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EVALUATION OF FIVE PROCESSORS AND HARVESTERS

Robin Richardson, Eng.

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Ce Rapport technique est disponible en français.

Preface

The use of trade names throughout the text is simply to assist identification of the machines on the operations selected for the study. It does not constitute special approval or endorsement by the Forest Engineering Institute of Canada.

The reader should keep in mind that the results presented here are specific to the operations studied in regard to site conditions, machines, operators and pattern of work. Extrapolation of these results to other sites and conditions should be done with caution.

Details of the study procedures and analyses, plus results of limited interest, have been omitted from this report for the sake of reasonable brevity. Further details of the study will be supplied on request.

Acknowledgement

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Author

Robin Richardson is a graduate of the University of New Brunswick where she obtained her B.Sc. in Forest Engineering in 1983. She joined FERIC's eastern division Woodlot Technology group as a researcher in 1985 and transferred to the Wood Harvesting group in 1987. She is a registered engineer with L'Ordre des Ingénieurs du Québec.

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Summary

Currently, over 10 different models and over 40 individual multi-function machines are operating in eastern Canada mainly in shortwood or log-length systems. Evaluations of five different models of multi-function machines are presented in this report. The Steyr KP40 processing head and the Rottne Rapid 860 two-grip processor are capable of delimbing and bucking pre-felled stems to length. Harvesters, such as the Bruun 7610, the Rottne EGS-85 and the Timberjack FMG 990 studied, fell trees, delimb and buck to length.

Productivity: Essentially, these machines are single-stem, multi-function machines and therefore, have lower productivity than the multi-stem, single-function equipment generally used in tree-length or full-tree systems. Their productivity is highly variable depending on operating conditions. Perhaps the most influential factor on productivity, especially in harvester operations, is operator skill. Other factors which may affect the production rate are the number of merchantable stems per hectare, the number of unmerchantable stems per hectare, the volume per hectare, tree size, the bolt or log length accuracy requirements, slope, ground conditions, visibility reduction from undergrowth, and butt indexing requirements for subsequent forwarding.

For the processors, the Steyr KP40 averaged 76 trees/PMH producing shortwood at roadside and 84 trees/PMH producing tree lengths off-road, and the Rottne Rapid 860 two-grip averaged 101 trees/PMH producing shortwood off-road. The Steyr operator was considered inexperienced while the Rottne operator was proficient. A longer-term study of the Rottne processor showed a productivity of 68 trees/PMH and 82 trees/PMH in manually-cut and feller-bunched wood respectively.

The harvesters had a wide variation in their short-term productivity levels, reflective of wide variations in stand and operating conditions. The Bruun 7610H averaged 86 to 111 trees/PMH, the Rottne EGS-85 averaged 75 to 91 trees/PMH and the Timberjack FMG 990 averaged 74 to 77 trees/PMH. Sustainable production levels for such machines will probably not exceed 100 trees/PMH in eastern Canadian conditions.

Availability: This new generation of multi-function machines has far greater reliability than those used in the 1970s. However, they are complex machines. Many have a large number of moving parts, complex hydraulic circuitry, electric over hydraulic controls, and a computer to control the automatic or semi-automatic processing. Well-trained operators with a good understanding of the machine and skilled in trouble-shooting can increase the mechanical availability, as can an adequate parts supply and adherence to a preventive maintenance and servicing schedule.

Mechanical availabilities varied with operator, contractor and company level of commitment and organization. Availability ranged from 75% to 87%, while utilization ranged from 69% to 79%. A mechanical availability of 80%+ and a utilization of 75%+ should be attainable for new harvester and processor operations.

Repair Statistics: On two models of harvesters, the Rottne EGS-85 and the Timberjack FMG 990, repair statistics were tracked. Saw chains and hydraulic hoses proved to be the most frequently broken items accounting for approximately 40% of all repair occurrences. An additional 20% of repairs or replacements occurred on saw bars and other hydraulics.

Delimbing Quality: The two processors seemed to have better delimbing capabilities then the harvesters. However, all machines had trouble with double tops and over-size branches, especially when in clusters. The Bruun 7610H was the least effective in bushy trees with thick branches and probably should be restricted to trees under 0.3 m^3 to maintain delimbing quality as well adequate production.

Length Measuring Accuracy: Length measuring accuracy need be only as precise as required by the mill, transport, or handling phases. Where strict measurement tolerances are required, frequent recalibration of the measuring system may be required. The Steyr had an automatic measuring/slashing system which was very accurate; 98% of the samples were within 2 cm of the means. However, it had the slowest feed speed. The four other models had semi-automatic feeding/slashing systems. Their length measurement accuracy showed large variation but this depended mainly on company requirements and not on machine capabilities.

Processors and harvesters can work effectively under many eastern Canadian stand and terrain conditions. However, they are expensive to run and therefore they must be operated efficiently. A number of different system adaptations have been tried in an effort to maximize productivity, maximize wood value and minimize cost. This has involved integrating existing equipment such as skidders, forwarders and feller-bunchers; working off-road, at roadside or at landings; manually brushing small unmerchantable stems before harvesting; producing random-length pulpwood or fixed-length; and trying different sorting options.

1. Introduction

Tree-length and shortwood harvesters were common in eastern Canada in the 1970's but thereafter faded from favour. Now, a new generation has been developed in Europe, mainly in the Nordic countries. These have overcome many problems of the original designs and have better mechanical reliability. First introduced to eastern Canada in 1983, these machines have been gaining in popularity and are now found in all six eastern provinces. There are currently over 10 models and over 40 individual machines in operation in eastern Canada.

FERIC's first report on these new machines served as an introduction to European harvesters and processors, and provided a general description of their features and componentry [Richardson 1988]. Technical specifications of the machines discussed in this text are provided in that first report. The objective of this second report is to present an operational evaluation of five different machines at work in eastern Canada. The report consists of case studies of two processors, the Steyr KP40 one-grip and the Rottne Rapid 860 two-grip, and three one-grip harvesters, the Bruun 7610H, the Rottne EGS-85 and the Timberjack FMG 990. The report presents information on machine performance in the operating conditions encountered. Some long-term studies were conducted to provide information on mechanical availability, utilization and repairs.

2. Study Methods

In general, a case study approach was used describing the performance of each machine under its own specific operating conditions. Whenever possible however, the machines were studied in more than one site and/or application. The field studies took place in 1987 and 1988.

Both shift-level and short-term detailed studies were conducted. While the short-term studies were carried out by FERIC personnel, the long-term studies were conducted in conjunction with the cooperating companies, so that data collection methodology differed somewhat.

In the cases where utilization and availability were tracked, the machines were equipped with mechanical activity recorders. However, because of the low vibration levels of this type of machine, the recorders did not provide consistent information and not all shifts could be retained in the analysis. Foremen and operator's reports were used to supplement the activity charts. On two studies, the number and types of repairs were also documented through mechanics' reports and parts replacement lists.

The data collection procedures for the short-term studies were the same where possible. The stand conditions and productivity of the machines at work were measured in one or more microsites within the stands. General timing was carried out in all the studies to determine production rates over time, and a sample of bolts or trees produced were scaled. Results are presented with the 90% probability confidence interval.

Detailed timing of the work cycle was also conducted on every study. However, the time elements measured were not necessarily always the same for the various machines because of their different modes of operation.

All machines studied were subjected to a basic ergonomic evaluation, but since most conformed to ISO recommendations regarding cab size, cab access, seat and safety features, only the peculiarities of specific machines are presented.

The reader is again cautioned that the study results are specific to the machines, operators and operations studied, and should only be applied elsewhere with due discretion. Moreover, the short-term studies are based on limited observation encompassing few delays, and thus may not be representative of the long-term potential of the machines. As such, no cost figures have been provided in this report so as to preclude unfair comparison, especially given the diversity of operating conditions and operator experience encountered.

3. Processor Studies

Processors are machines which delimb and buck prefelled stems to length. Two off-road processors used in eastern Canadian logging operations were studied in 1987 and 1988. They were the Steyr KP40 one-grip and the Rottne Rapid 860 two-grip.

3.1 Steyr KP40 One-grip Processing Head

Machine Description

Made in Austria, the Steyr one-grip processing head was the only non-Nordic unit studied. It differs substantially from the others with its circular bucking saw, five-knife delimbing system, chain feed drive, direct length measuring system, and automatic slashing. The head, which has a feeding force of 25 kN and a weight of 810 kg, can be mounted on any carrier of 88 kW or more (Figure 1).

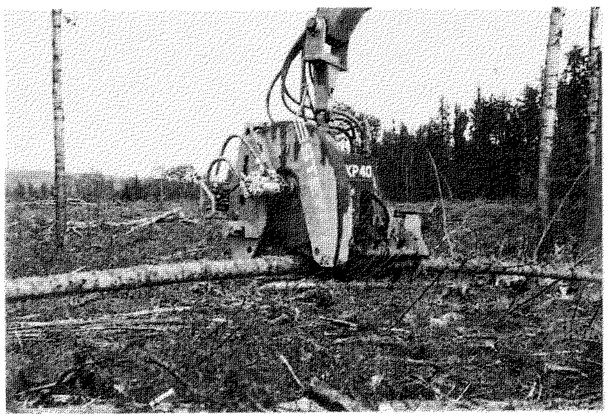

Figure 1. The Steyr KP40 processing head.

Study Location

In June 1987, FERIC studied the Steyr KP40 processing head mounted on a Mitsubishi M5180LC excavator. The unit was being demonstrated by Vulcan Equipment Ltd. on the limits of Canadian Pacific Forest Products Ltd. near Thunder Bay, Ont. The operator was a mechanic for the distributor and did not have the proficiency of an experienced full-time operator.

Two types of operations were studied during the demonstration. In the first, the processing unit produced tree lengths in the stand following a Case 1187 feller-buncher. The second was a shortwood-at-roadside operation where full-tree bunches had been skidded to within about 5 m from roadside. The processor worked at roadside and extracted the trees from the pile, delimbed and slashed them into 2.54 or 5.01-m lengths and then piled the bolts next to the road.

Stand Description

The study was conducted in a mature spruce-jack pine stand of highly variable tree size, and on flat, even terrain. The regeneration and the underbrush had been trampled down during the felling stage. Table 1 summarizes the site and stand variables.

Table 1. Site and stand factors in the Steyr KP40 study

Terrain*	1.2.1
Slope range (%)	0-5
Stand composition (%)	
- spruce	73
- jack pine	24
- aspen	3
Butt diameter (cm)	
- avg	20
- range	10-46
Merch. tree length (m)	
- avg	11.0
- range	6.0-18.5
Tree volume (m^3)	
- avg	0.24
- range	0.03-1.29

* Based on the CPPA terrain classification system (ground strength, roughness, slope) [Mellgren 1980] in this and subsequent similar tables.

Productivity

The productivities of the two operating scenarios are presented in Table 2. The machine averaged 84 trees per productive machine hour (PMH) when processing to tree length in the stand and 76 trees/PMH when producing shortwood at roadside.

Table 2. Steyr KP40 processor productivity summary

	Off-road tree-length processing	Roadside shortwood processing
Productive time measured (PMH)	4.1	2.6
Total merchantable trees	344	201
Average productivity*		
- trees/PMH ± conf. int.	84±19	76±13
- m^3/PMH ± conf. int.	20.0±4.6	18.0±3.1

* At a 90% confidence level in this and subsequent similar tables.

Table 3. Cycle times for the Steyr processor

Work element	Off-road tree-length processing [n = 282]		Roadside shortwood processing [n = 110]	
	Avg time (min)	% of total	Avg time (min)	% of total
Load	0.25	33	0.38	49
Process	0.28	37	0.32	41
Move slash*	-	-	0.03	4
Straighten pile*	0.04	5	0.02	3
Move machine*	0.13	18	0.01	1
Delays**	0.04	6	0.01	2
Total cycle time	0.74	100	0.78	100

* These time elements did not occur every cycle and are thus prorated.
** In this and subsequent similar tables, delays under .05 min are included in the time element in which they occurred while delays over 15 min are not considered productive time and are excluded from the sample.

In other published studies on the Steyr, production rates ranged from 113 to 162 trees/PMH and 74 to 90 m^3/PMH in a cut-to-length system on a landing in the large tree conditions of British Columbia [MacDonald, A.J. 1988]. In January 1989, a Steyr mounted on a Komatsu excavator was tried for a total of 17 PMH by Miramichi Pulp and Paper Inc. in New Brunswick. They reported a productivity of 94 trees/PMH while processing to shortwood in the stump area after a feller-buncher [Robichaud 1989].

For periods totaling 3.5 PMH in the tree-length study and 1.4 PMH in the shortwood study, the elemental times were recorded within each work cycle. The results are shown in Table 3. Loading time which includes the time to swing out, grapple a stem and position it before processing was substantially higher in the shortwood study because it proved more difficult and time consuming to pull a single stem from the large pile at roadside than to break out stems from the smaller bunches in the cutover. The moving element occurred mainly in the tree-length study since the machine had to travel 10 to 30 m between bunches.

Cycle time was found to be correlated to tree diameter (r^2 = 0.37) in the tree-length study. The correlation between volume per tree and productivity in m^3/PMH was even higher (r^2 = 0.90). This means that although larger trees take longer to process, the higher volume of wood that they contain results in productivity increases (m^3/PMH) up to a critical limit (Figure 2).

Another FERIC study conducted in British Columbia reported that a Steyr processed trees efficiently up to 0.75 m^3 (the maximum encountered) without suffering productivity reductions [MacDonald, A.J. 1988].

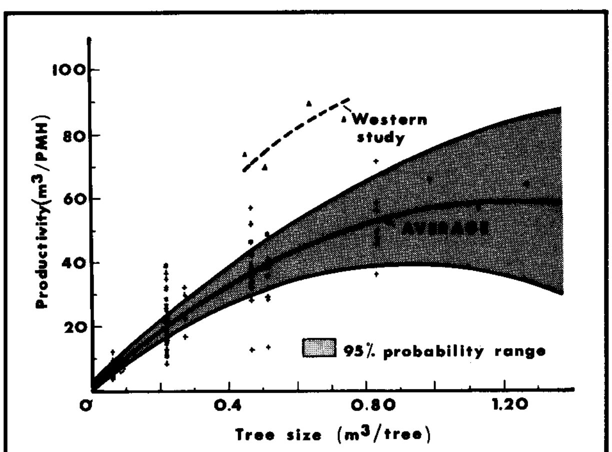

Figure 2. Steyr KP40 productivity (m^3/PMH) as influenced by tree volume.

NOTE: The shaded area in this and subsequent figures illustrates the *range* of predicted productivity (at the confidence level specified) as a function of the factor on the horizontal scale.

Delimbing Quality and Length Measuring Accuracy

In general, the Steyr delimbed large trees well. It had more than enough power for delimbing the spruce, though some of the large jack pine branches (>8 cm) occasionally proved difficult, especially if in clusters. These branches could be sawn or broken off with the head, but this was time consuming and reduced productivity considerably.

The Steyr's computer can be programmed for seven different length settings. In the demonstration, it was set for two: 5.01 and 2.54 m. The length measuring system is incorporated in the feed mechanism and was very accurate for both lengths. The standard deviation was 2 cm on the logs (n = 9) and 1 cm on the pulp bolts (n = 25). Ninety eight percent of the sample was within 5 cm of the means. The unit being demonstrated was equipped with a locally-bought limit switch which indicated when the minimum top diameter had been reached.

3.2 Rottne Rapid 860 Two-Grip Processor

Machine Description

The Swedish Rottne Rapid 860 is a two-grip processor which can also be converted to a harvester by replacing the loader grapple with a chain-saw felling head. The 72-kW carrier has 6 wheels, hydrostatic drive, bogies on the rear chassis, a comfortable, climate-controlled cab and dual driving controls (Figure 3). The processing unit swivels and consists of a length measuring wheel, three delimbing knives, a hydraulic chain saw and two large rubber feed wheels with chains. These wheels transfer a delimbing force of 48 kN.

Study Location

In August 1987, FERIC conducted a 3-day study of a Rottne Rapid processor working behind manually-felled trees. A longer-term shift-level study was also set up to compare the processor's productivity in feller-bunched wood versus manually-felled wood.

The unit was owned by Lee Johnston Harvesting Ltd. contracting for Miramichi Pulp and Paper Inc. near Newcastle, N.B. The machine was running two shifts a day, five days a week. Only the day shift operator was timed. The processor travelled at right angles to the pre-felled trees, and delimbed and slashed them into three different lengths according to their quality for veneer logs, saw logs or pulpwood bolts.

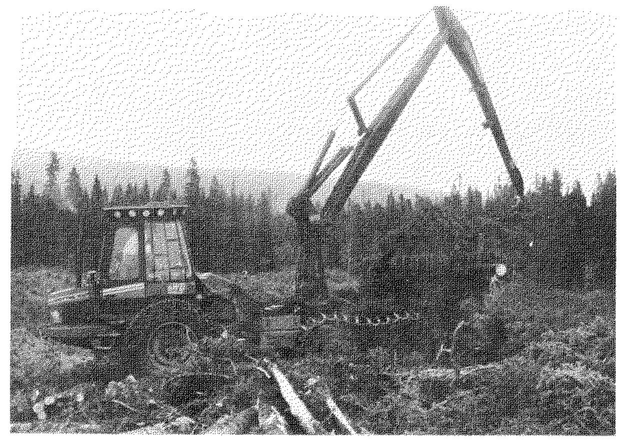

Figure 3. The Rottne Rapid 860 two-grip processor.

Stand Description

The stand was on flat, even terrain and consisted of mature spruce and fir that were damaged from repeated budworm attacks. All underbrush was cut prior to the processing phase. A complete description of the site and stand factors is supplied in Table 4.

Table 4. Site and stand factors in the Rottne Rapid two-grip study

Terrain	1.1.1
Slope range (%)	0-10
Stand composition (%)	
- black spruce	66
- balsam fir	34
Butt diameter (cm)	
- avg	18
- range	10-38
Merch. tree length (m)	
- avg	8.3
- range	2.5-20.3
Tree volume (m^3)	
- avg	0.16
- range	0.06-0.80
Trees/ha	1900

Productivity

During the 6.9 PMH of timing, the Rottne Rapid two-grip processed an average of 101 trees per PMH. Further details on the productivity measurements are provided in Table 5.

Table 5. Rottne Rapid processor productivity summary

Productive time measured (PMH)	6.9
Total merchantable trees	697
Average productivity	
- trees/PMH ± conf. int.	101±11
- m^3/PMH ± conf. int.	16.2±1.8

Detailed timing of the processor working in three separate plots provided elemental times for 121 cycles representing 1.3 PMH. These are summarized in Table 6. Loading including swing empty, swing with tree, and load bunk accounted for 56% of the cycle time (0.36 min), while processing represented 35%. No delays occurred during this short time period. In 16% of the cycles, two trees were processed together. This occurred mainly with smaller trees in the 10-16 cm diameter class.

Table 6. Cycle times for the Rottne Rapid processor

Element	Avg time (min)	% of total time
Swing empty	0.15	24
Swing with tree	0.14	21
Load bunk	0.07	11
Process	0.22	35
Straighten pile*	0.01	1
Move slash*	0.02	3
Move machine*	0.03	5
Total cycle time	0.64	100

* These time elements did not occur every cycle and are thus prorated.

Cycle time was correlated to diameter class ($r^2 = 0.31$). There was a better correlation ($r^2 = 0.85$) between productivity in m^3/PMH and tree size. Their relationship is illustrated in Figure 4.

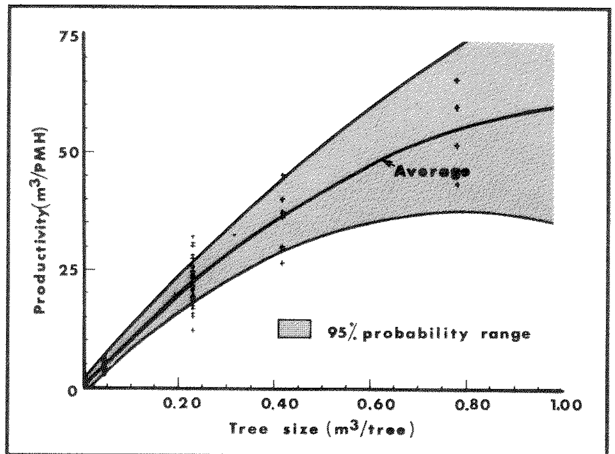

Figure 4. Rottne processor productivity (m^3/PMH) as influenced by tree volume

The largest stem processed during the study had a 38-cm diameter at the butt, well below the maximum delimbing diameter claimed by the manufacturer. Cycles where two trees were processed at once were about 20% longer than the norm for the same diameter class.

Delimbing Quality and Length Measuring Accuracy

Generally, the Rottne two-grip processor delimbed well. Neither the fir nor the spruce limbs caused much difficulty. The largest limb observed during the study had a 9.2-cm diameter and was severed after reversing once. Large diameter double tops caused some difficulties and reduction in productivity. Branches within 1.2 m of the butt are difficult to delimb because of the processing bunk configuration, but this was not a factor during the study because most of the lower boles were clear.

The length measuring/slashing system in the Rottne is semi-automatic (the feeding will stop automatically according to the operator's length selection, but the slashing saw will not engage automatically). The computer can be programmed for three different lengths, but actual lengths also depend on feed speed and braking distance. Often, if mill requirements are strict, the operator must jockey the stem back and forth until the appropriate length has been reached. Thus, length accuracy is a function of operator skill, as well as the calibration accuracy, species and stem form.

During the study, the pulpwood bolts averaged 2.55 m with a standard deviation of 4 cm (n = 62), the sawlogs averaged 5.03 m with a standard deviation of 6 cm (n = 14), and the veneer logs averaged 2.62 m with a standard deviation of 3 cm (n = 13). In the sample, 94% of the pulp bolts were within ±5 cm of the average.

Long-Term Performance

In conjunction with the contractor and Miramichi Pulp and Paper Inc., FERIC conducted a long-term shift-level study on the machine. The objectives were to determine long-term productivity, utilization and mechanical availability under two different operating scenarios.

For 10 weeks starting in July 1988, the processor was monitored working behind manual fallers. The machine was run two shifts per day, but only one operator was tracked. Performance was studied on two sites: Site 1 had steep slopes of up to 48%, rough ground conditions and small trees at 0.11 m^3/tree; site 2 was flatter with a maximum slope of 20%, ground conditions ranged from fair to soft and tree size averaged 0.14 m^3/tree. Both sites contained a mixture of spruce and hardwood.

Table 7. Long-term productivity of the Rottne processor

	Manually-felled trees		Feller-bunched trees	
	Site 1	Site 2	Same operator	Avg of all operators
No. of shifts	27	17	15	45
Average tree size	0.11	0.14	0.16	0.16
Trees/PMH	68	67	82	73
m^3/PMH	7.4	9.0	13.1	11.7
Utilization (%)*	78	80	73	74
Mechanical availability (%)*	83	84	77	79

* Machine time formulas in this and subsequent tables based on Folkema et al. (1981).

In January and February 1989, the machine's performance was monitored while operating in feller-bunched wood again producing shortwood in the cutover. Five different operators were studied during the day shift, with several of these being trainees. For three weeks, the same operator as during the summer study was tracked to provide a direct comparison to working in the manually-felled wood. The site was flat and the ground was frozen with 30 to 45 cm of snow. The stand was composed of spruce and fir averaging 0.16 m^3/tree. Table 7 shows the long-term results in these two studies.

A direct comparison of the same operator working after manual fallers and after feller-bunchers showed a 20% increase in the processor productivity (from 68 to 82 trees/PMH) when working after a feller-buncher.

The company's rigid adherence to a preventive maintenance program resulted in little downtime related to repairs (7% of SMH). A description of the shift-level time distribution is illustrated in Figure 5. Fuel consumption averaged 10 L/PMH.

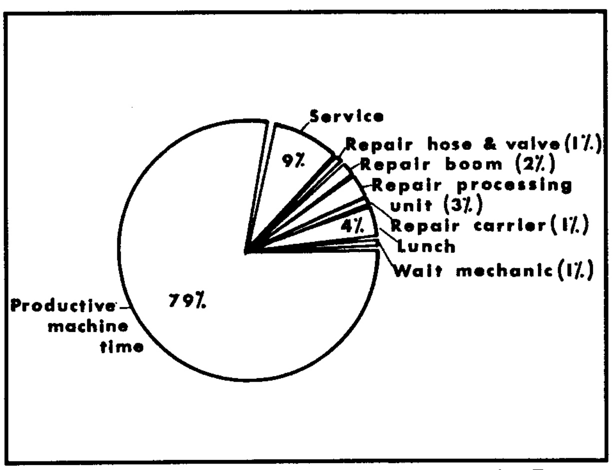

Figure 5. Shift-level time distribution for the Rottne processor.

4. Harvester Studies

Harvesters fell, delimb and slash trees to length. Three one-grip harvesters are covered in this report: the Bruun 7610H, the Rottne EGS-85 and the Timberjack FMG 990.

4.1 Bruun 7610H Harvester

Machine Description

Manufactured in Sweden, the Bruun 7610H single-grip harvester consists of a Ford carrier with a 72-kW Ford engine, six wheel drive with bogies on the rear section, mechanical transmission, a climate-controlled cab with swivel seat, dual driving controls and a short 5.1-m boom (Figure 6). The processing head has two spiked, metal feed rollers which provide a feeding force of 25 kN, four delimbing knives, a measuring roller mounted on a pivoting arm and a hydraulic circular saw.

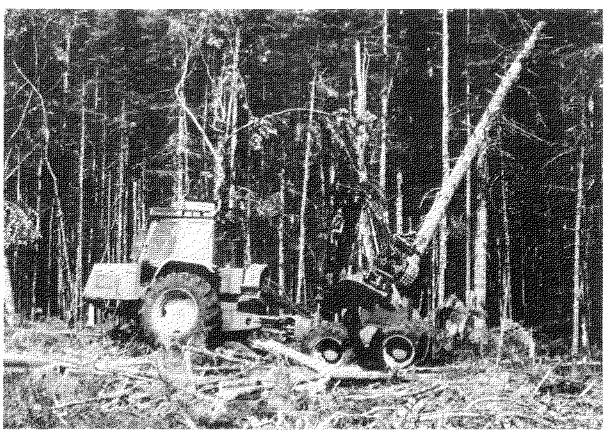

Figure 6. The Bruun 7610H one-grip harvester.

Study Location

FERIC conducted one longer-term and two short-term studies on the Bruun harvester. The first short-term study was conducted for three days in July 1987. A second, substantially-modified machine was followed for another three days in July 1988. The studies were conducted on the operations of Thomas F. Hayne Contracting Ltd. working for Stora Forest Industries Limited of Port Hawkesbury, Nova Scotia. Both short-term evaluations took place near Sherbrooke, N.S. and the same operator was working both years. The operator had only been operating the machine for a few weeks prior to the first study, compared to over a year before the second.

Stand Description

The first study was conducted in high-density stands of small spruce and fir, with numerous unmerchantable stems. The ground was flat, even and had good bearing capacity. In the second study, the machine worked in two different locations; both were on flat, fairly-even terrain with good bearing capacity. The stands were dense and stagnant. The overall site and stand conditions of the three areas are presented in Table 8.

Table 8. Site and stand factors in the Bruun short-term studies

	Study I (1987)	Study IIa (1988)	Study IIb (1988)
Terrain	1.1.1	1.2.1	1.1.1
Slope range (%)	0-15	0-10	0-9
Stand composition (%)			
- spruce	70	0	54
- fir	29	89	37
- birch	1	3	0
- maple	0	8	9
Underbrush	medium	medium	medium
Diameter (cm)	butt	dbh	dbh
- avg	14.5	14.1	15.5
- range	10-32	10-34	10-36
Merch. tree length (m)			
- avg	5.9	5.4	4.8
- range	2.4-16.9	2.4-9.7	2.4-12.1
Tree volume (m^3)			
- avg	0.09	0.08	0.09
- range	0.03-0.60	0.03-0.63	0.03-0.97
Vol/ha (m^3/ha)	280	250	180
Avg merch. trees/ha	3200	3300	2000
Avg unmerch. trees/ha*	3000	1200	2100

* Includes all unmerchantable species, and softwoods between 4 and 10 cm dbh.

Productivity

The productivities measured in the short-term studies are presented in Table 9.

Table 9. Bruun harvester productivity summary

	Study I (1987)	Study IIa (1988)	Study IIb (1988)
Productive time measured (PMH)	6.8	6.6	2.3
Total merchantable trees	752	696	196
Average productivity			
- trees/PMH ± conf.int.	111±15	111±10	84±13
- m^3/PMH ± conf.int.	9.7±1.3	8.3±0.7	7.4±1.1

A separate study [MacDonald, C.R. 1988] based on point sampling of a total of 24 plots at 25 trees per plot, conducted with the same operator and on the 1987 model machine, measured a productivity of 95 trees/PMH in black spruce stands and 104 trees/PMH in fir stands.

Detailed timing was conducted on two large plots (400 m^2 and 500 m^2) in the 1987 study, and five plots of 200 m^2 in each site during the 1988 study. The average element times per cycle are presented in Table 10. Swinging to a tree, cutting it and processing it accounted for almost three quarters of the machine's productive time. Of the other elements, cutting unmerchantables accounted for between 14% and 28% of the time.

Table 10. Cycle times for the Bruun harvester

Element	Study I (n=241)		Study IIa (n=225)		Study IIb (n=174)	
	avg time (min)	% of total time	avg time (min)	% of total time	avg time (min)	% of total time
Swing empty & cut	0.12	22	0.12	26	0.16	23
Process	0.29	54	0.22	44	0.32	44
Brush*	0.08	14	0.12	24	0.20	28
Move machine*	0.03	5	0.02	4	0.02	3
Delays*	0.02	5	0.01	2	0.01	2
Total time	0.54	100	0.49	100	0.71	100

* These time elements did not occur every cycle and are thus prorated.

Volume per hectare had a greater influence on productivity (m^3/PMH) than any other factor including average tree volume (Figure 7). The number of trees harvested per hour was influenced mainly by the number of merchantable stems per hectare (Figure 8). No other factors measured proved significant, though the company has found that high ratios of unmerchantable to merchantable stems could be a negative factor which kept production lower than original expectations.

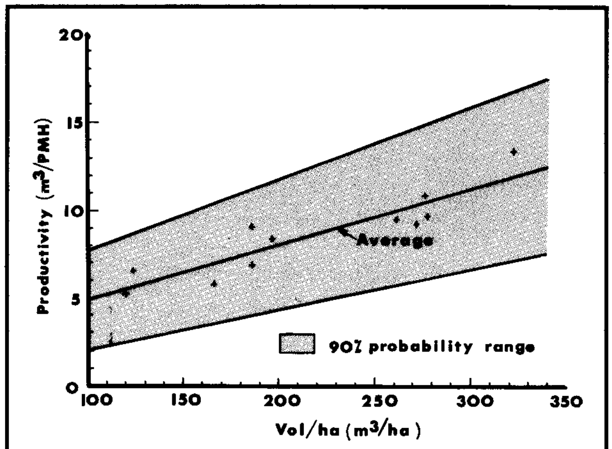

Figure 7. Bruun harvester productivity (m^3/PMH) as influenced by stand volume per area.

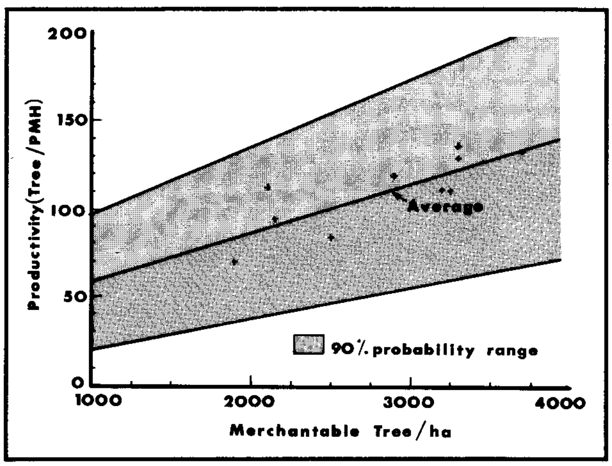

Figure 8. Bruun harvester productivity (trees/PMH) as influenced by stand density.

The largest stem processed during the studies had a dbh of 36 cm. However, the Bruun had difficulty with the larger stems (30 cm +) mainly because it did not have enough feed power to sever big limbs easily. The detailed timing data show that productivity (m^3/PMH) starts decreasing at about 0.3 m^3/tree or at approximately 24 to 26 cm dbh (Figure 9). The company is now limiting the Bruun to trees smaller than 26 cm, with larger stems left for manual cleanup.

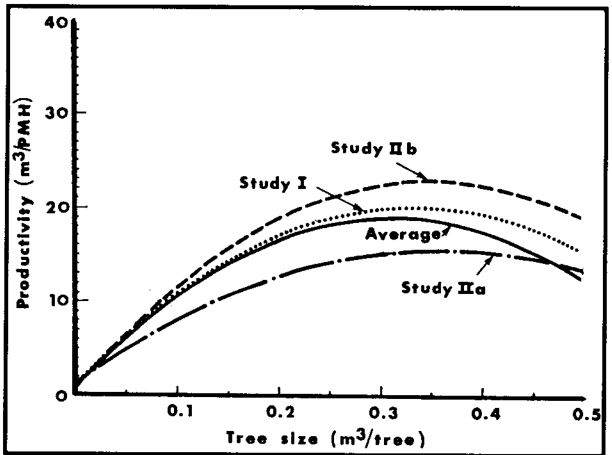

Figure 9. Bruun harvester productivity (m^3/PMH) as influenced by tree volume.

Delimbing Quality and Length Measuring Accuracy

The Bruun can easily delimb most small trees but large diameter limbs or groups of medium-sized limbs on larger trees cause slippage in the feed rollers and productivity losses.

The semi-automatic length measuring/slashing system relies on a roller measuring device mounted with a pulse generator on a pivoting arm. Although the Bruun can be programmed for three different lengths, only one was used because of the small tree size. In the first study, pulpwood bolts averaged 2.42 m with a standard deviation of 4 cm (n = 72) and 96% were within ±5 cm of the average. The slashing was less accurate in the second and third studies; pulpwood bolts had an average length of 2.42 m but the standard deviation was 6 cm (n = 99) and only 87% were within ±5 cm of the average.

Long-Term Performance

Mechanical activity recorders had been placed in two Bruun Harvesters by the company and the operators filled out daily report forms on production. Partial information was provided to FERIC from September 1988 to January 1989 and the results are shown in Table 11. Not every shift was retained in the compilation because of missing data, and no stand information was available. As such, these data should be considered as indicators only.

Table 11. Long-term productivity of the Bruun harvester

	Machine 1		Machine 2
	Sept. '88 to Oct. '88	Nov. '88 to Jan. '89	Nov. '88 to Jan. '89
No. of shifts	11	27	41
Trees/PMH	58	-	-
m^3/PMH	-	4.8	3.8
Utilization (%)	75	67	60
Mechanical availability (%)	85	75	75
Fuel consumption (L/PMH)	9.6	7.7	9.1

The distribution of scheduled machine time elements for the more skilled operator (Machine 1) from September to January is shown in Figure 10. Normally, one half hour per shift was scheduled for servicing.

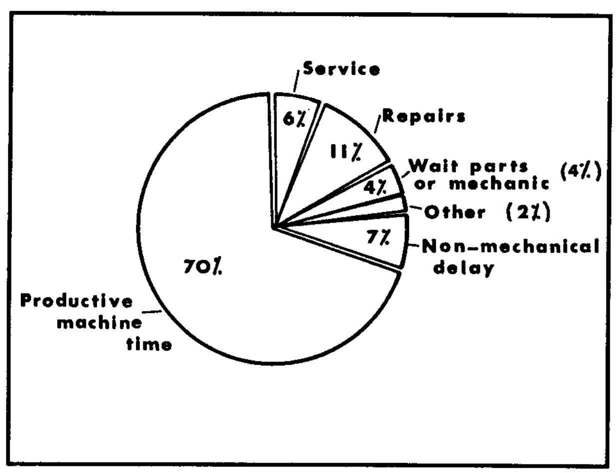

Figure 10. Shift-level time distribution for the Bruun harvester (Machine 1).

4.2 Rottne EGS-85 One-Grip Harvester

Machine Description

The carrier, boom and cab are the same as on the Rottne two-grip model as described earlier. The large boom mast partially blocks the forward view making it difficult to fell trees directly in front of the machine. The 600-kg EGS-85 harvesting head has two rubber-tired feed wheels with chains that provide a feed force of 20 kN. The head features four delimbing knives, a hydraulic chain saw and a measuring wheel located between the two rollers (Figure 11).

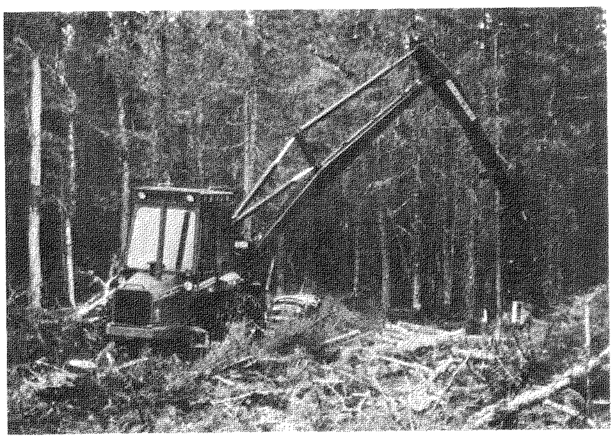

Figure 11. The Rottne EGS-85 one-grip harvester.

Study Location

Two short-term and two long-term studies were carried out on Rottne EGS one-grip harvesters. The first short-term study was conducted in July 1987 near Sherbrooke, N.S. on an older model. Both tree-length and shortwood production were measured. The machine was owned by Mac Forestries Ltd., a contractor for Stora Forest Industries. A longer-term study was carried out for six weeks in September and October 1987 on this machine.

The second short-term study was conducted on three new machines in central Newfoundland in October 1988. The machines were owned and operated by Abitibi-Price Inc. and were producing pulpwood only. Longer-term repair data were collected by Abitibi-Price on all their Rottne harvesters. FERIC obtained this information for a three-month period starting in June 1988.

The operator in the Nova Scotia operation had only 6 weeks experience prior to the study, while the Newfoundland operators varied in experience from 6 weeks to 6 months.

Stand Description

A description of site and stand conditions during both short-term studies is given in Table 12. The stands in Nova Scotia were very variable in terms of tree size, slope, ground bearing capacity and underbrush. The main species were spruce and fir with occasional white pine. The dense stands in Newfoundland were more homogeneous, but less favourable with a high unmerchantable content. These fir stands had been attacked by a looper infestation several years earlier which resulted in almost 100% mortality.

Table 12. Site and stand factors in the Rottne EGS one-grip harvester studies

	Nova Scotia	Newfoundland
Terrain	2.2.2	2.2.2
Slope range (%)	0-28	0-24
Underbrush	very dense	very light
Stand composition (%)		
- spruce	47	1
- fir	47	96
- white pine	6	0
- birch	0	3
Diameter (cm)	butt	dbh
- avg	16.0	14.4
- range	10-44	10-40
Merch. tree length (m)		
- avg	7.5	7.6
- range	2.4-14.5	2.5-17.7
Tree volume (m^3)		
- avg	0.11	0.10
- range	0.03-1.15	0.03-0.95
Vol/ha (m^3/ha)	170	270
Avg merch. trees/ha	1600	2700
Avg unmerch. trees/ha	600	2700

Productivity

Overall productivity measurements during the short-term studies are given in Table 13. In Nova Scotia, the productivity (trees/PMH) was the same producing shortwood versus tree length. The productivity of the machines in Newfoundland was lower than in Nova Scotia averaging 75 trees/PMH versus 86 trees/PMH, mainly because more brushing was required in these stands.

Table 13. Rottne EGS harvester productivity summary

	Nova Scotia Tree length	Nova Scotia Shortwood	Newfoundland Shortwood
Productive time measured (PMH)	7.7	3.6	14.9
Total merchantable trees	701	307	1117
Avg productivity			
- trees/PMH ± conf. int.	91±11	86±31	75±6
- m^3/PMH ± conf. int.	10.2±1.2	9.6±3.5	7.5±0.6

Some detailed timing was conducted during all the studies and the results are presented in Table 14.

Table 14. Cycle times for the Rottne EGS harvester

Element	N.S. tree-length (n = 112) avg time (min)	N.S. tree-length (n = 112) % of total time	N.S. shortwood (n = 118) avg time (min)	N.S. shortwood (n = 118) % of total time	Nfld shortwood (n = 203) avg time (min)	Nfld shortwood (n = 203) % of total time
Swing empty, cut & drop	0.32	57	0.31	52	0.31	39
Process	0.11	19	0.24	38	0.27	34
Brush*	0.01	2	0	0	0.10	12
Move machine*	0.04	8	0.05	8	0.05	6
Delays*	0.08	14	0	2	0.07	9
Total	0.56	100	0.60	100	0.80	100
Trees/cycle	1.0		1.0		1.03	

* These time elements did not occur every cycle and are thus prorated.

The major differences between the Nova Scotia and Newfoundland data were in the brushing element. In Newfoundland, the high number of unmerchantable trees required frequent brushing. Also, operators on these machines had been instructed to remove small stems to reduce the risk of hose damage.

Productivity was correlated to tree size in the studies as illustrated in Figure 12. The largest stem harvested in tree-length form during the studies was 26 cm dbh. In the shortwood studies, trees up to 36 cm dbh were processed although some delays occurred because of the larger limbs.

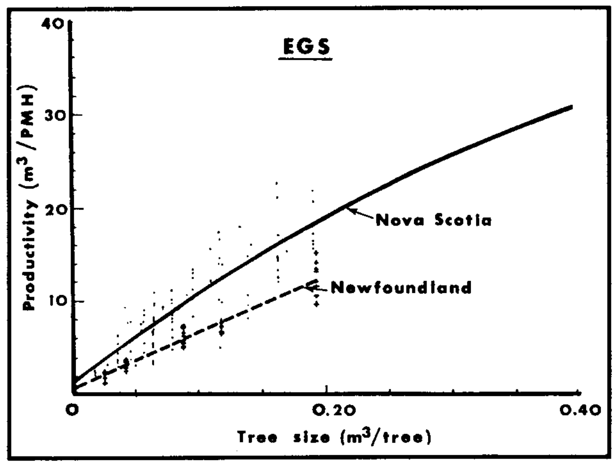

Figure 12. Rottne EGS harvester productivity (m^3/PMH) as influenced by tree volume (shortwood).

Delimbing Quality and Length Measuring Accuracy

The small spruce and fir were easily delimbed but the large limbs on large stems caused problems. Such limbs sometimes were severed only after many tries and by opening the knives slightly, which left branch stubs.

The measuring wheel is not fixed but floats, so that minor sweeps and crooks in the stem do not necessarily cause inaccuracies. Bark peeling off the trees occasionally jammed the wheels in summer. The machine working in Nova Scotia produced bolts averaging 2.43 m with a standard deviation of 5 cm (n = 50). The bolts were within ±5 cm of the mean 69% of the time. There was a wider variation of the bolt lengths produced by the harvesters in Newfoundland. The most accurate machine averaged 2.55 m with a standard deviation of 6 cm, with 82% within ±5 cm of the 2.54-m target (n = 50). In the worst case, bolt lengths averaged 2.62 m and the standard deviation was 26 cm. Only 42%

of the bolts were within ±5 cm of 2.54 m. *However*, Abitibi-Price were not very stringent in their length requirements as long as the bolts exceeded 2.44 m.

Long-Term Performance

A mechanical activity recorder was mounted in the Nova Scotia machine but did not work well. Therefore, it became necessary to rely on forms filled out by the operator or the foreman which were often incomplete. Out of six weeks of data collection, only 11 days could be retained for analysis. Table 15 presents the production results from those shifts. Fuel consumption averaged 11.0 L/PMH.

Table 15. Long-term productivity of the Rottne EGS harvester (Nova Scotia)

No. of shifts	11
Trees/PMH	63
Utilization (%)	72
Mechanical availability (%)	76

The distribution of scheduled machine time during this period for the Rottne EGS harvester is shown in Figure 13. Servicing and maintenance were carried out sporadically and constituted only 4% of total scheduled time. Consequently, a high amount of time (19%) was spent on repairs.

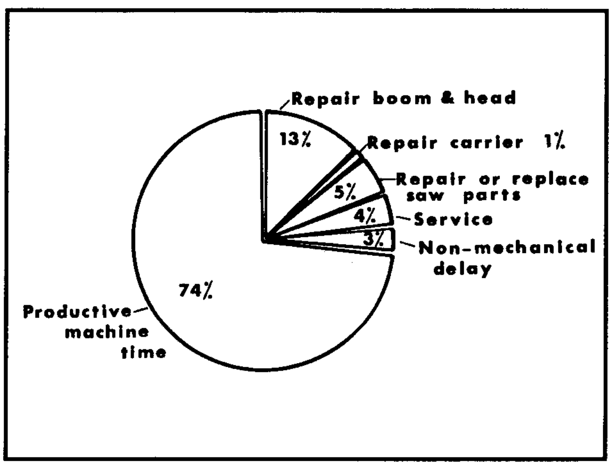

Figure 13. Shift-level time distribution for the Rottne EGS harvester.

Abitibi-Price in Newfoundland have been collecting repair information on their five Rottne EGS harvesters since June 1988. Data were provided to FERIC covering a period totalling 746 PMH of day shift and 737 PMH of night shift, between June to September, 1988. There were 223 items repaired or replaced during the day shift and 271 during the night shift for an average of one repair occurrence for every 3.3 PMH on day shift and every 2.7 PMH on night shift (Table 16).

Eighty-four percent of the repairs were on the harvesting heads. Saw bars and chains were the most frequently repaired items accounting for 38% of all occurrences with an average occurrence rate of once every 8.1 PMH. Hydraulic items accounted for 22% of repair occurrences at an average of one repair or replacement every 13.7 PMH.

Generally, there was no significant difference between day shift and night shift in terms of the type and number of repairs except for lights. Also, saw bars and chains were broken or damaged more often at night, possibly because of poorer visibility. It should be noted however that this analysis pinpoints the time of repair and not necessarily the time of failure, and thus may be misleading.

Table 16. Frequency of repair occurrences on the Rottne EGS harvesters in Newfoundland

	Day frequency	Night frequency	Total frequency	% of total
Saw chains	64	77	141	29
Hydraulic hoses	31	35	66	13
Saw bars	18	25	43	9
Other hydraulics	27	15	42	9
Valve bank	17	19	36	7
Lights	3	27	30	6
Feed roller	13	15	28	5
Measuring wheel	8	6	14	3
Electrical	6	4	10	2
Air conditioning	5	3	8	2
Boom & extension	7	4	11	2
Bolts	2	10	12	2
Welding	6	2	8	2
Joystick control	4	6	10	2
Other saw items	2	2	4	1
Other	10	21	31	6

4.3 Timberjack FMG 990 One-Grip Harvester

Machine Description

The Timberjack FMG 990 one-grip harvester is a recent import from Finland into Canada. There is a four-wheeled model and a six-wheeled model available but all the machines in Canada so far have been six-wheel-drive machines.

The machines used in the study had telescopic stick booms for a maximum reach of 10 m, and the 950-kg FMG 762 harvester head (Figure 14). This head features two rubber feed wheels with chains (feed force of up to 24 kN), a hydraulic chain saw, five delimbing knives and a length measuring wheel. Unlike other machines, the Timberjack FMG 990 is driven and operated in the same direction. Therefore, the seat does not swivel and the driving controls are not duplicated.

The cab is adequate in size and the front window slopes back to allow the operator an upward view. An additional skylight affords a view of the tree crowns. The boom mast is placed close to the cab and directly in front of the operator which causes a blind zone. Operators can work on either side of the machine or articulate the machine slightly to see around the boom.

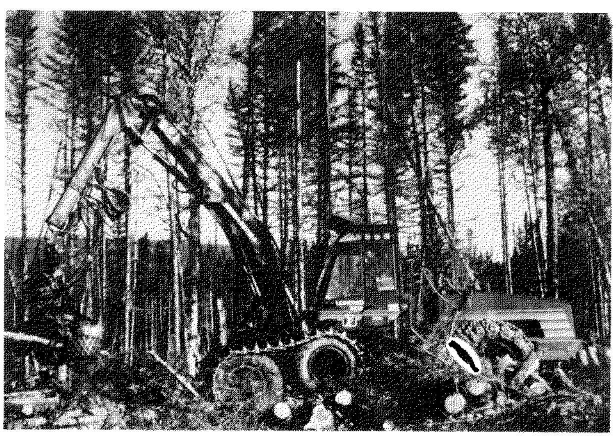

Figure 14. The Timberjack FMG 990 one-grip harvester.

Study Location

A detailed time study was conducted by FERIC in October 1988 on two Timberjack FMG 990 harvesters working in central Newfoundland for Abitibi-Price. At that time, the machines were producing shortwood bolts during two shifts per day, seven days per week. Only day shift operations were studied. Two of the operators timed were rated as good, while the other two were still at the low end of their learning curve. Also, Abitibi-Price provided repair data on three machines for FERIC to determine the nature and frequency of parts replacement.

Stand Description

Table 17 describes the site and stand conditions encountered during these studies. The stands were mainly fir and were very patchy, with a high unmerchantable content. The machines occasionally recovered wood (<60 m^3/ha) left behind by previous cut and skid operations. The ground was swampy with poor bearing capacity; machines broke through after one or two passes.

Table 17. Site and stand factors in the Timberjack FMG 990 study

Terrain	4.2.1
Slope range (%)	0-15
Underbrush	medium
Stand composition (%)	
- fir	89
- spruce	8
- hardwood	3
Diameter dbh (cm)	
- avg	13.5
- range	10-32
Merch. tree length (m)	
- avg	5.8
- range	2.5-12.7
Tree volume (m^3)	
- avg	0.07
- range	0.03-0.48
Vol/ha (m^3/ha)	160 (60 m^3/ha in low volume areas)
Average merch. trees/ha	2200
Average unmerch. trees/ha	2300

Productivity

The overall productivity of the machines is given in Table 18. Over 18.8 PMH, the Timberjack FMG 990 harvesters felled and processed an average of 74 trees/PMH. It should be noted that since the study was done, shifting regime and personnel changes have led to improved machine productivity.

Table 18. Timberjack FMG 990 harvester productivity summary

	Including harvest of low-volume recovery areas	Excluding harvest of low-volume recovery areas
Productive time measured (PMH)	18.9	17.2
Total merchantable trees	1371	1299
Avg productivity		
- trees/PMH ± conf. int.	74±6	77±5
- m^3/PMH ± conf. int.	5.3±0.4	5.9±0.4

Elemental times were recorded for individual processing cycles in five 200-m^2 plots over a total of 3.6 PMH. These results are shown in Table 19. The number of trees processed per cycle averaged 1.04 during this time.

Table 19. Cycle times for the Timberjack FMG 990 harvester

Element	Avg time (min)	% of total time
Swing empty	0.24	28
Cut and drop	0.13	14
Process	0.15	18
Brush*	0.14	16
Move machine*	0.06	8
Delays*	0.14	16
Total cycle time	0.86	100

* These time elements did not occur every cycle and are thus prorated.

The largest tree harvested during the study was 32 cm dbh, well below the manufacturers recommended maximum of 50 cm. Figure 15 illustrates the relationship between productivity and average tree size in the study conditions.

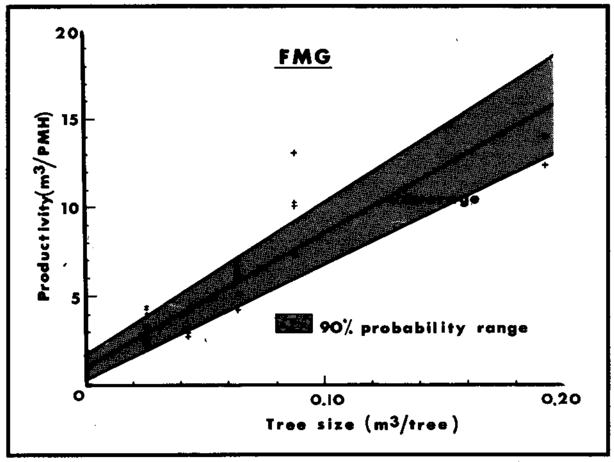

Figure 15. Timberjack FMG 990 harvester productivity (m^3/PMH) as influenced by tree volume.

Delimbing Quality and Length Measuring Accuracy

The small spruce and fir harvested in the study did not challenge the Timberjack FMG 990's delimbing capabilities. Only a low percentage of the trees (6%) had to be reversed and run through the knives a second time. The delimbing quality was generally excellent.

The operators can jockey the stems back and forth until the right length has been reached before slashing. The Timberjack FMG 990 has higher feed speeds than some of the other models studied, and it may be difficult to maintain both high productivity and high accuracy. However, it should be noted that precise length measurement was not a priority on this operation because of tolerant mill standards, and thus there was no tight quality control of either the machines or operators.

The lengths of bolts produced by the three machines and operators varied substantially. The bolts processed by one machine during the night shift averaged 2.44 m but had the widest spread in bolt size with a standard deviation of 42 cm (n=50). In this sample, 44% were within ±5 cm of the average. The other two machines during day shift produced bolts averaging 2.50 m and 2.56 m, both with standard deviations of 8 cm (n=43 and n=50), and within ±5 cm of the average 67% and 68% of the time.

Stems with sweeps or crooks are not easy to measure accurately because the measuring wheel only has a small amount of lateral displacement and easily loses contact with the stems. Other inaccuracies occurred when the stem was held too loosely and fell out of contact with the wheel.

Long-Term Reliability

Since the machines started up in June 1988, Abitibi-Price have been monitoring the repairs and the frequency of parts replacement. Data collected for three months from the end of June until mid-September 1988 covering 1675 PMH during day shift and 1908 PMH during night shift are shown in Table 20. There were 272 items repaired or replaced during the day shifts and 224 for the night shifts, representing an average of one repair item for every 6.2 PMH during day shift and one repair item every 8.5 PMH during night shift. Seventy-six percent of the repairs were on the harvesting heads. Hydraulic hoses, pumps and other hydraulic items accounted for the highest number of repairs and/or parts replacement. Saw bars and chains were also replaced frequently.

Table 20. Frequency of repair occurrences on the Timberjack FMG 990 harvesters in Newfoundland

	Day frequency	Night frequency	Total frequency	% of total
Hydraulic hoses	60	54	114	23
Saw chains	41	36	77	16
Other hydraulics	36	29	65	13
Saw bars	23	21	44	9
Feed roller	20	22	42	8
Electrical	23	13	36	7
Other saw items	13	6	19	4
Computer	11	5	16	3
Measuring wheel	9	6	15	3
Air conditioning	4	2	6	1
Other	32	30	62	13
Total	272	224	496	100

5. Discussion

5.1 Productivity

Processors and harvesters are essentially single-stem multi-function machines and as such are more limited in the number of trees they can handle per hour than multiple-stem machines.

The processors studied had average productivities of 76 and 84 trees/PMH for the Steyr KP40 and 101 trees/PMH for the Rottne two-grip. With equal operator skill and in small timber, the productivity of the two machines would likely have been comparable at between 90 and 95 trees/PMH. The long-term study of the Rottne processor showed a sustainable production level of 68 trees/PMH in manually-cut wood and 82 trees/PMH in feller-bunched wood.

The harvesters had more variation in their short-term productivity levels reflective of wide variations in stand conditions. The Bruun 7610H averaged 84 to 111 trees/PMH, the Rottne EGS averaged 75 to 91 trees/PMH, and the Timberjack FMG 990 averaged 74 to 77 trees/PMH. Sustainable production levels of such machines will probably not exceed 100 trees/PMH in eastern Canadian conditions.

Tree size has a large influence on the productivity in terms of m^3/PMH. During the short-term studies, the processors averaged between 16 and 20 m^3/PMH. The harvesters had productivities ranging from 5.9 to 10.6 m^3/PMH. In most cases, the tree diameters were small and critical sizes could not be determined. The Bruun was found to reach its maximum productivity at about 0.3 m^3/tree or 24 to 26 cm dbh. The Rottne EGS and the Timberjack FMG 990 are expected to work better in trees larger than the ones encountered during the studies.

The production rate of harvesters, and to a lesser extent processors, is strongly related to operator skill and motivation. Other factors which may affect productivity include the number of merchantable stems per hectare, the number of unmerchantable stems per hectare, the volume per hectare, the slope, ground conditions and undergrowth density. The requirements for good indexing of the piles to improve forwarder productivity will also influence production rates.

With harvesters, productivity is affected by the number of small unmerchantable stems per hectare, and by the ratio of unmerchantable to merchantable stems, because the heads are not well designed for brushing. The Bruun harvester is less affected by unmerchantable stems because its circular saw can mow down small trees quickly. In an effort to reduce delays caused by unmerchantable trees, some contractors are now manually falling unmerchantable trees with brush saws before the harvester operation.

Slopes can adversely affect productivity. Both harvesters and processors must travel up and down the slope because the machines are fairly narrow. Thus, some extra time is spent manoeuvering the machines when the terrain is rolling. Also, when working downhill, the visibility is poor because the head must be placed well below eye level and sometimes the view becomes blocked by the chassis or the wheels.

Undergrowth density also affects visibility which is an important factor in harvester operations. The operators need to see whether they might strike a rock or whether the bar might get pinched while cutting. Small trees and bushes causing poor visibility often result in higher downtime for repairing chains, bars and hoses. In processor operations, regeneration is less of a problem since it usually gets tamped down during the felling phase.

5.2 Mechanical Availability

In general, complex machines have a lower mechanical availability and utilization than simpler machines. The European harvesters and processors are complex machines. They have many moving parts, complex hydraulic systems, many have electric over hydraulic joystick controls and most have a computer to control the automatic or semi-automatic slashing to length.

The Rottne two-grip processor was being operated by a well-organized contractor who employed a mechanic, had a well-stocked parts trailer and had sent several of his people on training courses. They adhered rigidly to a preventative maintenance and servicing schedule developed by the distributor. Consequently, their mechanical availability averaged 83% and their utilization averaged 79%.

The Bruun harvesters were also operated efficiently with a well-stocked parts trailer on site. The operators had received some training in trouble-shooting and operation. In the summer and fall, availability ranged from 85 to 87% and utilization ranged from 73 to 75%, while in the winter, mechanical availability dropped to 75% and utilization to 67%.

The Rottne EGS harvester working in Nova Scotia had an availability of 76% and a utilization of 73%. On this operation, the parts trailer was not well stocked, the operator had little skill in trouble-shooting, and servicing and preventative maintenance were not a priority.

Five months after start-up, the Timberjack FMG 990 harvesters were experiencing 75% mechanical availability and 69% utilization according to the equipment distributor. These numbers have been steadily increasing since start-up. They had a parts trailer, some of the operators had received training in better operating techniques, and they were beginning to use a new maintenance program developed by the supplier.

A mechanical availability of 80% + and a utilization of 75% + should be attainable for new harvesters and processors on well-run operations where the machines are properly maintained, where operators are well-trained and motivated, where there is an adequate parts supply and where work is well planned to reduce unnecessary delays.

5.3 Delimbing Quality

The two processors studied seemed to have better delimbing capabilities than the harvesters. The Rottne two-grip processor has twice the feed force of the other machines and the Steyr processor has an excellent delimbing force because of its chain feeding device with metal spikes to prevent slippage. However, all machines had trouble with double tops and over-sized branches, especially when in clusters. The Bruun one-grip harvester seemed to have the most difficulty when delimbing.

5.4 Length Measuring Accuracy

Length measuring accuracy in the forest need be only as precise as that required by other processes down stream, i.e., during transport, handling, or in the mill.

The automatic feeding/length measuring/slashing system of the Steyr processor was by far the most accurate of the machines studied. During the study, 98% of the bolts and logs were within ±5 cm of the the mean desired length. However, it also has the slowest feed speed.

The four other machines had semi-automatic feeding/slashing systems. The Rottne two-grip slashed 94% of its pulpwood bolts to within ±5 cm of the mean. With the Bruun, between 87 and 96% were within ±5 cm of target lengths. The Rottne EGS harvester produced wood where 42 to 82% of bolts were within ±5 cm of the desired mean. The Timberjack FMG 990 machines were measured at 44 to 68% of the bolts within ±5 cm of the mean; however, tight control was not stressed on either the Rottne EGS or Timberjack FMG 990 operations because of the tolerant mill standards.

5.5 Systems Options

A number of different system adaptations have been tried in an effort to maximize processor and harvester-based system productivity and to minimize cost. In some cases, this involved integrating existing equipment such as skidders, forwarders or feller-bunchers.

Both off-road and roadside processing were tried during the Steyr KP40 study. The study results did not show any significant productivity difference between the two. However, other factors favour off-road processing: neat piles are not as critical off-road; the slash, cones and nutrients are left on the harvest site; and sorting can be carried out by the less expensive forwarder. On the other hand, if the original fleet contains skidders rather than forwarders, it would be logical to use the processor in a roadside operation.

The Rottne study in New Brunswick showed substantial production gains when working behind a feller-buncher as opposed to after manual fallers. The Steyr and an older Rottne two-grip processor have also shown increased productivity when working behind feller-bunchers in the Maritimes.

In harvester operations, systems have been built around delivering tree-length, shortwood and random-length stems to roadside. The study on the Rottne EGS one-grip harvester did not show any significant difference in harvester productivity when producing shortwood off-road versus tree length off-road, although productivity gains have been noted in other tree-length trials. In such case, the subsequent slashing cost must be taken into account. Also, stems can be better merchandized when processed by a harvester rather than slashed at roadside by a multi-stem slasher. Whenever possible, production of random-length wood may be the most economical because of a reduction in processing time as the length measurements do not have to be as precise.

6. Conclusions

This report has provided an evaluation of five different multi-function machines operating in cut-to-length or tree-length systems in eastern Canada: the Steyr KP-40 processor, the Rottne Rapid 860 two-grip processor, the Bruun 7610H harvester, the Rottne EGS-85 harvester and the Timberjack FMG 990 harvester.

The processors showed productivities ranging from 76 to 101 trees/PMH with utilization levels attaining 73 to 80%. Their production rates are essentially dependent on tree size, log length accuracy requirements, ground conditions and butt indexing requirements. They have good delimbing capabilities and measuring accuracies.

The productivity of the harvesters ranged from 74 to 111 trees/PMH and utilization levels ranging from 67 to 75%. The production capabilities of this type of machine is mainly related to operator skill, average tree size, stand density, unmerchantable density and ground conditions.

Processors and harvesters can work effectively under many eastern Canadian stand and terrain conditions. However, they are expensive to run and therefore they must be operated efficiently. Production rates especially with harvesters are more operator dependent than most other types of harvesting machinery. The high costs of these machines may be partially offset by the extraction of higher value wood products from every tree, reduced silvicultural costs, reduced accident rates, reduced clean up costs of roadside slash, increased operator comfort and reduced infrastructure requirements.

Some companies are examining the feasibility of mounting European harvester heads on North American carriers to reduce overall cost and possibly improve the suitability of these configurations to Canadian logging conditions. These will be the subject of future FERIC reports as they become operational. Also, FERIC will publish an integrated analysis of the advantages, disadvantages, cost and suitability of harvester/processor/forwarder systems in eastern Canadian conditions in 1991.

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