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WORKER PRODUCTIVITY IN REMNANT REMOVAL OPERATIONS - Part II

INTRODUCTION

In Nova Scotia, a remnant removal treatment is defined as the harvest of all merchantable wood from low volume, non-commercial forest stands. To be eligible for treatment, these stands must have an average merchantable diameter greater than 14 cm and a merchantable volume greater than 17 m^3/ha and less than 75 m^3/ha. The proportion of basal area which is dead must be less than 35%. All unmerchantable stems that will interfere with the new stand must be cleared during this treatment. The purpose of the treatment is to create or enhance the conditions necessary for the establishment of new and productive stands. Between 1980 and 1989, over 12,000 hectares received a remnant removal treatment in Nova Scotia.

To provide data necessary for refining silvicultural assistance rates, 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 has been collected. This report summarizes the results derived from the entire data base for remnant removal operations.

METHODS

Eight non-commercial stands meeting the criteria for a remnant removal operation were chosen for study. These stands were divided into 16 blocks (average 2 per stand) with uniform site and stand conditions. Each block was large enough to keep one worker busy for approximately two days. Site and stand characteristics capable of affecting worker productivity were recorded (Appendix 1). Softwoods dominated in twelve of the blocks [mostly white spruce (*Picea glauca* (Moench) Voss)] while hardwoods dominated in four blocks [mostly sugar maple (*Acer saccharum* Marsh.)]. The distribution of remnant trees on the sites varied

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from evenly scattered to small clumps.

The remnant removal operations were performed between January, 1987 and October, 1988. Thirteen blocks were cut by 6 forestry instructors from the Commercial Safety College in Masstown, Nova Scotia (NSDLF, 1989). The remaining 3 blocks were cut by local contractors employing woods workers of average experience.

The harvested trees were cut into random length logs and/or 2.4 metre pulpwood, and piled at the stump for forwarding. The operations were carried out using chainsaws.

Time Study

Fixed interval activity sampling (Stjernberg, 1991) was used to determine the relative amount of time spent on various activities by each worker. The technique consisted of taking observations at predetermined time intervals (for this study, every 30 seconds) and noting which activity (e.g. felling, limbing, or saw maintenance) was occurring. The activities were grouped as either productive or non-productive (Appendix 2). 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. On average, each block was sampled for 3 hours and 27 minutes. This sampling was undertaken in intermittent periods over the entire work day. The average total time to harvest a block was 12 hours.

All wood harvested was scaled for solid volume. The inside bark volume of each piece of pulpwood was obtained by inputting top and butt diameter measurements into Smalian's formula (Husch et al. 1972). Sawlog volume was calculated using the New Brunswick log rule. Productivity (P) was calculated by dividing the volume harvested by the productive time. Volumes were also expressed in stacked measure by multiplying solid cubic metres (m^3) by 1.6.

Data Analyses

Non-linear and linear regression were used to relate productivity to various pre-treatment stand and site factors (Appendix 1). The results section discusses only the best relationship. Stand Index and Crown Length were used as predictors of productivity in this relationship. Stand Index was computed by dividing the number of merchantable trees by the solid merchantable volume (pre-treatment values). Crown Length is a subjective estimate of the proportion of the merchantable bole occupied by live and dead branches. For the purposes of regression analysis, Crown Length was coded as a dummy variable (Table 1.)

Table 1. Assignment of dummy variables to Crown Length codes prior to regression analysis.

Crown Length Code	Proportion of the Merchantable Bole occupied by branches	Dummy variables	
		D1	D2
1	<1/3	0	0
2	≥1/3 or <2/3	0	1
3	≥2/3	1	0

The following equation was used to relate harvest production to stand conditions:

$$P = B_0SI + B_1D1 + B_2D2 + B_3 \quad [1]$$

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

B_n = Regression coefficients,

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

D1,D2 = Dummy variables representing the 3 possible crown codes.

RESULTS AND DISCUSSION

Activities

Productive activities accounted for 80% of the total time (Table 2). Limbing and bucking took up most of the productive time (41%) followed by felling preparation (14%), felling merchantable trees (14%), felling unmerchantable trees (12%), piling (7%), moving (6%), freeing hung up trees (3%), and other productive activities (3%). Of the activities classified as non-productive, saw maintenance was the most time consuming (57%) followed by personal breaks (26%), saw repair (13%) and other non-productive (4%).

Productivity versus Stand Index and Crown Length

Productivity was found to be inversely related to Stand Index and Crown Length according to the following equation:

P = -0.08(SI)-0.26(D1)-0.66(D2)+2.33

Table 2. Percent of time spent on productive and non-productive remnant removal activities

Activities	Percent of		
	Total Time	Productive Time	Non-Productive Time
PRODUCTIVE			
Felling Unmerchantable Trees	9	12	NA[1]
Felling Preparation	11	14	NA
Felling Merchantable Trees	11	14	NA
Freeing Hung-Up Trees	2	3	NA
Limbing and Bucking	33	41	NA
Piling	6	7	NA
Moving	5	6	NA
Other	3	3	NA
Total Productive	80	100	NA
NON-PRODUCTIVE			
Breaks	5	NA	26
Saw Maintenance	11	NA	57
Saw Repair	3	NA	13
Other	1	NA	4
Total Non-Productive	20	NA	100

[1]NA = Not Applicable

Figure 1 depicts this relationship and shows the "goodness of fit" ($R^2 = 0.82$, standard error of estimate = 0.28 m^3/PMH). Table 3 illustrates how daily production varies depending on the Stand Index and Crown Length. For a Stand Index of 16 (or a merchantable diameter (MD) of 15 cm) and 2/3 or more of the merchantable bole covered with limbs, a chainsaw operator could be expected to produce 2.4 m^3/day (1.1 cords/day). With the same Stand Index but only

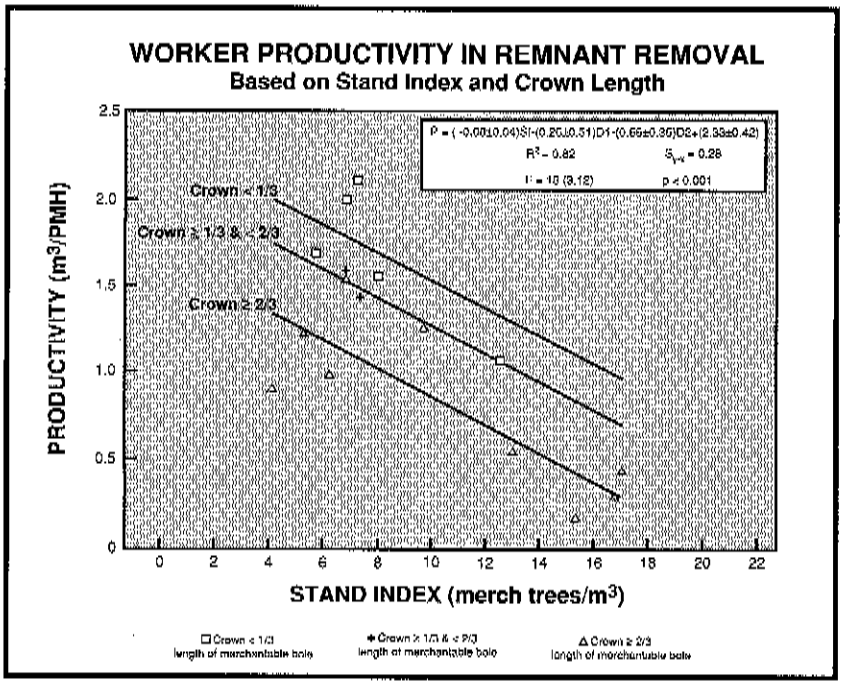

Figure 1. Predicted (P) and actual productivity in solid cubic metres per productive man hour versus pre-treatment Stand Index (SI) and Crown Length (D1, D2).

Table 3. Predicted daily production in Remnant Removal operations by Stand Index, Merchantable Diameter, and Crown Length.

Stand Index (Merch trees/m^3)	Merchantable Diameter[2]		Production[1] per Day								
			Crown<1/3 of the Merchantable Bole			Crown ≥1/3 and <2/3 of the Merchantable Bole			Crown ≥2/3 of the Merchantable Bole		
	cm	in	m^3	m^3(s)	cords	m^3	m^3(s)	cords	m^3	m^3(s)	cords
4	24	9.6	12.9	20.6	5.7	11.2	18.0	4.9	8.6	13.8	3.8
6	21	8.3	11.8	18.9	5.2	10.2	16.3	4.5	7.6	12.1	3.4
8	19	7.6	10.8	17.3	4.8	9.2	14.6	4.1	6.5	10.5	2.9
10	18	7.0	9.8	15.6	4.3	8.1	13.0	3.6	5.5	8.8	2.4
12	17	6.6	8.7	13.9	3.8	7.1	11.3	3.1	4.5	7.2	2.0
14	16	6.3	7.7	12.3	3.4	6.0	9.7	2.6	3.4	5.5	1.5
16	15	6.0	6.6	10.6	2.9	5.0	8.0	2.2	2.4	3.8	1.1

[1] Assuming 6.4 productive man hours per day (80% of an 8 hr day) and productivity based on equation [1].
[2] Based on the equation $MD = 38.75(SI)^{-0.34}$ where $r^2 = 0.84$ and $S_{y \cdot x} = 1.2$ cm.
Predicted values within shaded area are outside the range of the field data.

one third or less of the merchantable bole covered with crown, production would almost triple to 6.6 m^3/day (2.9 cords/day). For stands with larger trees, eg. a Stand Index of 4 (MD of 24 cm) and a crown ratio of ≥2/3 and <1/3, production would increase to 8.6 m^3/day (3.8 cords/day) and 12.9 m^3/day (5.7 cords/day) respectively.

SUMMARY

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

1. Workers spent 80% of their time on productive activities. The most time consuming productive activity was limbing and bucking (41%) while the most time consuming non-productive activity was saw maintenance (57%).
2. Worker productivity (P), expressed in merchantable cubic metres solid per productive man hour (m^3/PMH) is inversely related to Stand Index (SI) and Crown Length (D1,D2; Table 1) according to the following equation:

$$P = -0.08(SI)-0.26(D1)-0.66(D2)+2.33$$

3. Based on this regression equation and assuming 6.4 productive hours per day (80% of an 8 hour day), a chainsaw operator working in a forested area with a Stand Index of 8 (MD of 19 cm) could expect to attain daily productions of 6.5 and 10.8 m^3/day (2.9 and 4.8 cords/day), for live crown ratios of ≥2/3 and <1/3 respectively.

LITERATURE CITED

Husch, B.,C.I. Miller and T.W. Beers. 1972. Forest Mensuration, Toronto: John Wiley & Sons, 410 pp.

NSDLF. 1989. Worker productivity in merchantable thinning, shelterwood and remnant removal operations. Nova Scotia Dept. of Lands and Forests. FRR #16. 8 pp.

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APPENDIX 1.

Site and stand characteristics prior to remnant removal.

Block	Prod[1] (m^3/ PMH)	Height (m)		Density (trees/ha)		Basal Area (m^2/ha)		Diameter (cm)		Volume (ib, m^3/ha)		Stand[10] Index (trees /m^3)	Crown[11] Length (code)	Temp[12] (°C)	Site[13] History (code)	Tree[14] Species (code)	Operator[15] (code)
		Total[2]	Merch[3]	Total[4]	Merch[5]	Total[4]	Merch[5]	Total[6]	Merch[7]	Total[8]	Merch[9]						
1	0.18	7.2	7.3	1783	965	23	20	12.9	16.2	81	63	15.3	3	-17	4	wS	4
2	0.30	6.0	6.4	3051	907	25	19	10.3	16.5	76	54	16.8	3	-17	4	wS	3
3	0.44	7.0	7.3	1270	702	15	13	12.1	15.5	50	41	17.1	3	-17	4	wS	1
4	0.55	7.0	7.3	2325	763	23	18	11.3	17.5	80	59	13.0	3	-15	4	wS	2
5	0.91	1.9	11.1	3976	159	12	8	4.4	25.3	44	39	4.1	3	15	4	wS	4
6	0.99	1.8	10.3	7740	261	24	9	5.6	21.0	59	42	6.2	3	15	4	bF	3
7	1.06	3.9	10.0	7572	394	16	8	4.4	15.7	52	32	12.5	1	19	2	wS	3
8	1.22	10.1	10.1	299	299	13	13	23.4	23.4	61	57	5.3	3	18	1	wS	4
9	1.26	ND[16]	12.1	2325	613	16	13	ND	16.3	79	63	9.7	3	16	3	bS	6
10	1.43	2.9	13.2	8151	448	19	11	4.3	17.9	75	61	7.3	2	19	2	wS	4
11	1.55	ND	12.4	1819	514	16	15	ND	19.1	87	75	6.8	3	16	3	bS	7
12	1.56	12.2	12.5	829	371	11	10	12.9	18.1	57	47	8.0	1	13	1	sM	3
13	1.59	11.8	11.9	499	460	14	13	18.5	19.3	74	68	6.8	2	9	4	wS	5
14	1.69	10.9	10.9	390	390	16	16	22.5	22.5	73	68	5.7	1	11	2	rM	4
15	2.00	10.6	10.7	568	468	17	16	19.2	20.9	76	69	6.8	1	11	2	sM	3
16	2.11	11.3	11.4	741	404	14	12	15.2	19.8	66	57	7.1	1	13	1	sM	4

[1]Prod = Productivity measured in solid merchantable m^3 harvested per productive man hour.

[2]Total Height = Total Lorey's height (height of the tree of average total basal area).

[3]Merch Height = Merchantable Lorey's height (height of the tree of average merchantable basal area).

[4]Total = All trees taller than Breast Height (1.4 m).

[5]Merch = All trees exceeding 9 cm diameter at Breast Height.

[6]Total Diameter = Diameter of the tree of average basal area.

[7]Merch Diameter = Diameter of the tree of average merchantable basal area.

[8]Total Volume = Total inside bark volume for all trees.

[9]Merch Volume = Total inside bark volume of all merchantable trees excluding a 15 cm stump and top <7 cm diameter inside bark.

[10]Stand Index = Expressed as merchantable trees per solid cubic metre of merchantable volume(pre-harvest values)

[11]Crown Length = Limbs on merchantable bole of tree: 1- <1/3 of bole, 2- ≥1/3 and <2/3 of bole, 3- ≥2/3 of bole.

[12]Temp = Average temperature in degrees Celsius on the day of operation.

[13]Site History = Origin of present stand: 1 - Softwood cut, 2 - Partial cut, 3 - Fire, 4 - Old field.

[14] Species Initial = Most numerous merchantable tree species in the block. wS - white spruce(*Picea glauca* (Moench) Voss) bS - black spruce (*Picea mariana* (Mill.) B.S.P.) bF - balsam fir (*Abies balsamea* (L.) Mill.) sM - sugar maple (*Acer saccharum* Marsh.) rM - red maple (*Acer rubrum* L.).

[15]Operator = Each operator was assigned a number. 1-4 Commercial Safety College Instructors, 5-7 average woods workers.

[16] ND = No data.

APPENDIX 2.

Definitions of work activities recorded during the time studies.

Productive Activities:

Felling Preparation - Determining the direction of fall, clearing unmerchantable stems beside the crop tree, and limbing lower portion of the tree before felling.

Felling Unmerchantable Trees - Felling non commercial or poor quality unmerchantable trees scattered throughout the stand or in clumps.

Felling Merchantable Trees - Includes all activities between the initial notching and the tree hitting the ground or becoming hung-up.

Freeing Hung-Up Trees - Includes all activities required to free hung-up trees and lay them on the ground, including getting help if necessary.

Limbing and Bucking - Removing branches, top, and cutting the tree into product lengths. Includes moving brush to facilitate limbing and bucking.

Piling - Piling pulpwood or logs for the forwarder or skidder.

Moving - Moving during productive activities only.

Other - Productive activities other than the preceding categories (e.g. freeing jammed saws, moving brush, helping their partner).

Non-Productive Activities:

Breaks - Personal breaks.

Saw Maintenance - Routine saw maintenance including filling with gas and oil, and filing. Includes moving to carry out these activities.

Saw Repair - Repairing the chainsaw (includes moving).

Other - Other non-productive activities not listed (e.g. looking for lost/ misplaced equipment).

Other:

Lunch - Formal lunch break. The time taken for formal lunch breaks was subtracted from the total time and not considered either as a productive or non-productive activity.

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