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REPORT

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PRODUCTIVITY OF A VALMET® 901 SINGLE-GRIP HARVESTER IN MERCHANTABLE THINNINGS

INTRODUCTION

Merchantable thinning can increase stand yields by 25 to 35% primarily by salvaging trees that would otherwise be lost to mortality (Daniel et al., 1979: 420). At the same time, the sawlog potential of the stand is increased by concentrating wood production on the largest and best quality trees. For these reasons, merchantable thinnings are carried out extensively in many countries of the world. For example, in Sweden an estimated 30% of the annual wood supply is derived from merchantable thinnings, the majority of which are completed using mechanical methods (Paille, 1980; Fryk et al., 1985).

In Nova Scotia, merchantable thinning has not been practised on a large scale for a variety of reasons including: (1) the high cost, (2) increased risk of blowdown on many sites, (3) unlikely response due to stand over-maturity and (4) unsuitable stand structure. Blowdown can be minimized by (1) careful selection of stands, (2) conducting the thinning operation so that a uniform spacing is achieved, and (3) following the recommendations in the Forestry Field Handbook (NSDLF, 1988). Cost, on the other hand, can be reduced by switching from power saws to more efficient mechanical equipment such as that recently developed by Nordic manufacturers. One example of a machine that could be used for thinning is the Valmet® 901 single-grip harvester. This report summarizes the results of a thinning trial designed to determine the productivity of the Valmet® operating in natural and managed softwood stands.

SITE DESCRIPTION

The three stands chosen for this thinning trial are located in Colchester County near the communities of McCallum Settlement, Hilden and Truro. A description of stand conditions by location and block number is found in Tables 1, 2 and 3.

At McCallum Settlement, the 7.7 ha stand was composed mainly of red spruce (*Picea rubens*

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Sarg.) and balsam fir (*Abies balsamea* (L.) Mill.). It was cleaned in 1967 and at the time of the experiment averaged 12.5 cm in dbh, 11.2 m in height, 4211 trees/ha and 55.2 m^2/ha in basal area.

The Truro stand consisted of 0.8 ha of predominantly red spruce which had been thinned in 1982, thus there were no trees of unmerchantable size. The stand averaged 19.4 cm in diameter, 16.4 m in height, 1661 trees/ha and 49.0 m^2/ha.

The 2.4 ha predominantly spruce-fir stand at Hilden was the only one not previously cleaned or thinned (average height of 11.3 m, dbh of 9.3 cm, 7159 trees/ha and a basal area of 48.9 m^2/ha. The number of unmerchantable stems was higher than at the other sites. The average merchantable dbh (trees exceeding 7 cm) was 13.1 cm; slightly less than the minimum diameter (14.0 cm) required to be eligible for thinning under the Federal/Provincial Forest Management Agreement (Section L of the Cooperation Program Reference Guide).

Table 1. Pre-treatment stand description for McCallum settlement by plot and zone.

Plot	Pre-treat	Zone[1]	Diameter (cm)		Basal Area (m^2/ha)		Volume (m^3 (s)/ha)	Density (trees/ha)			Ratio[4] (UMT/MT)	Stand Index[5] (trees/m^3 (s))
			Total[2]	Merch.[3]	Total	Merch.	Merch.	Merch.	Unmerch.	Total		
1	Cleaned	Extract	14.3	14.8	35.4	34.9	255	2028	184	2212	0.09	8.69
		Thin	14.9	15.2	41.4	41.2	309	2258	108	2365	0.05	7.65
		Combined	14.8	15.1	40.0	39.7	297	2206	125	2331	0.06	7.85
2	Cleaned	Extract	10.7	12.8	51.4	43.5	315	3401	2313	5714	0.68	18.17
		Thin	12.7	14.3	53.4	48.8	388	3056	1191	4246	0.39	10.95
		Combined	12.1	13.9	52.9	47.6	371	3134	1444	4578	0.46	12.33
3	Cleaned	Extract	10.7	13.7	63.1	51.7	397	3507	3507	7013	1.00	17.67
		Thin	12.7	14.8	57.3	51.1	413	2955	1553	4508	0.53	10.91
		Combined	12.1	14.6	58.6	51.2	410	3079	1994	5074	0.65	12.39
4	Cleaned	Extract	12.2	15.6	29.3	25.5	214	1329	1163	2492	0.88	11.65
		Thin	12.3	14.7	57.7	50.4	405	2956	1938	4894	0.66	12.08
		Combined	12.3	14.8	51.3	44.8	362	2588	1763	4352	0.68	12.02
All		**Extract**	**11.3**	**13.8**	**46.5**	**40.0**	**295**	**2566**	**1792**	**4358**	**0.70**	**15.30**
		Thin	**12.9**	**14.7**	**57.7**	**48.3**	**383**	**2840**	**1244**	**4085**	**0.44**	**10.67**
		Combined	**12.5**	**14.5**	**55.2**	**46.4**	**365**	**2804**	**1406**	**4211**	**0.50**	**11.54**

1 Each plot was subdivided and flagged into two zones before it was thinned; Extract = Extraction trail, Thin = Area to be thinned, Combined = Entire plot.
2 Based on trees exceeding 3 cm dbh.
3 Based on trees exceeding 7 cm dbh.
4 Ratio of unmerchantable trees (UMT) to merchantable trees (MT).
5 Calculated by dividing the total number of trees by the total merchantable volume in stacked cubic metres (m^3 (s)) prior to harvest.

Table 2. Pre-treatment stand description for Hilden by plot and zone.

Plot	Pre-treat	Zone[1]	Diameter (cm)		Basal Area (m^2/ha)		Volume (m^3 (s)/ha)	Density (trees/ha)			Ratio[4] (UMT/MT)	Stand Index[5] (trees/m^3 (s))
			Total[2]	Merch.[3]	Total	Merch.	Merch.	Merch.	Unmerch.	Total		
1	None	Extract	9.5	13.5	61.2	48.4	386	3401	5170	8571	1.52	22.21
		Thin	9.4	13.0	60.6	49.5	376	3730	4921	8651	1.32	23.01
		Combined	9.5	13.1	60.7	49.3	378	3656	4977	8633	1.36	22.83
2	None	Extract	9.6	13.7	52.6	38.2	306	2585	4762	7347	1.84	23.99
		Thin	9.5	13.2	51.2	40.0	304	2937	4326	7263	1.47	23.86
		Combined	9.5	13.3	51.5	39.6	305	2857	4424	7281	1.55	23.89
3	None	Extract	7.8	10.6	32.1	23.0	136	2585	4082	6667	1.58	48.87
		Thin	8.3	11.5	47.6	36.1	242	3453	5437	8890	1.57	36.68
		Combined	8.2	11.4	44.1	33.1	218	3257	5131	8388	1.58	38.40
4	None	Extract	7.9	11.3	53.4	35.2	229	3538	7483	11021	2.12	48.05
		Thin	8.3	11.8	46.6	34.8	238	3215	5477	8692	1.70	36.52
		Combined	8.2	11.6	48.2	34.9	236	3287	5930	9217	1.80	39.05
5	UMT C[6]	Extract	8.6	13.0	37.7	26.5	205	2000	4428	6428	2.21	31.31
		Thin	9.5	13.8	51.9	39.4	310	2625	4625	7250	1.76	23.41
		Combined	9.4	13.7	48.7	36.5	286	2483	4580	7063	1.84	24.69
6	UMT C	Extract	9.1	12.5	46.7	34.9	260	2857	4286	7143	1.50	27.51
		Thin	9.3	13.6	42.9	32.0	252	2208	4125	6333	1.87	25.10
		Combined	9.2	13.3	43.7	32.6	254	2355	4161	6516	1.77	25.65
7	UMT C &F[7]	Extract	9.9	14.0	52.0	39.5	322	2571	4143	6714	1.61	20.82
		Thin	10.0	14.3	48.0	37.6	307	2333	3750	6083	1.61	19.81
		Combined	10.0	14.2	48.9	38.0	311	2387	3838	6225	1.61	20.05
8	UMT C & F	Extract	13.5	15.1	55.4	35.7	302	2000	1857	3857	0.93	12.77
		Thin	12.0	15.9	41.4	36.3	316	1833	1833	3666	1.00	11.59
		Combined	12.4	15.7	44.5	36.2	313	1871	1838	3709	0.98	11.85
All		**Extract**	**9.3**	**12.9**	**48.9**	**35.2**	**268**	**2700**	**4547**	**7247**	**1.68**	**27.01**
		Thin	**9.3**	**13.2**	**48.8**	**38.3**	**293**	**2805**	**4329**	**7134**	**1.54**	**24.33**
		Combined	**9.3**	**13.1**	**48.9**	**37.6**	**288**	**2781**	**4378**	**7159**	**1.57**	**24.90**

1 Each plot was subdivided and flagged into two zones before it was thinned; Extract = Extraction trail, Thin = Area to be thinned, Combined = Entire plot.
2 Based on trees exceeding 3 cm dbh.
3 Based on trees exceeding 7 cm dbh.
4 Ratio of unmerchantable trees (UMT) to merchantable trees (MT) before the treatment.
5 Calculated by dividing the total number of trees by the total merchantable volume in stacked cubic metres (m^3 (s)) prior to harvest.
6 Unmerchantable trees were cut and left standing prior to thinning (C).
7 Unmerchantable trees were cut and felled prior to thinning (C&F).

Table 3. Pre-treatment stand description for Truro by plot and zone.

Plot	Pre-treat	Zone[1]	Diameter (cm)		Basal Area (m^2/ha)		Volume (m^3 (s)/ha)	Density (trees/ha)			Ratio[4] (UMT/MT)	Stand Index[5] (trees/m^3 (s))
			Total[2]	Merch.[3]	Total	Merch.	Merch.	Merch.	Unmerch.	Total		
1	Thinned	Thin	20.0	20.0	51.7	51.7	607	1644	0	1644	0	2.71
2	Thinned	Thin	18.3	18.3	40.1	40.1	458	1524	0	1524	0	3.33
3	Thinned	Thin	18.9	18.9	52.4	52.4	608	1861	0	1861	0	3.06
All		**Thin**	**19.4**	**19.4**	**49.0**	**49.0**	**571**	**1661**	**0**	**1661**	**0**	**2.91**

1 Each plot was subdivided and flagged into two zones before it was thinned; Extract = Extraction trail, Thin = Area to be thinned, Combined = Entire plot.
2 Based on trees exceeding 3 cm dbh.
3 Based on trees exceeding 7 cm dbh.
4 Ratio of unmerchantable trees (UMT) to merchantable trees (MT).
5 Calculated by dividing the total number of trees by the total merchantable volume in stacked cubic metres (m^3 (s)) prior to harvest.

METHODS

Equipment

Merchantable thinning treatments were carried out by a Valmet® 901 single-grip harvester fitted with a Valmet® 955 cutting-head (Appendix I; Figure 1). This machine weighs 11,000 kg, is wheel-mounted and fitted with a telescopic boom capable of extending 7.6 metres. Other capabilities include computer-guided continuous timber measuring of diameters and lengths. All felled wood was extracted to roadside by a Valmet® 836 forwarder (Appendix I).

Treatments

At each site, parallel extraction trails, spaced approximately 20 metres apart and 3 metres wide, were marked prior to the low thinning (Smith, 1962: 64). The harvester cut out a section of the trail, then performed a thinning in the "leave" strips by extending its boom into the stands at the McCallum Settlement and Hilden sites. At Truro, the trails were cut during the previous thinning. Thinning in the strip beyond reach of the 7.6 metre boom was performed by chain saw operators. Two experienced operators ran the Valmet® throughout this study.

The objective of the thinning operation was to remove 40% of the total basal area from the McCallum Settlement and Hilden sites and 30% from the Truro site. All merchantable trees harvested by the Valmet® were delimbed, cut into random length logs (2.44-4.88 m) and/or 2.44 m pulpwood, and piled along the trails for extraction by the forwarder. Two pre-thinning treatments were carried out at Hilden to determine their effect on production rates. A spacing saw was used in plots 5 and 6 to cut all unmerchantable trees prior to the harvester entering the stand. No effort was made to fell these trees to the ground. In plots 7 and 8, all unmerchantable trees were cut with a spacing saw and felled prior to the harvester entering them.

Thinning operations and time studies were carried out near the end of April, 1989 at McCallum Settlement and early July, 1989 at the Hilden and Truro sites.

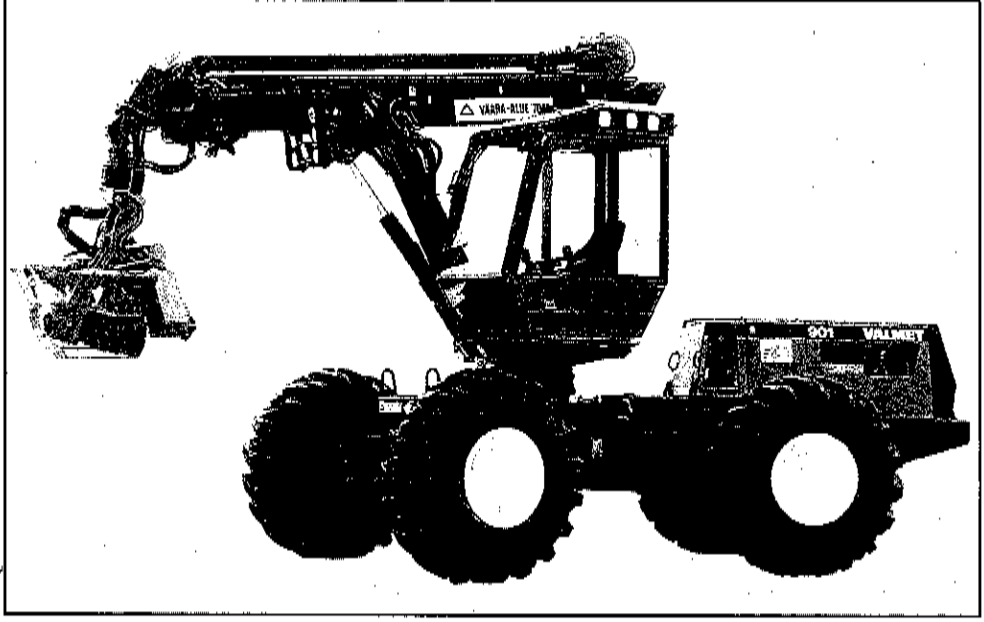

Figure 1. The Valmet® Harvester

Data Collection

Data collection and observations were a joint effort by the Nova Scotia Department of Lands & Forests and Stora Forest Industries personnel. Data were collected in three phases;

1) pre-treatment phase: to assess stand conditions;
2) time-study phase: to determine machine-productivity;
3) post-treatment phase: to determine productivity and job quality.

Pre-treatment phase

Stand assessments were carried out by Lands & Forests staff in each of the 3 locations prior to thinning. The results of the cruise were used to divide the stands into blocks of homogenous characteristics. Within the blocks, plots were established measuring approximately 12.5 metres along the trail and 20 metres across the trail. These plots were centred on the trails. Each of the plots, therefore, consisted of a section of trail in the centre (extraction zone) and the adjacent thinning strips (thinning zone) on either side. Four plots were established at McCallum, eight at Hilden and three at Truro.

Time-study phase

Time-studies were carried out to determine the time required for each phase of merchantable thinning. All time-studies utilized work sampling techniques (Miyata et. al., 1981). The data for the Truro site is limited to thinning, since the extraction trails were already in place.

Harvester productivity was determined separately for the extraction and thinning zones within each plot established at the McCallum Settlement and Hilden sites. These data were collected by Stora Forest Industries. Within each plot, the diameters of all merchantable trees were recorded then painted on the boles. Also, all unmerchantable trees greater than 3 cm in diameter were counted. Timing began when the machine entered the plot and ended when it exited. The time, in hours, required by the machine to thin the plot was referred to as the productive-machine time (PMH). While the machine was operating, the diameter and number of bolts cut from each harvested tree were tallied. These tallies were then converted to m^3 stacked (m^3(s)) according to Stora's Volume tables. Productivity (m^3(s)/PMH) was determined by dividing 90% of the harvested volume from a particular zone and plot by the time required to harvest it. The volume was reduced by 10% to account for machine delays less than 15 minutes that would normally occur under operational conditions (Appendix II). These delays were not measured in this time study.

Additional data were collected by Lands & Forests staff on the time required by the harvester to complete separate thinning activities (felling, bucking, etc.). The type of harvester activity was tallied at intervals of 20 seconds for 1 hour periods. This data was not collected by zone. If the machine was inoperable or the operator was involved in a non-work related activity, the assessment was not carried out. The study therefore only provides information on productive-work activities.

Post-treatment phase

Post-treatment assessments were conducted in each of the areas thinned. The objective was to determine the percentage of basal area and volume removed from each plot and zone and to assess the quality of the treatment in terms of the number of residual trees damaged. The severity of this damage was not recorded. The number of trees left standing and their diameters were recorded in each plot.

Stand Index

A stand index was calculated for each plot and zone prior to harvest. This index is based on the total number of trees (merchantable and unmerchantable) divided by the total merchantable volume prior to harvest. Merchantable volume was estimated from diameter measurements, predicted heights, and Honer's Volume equations (Honer, 1967). The predicted heights were calculated from a diameter versus height function derived from plot measurements. The stand index is a measure of the average tree size in a stand and was used as a predictor of thinning productivity.

Data Analyses

The following non-linear regression model was used to relate harvester production to stand conditions.

$$P = b_o \, SI^{b_1} \qquad [1]$$

where, P = Productivity in $m^3(s)$/PMH based on the merchantable volume extracted divided by productive machine hours to cut and process this wood,

b_o & b_1 = Regression coefficients,

SI = Stand Index, expressed in trees/$m^3(s)$, based on the total number of trees (merchantable and unmerchantable >3 cm dbh) divided by the total standing merchantable (trees > 7 cm dbh) volume prior to harvest,and

$m^3(s)$ = Stacked cubic metres.

The pre-treated plots at Hilden were not included in the regressions.

RESULTS & DISCUSSION

Productive-Machine Activities

Table 4 shows the percentage of productive time dedicated to various harvesting activities. The two most time consuming activities for the harvester were positioning the boom to fell and the actual felling process. These two activities account for approximately half of all productive time. The only activities for which the percentage of productive time varied by location were unmerchantable felling, delimbing and travel. At Hilden, where there was a greater number of unmerchantable stems, unmerchantable felling accounted for 13% of the total productive time. In contrast, this percentage was approximately 3% at the other 2 sites. Delimbing and travel accounted for less of the productive time at Hilden than at the other sites.

Table 4. The percentage of productive time required to perform each work activity by location; thinning and trail cutting combined.

Activities[1]	McCallum Settlement	Hilden[2]	Truro
Felling	27	27	25
Position boom to fell	20	23	20
Delimbing	15	12	19
Bucking	12	10	13
Travel working	11	7	12
Moving brush (discard tops)	5	3	2
Unmerchantable felling	3	13	4
Tree selection	4	3	4
Other	3	1	1
Total	100	100	100

1 Non-productive activities (repairs, breaks, etc.) were not recorded.

2 Data is for plots 1-4 (unmerchantable stems were not cut prior to thinning).

Harvester Productivity

Thinning

Thinning productivity (m^3(s)/PMH) was found to be inversely related to the stand index (trees/m^3(s)) in a non-linear fashion (Figure 2, r^2=0.94). The regression indicates that machine production decreases rapidly (47%) as the stand index increases from 3 to 10. Beyond this point, production continues to decrease but at a reduced rate. For example, between 10 and 17 trees/m^3(s) production decreases from 6.7 to 5.0 m^3(s)/PMH (25%). Production begins to level off after this point.

It is interesting to note, that for the plots at Hilden where the unmerchantable stems were cut and felled prior to thinning (plots 7 and 8), actual harvester production averaged 40% higher than it would have, if the unmerchantable trees were not cut (Figure 2). In the plots where the unmerchantable stems were cut and left standing (Hilden, plots 5 and 6), production only improved by 3% on average.

Average machine productivity was 70 and 205% higher respectively, at McCallum Settlement and Truro (7.0 and 12.5 m^3(s)/PMH respectively) compared to Hilden (4.1 m^3(s)/PMH, Table 5). The increases were directly related to larger tree sizes at those sites (an average merchantable diameter of 13.1 cm at Hilden versus 14.5 and 19.4 cm at McCallum Settlement and Truro respectively, Tables 1, 2 and 3). Appendix III summarizes predicted productivity values for thinning operations by stand index and merchantable diameter.

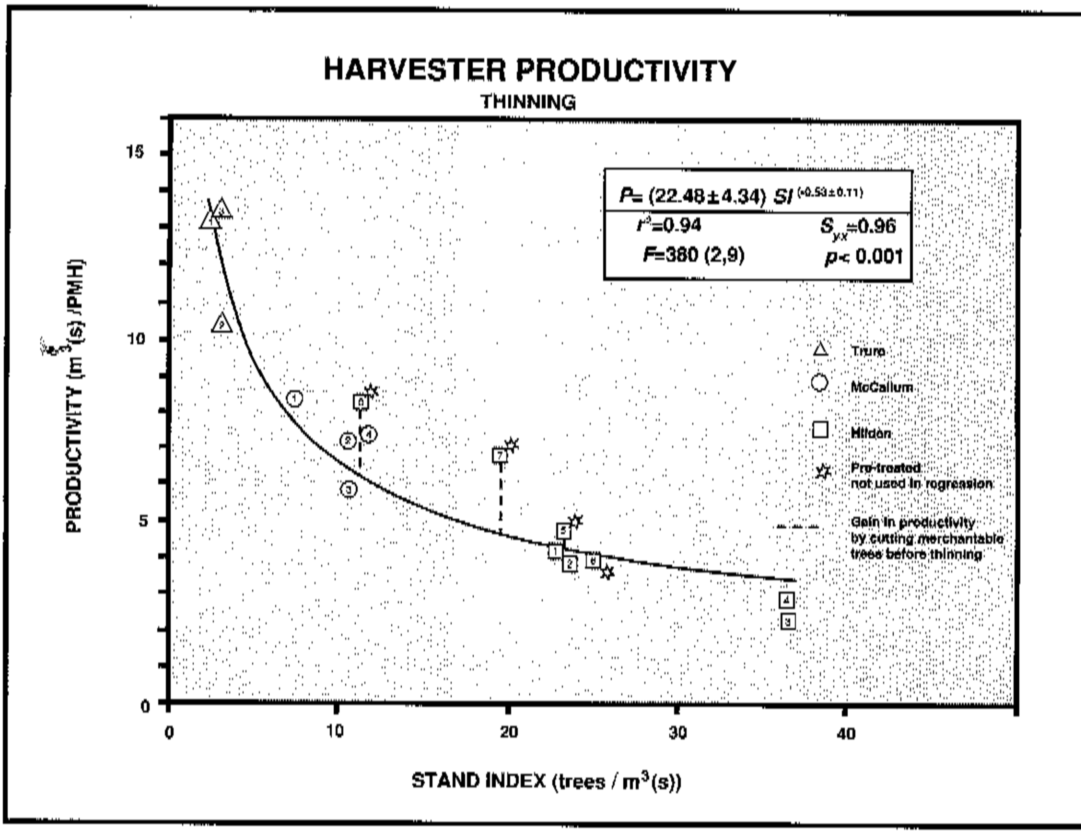

Figure 2. **Harvester productivity (P= m^3 stacked per productive machine hour) versus stand index (SI= total trees per m^3 stacked) for thinning at McCallum Settlement, Hilden and Truro. Plot descriptions are found in Tables 1, 2 and 3.**

Table 5. Harvester productivity (m3 (s)/PMH) for thinning, trail cutting and combined operations.

Location	Thinning		Trail-cutting		Combined	
	Productivity (m^3 (s)/PMH)	Stand Index (trees/m^3 (s))	Productivity (m^3 (s)/PMH)	Stand Index (trees/m^3 (s))	Productivity (m^3 (s)/PMH)	Stand Index (trees/m^3 (s))
McCallum	7.0	10.7	10.3	15.3	7.9	11.5
Hilden[1]	4.1	22.0	7.4	24.3	5.2	22.5
Truro	12.5	2.9	-	-	-	-

1 Stand indicies at Hilden exclude unmerchantable trees cut and felled prior to thinning.

Trail-cutting

Productivity of the harvester during trail-cutting was higher than for thinning and inversely related to the stand index in a non-linear fashion (Figure 3). A comparison of the two operations reveals that, for stands having a stand index of 10 trees/m^3(s), harvester productivity was 105% higher during trail-cutting. The magnitude of the difference decreased as stand index increased (85% at 20 trees/m^3(s)).

Trail-cutting productivity varied considerably between sites. For example, at McCallum Settlement, production was 39% higher than at Hilden (10.3 versus 7.4 m^3(s)/PMH, Table 5). Appendix III summarizes predicted productivity values for trail-cutting operations by stand index and merchantable diameter.

Combined (Thinning & Trail-cutting)

Figure 4 shows the non-linear regression (r^2=0.97) line for combined production (thinning and trail-cutting) versus stand index for the McCallum Settlement and Hilden sites. At Hilden, actual productivity averaged 23% and 38% higher when the unmerchantable trees were cut only and cut and felled prior to thinning, respectively.

Harvester production was on average 52% higher at the McCallum Settlement site than at Hilden (7.9 versus 5.2 m^3(s)/PMH, Table 5). Appendix III shows predicted productivity values for combined operations by stand index and merchantable diameter.

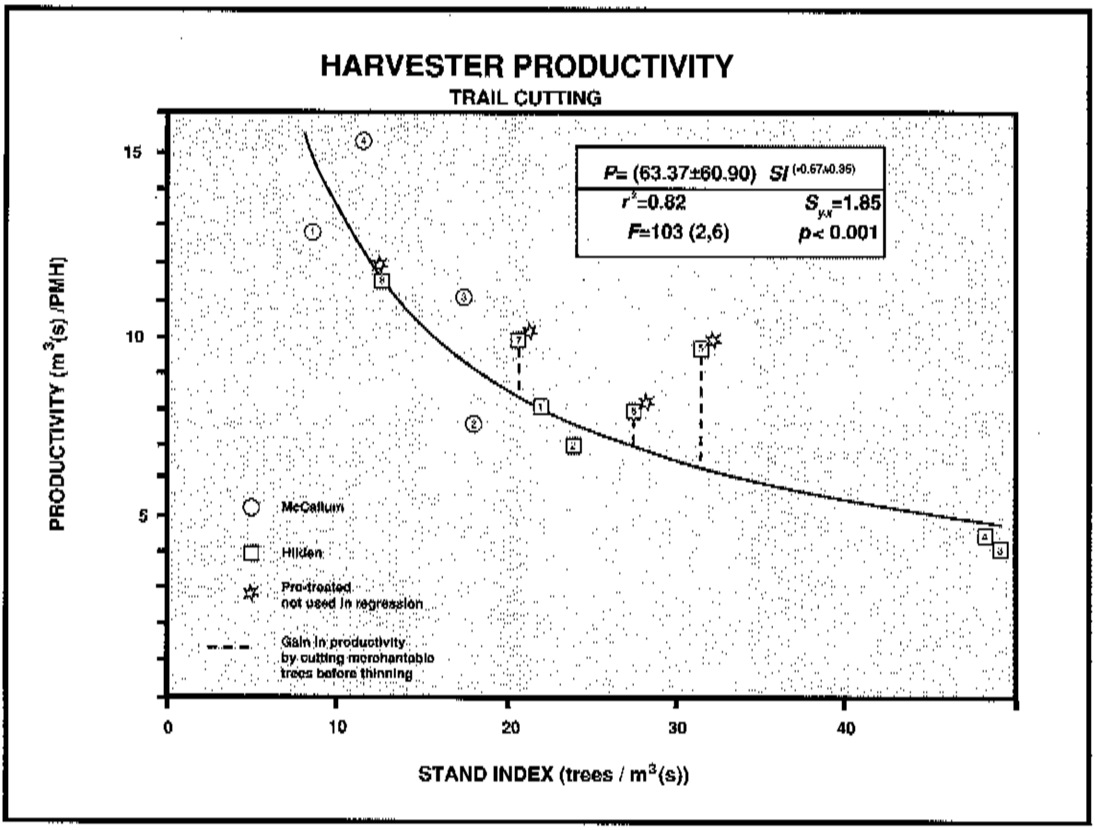

Figure 3. **Harvester productivity (P= m^3 stacked per productive machine hour) versus stand index (SI= total trees per m^3 stacked) for trail-cutting at McCallum Settlement and Hilden. Plot descriptions are found in Tables 1 and 2.**

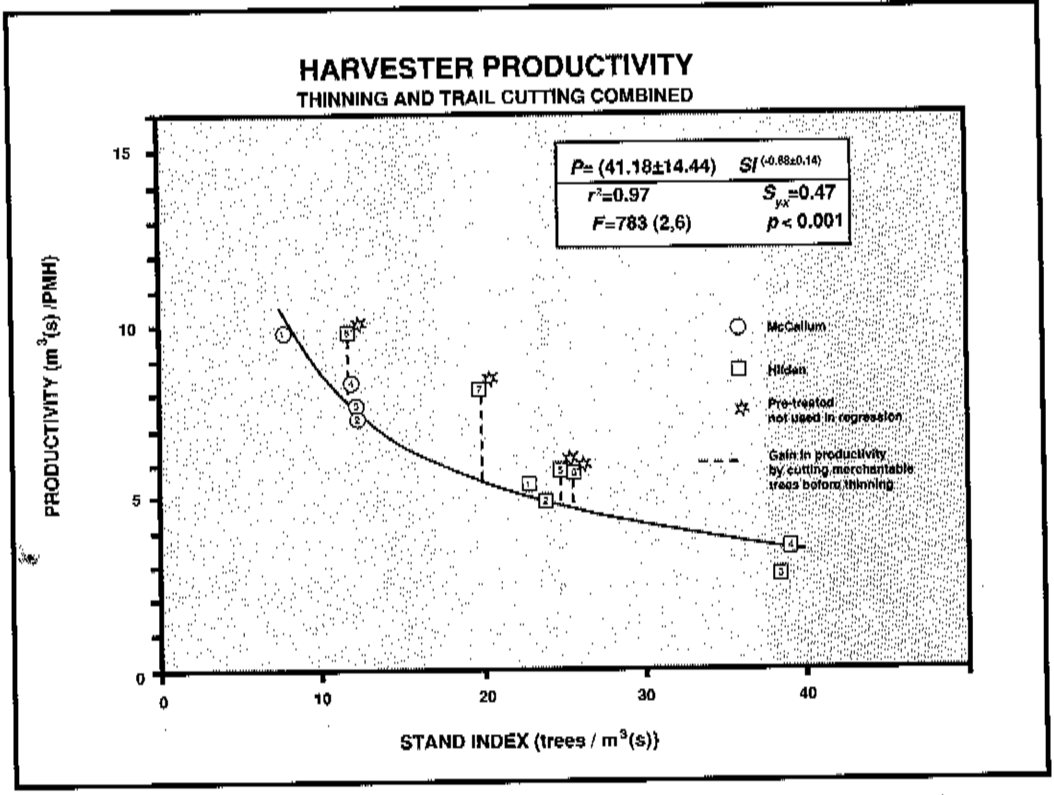

Figure 4. Harvester productivity (P= m³ stacked per productive machine hour) versus stand index (SI= total trees per m³ stacked) for thinning and trail-cutting combined at McCallum Settlement and Hilden. Plot descriptions are found in Tables 1 and 2.

Forwarder Productivity

Production rates for forwarding were also influenced by stand conditions (Table 6). At Hilden productivity was only 8.4 m^3(s)/PMH compared to 12.6 and 11.9 respectively for the Truro and McCallum sites. The lower productivity at Hilden is partially attributed to the additional time necessary to load and unload the smaller wood.

Post-thinning Assessment

Leave-Tree Damage

Leave-tree damage ranged from a high of 15.7% at Hilden to 8.3 and 9.4% respectively at McCallum Settlement and Truro (Appendix IV). The higher damage at Hilden is attributed to the higher pre-thinning density and the fact that the thinning operation took place when the trees were actively growing, making them more susceptible to bark damage. Truro was also thinned during the summer months but damage was less, presumably as a result of the lower tree density at this site. At McCallum Settlement, operations were completed prior to sap flow and when the bark is more rigid and less prone to damage.

Basal Area & Volume Removal

Overall 53.0% of the total basal area and 43.9% of the volume was removed from each of the stands during harvesting (Table 7). Within the thinned strips, basal area removals were within 10% of their targeted values. The low basal area removal from the Truro site (27.6%) was a result of the earlier thinning which reduced both the merchantable volume and density of the stand. The average volume removed from the thinned strips at Truro was 24.9%.

Table 6. Stand level forwarding productivity.

Location	PMH[1] (hrs)	Loads (#)	Volume Extracted (m^3 (s))	Productivity	
				(PMH/Load)	(m^3 (s)/PMH)[2]
McCallum	100.0	95.0	1187	1.1	11.9
Hilden	36.5	23.5	307	1.6	8.4
Truro	8.5	6.0	107	1.4	12.6

1 Productive machine hours.
2 Volume forwarded per productive machine hour.

Table 7. Percentage removal of total basal area (m^2) and volume (m^3 (s)) from the thinned areas and total area by location..

Location	Basal Area Removal (%)		Volume Removal (%)	
	Overall	Thinned Strips[2]	Overall	Thinned Strips
McCallum	59.3	48.8	51.5	40.3
Hilden	58.4	46.3	41.2	25.6
Truro[1]	41.2	27.6	39.0	24.9
All	**53.0**	**40.9**	**43.9**	**30.3**

1 Estimated overall removal based on the assumption that stand conditions were identical within the trails and the thinning zones
2 Target total basal area removals were 40% at McCallum and Hilden and 30% at Truro.

Comparison of Volume Estimates

The volume extracted from each plot was estimated using both Stora's and Honer's volume tables (Methods section). The difference between these estimated values was 7.4% over all plots (Table 8). The maximum difference occurred at Truro (10.5%).

Table 8. A comparison of two volume calculation methods.			
Location	Merchantable Volume extracted (m^3 (s))		Difference (%)
	Stora[1]	Honer[2]	
McCallum	22.69	22.06	+ 2.8
Hilden	33.08	30.15	+ 8.9
Truro	18.30	16.38	+10.5
All	**74.07**	**68.59**	+ 7.4

1 Volume determined from Stora's volume tables.
2 Volume determined from Honer's volume tables.

SUMMARY

This study was undertaken to determine the productivity of the Valmet® 901 single-grip harvester in thinning managed and unmanaged stands. The major findings are as follows:

1) Thinning productivity (m^3(s)/PMH) decreased curvilinearly as the number of trees/m^3(s) increased. The following regression equation quantifies this trend,

$$\text{Productivity} = 22.48\ (\text{SI})^{-0.53}$$

where, **SI or Stand Index,** represents the total number of trees (merchantable and unmerchantable) divided by the total merchantable volume prior to harvest.

2) Harvester productivity (m^3(s)/PMH) during trail-cutting was approximately double that for thinning. It was also inversely related to the stand index (trees/m^3(s)) in a curvilinear fashion according to the regression equation,

$$\text{Productivity} = 63.37\ (\text{SI})^{-0.67}$$

3) The regression for the combined productivity in m^3(s)/PMH (thinning and trail-cutting) is:

$$\text{Productivity} = 41.18\ (\text{SI})^{-0.68}$$

4) Positioning the boom to fell and felling required the highest proportion of productive time, averaging 21 and 26% respectively over the 3 locations.

5) In plots where unmerchantable trees were cut and felled prior to thinning, the productivity of the harvester increased 40% from 5.4 to 7.5 m^3(s)/PMH.

6) Between 8 and 16% of the leave-trees were damaged to some extent during harvesting and forwarding operations. Damage was usually attributable to higher stand densities and/or thinning at times when trees were actively growing making them more susceptible to bark damage.

7) Overall, 53% of the total basal area and 44% of volume was removed from each site during harvesting. Basal area removals were within 10% of the targeted levels.

8) Volume estimates derived from Honers Standard Volume Tables were within 8% of volume estimated according to Stora's volume tables.

Additional merchantable thinning studies were carried out during 1990 using the Valmet® and other mechanical harvesters. The results of these studies will be presented in an upcoming report.

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APPENDIX I

SPECIFICATIONS FOR THE VALMET® 901 SINGLE-GRIP HARVESTER & VALMET® 836 FORWARDER

Harvester		Forwarder	
Dimensions		**Dimensions**	
Length	: 5.8 m	Length	: 8.3 m
Width	: 2.5 m	Width	: 2.5 m
Height	: 3.7 m	Height	: 3.7 m
Ground Clearance	: 0.60 m	Ground clearance	: 0.6 m
Weight	: 11,000 kg	Weight	: 9,900 kg.
Harvester Boom		**Load Capacity**	
Type	: Valmet 996 2-stage telescopic	Gross load	: 10,000 kg
Reach	: 7.6 m (max.)	Load area	: 2.7-4.0 m²
Felling Head		**Loader**	
Type	: Valmet 955	Type	: Cranab 570
Grab Opening	: 0.57 m max., range 0.33 to 0.57 m	Grip	: Cranab 28
Other Specifications			
computer-guided timber measuring			
continuous measuring of diameter & lengths			
feed speeds (4 metres/sec, max.)			
engine type: Volvo TD45B 4-cyl. turbo diesel			

APPENDIX II

PRODUCTION VALUES FOR THE VALMET® 901 HARVESTER BY LOCATION, PLOT AND ZONE

McCALLUM SETTLEMENT

Plot	Zone	Trees cut (#)	Time (min)	Volume Cut[1] (m^3 (s))	Trees PMH	m^3 (s) PMH	Trees[2] m^3 (s)
1	Extract	11	5.7	1.35	104	12.79	8.2
	Thin	19	12.1	1.89	85	8.42	10.1
	Combined	30	17.8	3.24	91	9.82	9.3
2	Extract	25	16.9	2.36	80	7.54	10.6
	Thin	47	34.2	4.57	74	7.21	10.3
	Combined	72	51.1	6.93	76	7.32	10.4
3	Extract	27	16.1	3.30	91	11.06	8.2
	Thin	39	31.8	3.44	66	5.84	11.3
	Combined	66	47.9	6.74	74	7.60	9.8
4	Extract	8	4.1	1.17	105	15.34	6.9
	Thin	41	33.7	4.63	66	7.41	8.9
	Combined	49	37.8	5.80	70	8.27	8.5
All	Extract	71	42.8	8.18	90	10.32	8.7
	Thin	146	111.8	14.53	71	7.02	10.0
	Combined	217	154.6	22.71	76	7.93	9.6

1 Production values reduced by 10% to account for delays of less than 15 minutes that were paid for. To convert stacked (m^3 (s)) to solid cubic metres (m^3), multiply by 0.625.
2 Calculated by dividing the trees harvested by the merchantable volume harvested.

APPENDIX II
Continued

HILDEN

Plot	Zone	Trees cut (#)	Time (min)	Volume Cut[1] (m^3 (s))	Trees / PMH	m^3 (s) / PMH	Trees[2] / m^3 (s)
1	Extract	25	22.1	3.28	61	8.01	7.6
	Thin	54	48.4	3.70	60	4.13	14.6
	Combined	79	70.5	6.98	61	5.35	11.3
2	Extract	19	17.5	2.28	59	7.03	8.3
	Thin	38	37.8	2.67	54	3.81	14.3
	Combined	57	55.3	4.95	56	4.83	11.5
3	Extract	19	12.4	0.91	83	3.98	20.8
	Thin	43	37.6	1.60	62	2.30	26.9
	Combined	62	50.0	2.51	67	2.72	24.7
4	Extract	26	18.8	1.53	75	4.38	17.0
	Thin	34	29.4	1.55	62	2.85	21.9
	Combined	60	48.2	3.08	67	3.45	19.5
5	Extract	14	8.3	1.48	91	9.61	9.5
	Thin	26	32.1	2.82	44	4.75	9.2
	Combined	40	40.4	4.30	53	5.75	9.3
6	Extract	15	12.4	1.79	87	7.81	11.2
	Thin	20	15.1	1.08	54	3.87	13.9
	Combined	35	27.5	2.87	69	5.65	12.2
7	Extract	18	12.3	2.26	79	9.91	8.0
	Thin	24	16.8	2.10	77	6.76	11.4
	Combined	42	29.1	4.36	78	8.09	9.6
8	Extract	14	10.0	2.12	76	11.46	6.6
	Thin	18	12.4	1.90	78	8.28	9.5
	Combined	32	22.4	4.02	77	9.70	8.0
All	Extract	155	113.8	15.65	74	7.43	9.9
	Thin	252	229.6	17.43	59	4.10	14.5
	Combined	407	343.4	33.08	64	5.20	12.3
				TRURO			
1	Thin	34	39.0	9.51	47	13.17	3.6
2	Thin	21	20.0	3.83	57	10.34	5.5
3	Thin	24	20.0	4.96	65	13.39	4.8
All	Thin	79	79.0	18.30	54	12.50	4.3

1 Production values reduced by 10% to account for delays of less than 15 minutes that were paid for. To convert stacked (m^3 (s)) to solid cubic metres (m^3), multiply by 0.625.
2 Calculated by dividing the trees harvested by the merchantable volume harvested.

APPENDIX III

PREDICTED PRODUCTION LEVELS (m^3 (s)/PMH) BY STAND INDEX (trees /m^3 (s)) AND MERCHANTABLE DIAMETER FOR THINNING, TRAIL-CUTTING AND COMBINED OPERATIONS

Stand Index (Trees / m^3 (s))	Merchantable Diameter (cm)	Productivity[1] (m^3 (s)/PMH)[2]		
		Thinning	Trail-cutting	Combined
5	17.4	9.61	21.58	13.84
10	15.3	6.66	13.57	8.65
15	14.2	5.38	10.35	6.57
20	13.5	4.62	8.53	5.41
25	13.0	4.11	7.35	4.65
30	12.6	3.73	6.51	4.11
35	12.2	3.44	5.87	3.70
40	11.9	3.21	5.37	3.38
45	11.7	3.01	4.96	3.12
50	11.5	2.85	4.62	2.91

1 Based on equation [1].
2 Productive machine hours.

APPENDIX IV

THE PERCENTAGE OF TREES DAMAGED DURING THE VALMET® 901 MECHANICAL THINNING TRIALS AT McCALLUM SETTLEMENT, HILDEN AND TRURO BY DAMAGING AGENT.

	Damage[1] (%)								
	Harvester		Forwarder			Other		Total	
Location	Boom	Felled tree	Loader	Pins	Wheels	Damaged Roots	Unknown	(%)	Stems/ha
McCallum	1.0	1.7	0.3	0.3	1.2	1.2	2.6	8.3	84
Hilden	2.0	3.2	0.6	1.2	3.2	2.0	3.5	15.7	260
Truro	1.3	0.6	0.6	0.0	1.3	3.1	2.5	9.4	80

1 The severity of damage was not recorded

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