costs of a medium-sized forwarder were added to the costs of harvesters. Cost data for the widely used medium-sized harvester system were added to the comparisons made for the forwarding distance of 250 metres. The thinning harvester system had the lowest costs for both two and five timber assortments. In the case of five assortments, which is the typical number in thinnings in Finland, the medium-sized harvester system had lower costs than the harvester-forwarder above a stem size of 60 dm^3. At an average stem size of 200 dm^3 the difference between the harvester systems was minimal. In the case of two assortments, the competitiveness of the harvester-forwarder was better, and below a stem size of 100 dm^3 its costs were lower and between 100-200 dm^3 at the same level as for the medium-sized harvester system. The thinning harvester system was still the cheapest alternative.

Thinning harvesters and harvester-forwarders are interesting alternatives for thinnings. The high capacity and all the properties of medium-sized harvesters cannot be fully exploited in thinnings. Thus machinery with lower capital costs and reasonable productivity can be competitive. Some of the studied machines can be used effectively in clear cuttings with a reasonable stem size. The harvester-forwarder is an interesting type of machine that is currently undergoing rapid development. The harvester-forwarder is most competitive in small stands with a short forwarding distance.

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INTRODUCTION

Thinnings play an essential role in wood production in the Nordic countries. The estimated need for first thinnings in Finland between 1987-1996 was 220000 hectares/year [21], but only 1/3 was actually carried out [20]. Since then, the amount of first thinnings has increased from 100000 hectares to 150000 hectares/year. However, first thinnings are late on a total area of 400000 hectares. Thus the silvicultural need for first thinnings is today 250000 hectares/year [20, 21].

High harvesting costs and marketing problems, partly caused by technical properties related to first thinning wood, are the main problems in first thinnings. Small stem size, low removal/hectare, high number of remaining trees, and often also dense non-marketable undergrowth, mean low machine productivity and high costs. In 1998 the average cost of mechanized harvesting in first thinnings was 10.4-13.3 US$ and 4.4-5.2 US$ in final fellings [5, 6]. The costs of manual cutting with forwarding in first thinnings is even higher, on the average 15.9 US$ in the year 2000 [22].

Near 90% of the thinnings carried out by the Finnish forest industry and Forest and Park Service is mechanized. Most of the thinnings are cut with medium-sized, one-grip harvesters with a mass of 13-15 tonnes, and forwarded with 11-13 tonne forwarders. The estimated hourly operating cost for a medium-sized harvester is over 60 US$ and for forwarder 45 US$.

Machines with lower operating costs can be one solution for cost-efficient first thinnings [7, 16]. A research project partly funded by Tekes, The National Technology Agency, investigated the productivity, costs and silvicultural thinning result of thinning harvesters and harvester-forwarders [8]. A harvester-forwarder is a combination machine that performs both cutting and forwarding. Metsäteho, The Finnish Forest Research Institute and The Work Efficiency Institute participated in the project. This paper presents the results of the follow-up study on thinning harvesters and harvester-forwarders. This part of the project was carried out by the Finnish Forest Research Institute.

MATERIALS AND METHODS

The long-term productivity of thinning harvesters and harvester-forwarders was investigated in a follow-up study in 1999-2000. The productivity data were based on Kienzle data collection clocks and information collected by machine operators. The machine operator changed the clock chart once a week. For every work shift the operator filled in a form showing the starting and ending time of the shift, the cause and ending time of breaks and interruptions, and the time for machine service or stand planning. The machine operator also printed out the harvested volume, divided into timber assortments, from the measurement device. The average hauling distance, stand area in hectares and other stand information were also reported by the machine operators.

The clock chart information was analyzed and combined with the operators´ and measurement reports. MS Excel and SPSS software were used in the data processing. The data were processed at two levels. The results for the harvesters were calculated for both single work shifts and whole stands. It is impossible to calculate the productivity of a single shift with a harvester-forwarder because the amount of cut and hauled wood is often different at the shift level. Thus the productivity comparisons are based on stand level productivity. In data processing the results were weighted with the harvested volume of the stands. The results were also calculated without weighting. The difference between the weighted and unweighted results were small. The cost comparisons were made between the thinning harvester system and the harvester-forwarder. For these calculations the productivity of the harvester-forwarder was converted to a 250 m hauling distance using the time study data results [12]. The costs for forwarding and the cost levels of the medium-sized harvester system used in the comparisons were obtained from Metsäteho. In the cost calculations the currency conversion rate of 1 • = 0.881 US$ was used.

The study material was collected from five thinning harvesters (one Nokka Profi, two Sampo 1046X, and two Prosilva Ässä 810 machines) and three harvester-forwarders (Pika 828). The structure of the study stands is presented in Table 1, and technical information about the machines in Table 2. The total number of machine operators was one for Nokka Profi, three for Sampo 1046X, two for Ässä 810 and seven for Pika 828 harvester-forwarder. All the studied operators were classified as skilled.

For the harvester-forwarders 67% of the volume was Scots pine (*Pinus sylvestris*), 25% Norway spruce (*Picea abies*) and 8% leaf trees, mainly birch. For the thinning harvesters the proportion of pine was 46%, of spruce 35% and the remainder 19% leaf trees. Pulpwood was cut to 3-5 metre lengths. The average number of tree assortments in thinning was 4.6 for the harvester-forwarders and 5.4 for the harvesters. Almost 60% of the stands were located in easy terrain, 1/3 in medium and less than 10% in difficult terrain. Half of the stands had no disturbing non-marketable undergrowth, and less than 10% of the stands had a dense undergrowth.

Table 1. Structure of the study stands.

Machine type	Treatment	Number of stands	Volume, m^3	Average stem size, dm^3	Average removal, m^3/hectare
Harvester-forwarder	First thinning	15	4661	86.8	42.9
	Later thinning	12	2123	151.8	45.2
	Clear cutting	19	4041	252.6	147.4
	Regeneration felling	7	1035	297.7	102.6
	Total	53	11859	188.8	88.4
Thinning harvester	First thinning	27	4420	103.6	50.3
	Later thinning	21	5503	140.3	82.3
	Clear cutting	17	4658	336.7	184.6
	Regeneration felling	12	2421	311.5	117.5
	Total	77	17002	209.0	107.0

Table 2. Machine technical information.

		Sampo Rosenlew 1046X (harvester)	Nokka Profi (harvester)	Ässä 810 (harvester)	Pika 828 (harvester-forwarder)
Base machine	Mass, kg	7000	11500	10000	13900
	Width, mm	2300	2500	2600	2900
Engine	Type	Valmet 420 DRS	Perkins 100-4T	Perkins 1006-6T	Perkins 1006-60T
	Power, kW	74	95	114	113
Transmission		Hydrostatic-mechanical	Hydrostatic	Hydrostatic	Hydrostatic-mechanical
Boom	Type	Mowi	Logmer 990	Logmer 990	Marttiini M100SP
	Reach, m	7.2	9.0	9.0	9.6
Harvester head	Type	Keto 51	Keto 51	Keto 100	Pika 400

Table 3. The machine prices (US$ excluding taxes) and the calculated operating costs (US$ per E_{15} hours) used in cost comparisons. Operating costs include both time dependent and variable operating expenses.

Machine	Machine price, US$ excluding taxes	Operating costs, US$ per E_{15} hour excluding taxes
Medium-sized harvester	241 476	58.0
Sampo 1046X	123 777	47.6
Nokka Profi	197 154	54.2
Ässä 810	148 236	50.1
Pika 828 harvester-forwarder	237 178	54.7
Forwarder	151 942	45.1

The machine prices excluding taxes and the calculated operating costs US$ per E_{15} hours [8] used in cost comparisons are presented in Table 3. The operating costs were calculated with machine calculation program of Metsäteho. The calculation program needs basic data on annual harvested volume, average stem size and operating hours, proportion of thinnings, machine price and depreciation period of base machine and harvester head. The calculation procedure is presented in final report of the joint project [8]. Cost comparisons were done for harvesting systems. A harvesting system typically includes a one-grip harvester and a forwarder.

Operating costs include both time dependent costs (capital depreciation, interest expenses, labor costs, insurance fees, administration expenses) and variable operating expenses (fuel, repair and service, machine transfers). The depreciation period for base machine in cost calculation is 4.7 years and for harvester head 2.3 years.

RESULTS

Distribution of time consumption

Time elements were calculated according to the joint Nordic (NSR) recommendations [10], which are widely used in Scandinavia. The average proportion of gross effective time (E_{15} hours) out of work place time (W_0) with harvester-forwarders was 84.6% and with thinning harvesters 81.6%. The average proportion of E_0 (effective time including no interruptions) out of work place time (W_0) with harvester-forwarders was 76.9% and with thinning harvesters 76.3%. The average technical availability of harvester-forwarders was 79.1% and of thinning harvesters 84.5%.

The machine operator was the most common reason for interruptions shorter than 15 minutes. With harvester-forwarders a total of 63% and with thinning harvesters

54% of the short interruptions were caused by the operator. These interruptions consisted of coffee breaks, phone calls etc. The most common technical interruptions were caused by the harvester head, mainly the chain saw, with both machines types. Planning and contact with the work supervisors also caused a lot of short interruptions.

Productivity of harvester-forwarders

The productivity of harvester-forwarders was calculated for a forwarding distance of 250 metres. The average productivity per operating hour (E_{15} hours, includes interruptions shorter than 15 minutes) [10], its variation between machines, average stem size (dm^3) and removal (m^3/hectare) in different harvesting conditions are presented in Table 4. Regression models for harvester-forwarder productivity in thinnings and clear cuttings (including regeneration cuttings) are presented in Table 5. Average stem size, removal and number of timber assortments were factors affecting productivity in both thinnings and clear cuttings. Each extra assortment lowered the productivity of the harvester-forwarders by 0.147 m^3 during one operating hour in thinnings.

Table 4. Productivity (m^3/E_{15} hours) of harvester-forwarders in different types of cutting.

	Productivity, m^3/E_{15} hours	Average stem size, dm^3	Average removal, m^3/hectare
First thinning	3.81 (2.68 – 4.22)	89.4	41.5
Later thinning	4.41 (4.09 – 4.98)	137.0	45.6
Clear cutting	7.48 (5.11 – 9.65)	264.6	159.5
Regeneration cutting	7.87 (7.85 – 7.87)	276.3	152.8

Table 5. Regression models for the productivity of harvester-forwarders. Forwarding distance is 250 metres.

$$y = a + bx_1 + cx_2 + dx_3 \quad [1]$$

where
y = productivity, m^3/E_{15} hours
x_1 = average stem size, dm^3
x_2 = removal, m^3/hectare
x_3 = number of timber assortments, pieces

a = constant
b, c and d = parameter estimates

Thinning

	Parameter estimate	Std. error	t-value	Pr>[T]
a	2.171	0.040	53.610	<0.0001
b	0.0106	<0.0001	43.734	<0.0001
c	0.0320	0.001	32.173	<0.0001
d	-0.147	0.003	-44.839	<0.0001
			N = 27	$R^2 = 0.400$

Clear cutting

	Parameter estimate	Std. error	t-value	Pr>[T]
a	5.808	0.099	58.483	<0.0001
b	0.0070	<0.0001	26.109	<0.0001
c	0.0047	<0.0001	9.793	<0.0001
d	-0.125	0.015	-8.298	<0.0001
			N = 26	$R^2 = 0.156$

The work of harvester-forwarder includes both cutting and forwarding. Thus the productivity does not rise as rapidly as with harvester, when the stem size rises. Figure 1 presents the productivity of harvester-forwarders as a function of the average stem size, when the removal (m^3/ha) increases from 40 to 80 as the average stem size (dm^3) rises from 40 to 200. The number of timber assortments is five.

Productivity of thinning harvesters

Of the studied harvesters, the application area of Sampo 1046X is clearly thinnings, and Nokka Profi and Ässä 810 are also intended for clear cuttings with a smaller stem size. Table 6 presents the productivity of harvesters in different harvesting conditions. The data for Sampo 1046X in clear cuttings consist of only one stand.

Productivity of the different machine makes was compared with regression. The productivity levels of Nokka Profi and Ässä 810 did not differ from each other, but the productivity of Nokka Profi and Ässä 810 differed from that of Sampo 1046X. Regression models for the productivity of thinning harvesters are presented in Table 7.

Regression models for the productivity of Nokka and Ässä in clear cutting are given in Table 8. Figure 2 shows the productivity of thinning harvesters as a function of the average stem size of the stand and Figure 3 the harvesting costs with different makes of harvester in thinnings. The cost per operating hour used for Nokka Profi was 54.2 US$, for Sampo 1046X 47.6 US$, and 50.1 US$ for Ässä 810. The strong influence of the operator on productivity and costs should be kept in mind when comparing the machine costs.

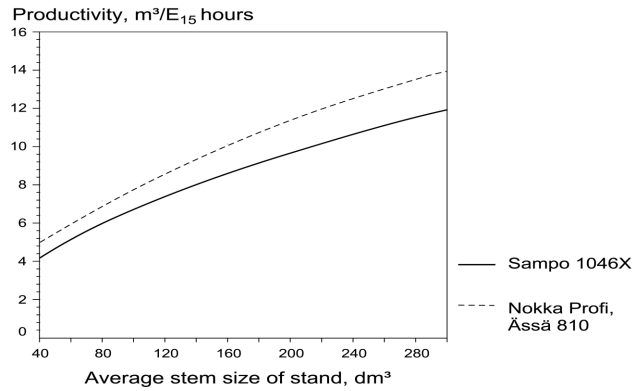

Figure 2. Productivity (m^3/E_{15} hours) of harvesters as a function of the average stem size of the stand in thinnings.

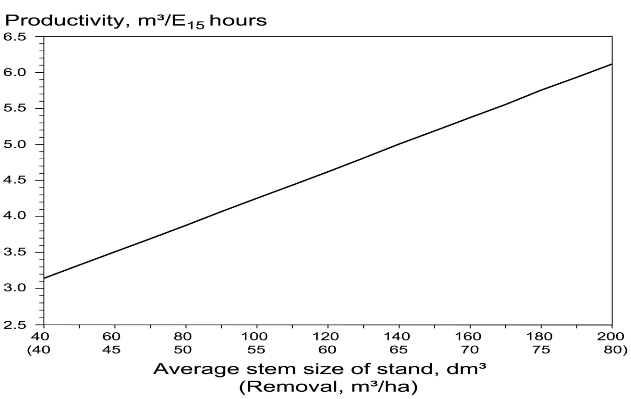

Figure 1. Productivity of harvester-forwarders in thinnings.

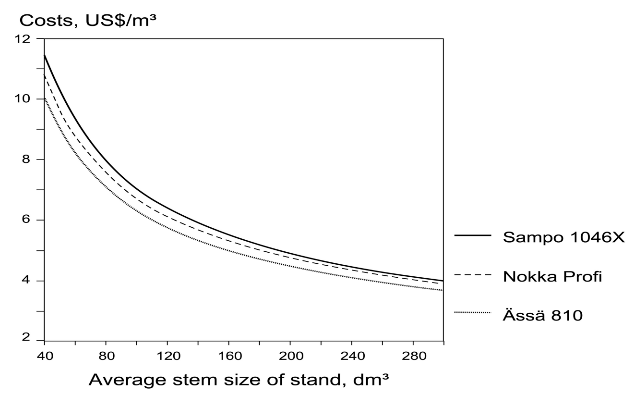

Figure 3. Costs (US$/$m^3$) of harvesters as a function of the average stem size of the stand in thinnings.

Table 6. Productivity (m^3/E_{15} hours) of thinning harvesters in different types of cutting. Average stem size (dm^3) is given in parentheses.

Machine	First thinning	Later thinning	Clear cutting	Regeneration cutting
		Productivity, m^3/E_{15} hours		
Nokka Profi	8.81 (131.1)	10.28 (129.5)	12.07 (168.4)	11.82 (362.5)
Sampo 1046X	6.26 (94.6)	7.76 (121.7)	12.97 (302.6)	7.08 (82.0)
Ässä 810	7.65 (112.0)	10.43 (177.5)	19.47 (465.3)	16.53 (380.8)
Total	6.92 (103.6)	9.20 (140.3)	16.18 (336.8)	14.02 (311.5)

Table 7. Regression models for the productivity of thinning harvesters. Base level Nokka Profi and Ässä 810.

$$y = a + bx + ck \qquad [2]$$

where
y = productivity, m^3/E_{15} hours
x = stem size, dm^3
k = dummy variable, = 1 if machine is Sampo 1046X, otherwise 0

a = constant
b and c = parameter estimates

	First thinning Parameter estimates	Std. error	t-value	Pr>[T]
a	4.046	0.075	53.713	<0.0001
b	0.0336	0.001	55.203	<0.0001
c	-0.976	0.032	-30.385	<0.0001
			N = 27	$R^2 = 0.603$
	Later thinning Parameter estimates	Std. error	t-value	Pr>[T]
a	6.864	0.044	154.734	<0.0001
b	0.0225	<0.0001	85.151	<0.0001
c	-1.836	0.027	-68.795	<0.0001
			N = 21	$R^2 = 0.765$

Table 8. Regression model for Nokka Profi and Ässä 810 in clear cutting.

$$y = a + bx \qquad [3]$$

where
y = productivity, m^3/E_{15} hours
x = stem size, dm^3

a = constant
b = parameter estimate

	Parameter estimate	Std. error	t-value	Pr>[T]
a	9.732	0.050	192.751	<0.0001
b	0.0194	<0.0001	155.016	<0.0001
			N = 17	$R^2 = 0.843$

Costs comparison of harvesting systems

Cost comparisons of the harvesting systems were made for thinnings with a forwarding distance of 250 metres and five timber assortments (Figure 4). Nokka Profi was the thinning harvester used in the comparisons. The calculated cost for a harvester-forwarder was 54.7 US$, for a medium-sized harvester 58.0 US$, and for a forwarder 45.1 US$ per operating hour.

The cost of harvesting was calculated as a function of the average stem size of the stand, which varied from 40 dm^3 to 200 dm^3. Removal, m^3/ha, varied within the same range from 40 to 80 m^3/ha. In the cost calculations removal affected productivity and costs of the forwarder and harvester-forwarder, but not costs of the harvester.

The thinning harvester system had lower costs than the medium-sized harvester system or harvester-forwarder. When the number of timber assortments was decreased from five to two, which is often the case in young pine stands, the order of the alternatives changed. In the case of two assortments, the thinning harvester system still had the lowest costs, but the harvester-forwarder had lower costs than the medium-sized harvester system when the average stem size remained below 100 dm^3.

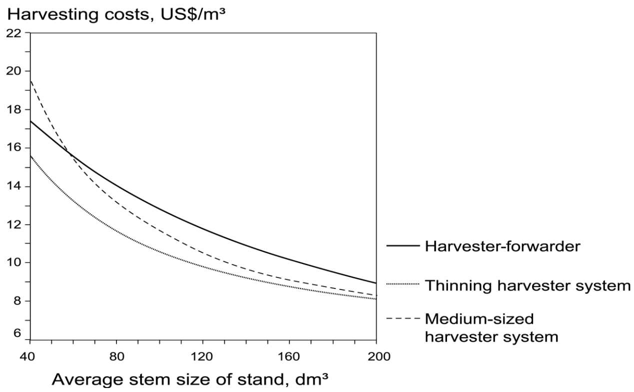

Figure 4. Harvesting costs of a harvester-forwarder and harvester systems including a harvester and a forwarder in thinnings. Cost information of the medium-sized harvesting system and forwarding were obtained from Metsäteho.

DISCUSSION

The study material was relatively large, with almost 12 000 m^3 for harvester-forwarders, and 17 000 m^3 for thinning harvesters. However, only three different machines of the same make of harvester-forwarder were involved. No other harvester-forwarders were available for the follow-up study in 1999-2000; since then, new machine makes and prototypes have come onto the market. Three makes of thinning harvester, with a total of five machines, were studied. The study material for the harvester-forwarders is concentrated in the snowless period, but material for the harvesters was collected also during wintertime.

The machine operator has a considerable influence on productivity [11, 15]. Thus, the differences in productivity between thinning harvesters can be caused by both machines and operators. Although the material had some restrictions, the results concerning factors affecting productivity were logical and the coefficients of determination mainly satisfactory.

For harvester-forwarders the average stem size of the stand, removal per hectare and number of timber assortments explained the productivity. The hauling distance also affects the productivity [12]. In this study, however, the productivity was calculated for hauling distance of 250 m in order to make the cost calculations of the harvesting systems comparable.

The productivity of the harvester-forwarders in this study was lower than that reported in time studies [9,12], even though the productivity obtained in the time studies was converted to correspond to the long-time productivity using a coefficient of 1.36. The differences in the productivity levels were not larger than 0.5 m^3/E_{15} hours. Furthermore, makes of harvester-forwarder other than Pika 828 were investigated in the time studies. A forwarder-based, harvester-forwarder and a prototype machine with a rotating cabin participated in the study. Pika 828 and the prototype machine a had higher productivity than the forwarder-based machine, especially in later thinnings [12].

The number of timber assortments clearly affected the productivity of the harvester-forwarder. The change from two assortments to five, which is the typical number in Finnish thinnings, lowers the productivity by 0.44 m^3/E_{15} hours. The harvester-forwarder head is a compromise, and sorting especially during unloading is not as effective as with the grapple of a forwarder [12]. The number of timber assortments was also found to affect productivity in recent Swedish studies on the harvester systems [3]. In harvester work, one extra assortment lowered the productivity by only 1%, but in forwarding one extra assortment increased the time consumption by almost 3 %.

Of the thinning harvesters, Sampo 1046X had a lower productivity than Nokka Profi and Ässä 810. The effect of the operator on this result is difficult to estimate. However, the result is logical, when price, properties and the application areas of these machines are taken into account. Sampo 1046X is a light machine designed solely for thinnings, Nokka Profi and Ässä 810 are slightly heavier and more expensive machines that are also capable of clear cuttings. When costs/m^3 in thinnings were compared, Prosilva Ässä 810 had the lowest costs due to its high productivity and low operating costs. However, cost differences between the machine makes were small and may have been caused by differences in operator skills.

The productivity of the thinning harvesters in this follow-up study was much lower than that reported in time studies carried out by the Work Efficiency Institute [13]. As the results of the time studies were converted to correspond to the long-time productivity by means of coefficients, the productivity levels should be similar to those of the follow-up study. Ässä 810 was not included in the time studies, but Sampo 1046X had a higher productivity than Nokka Profi [13]. This illustrates the large variation in machine productivity and the influence of human factors on the results. The differences between productivities obtained in the time and follow-up studies were significantly larger with harvesters than with harvester-forwarders.

There are some possible explanations for the differences between the results of the follow-up and time studies. When several machines participate in comparative time studies, all the work must be carried out under the same conditions. For this reason such studies are often carried out in high volume stands with minimum undergrowth in relatively easy terrain. A comparative study can also lead to competition between the makes of machine. High productivity can also be the result of poor quality in silviculture and in the size of the bundles. Time studies are often based on sample plots, while at actual work sites all the stand is harvested. This could explain the differences in productivity with the harvester-forwarder especially, because only a few remaining bolts in the stand can mean one extra trip, thus increasing time consumption but reducing productivity.

The harvester-forwarder, thinning harvester system and medium-sized harvester system were compared in a cost comparison. The cost figures for forwarding and a medium-sized harvester system were mainly obtained from Metsäteho. Cost comparisons were made in thinnings with average stem sizes ranging from 40 to 200 dm^3. The stem size was restricted to 200 dm^3, because all the study material for harvester-forwarders in thinnings was obtained in stands with a small average stem size. A change in the removal per hectare was also included, thus affecting the costs of forwarding and the harvester-forwarder.

The thinning-harvester system had the lowest costs with both two and five timber assortments. In the case of five assortments, the medium-sized harvester had lower costs than the harvester-forwarder at a stem size above 60 dm^3. At 200 dm^3 the difference in average stem size of the harvester systems was minimal. In the case of two assortments, the competitiveness of the harvester-forwarder was better, and its costs below a stem size of 100 dm^3 were lower, and between 100-200 dm^3 at the same level, as for the medium-sized harvester system. The thinning harvester system was still the cheapest alternative. In the costs comparison the costs of moving the timber were not included. However, the influence of moving the machine is rather reasonable, 0.22 US$/$m^3$ [12].

When the costs of a harvester-forwarder with a rotating cabin (Pika 828), a forwarder-based harvester-forwarder, and a medium-sized harvester system were compared in time studies, the forwarder-based harvester-forwarder was the cheapest alternative up to an average stem size of 75 dm^3. Above this size the Pika 828 and harvester harvesting system, which had similar costs, were clearly cheaper than the forwarder-based machine [12].

Thinning harvesters and harvester-forwarders are interesting alternatives for carrying out thinnings. In contrast, the high capacity of medium-sized harvesters cannot be fully exploited in thinnings. Thus machinery with lower capital costs and reasonable productivity can be competitive. The silvicultural result of thinning harvesters is also acceptable [14,18,19]. With thinning harvesters, cutting strip methods that require fewer forwarding strip roads can be used economically, and they are recommended in first thinning pine stands with a varying stem quality [19]. The advantage of the cutting strip method is the even distribution of the remaining trees [14,19]. However, the risk of tree damage is high with the cutting strip method, and it sets great demands on the machine operator [4,14,19]. In spruce stands, the risk of tree damage and poor visibility can restrict the use of the cutting strip method [19].

The study area also included some clear cuttings. Of the thinning harvesters studied, Nokka Profi and Ässä 810 can be used effectively in clear cuttings with a reasonable stem size. Sampo 1046X is clearly designed for thinnings. Pika 828 harvester-forwarder is technically well suited for clear cuttings. The harvester-forwarder is an overall machine for small-sized stands ranging from thinnings to clear cuttings. The same conclusion concerning the application areas of harvester-forwarders has also been drawn in time studies [12].

Harvester-forwarders are currently undergoing an intensive development process. Both the machines and working methods are being developed and studied. The harvester-forwarder is the most competitive in small stands with a short forwarding distance. Also the operator´s work is less monotonous than that of a pure harvester or forwarder operation. In thinning, however, the capacity balance of the harvester and forwarder is often poor. As the same machine takes care of cutting and forwarding, heavy snowfall does not cause the sort of severe problems encountered with the harvester system [12]. The low number of passes on sensitive soils can be one advantage of the harvester-forwarder. The number of passes and degree of rutting are highly correlated [17]. The total travel of a harvester system is 4.5- to 5.0-fold and with a harvester-forwarder 2.5- to 3.0-fold the total length of the strip roads [1].

With a harvester-forwarder, part of the work elements can be combined. However, in practical work this advantage is often incompletely utilized. Traffic intensity is a term developed in Sweden to include the base machine and crane movements [2]. Traffic intensity can be expressed in terms of metres/m^3 or metres/ha. In the Finnish thinning comparison the traffic intensity with a harvester-forwarder was 309 metres/m^3 and 15450 metres/ha, with a harvester system 326 metres/m^3 and 16300 metres/ha. The small differences showed that the capacity to combine work elements in the case of a harvester-forwarder was poorly used [19]. Harvester-forwarder work also sets great demands on the operator.

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