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FOREST RESEARCH REPORT

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THE PRODUCTIVITY OF FOUR SINGLE-GRIP HARVESTERS IN COMMERCIAL THINNINGS

INTRODUCTION

Since 1981, approximately 15 000 hectares of commercial thinning[1] and shelterwoods have been conducted in Nova Scotia. Until recently most of this work has been completed using motor-manual methods. However, with the introduction of single-grip harvesters, an increasing number of these operations are being performed mechanically.

A preliminary report (NSDLF, 1991), described the use of a Valmet® mechanical harvester in commercial thinnings. This report summarizes the results of further studies to evaluate the productivity of the Valmet® as well as the Tufab, Rottne and Hanover®.

SITE DESCRIPTIONS

Eight stands were selected for these trials; 4 were located in Colchester County, near Trout Lake, Belmont Mountain, McCallum Settlement and Hilden; 1 in Cumberland County, near Tidnish, and 3 near Trafalgar in Guysborough County. A pre-treatment description of each stand is found in Table 1 and Appendix I.

All stands were predominantly softwood. They were 40 to 95 years old, contained 187 to 382 merchantable cubic metres per hectare (m^3/ha) and averaged 12 to 24 cm in merchantable diameter.

Three of the stands had been precommercially thinned[2] in the early 1970's. In one stand 70 - 90% of the unmerchantable stems were felled just prior to the stand being commercially thinned (referred to as unmerchantable felling; UMF). Four of the sites received no prior treatment (Table 1; Appendix I).

1 formerly called merchantable thinning
2 formerly called cleaning
® Valmet, Valmet Logging Inc.
® Hanover, Marathon Letourneau Inc.

Canada

Nova Scotia

Table 1. Harvesters tested and average stand values prior to commercial thinning by location.

Location	Harvester Tested	Pre-treatment	Merchantable			Density (total stems/ha)	Ratio (Unt/Mt)[1]	Stand Index[2] (trees/m³)
			Diameter (cm)	Basal Area (m²/ha)	Volume (m³/ha)			
McCallum Settlement	Valmet®	PCT[3], 1970	14.5	45	382	4084	0.48	10.7
Hilden	Valmet®	None	11.6	35	187	8380	1.57	44.8
Trout Lake	Valmet®, Tufab	PCT, 1973	16.3	39	189	3194	0.64	16.7
Belmont	Valmet®, Tufab	None	15.1	52	286	6455	1.23	22.5
Tidnish	Tufab	UMF[4], 1991	17.1	43	241	2048	0.09	8.5
Liscombe	Rottne	PCT, 1970	14.1	37	192	4293	0.78	22.3
MacDonald Lake	Hanover®	None	15.9	49	223	2287	0.09	10.3
MacQuarrie Lake	Hanover®	None	24.1	44	314	1086	0.11	3.5
Average			16.7	43	246	3978	0.62	17.4

1 Ratio of unmerchantable trees to merchantable trees.
2 Stand Index is determined by dividing the total stems by the merchantable volume.
3 Precommercial thinning.
4 Unmerchantable trees felled prior to commercial thinning.

EQUIPMENT

Four single-grip mechanical harvesters were used in this trial; a Valmet®, Tufab, Rottne and Hanover® (Figures 1-4). Each is single-grip and multi-functional; capable of felling, delimbing, and bucking to length. All are produced by Scandinavian manufacturers except for the Hanover® which is produced by Marathon Letourneau of Quebec. For this trial, the Hanover® was fitted with a Tapio 600R single-grip processing head.

The width and height of the machines are very similar, averaging 2.8 and 3.5 m, respectively. The length of the machines ranged from 3.3 m for the Hanover® to 11.7 m for the Rottne (Table 2). The average reach is about 8.0 m, ranging from 6.5 m for the Tufab to 10 m for the Rottne. The Tufab is the lightest of the four harvesters, weighing approximately 7 000 kg less than the average of the 3 other harvesters.

The harvesters range in price from approximately $180,000 for the Tufab, to $450,000 for the Valmet®. Each of the operators for the trial were experienced in commercial thinning except for the operator of the Rottne who, at the time of the trial, had less than 3 weeks experience thinning.

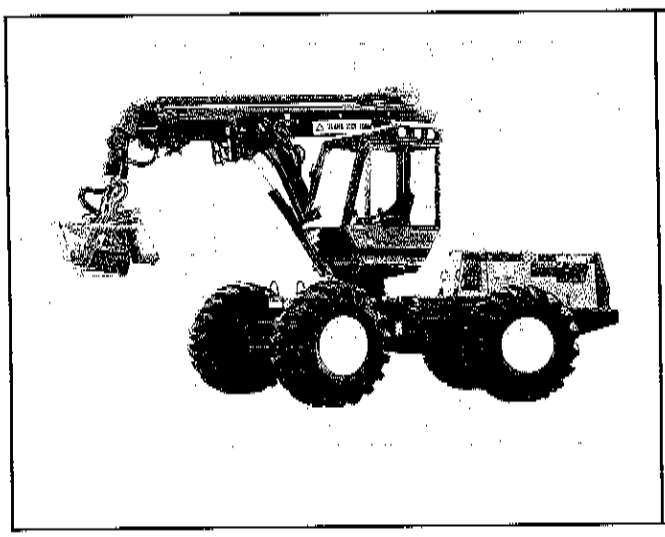


Figure 1. A Valmet® 901 harvester

Figure 2. A Tufab harvester

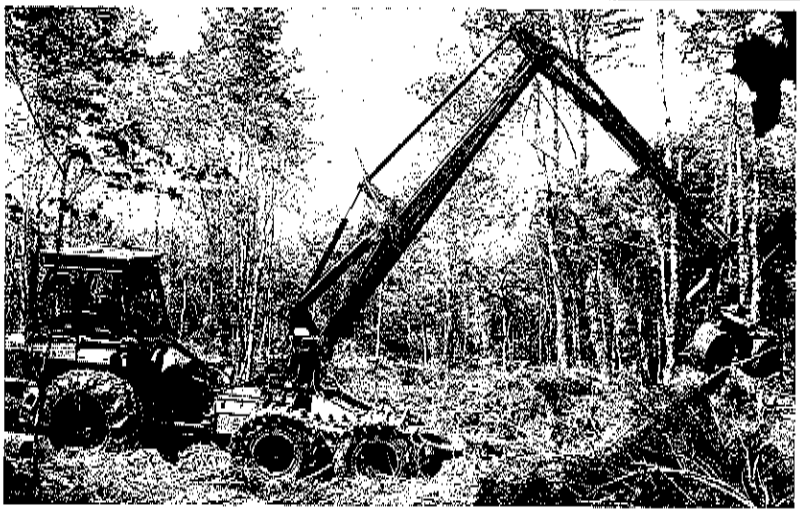


Figure 3. A Rottne harvester

Figure 4. A Hanover® harvester

Table 2. Specifications for the Valmet®, Tufab, Hanover® and Rottne single-grip harvesters.

Components	Valmet®	Tufab	Rottne	Hanover®
CARRIER				
Length (m)	5.8	4.0	11.7	3.3
Width (m)	2.5	2.6	2.8	3.2
Height (m)	3.7	2.9	3.7	3.5
Clearance (m)	0.6	0.6	0.6	0.7
Weight (kg)	11 000	5 500	13 100	14 700
BOOM				
Type	Valmet® 996	Mowi-Parr[1]	Rottne RG-81	Timberwolf
Reach (m)	7.6	6.5	10.0	8.0
FELLING HEAD				
Type	Valmet® 955	Tufab GS 301	Rottne RP-860	Tapio 600R
Grab Opening (m)	0.57	0.35	0.53	0.55
APPROXIMATE PRICE ($)	450,000	180,000	425,000	300,000

1 Mowi-parallelogram boom loader.

TREATMENTS

The machines were tested in eight different stands, however there were only two stands where the harvesters were working side-by-side (Valmet® & Tufab at Belmont & Trout Lake). Therefore the reader is cautioned not to make direct comparisons between machines used at different sites.

The commercial thinning was accomplished by first marking the location of parallel 3.5 metre wide extraction trails. The trails were spaced 15 to 20 m apart. Each harvester cut a section of trail before thinning the adjacent part of the leave strip by extending its boom into the stand. The operator was instructed to thin from

below and remove 40% of the merchantable basal area from within the thinned strips. At McCallum Settlement and Hilden, due to wider leave strips, a chainsaw was used to thin the portion of the leave strip beyond the harvesters reach.

At all but 2 sites, the merchantable trees cut were processed into random length logs (2.44 - 4.88 m) and/or 2.44 m pulpwood. At Trout Lake and Belmont, the Tufab was contracted to produce tree length wood (average length 7 m). In most cases the trees were processed in front of the harvester and piled along the trail. The branches and tops acted as a brush mat on which the harvester and forwarder travelled.

DATA COLLECTION & ANALYSES

Except for 2 sites, data collection and analyses were performed by the Nova Scotia Department of Natural Resources (DNR). At McCallum Settlement and Hilden, the task was a co-operative effort between DNR and Stora Forest Industries (SFI).

Pre-treatment assessment

In each stand 4 to 6 plots, measuring 15-17 m wide and 20 to 30 m long, were established (30 m plots were used in low density stands). The plots were selected to sample the range of stand conditions at each location (Appendix I).

In each plot, the diameter of every tree (>1 cm DBH; living and dead) was recorded. Fifteen trees were measured for height and diameter over the range of diameter classes within the plot. This information was used to estimate the height based on diameter for all trees. The height and diameter data was then entered into Honer's Volume equations (Honer, 1967) to estimate merchantable volume for each plot.

A Stand Index was calculated for each plot prior to commercial thinning by dividing the total number of stems by the merchantable volume (trees >9.1 cm DBH) of the plot. Stand index was used to predict commercial thinning productivity. The commercial thinning treatment will be referred to as "thinning" for the balance of the report.

Time study

Continuous time studies were performed in each plot during thinning to estimate machine productivity. Timing began when the machine entered the plot and ended when it exited. The time required to thin the plot, excluding delays or non-productive time, is referred to as productive machine-hours (PMH).

While each harvester was thinning, motion studies were performed using a work sampling technique (Miyata, et. al., 1981). This technique involved recording the machine activity occurring at 20 second intervals. Data was not collected when the machine was inoperable or not working. The results, therefore, define productive work activities only. The motion studies were used to estimate the percentage of total productive time required for each activity. Motion studies were not completed at McCallum Settlement, Hilden, MacDonald Lake and Liscombe.

Productivity

Productivity was determined by dividing the harvested volume by the PMH required to harvest it (m^3/PMH). The average number of merchantable trees harvested per productive machine hour was also calculated (trees/PMH).

Post-treatment assessment

Following thinning and extraction, an assessment was made to determine the damage to residual trees in each plot. In addition, the residual basal area and volume remaining in the plots were measured.

Data analyses

The following non-linear model was used to relate harvester productivity to stand index,

$$P=b_0 SI^{b_1}$$

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

b_0 & b_1 = Regression coefficients,

SI = Stand Index, expressed in trees/m^3, based on the total living and dead trees (>1 cm DBH) divided by the total standing merchantable volume (trees >9.1 cm DBH) prior to harvest, and

m^3 = Solid cubic metres.

RESULTS AND DISCUSSION

Productive-machine activities

The percentage of productive time dedicated to the various thinning activities for the Valmet®, Tufab and Hanover® is shown in Table 3. Felling (which includes positioning the boom to fell) and delimbing were the most time consuming activities for the harvesters. These 2 activities, accounted for 49% (29% and 20% respectively) of the productive time.

Table 3. Percentage of productive time to perform each work activity by harvester and location.

	Location						Average
	Valmet®		Tufab			Hanover®	
Activities	Trout Lake	Belmont	Trout Lake	Belmont	Tidnish	MacQuarrie Lake	
Felling[1]	33	33	33	41	19	15	29
Delimbing	15	14	25	17	18	32	20
Bucking	9	11	8	10	13	15	11
Positioning Boom to Process	6	13	3	3	13	13	9
Felling of Unmerchantable Trees	12	9	7	9	13	15	11
Discarding Tops	9	9	6	10	10	4	8
Travel	9	6	15	7	11	6	9
Selecting Trees	7	6	3	4	2	1	4

1 Felling also includes positioning the boom to fell.

Harvester productivity

The average productivity of the harvesters was 4.5 m^3/PMH, ranging from 1.5 to 10.2 m^3/PMH (Table 4). The number of merchantable trees processed per PMH averaged 63 and ranged from 24 to 113 trees/PMH.

As Stand Index increased (smaller tree size), harvester productivity rapidly decreased (Figure 5; Table 5) up to an SI of 10. Beyond SI 10, the rate of decrease was considerably less. For example, for an increase in Stand Index of 7, from 3 to 10 trees/m^3, predicted productivity decreases by 42%. However, for a similar increase in Stand Index, from 10 to 17, the decrease in productivity is 22%.

Valmet®

The relationship between Productivity and Stand Index for the Valmet® is shown in Figure 6 and Table 5. Harvester productivity over 4

Table 4. Productivity values for each harvester.

Harvester	Productivity			
	Average	Range	Average	Range
	(m^3/PMH)		(trees /PMH)[1]	
Valmet®	4.0	1.5 - 7.4	52	24 - 94
Tufab	4.3	2.8 - 5.8	69	45 - 81
Rottne	3.6	1.8 - 4.9	67	41 - 86
Hanover®	5.9	3.4 -10.2	63	47 -113
Average	4.5	1.5 -10.2	63	24 -113

1 Merchantable trees harvested per productive-machine hour.

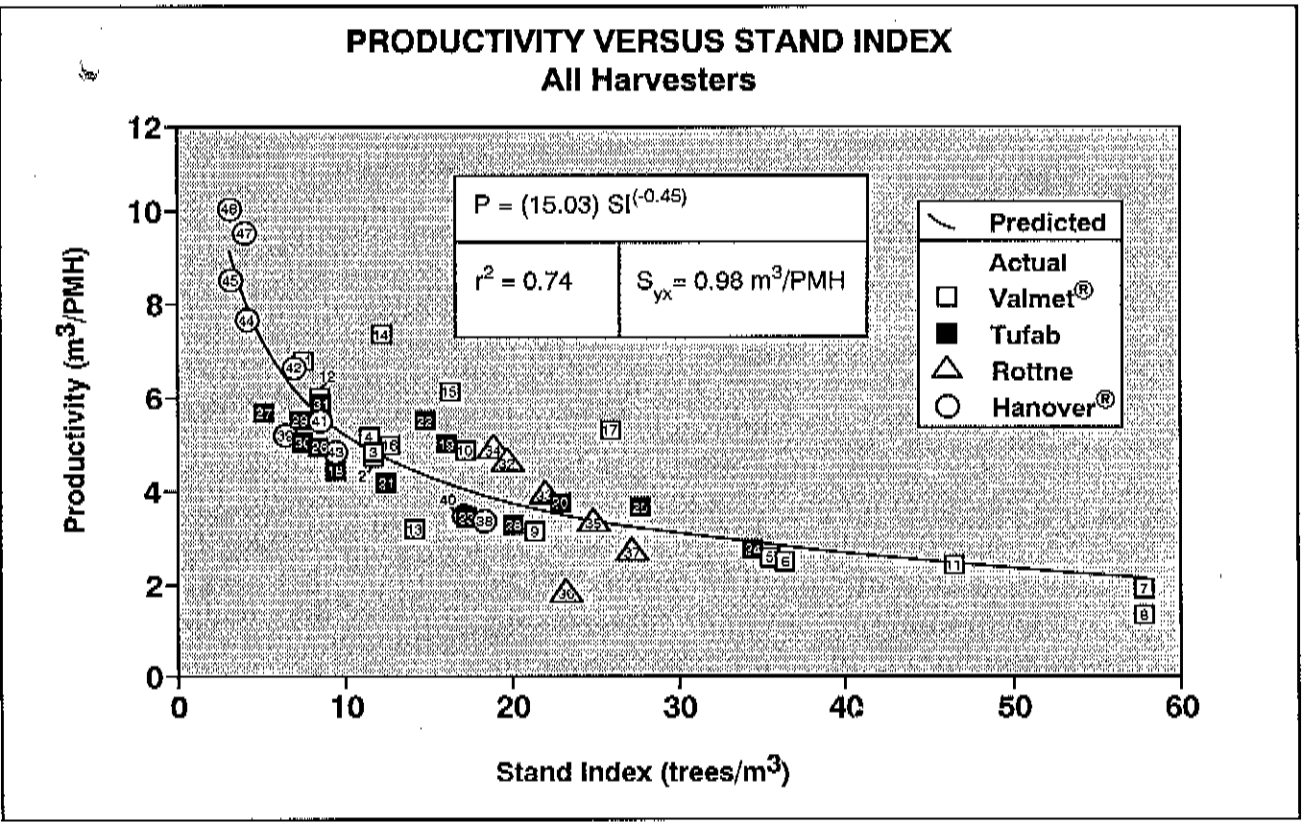


Figure 5. Predicted (P) and actual productivity in solid cubic metres per productive machine hour (m^3/PMH) versus Stand Index (SI), expressed in pre-treatment total trees per merchantable cubic metre (trees/m^3) for the Valmet®, Tufab, Rottne and Hanover® single-grip harvesters. Detailed plot data found in Appendices I and II are cross referenced by plot number (e.g. 14.)

Table 5. Predicted production levels for the Valmet®, Tufab and Hanover® harvesters by Stand Index and merchantable diameter[1].

Stand Index (trees/m³)[2]	Merchantable Diameter[3] (cm)	Productivity (m³/PMH)[4]			
		Valmet®	Tufab	Hanover®	Combined[5]
3	23.6	-	-	9.7	9.2
4	21.9	-	-	8.2	8.0
5	20.7	8.4	6.0	7.2	7.2
10	17.4	5.8	4.9	4.8	5.3
15	15.7	4.7	4.3	3.8	4.4
20	14.6	4.0	3.9	3.2	3.8
25	13.8	3.6	3.7	-	3.4
30	13.1	3.3	3.5	-	3.2
35	12.6	3.0	3.3	-	.9
40	12.2	2.8	-	-	2.8

1. The Rottne productivity was not regressed against Stand Index (SI) due to a limited sample size.
2. Determined by dividing the total number of trees by the merchantable volume prior to treatment.
3. Merchantable Diameter=(31.227) $SI^{(0.255)}$, $r^2 = 0.84$, $S_{yx} = 1.33$ cm.
4. Productive machine hours.
5. Based on all harvesters, including the Rottne.
- Outside range in which harvesters were tested.

locations averaged 4.0 m³/PMH, ranging from 1.5 to 7.4 m³/PMH (Table 4). The harvester processed, on average, 52 trees/PMH, ranging from 24 to 94 (Appendix II).

Tufab

The productivity of the Tufab as a function of Stand Index is illustrated in Figure 6 and Table 5. Over 3 sites, its productivity averaged 4.3 m³/PMH, ranging from 2.8 to 5.8 m³/PMH (Table 4). The number of trees processed/PMH averaged 69, ranging from 45 to 81.

The regression for the Tufab showed no sharp decline in productivity with increasing Stand Index. For example, the drop in productivity between 5 and 10 trees/m³ (18 %) is approximately the same as the decrease between 10 and 15 trees/m³ (12 %). This indicates that the Tufab had a fairly constant rate of production, for the tree sizes encountered. The Tufab does not appear to be as efficient as the larger more powerful harvesters in processing and delimbing larger trees (Table 5).

Rottne

The Rottne was tested at only one site, therefore no regression results are shown. Productivity averaged 3.6 m³/PMH, and ranged from 1.8 to 4.9 m³/PMH (Table 4 and Figure 7). On average the number of trees processed/PMH was 67, ranging from 41 to 86 trees per PMH. Measurements were taken from a limited number of samples that represent a narrow range of Stand Indices and the machine operator was inexperienced at thinning.

Hanover®

The regression for the Hanover® is shown in Figure 7 and Table 5. Over the 2 sites sampled, the harvester averaged 5.9 m³/PMH and ranged from 3.4 to 10.2 m³/PMH. The number of trees processed averaged 63, ranging from 47 to 113 trees/PMH. Productivity decreased at an increasing rate as tree size decreased. Between 3 and 10 trees/m³, productivity decreased by 51% from 9.7 to 4.8 m³/PMH.

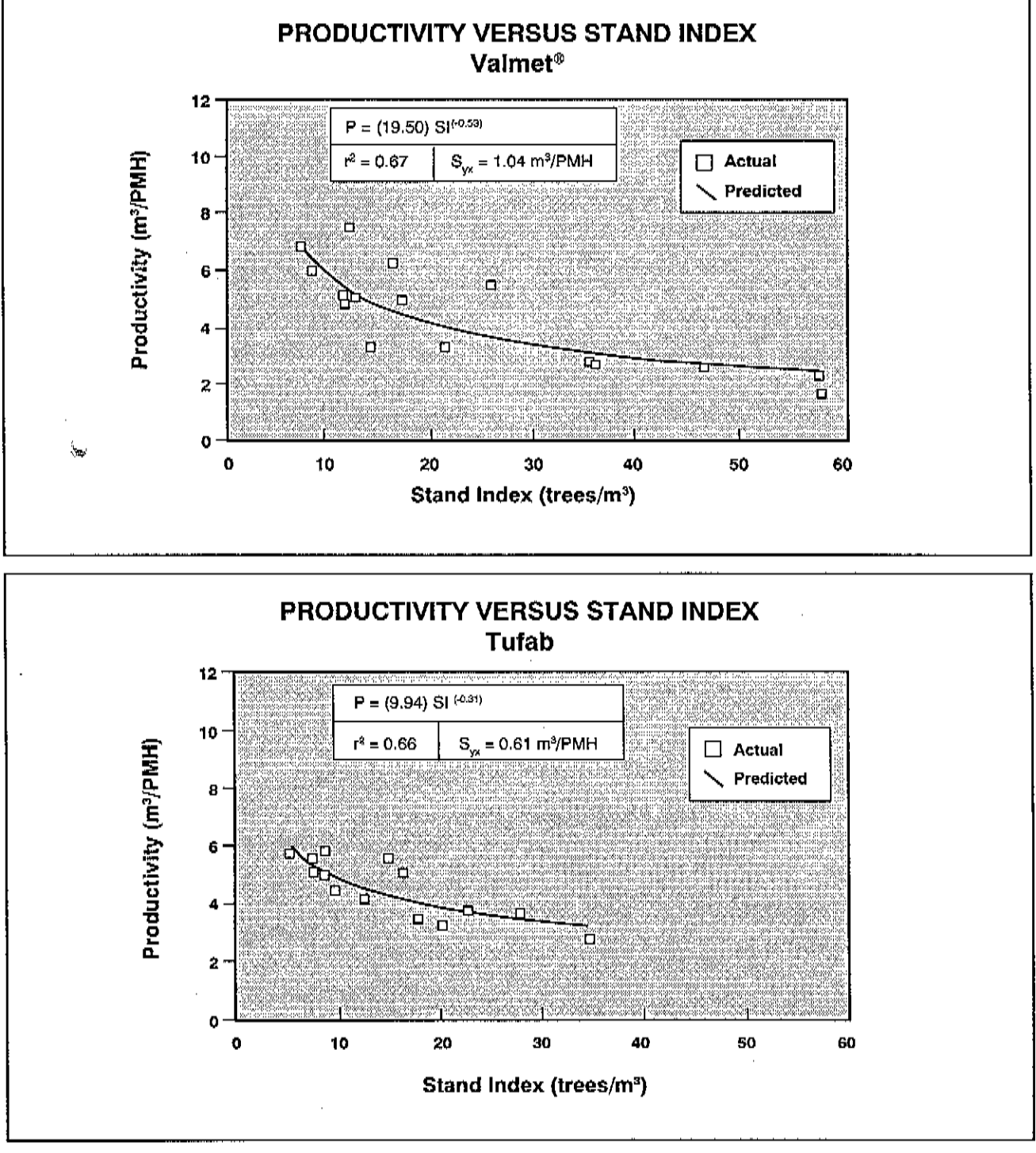
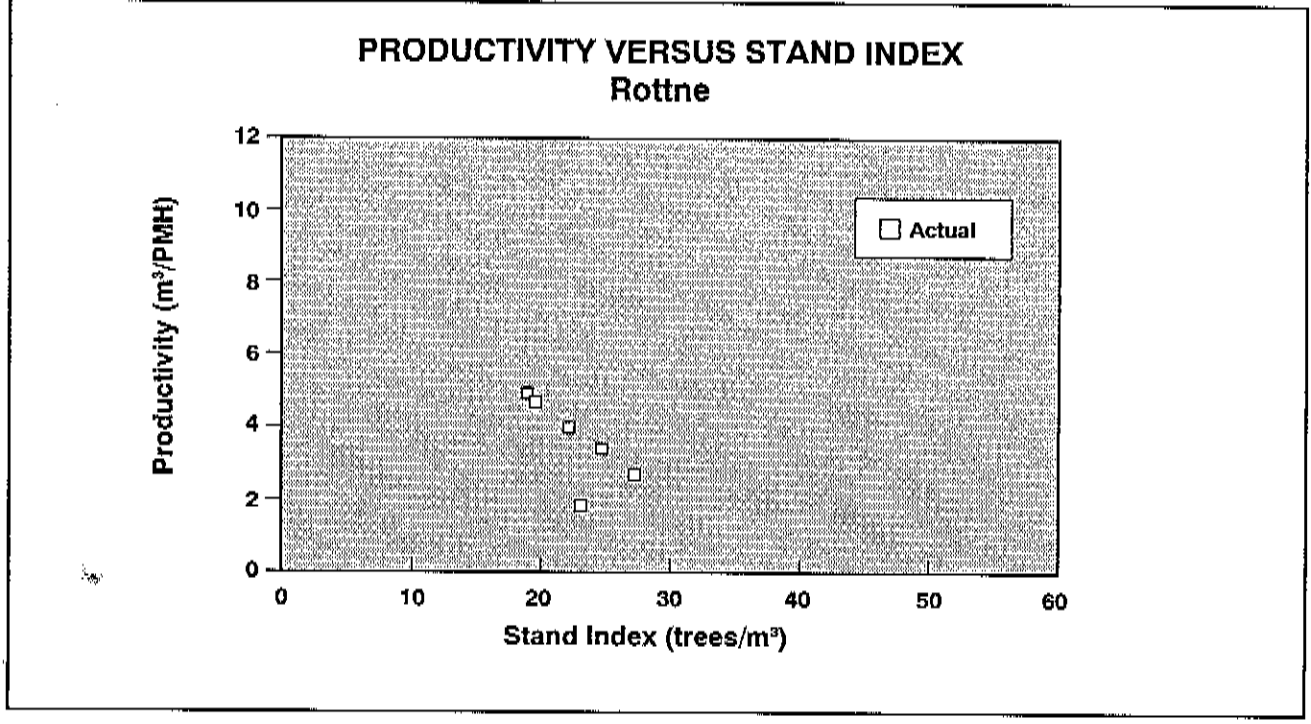


Figure 6. Predicted (P) and actual productivity in solid cubic metres per productive machine hour (m^3/PMH) versus Stand Index (SI), expressed in pre-treatment total trees per merchantable cubic metre (trees/m^3) for the Valmet® and Tufab single-grip harvesters.

POST-TREATMENT ASSESSMENT

Basal area and volume removal

On average, including trails, 51% of the total basal area (45% of the volume) was removed during thinning (Table 6). Within the thinned strips, 39% of the total basal area (30% of the volume) was removed. Basal area removals from the thinned strips were within 10% of targeted levels of 40% at all sites, with the exception of the Tufab at Trout Lake and the Rottne at Liscombe.



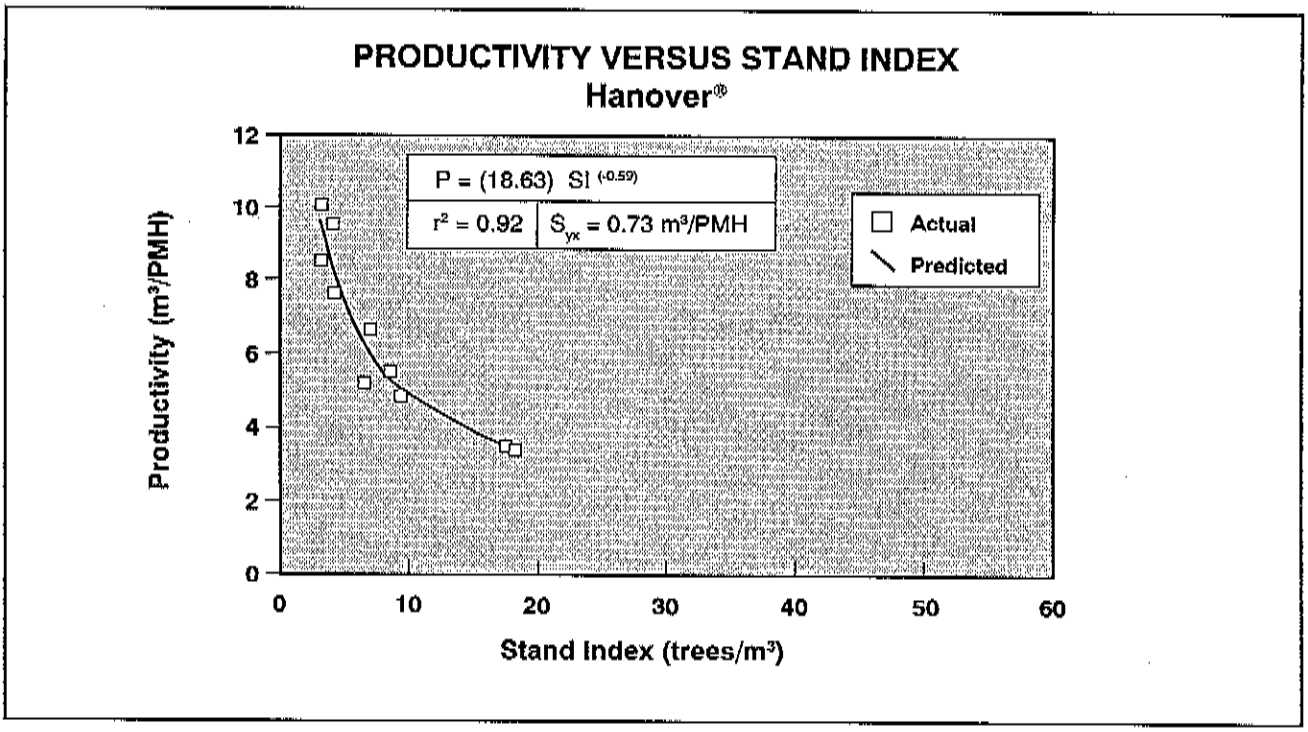


Figure 7. Predicted (P) and actual productivity in solid cubic metres per productive machine hour (m^3/PMH) versus Stand Index (SI), expressed in pre-treatment total trees per merchantable cubic metre (trees/m^3) for the Hanover.® Actual productivity versus Stand Index is shown for the Rottne single-grip harvester.

Leave-tree damage

The percentage of leave-trees damaged during thinning operations averaged 12% (Table 6). Damage levels ranged from 3% at McCallum Settlement to 23% at Tidnish. Damage was defined as any exposure of the cambium.

Table 6. Percentage of total basal area and volume removed from the thinned strips and extraction trails, and the percentage of trees damaged during thinning operations by harvester and location.

Harvester	Location	Basal Area Removal (%)		Volume Removal (%)		Damaged Trees (%)
		Overall[1]	Thinned Strips[2]	Overall[1]	Thinned Strips	
Valmet®	McCallum Sett	59	49	52	40	8
	Hilden	58	46	41	26	16
	Trout Lake	55	40	53	34	11
	Belmont	46	34	42	26	8
Tufab	Trout Lake	39	20	37	16	9
	Belmont	55	37	50	34	19
	Tidnish	51	36	46	33	23
Hanover®	MacDonald Lake	34	36	32	18	NA[3]
	MacQuarrie Lake	49	38	46	36	3
Rottne	Liscombe	61	51	52	32	NA
	Average	51	39	45	30	12

1 Estimated overall removal, based on the assumption that stand conditions were identical within trails and thinning zones.
2 Target basal area removals were 40% at all locations.
3 Data not available.

SUMMARY

The results of this study to obtain estimates of productivity of 4 mechanical harvesters (Valmet®, Tufab, Rottne and Hanover®) in commercial thinnings are as follows:

1. Productivity of the 4 harvesters was strongly related to Stand Index according to the following equation:

$$P=15.03(SI)^{-0.45}$$

where,
productivity (P) is solid cubic metres harvested per productive machine hour (m^3/PMH). Stand Index (SI) is the total number of trees (>1 cm DBH) per cubic metre of merchantable wood (trees/m^3) prior to thinning.

2. The combined productivity over 8 locations (47 plots) was 4.5 m^3/PMH,ranging from 1.5 to 10.2 m^3/PMH. The number of trees processed/PMH averaged 63, ranging from 24 to 113.

3. Valmet® productivity was related to Stand Index according to the following equation:

$$P=19.50(SI)^{-0.53}$$

The average productivity over 3 locations (17 plots) was 4.0 m^3/PMH, ranging from 1.5 to 7.4 m^3/PMH. The number of trees processed per PMH averaged 52, ranging from 24 to 94.

4. Tufab productivity was related to Stand Index according to the following equation:

$$P = 9.94(SI)^{-0.31}$$

The average productivity over 3 locations (14 plots) was 4.3 m^3/PMH, ranging from 2.8 to 5.8 m^3/PMH. The number of trees processed/PMH averaged 69, ranging from 45 to 81.

5. Rottne productivity was not regressed against Stand Index because of a limited sample size. The average productivity (6 plots) was 3.6 m^3/PMH, ranging from 1.8 to 4.9 m/PMH. The number of trees processed/PMH averaged 67, ranging from 41 to 86.

6. Hanover® productivity was related to Stand Index according to the following equation:

$$P = 18.63(SI)^{-0.59}$$

The average productivity at 2 locations (10 plots) was 5.9 m^3/PMH, ranging from 3.4-10.2 m^3/PMH. The number of trees processed/PMH averaged 63, ranging from 47 to 113.

7. The two most time consuming activities for the harvesters in commercial thinning were felling (includes positioning the boom to fell) and delimbing. These two activities together accounted for 49% of productive time (29 and 20% respectively).

8. On average, 51% of the total basal area and 45% of the volume was removed from each of the stands during the thinning operations. Within the thinned strips, 39% of the basal area and 30% of the volume were removed.

9. Approximately 12% of the trees were damaged during thinning operations.

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APPENDIX I

Plot averages by location and harvester prior to commercial thinning.

Location	Plot	Pre-Treatment	Diameter (cm)		Basal Area (m^2/ha)		Volume[1] (m^3/ha)	Density (trees/ha)			Ratio[2] (Umt/Mt)	Stand Index[3] (trees/m^3)
			Total	Merch.	Total	Merch.	Merch.	Merch.	Unmerch.	Total		
VALMET®												
McCallum Settlement	1	PCT[4]	14.8	15.1	40	40	315	2206	125	2331	0.06	7.40
	2	PCT	12.1	13.7	53	46	394	3134	1444	4578	0.46	11.62
	3	PCT	12.1	14.5	59	51	438	3079	1994	5074	0.65	11.58
	4	PCT	12.1	14.6	51	43	380	2588	1763	4352	0.68	11.45
		Average	12.8	14.5	51	45	382	2752	1332	4084	0.48	10.69
Hilden	5	None	9.4	12.4	60	44	243	3656	4977	8633	1.36	35.52
	6	None	9.5	12.2	52	37	202	2857	4424	7281	1.55	36.06
	7	None	8.2	10.6	44	29	145	3257	5131	8388	1.58	57.85
	8	None	8.1	11.1	48	32	159	3287	5930	9217	1.80	57.97
		Average	8.8	11.6	51	35	187	3264	5116	8380	1.57	44.81
Trout Lake	9	PCT	12.2	16.1	33	30	137	1366	1566	2933	1.15	21.41
	10	PCT	13.1	14.1	33	32	142	1933	500	2433	0.26	17.13
	11	None	10.8	13.5	57	45	210	2633	7166	9799	2.72	46.67
	12	PCT	17.7	18.6	61	61	348	2533	400	2933	0.16	8.43
	13	PCT	16.1	17.6	42	42	200	2300	233	2533	0.10	12.67
	14	PCT	14.6	16.6	47	46	243	2434	499	2933	0.21	12.07
		Average	14.1	16.1	46	43	213	2200	1727	3927	0.79	18.44
Belmont	15	None	17.2	17.4	53	50	295	2200	2600	4800	1.18	16.27
	16	None	13.7	16.5	48	46	268	2167	1633	3800	0.75	14.18
	17	None	14.4	14.5	53	49	263	2800	3999	6799	1.48	25.85
		Average	15.1	16.1	51	48	275	2389	2744	5133	1.15	18.67
All		Average	12.0	14.1	51	44	264	2651	2730	5381	1.03	20.38
TUFAB												
Trout Lake	18	PCT[4]	17.4	18.4	33	33	176	1300	367	1667	0.28	9.47
	19	PCT	14.4	15.6	37	37	155	1833	667	2500	0.36	16.13
	20	PCT	12.6	16.5	33	33	165	1667	2066	3733	1.24	22.62
	21	PCT	15.5	15.9	33	33	156	1700	233	1933	0.14	12.39
	22	PCT	14.5	16.1	37	37	167	1833	633	2466	0.35	14.77
		Average	14.9	16.5	35	35	164	1667	793	2460	0.48	15.00
Belmont	23	None	13.8	15.1	64	57	328	3200	2600	5799	0.81	17.68
	24	None	10.1	12.3	70	57	286	4066	5833	9899	1.40	34.61
	25	None	12.0	15.0	60	53	275	2899	4733	7632	1.63	27.75
		Average	12.0	14.1	65	56	296	3388	4389	7777	1.30	26.27

1 Solid cubic metres.
2 Ratio of unmerchantable to merchantable stems.
3 Calculated by dividing the total number of stems by the merchantable volume.
4 Precommercial thinning.

APPENDIX I Continued

Plot averages by location and harvester prior to commercial thinning.

Location	Plot	Pre-Treatment	Diameter (cm)		Basal Area (m^2/ha)		Volume[1] (m^3/ha)	Density (trees/ha)			Ratio[2] (Umt/Mt)	Stand Index[3] (trees/m^3)
			Total	Merch.	Total	Merch.	Merch	Merch.	Unmerch.	Total		
TUFAB (continued)												
Tidnish	26	UMF[4]	16.6	17.0	53	52	289	2282	154	2436	0.07	8.43
	27	UMF	19.7	20.2	45	45	295	1410	77	1487	0.05	5.04
	28	UMF	12.6	13.8	35	32	139	2128	667	2795	0.31	20.10
	29	UMF	17.2	17.4	35	35	202	1461	26	1487	0.02	7.36
	30	UMF	17.5	17.7	47	47	270	1897	52	1949	0.03	7.22
	31	UMF	16.4	16.6	45	44	251	2051	77	2128	0.04	8.48
	Average		16.7	17.1	43	43	241	1872	176	2048	0.09	8.50
All	Average		14.5	15.9	48	45	234	2309	1786	4095	0.77	17.50
ROTTNE												
Liscombe	32	PCT[5]	12.1	14.0	40	35	175	2311	1111	3422	0.48	19.55
	33	PCT	11.4	13.7	49	42	219	2844	2000	4844	0.70	22.12
	34	PCT	11.9	14.3	56	46	259	2689	2200	4888	0.82	18.87
	35	PCT	11.1	14.0	44	35	182	2623	1888	4511	0.72	24.79
	36	PCT	10.8	15.4	33	27	146	1221	2156	3377	1.77	23.13
	37	PCT	10.9	13.2	44	38	173	2819	1892	4711	0.67	27.23
	AVERAGE		11.4	14.1	44	37	192	2418	1875	4293	0.78	22.30
HANOVER[6]												
MacDonald Lake	38	None	12.9	13.6	48	45	168	2724	314	3038	0.12	18.08
	39	None	17.8	18.1	50	50	258	1607	59	1666	0.04	6.46
	40	None	12.7	13.0	45	45	175	2803	235	3038	0.08	17.36
	41	None	16.3	16.6	52	52	255	1960	196	2156	0.10	8.45
	42	None	17.8	17.9	52	52	257	1705	59	1764	0.03	6.86
	43	None	15.5	15.9	49	48	223	1980	78	2058	0.04	9.23
	Average		15.5	15.9	49	49	223	1830	157	2287	0.09	10.26
MacQuarrie Lake	44	None	21.4	25.2	31	30	210	600	267	867	0.44	4.13
	45	None	23.3	23.6	56	56	421	1267	44	1311	0.03	3.11
	46	None	24.6	25.7	43	43	298	824	78	902	0.09	3.03
	47	None	21.5	22.0	46	46	327	1206	59	1265	0.05	3.87
	Average		22.7	24.1	44	44	314	974	112	1086	0.11	3.46
All	Average		19.1	20.0	47	47	267	1402	135	1687	0.10	6.32

1 Solid cubic metres.
2 Ratio of unmerchantable to merchantable stems.
3 Calculated by dividing the total number of stems by the merchantable volume.
4 Unmerchantable stems were cut prior to commercial thinning.
5 Precommercial thinning.

APPENDIX II

Production figures by location, plot and harvester.

Location	Plot	Trees Cut (#)		Time[1] (min)	Volume Cut (m^3)	Merchantable Trees Cut (#/PMH)	m^3/PMH[2]	Merchantable[3] trees/m^3
		Merch.	Total					
VALMET®								
McCallum Settle.	1	28	30	17.8	2.02	94	6.79	13.9
	2	49	72	51.1	4.03	58	4.73	12.2
	3	40	66	47.9	3.84	50	4.81	10.4
	4	29	49	37.8	3.19	46	5.06	9.1
	Tot/Avg	146	217	154.6	13.07	57	5.07	11.2
Hilden	5	33	79	70.5	3.09	28	2.64	10.7
	6	22	57	55.3	2.34	24	2.54	9.4
	7	24	62	50.0	1.27	29	1.53	18.9
	8	21	60	48.2	1.71	26	2.13	12.3
	Tot/Avg	100	258	224.0	8.41	27	2.25	11.9
Trout Lake	9	21	62	21.2	1.12	59	3.17	18.8
	10	39	53	24.9	2.03	94	4.89	19.2
	11	66	245	74.3	3.05	53	2.46	21.6
	12	52	60	54.7	5.42	57	5.95	9.6
	13	39	43	30.6	2.54	76	4.98	15.4
	14	37	58	27.6	3.41	80	7.41	10.9
	Tot/Avg	254	521	233.3	17.57	70	4.52	14.5
Belmont	15	39	105	32.7	3.37	72	6.18	11.6
	16	37	75	49.5	2.65	45	3.21	14.0
	17	50	154	33.3	2.98	90	5.37	16.8
	Tot/Avg	126	334	115.5	9.00	65	4.68	14.0
All	Tot/Avg	632	1330	727.4	48.05	52	3.96	13.2
TUFAB								
Trout Lake	18	17	22	22.4	1.67	45	4.47	10.2
	19	27	37	23.2	1.96	70	5.07	13.8
	20	26	58	21.7	1.37	72	3.79	19.0
	21	21	24	19.8	1.38	64	4.18	15.2
	22	29	39	23.1	2.15	75	5.58	13.5
	Tot/Avg	120	180	110.2	8.53	65	4.64	14.1
Belmont	23	66	120	48.8	2.84	81	3.49	23.2
	24	91	222	82.5	3.86	66	2.81	23.6
	25	62	163	57.9	3.58	64	3.71	17.3
	Tot/Avg	219	505	189.2	10.28	69	3.26	21.3

1 Productive machine time (minutes) to harvest trees.
2 Determined by dividing the volume harvested by the productive machine hours (PMH).
3 Determined by dividing the merchantable trees cut by the merchantable volume harvested.

APPENDIX II Continued

Production figures by location, plot and harvester.

Location	Plot	Trees Cut (#)		Time[1] (min)	Volume Cut (m^3)	Merchantable Trees Cut (#/PMH)	m^3/PMH[2]	Merchantable[3] trees/m^3
		Merch.	Total					
TUFAB (continued)								
Tidnish	26	68	73	57.8	4.78	71	4.98	14.2
	27	37	39	29.7	2.85	75	5.76	13.0
	28	64	84	49.6	2.73	77	3.29	23.4
	29	39	40	41.2	3.50	57	5.09	11.1
	30	50	51	44.3	4.09	68	5.53	12.2
	31	38	39	28.7	2.79	79	5.83	13.6
	Tot/Avg	296	326	251.3	20.74	71	4.95	14.3
ALL *	Tot/Avg	635	1011	550.7	39.55	69	4.31	15.9
ROTTNE								
Liscombe	32	68	126	47.6	3.69	86	4.65	18.4
	33	91	205	76.7	4.99	71	3.90	18.2
	34	90	201	74.6	6.08	72	4.89	14.8
	35	69	177	67.4	3.74	61	3.33	18.4
	36	34	140	50.0	1.50	41	1.80	22.7
	37	61	173	55.1	2.47	66	2.69	24.7
	Tot/Avg	413	1022	371.4	22.47	67	3.63	18.4
HANOVER®								
McDonald Lk.	38	79	88	88.8	5.04	53	3.41	15.7
	39	44	46	46.5	4.04	57	5.21	10.9
	40	62	67	60.0	3.51	62	3.51	17.7
	41	56	62	50.6	4.66	66	5.53	12.0
	42	39	40	32.0	3.55	73	6.66	11.0
	43	72	75	50.2	4.07	86	4.86	17.7
	Tot/Avg	352	378	328.0	24.87	64	4.55	14.2
McQuarrie Lk.	44	38	55	20.2	2.59	113	7.69	14.7
	45	43	45	54.5	7.80	47	8.59	5.5
	46	25	27	30.6	5.19	49	10.18	4.8
	47	31	33	29.1	4.66	64	9.61	6.7
	Tot/Avg	137	160	134.4	20.25	61	9.04	6.8
All	Tot/Avg	489	538	462.4	45.12	63	5.85	10.8

1 Productive machine time (minutes) to harvest trees.
2 Determined by dividing the volume harvested by the productive machine hours (PMH).
3 Determined by dividing the merchantable trees cut by the merchantable volume harvested.

Metric	Conversion Factors	Imperial
cm	x 0.39370 =	in
m	x 3.28084 =	ft
ha	x 2.47105 =	ac
m^3/ha (2.44 m Swd)	x 0.17864 =	cds/ac
m^2/ha	x 4.356 =	ft^2/ac

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