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WORKER PRODUCTIVITY IN MERCHANTABLE THINNING OPERATIONS - Part II

INTRODUCTION

Over the past 11 years the amount of silviculture carried out in Nova Scotia has increased dramatically (Kuhnke, 1989). Most of this work is carried out by silvicultural contractors and paid for in large part from funds available under cost shared federal-provincial agreements. To provide data necessary for refining rates paid for this work, a series of productivity studies were initiated beginning in 1986. A preliminary report entitled "Worker Productivity in Merchantable Thinning, Shelterwood and Remnant Removal Operations" (NSDLF) was published in 1989. Since then, additional studies have been undertaken and more data have been collected. This report summarizes the results derived from the combined data base for merchantable thinnings.

METHODS

Sixteen softwood stands with greater than 60% stocking and 14 cm in merchantable diameter were chosen for this study. These stands were divided into thirty-six blocks with uniform site conditions. Each block was large enough to keep one worker busy for a minimum of two days. Site and stand characteristics capable of affecting worker productivity were recorded (Appendix I). A post-stand assessment was carried out to determine the actual amount of basal area removal.

The target basal area removal for each block was determined using pre-stand assessment data and the guidelines in the Nova Scotia Forestry Field Handbook (NSDLF, 1988). Parallel extraction trails, approximately 20 metres apart and 4 metres wide, were cut at the same time as the leave strips were thinned. The thinning was done from below (Smith, 1962: 64) and was carried out using chain-saws. The harvested wood was cut into random length logs and 2.4 metre pulpwood, and piled within reach of the forwarder.

Canada

Nova Scotia

The operations were performed between January 1987 and November 1989. The first 19 blocks were thinned by 6 forestry instructors from the Commercial Safety College in Masstown, Nova Scotia (NSDLF, 1989). The remaining 17 blocks were thinned by local contractors employing woods workers of average experience.

Time Study

A variation of the work sampling method (Miyata et al. 1981) was used to determine the relative amount of time spent on various activities by each worker. This method consisted of taking instantaneous observations of an operation at predetermined time intervals (for this study, every 30 seconds) and noting which activity (e.g. felling, limbing, saw maintenance) is occurring. The activities were grouped as either productive or non-productive (Appendix II). Productive man hours (PMH) were calculated by dividing productive activity occurrences by total occurrences and multiplying the quotient by the total time to harvest the block. Each block was work sampled for an average of 6 hours and 5 minutes. The average total time to harvest a block was 20 hours and 49 minutes.

All wood harvested was scaled for solid cubic volume. The pulp volume of each stick was obtained from top and butt diameter measurements and Smalian's formula. Sawlog volume was calculated using the New Brunswick log scale. Productivity was calculated by dividing the volume harvested (from the block) by the productive time. Volumes were also expressed in stacked measure. Cubic metres solid (m^3) was converted to cubic metres stacked $m^3(s)$ by multiplying by 1.6.

Data Analyses

Non-linear and linear regressions were used to relate productivity to various pre-treatment stand and site factors (Appendix I). The results section discusses only the best relationship. Stand Index was used as a predictor of productivity in this relationship and was computed by dividing the number of trees by the solid volume (pre-treatment values). Stand Index was then related to mean quadratic merchantable diameter (MD) which was based on trees greater than 9 cm in diameter at breast height.

RESULTS AND DISCUSSION

Activities

The time spent on productive activities was 84% (Table 1). Saw maintenance and repairs constituted an additional 8% of the time, while the remaining 8% was comprised of personal breaks and other non-productive activities.

Limbing and bucking took the largest amount of productive time (41%), followed by piling (17%) and felling merchantable trees (12%). Felling the unmerchantable trees took 7% of the productive time, the same amount as felling preparation (7%) and moving (7%). Saw maintenance took 46% of the non-productive time while personal breaks took 40%.

Table 1. Percent of time spent on productive and non-productive thinning activities.

Activities	Percent of		
	Total Time	Productive Time	Non-Productive Time
PRODUCTIVE			
Felling Unmerchantable	6	7	NA[1]
Felling Preparation	6	7	NA
Felling Merchantable	10	12	NA
Freeing Hung-Up Trees	5	6	NA
Limbing and Bucking	35	41	NA
Piling	14	17	NA
Moving	6	7	NA
Other Productive	2	2	NA
Sub Total	84	100	NA
NON-PRODUCTIVE			
Breaks	7	NA	40
Saw Maintenance	7	NA	46
Saw Repair	1	NA	8
Other Non Productive	1	NA	6
Sub Total	16	NA	100
Total	100	100	100

[1]NA = Not Applicable.

Productivity Versus Stand Index

From graphical analysis, it was found that productivity was inversely related, in a non-linear form, to Stand Index. The following model was used in the regression analysis:

$$P = b_0 SI^{b_1} \qquad [1]$$

Where, P = Productivity expressed in m^3/ PMH based on the scaled merchantable volume divided by the productive man hours to harvest and pile,

b_0 & b_1 = Regression coefficients,

SI = Stand Index, expressed in trees / m^3, based on the merchantable number of trees (> 9 cm DBH) divided by the total merchantable volume prior to harvest,

m^3 = Cubic metres solid.

Figure 1 shows the best fit regression equation based on this model ($r^2 = 0.41$, standard error of estimate = 0.40 m^3/PMH). This equation is similar to the one published in the previous report (NSDLF, 1989) except that productivity is expressed in cubic metres solid rather than cubic metres stacked.

Table 2 shows the predicted average daily production values for different levels of Stand Index and average quadratic merchantable diameter. Average daily production is based on an 8 hour day, comprised of 6.7 productive man hours, assuming 84% productive time (Table 1).

Figure 1 and Table 2 show that worker productivity increases at an accelerating rate as the Stand Index (SI) decreases. For example, when SI decreases from 12 to 10 trees/m^3, productivity improves by only 0.1 m^3/PMH. However, when SI decreases from 4 to 2, productivity improves by 0.7 m^3/PMH (Figure 1). For a Stand Index of 2 or a MD of 27 cm, a worker could expect to harvest approximately 14.3 m^3/day (6.3 cords/day), whereas for a stand with a

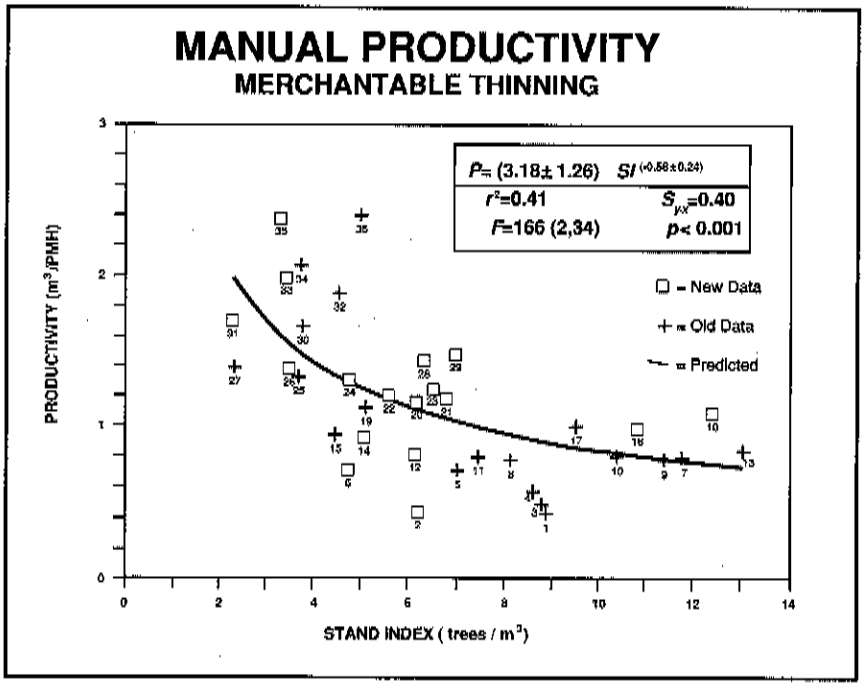

Figure 1. **Predicted (P) and actual productivity in m³ solid per productive man hour versus Stand Index (SI) expressed in merchantable trees per m³ solid prior to thinning.**

Table 2. **Predicted daily production[1] in merchantable thinnings by Stand Index and Merchantable Diameter.**

Stand Index	Merchantable Diameter[2]		Production per Day		
(trees/m³)	(cm)	(in)	(m³)	(m³ (s))	(cords)
2	27.1	10.7	14.3	22.9	6.3
3	23.5	9.3	11.3	18.1	5.0
4	21.2	8.4	9.6	15.3	4.2
5	19.6	7.7	8.4	13.5	3.7
6	18.4	7.2	7.6	12.1	3.4
7	17.4	6.9	6.9	11.1	3.1
8	16.6	6.5	6.4	10.3	2.8
9	16.0	6.3	6.0	9.6	2.7
10	15.4	6.1	5.7	9.1	2.5
11	14.9	5.9	5.4	8.6	2.4
12	14.4	5.7	5.1	8.2	2.2

1 Assuming 6.7 productive man hours per day and productivity based on equation [1].
2 Based on the equation MD = 34.655 (SI) $^{-0.35}$ where $r^2 = 0.97$ and $S_{y \cdot x} = 0.53$ cm

SI of 12, or a MD of 14 cm, production would drop to 5.1 m³/day (2.2 cords/day) (Table 2). To produce at least 9.6 m³/day (4.2 cords/day) the SI would have to be 4 or less, which is equivalent to an MD of 21 cm (8.4 in) or greater.

Other versions of Stand Index used as predictors of productivity, included total frequency (TF) divided by merchantable volume, and TF divided by total volume. Stand Index calculated from these variables did not improve the predictive power of SI.

Post Stand Assessment

In 26 of the blocks, pre and post-stand assessments were carried out. The total basal area removed averaged 38%. This average falls within the range recommended by the Forestry Field Handbook (NSLDF, 1988).

SUMMARY

The major results of this study to determine worker productivity in merchantable thinning treatments are as follows:

1. Workers spent 84% of their time on productive activities. The most time consuming productive activity was limbing and bucking (35%) while the most time consuming non-productive activities were personal breaks (7%) and saw maintenance (7%).

2. Worker productivity (P) expressed in merchantable cubic metres solid per productive man hour (m^3 /PMH) is inversely related to Stand Index (SI), (merchantable trees per m^3 of merchantable volume prior to thinning) in a curvilinear form according to the following regression equation:

$$P = 3.18(SI)^{-0.58}$$

3. Based on this regression equation and assuming 6.7 productive hours per man day, a worker would expect to produce 5.1, 9.6, and 14.3 m^3 solid per day (2.2, 4.2, and 6.3 cords per day) for stand indices of 12, 4 and 2 respectively and average merchantable diameters of 14, 21, and 27 cm respectively.

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APPENDIX I

SITE AND STAND CHARACTERISTICS PRIOR TO THINNING AND PRODUCTIVITY BY BLOCK NUMBER.

Block	Prod[1]	Temp[2]	Hist[3]	Topo[4]	Crown[5]	Height[6] (m)		Basal Area (m^2/ha)		Frequency (Trees/Ha)		Volume (m^3/ha)		Diameter (cm)		SI[7] (Trees /m^3)
(#)	(m^3/PMH)	(°C)				Tot	Merch	Tot	Merch	Tot	Merch	Tot	Merch	Tot	Merch	
1	0.43	-15	1	3	1	12	13	39	36	3121	1795	239	201	12.5	16.0	8.91
2	0.44	11	3	1	3	14	15	38	34	4791	1258	232	202	10.2	18.5	6.22
3	0.48	-9	1	1	1	13	14	43	40	2674	2092	285	237	14.3	15.7	8.83
4	0.57	-11	3	1	1	12	13	55	52	5122	2551	340	295	11.7	16.1	8.64
5	0.71	-13	3	1	1	13	13	42	40	2067	1699	275	241	16.0	17.4	7.05
6	0.72	14	1	1	3	15	15	34	33	1569	1030	242	218	16.5	20.1	4.72
7	0.77	8	1	1	1	12	12	34	33	2271	1940	206	170	13.9	14.6	11.40
8	0.77	-12	3	1	1	13	14	45	41	3377	1999	296	245	13.0	16.2	8.17
9	0.79	-1	3	1	1	11	11	49	42	4141	2439	273	207	12.3	14.9	11.80
10	0.80	17	1	1	1	12	12	31	28	2704	1577	186	151	12.1	15.1	10.41
11	0.80	-9	1	1	1	13	14	39	37	2427	1676	261	223	14.4	16.8	7.50
12	0.82	11	3	1	3	13	14	27	23	4443	828	158	134	8.9	18.8	6.18
13	0.83	20	3	1	1	11	12	35	31	3235	2025	201	155	11.8	14.0	13.08
14	0.93	14	1	1	3	15	15	30	29	1470	971	215	192	16.0	19.3	5.05
15	0.95	-7	ND[8]	ND	1	17	17	53	51	2095	1697	430	381	17.9	19.6	4.46
16	0.98	21	1	2	2	12	12	34	28	3875	1537	191	142	10.7	15.2	10.86
17	1.00	20	3	1	1	12	12	34	32	2149	1609	196	168	14.1	16.0	9.56
18	1.08	21	1	2	2	11	12	57	47	7729	2859	308	229	9.7	14.5	12.46
19	1.13	-11	ND	ND	1	17	17	43	42	1748	1549	343	306	17.7	18.6	5.07
20	1.16	22	1	ND	3	15	15	41	40	1974	1559	287	254	16.3	18.0	6.15
21	1.18	16	1	1	3	15	15	38	37	1811	1638	276	241	16.3	17.0	6.81
22	1.20	22	1	ND	3	15	15	37	35	2429	1231	251	221	14.0	19.1	5.58
23	1.24	8	1	1	3	13	14	36	32	2441	1253	226	192	13.7	18.0	6.53
24	1.32	6	ND	ND	2	16	16	35	35	1107	1107	255	234	20.3	20.3	4.73
25	1.33	-9	ND	ND	1	17	17	64	64	1778	1778	524	487	21.4	21.4	3.65
26	1.38	3	ND	ND	2	17	17	37	37	946	946	291	270	22.4	22.4	3.51
27	1.40	18	ND	ND	1	17	17	43	43	780	780	314	336	26.6	26.6	2.32
28	1.43	22	1	1	2	15	16	52	49	3091	2068	379	327	14.5	17.3	6.33
29	1.48	8	1	1	3	13	13	37	33	2397	1347	228	193	14.0	17.8	6.98
30	1.67	-12	ND	ND	1	18	18	43	42	1439	1240	364	330	19.5	20.8	3.76
31	1.71	10	3	1	3	20	20	49	48	1211	909	431	401	22.6	25.9	2.27
32	1.88	19	2	3	2	ND	14	40	39	1942	1114	257	248	16.3	21.1	4.50
33	1.99	11	3	1	2	18	19	37	35	2340	914	296	268	14.2	21.8	3.41
34	2.06	14	2	3	2	ND	15	34	32	1899	806	245	219	15.0	22.5	3.69
35	2.37	21	2	1	2	17	17	49	47	2399	1129	381	347	16.0	22.9	3.25
36	2.38	19	2	3	2	ND	12	45	44	2005	1241	278	251	16.9	21.2	4.95

[1]Prod = Productivity measured in m^3 solid per productive man hour.
[2]Temp = Mean temperature in °C on the day of thinning.
[3]Hist = Stand origin: 1 = Softwood cut 2 = Partial cut 3 = Natural
[4]Topo = Topography: 1 = Level (0-5%) 2 = Undulating (6-15%) 3 = Rolling (16-30%)
[5]Crown = Crown: Live and dead limbs as a percent of the merchantable stem: 1 = 0 - 33% 2 = 34 - 60% 3 = 61+%
[6]Height = Height of tree of average basal area (Lorey's Height).
[7]SI = Stand Index expressed in merchantable trees per m^3 solid merchantable volume (pre-treatment values).
[8]ND = No Data

APPENDIX II.

DEFINITIONS OF WORK ACTIVITIES RECORDED DURING THE TIME STUDIES.

Productive Activities:

Felling Preparation -The time required to determine the direction of fall and to clear unmerchantable stems beside the crop tree.

Felling Unmerchantable Trees -The time to fell unmerchantable trees scattered throughout the stand or in clumps.

Felling Merchantable Trees - The time from the initial cut to notch the tree to the time at which the tree hits the ground or becomes hung up.

Freeing Hung-Up Trees - The time from which the tree becomes hung up to when it is laying on the ground. It also includes the time required to get help, if necessary.

Limbing and Bucking - The time required to remove the branches, top, and cut the tree into sections. Includes time required to physically remove brush to facilitate limbing and bucking.

Piling - The time to pile pulpwood or logs for the forwarder or skidder.

Moving - The time spent moving during productive activities only.

Other Productive - The time spent on productive activities other than the preceding categories.

Non-Productive Activities:

Breaks - Personal breaks.

Saw Maintenance - Time spent doing routine saw maintenance including gas, oil, and filing. Includes the time spent moving to carry out these activities.

Saw Repair -Time spent repairing the chain-saw (includes moving).

Other Non Productive - Time spent in other non-productive activities not listed.

Other:

Lunch -Time spent by operator on a formal lunch break. This time was subtracted from the total time and not considered either as a productive or non-productive activity.

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