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HARVESTING ECONOMICS: HANDFALLING OLD-GROWTH TIMBER — CONVENTIONAL- VERSUS SELECTIVE-BUCKING TECHNIQUES

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Summary and Conclusions

This is the second report in a series of studies investigating the effect of tree size, species, and terrain on falling productivity and costs. This study also includes the effect of different bucking techniques on falling productivity and costs.

The study was undertaken in an old-growth stand located 22 km west of Port Alberni, B.C. One faller was studied as he utilized two different bucking techniques--conventional and selective bucking. Conventional bucking is where all trees are hand processed (measured, limbed, bucked, and topped) at the stump. Selective bucking is done in conjunction with processing at the roadside or other locations, and only oversize material is processed at the stump.

The cost sensitivity associated with varying diameter classes is highlighted in the detailed study results. The conventional falling cost of $14.00/m³ for the 10-cm diameter class was 47 times as expensive as for the 150-cm class at $0.30/m³.

Bucking technique significantly affected falling costs. The use of selective bucking resulted in a 70% increase in the number of trees felled per shift when compared to conventional bucking. The average cost of falling and conventional bucking was $1.28/m³ versus $0.76/m³ for falling and selective bucking. It must be kept in mind that the above only compares falling costs. From the point of operating economics, the final comparison must be on the cost differential from all logging phases. Whether or not selective bucking results in total overall savings will depend on the specific application.

Time spent limbing and bucking reduced from 21% of total time/tree in the conventional-bucking system to 5% in the selective-bucking system. This

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reduction resulted in more time available for moving and cutting and, therefore, more production per shift. Also, Workers' Compensation Board records indicate it is safer to buck logs in landings and at the roadside; therefore, accidents will be reduced with the selective-bucking system.

Regression equations allow the calculation of estimated weighting factors to adjust for changes in species and diameter classes. This information is useful to logging engineers, logging foremen, and others when budgeting and planning their operations.

Introduction

Historically, loggers have known the average logging costs of each harvesting phase (falling, skidding, yarding, loading, and hauling). A shortcoming of average costs is that they are a mixture of high and low costs. A given average cost may seem satisfactory and in line with profitable operations, yet a breakdown into component costs may reveal individual cost situations that are not satisfactory and not profitable (Adams 1965). To address this situation, the Harvesting Economics Project was initiated by FERIC member companies in 1983, and field work started in 1985.

This is a report on the second of several falling studies conducted for the Harvesting Economics Project. Although these falling studies show average results, they also examine how productivity and costs vary with individual fallers and with falling techniques, tree size, species, and terrain. Specifc data from each study will be stored in a central file and used in a predictive model for estimating marginal and aggregate harvesting costs.

Data in this report have been obtained through on-site, detailed measurements of faller productivity. Results are specific to the study conditions and should be applied elsewhere with caution. Costs were derived by FERIC and are not actual costs of the cooperating company.

Study Methods

Data were collected utilizing timing boards and hand-held stop watches. Timing began when the faller started to walk into the stand, and stopped when he arrived back at the crew bus at the end of the shift. Lunch time was excluded. Total time in this report refers to a 6.5-h falling shift. To gather data by diameter size (diameter at breast height or dbh), individual standing trees were measured with D-tapes and pre-marked by ribboning. Trees were classified into 10-cm diameter classes beginning at 5.0 cm. Trees smaller than 5.0-cm dbh were considered non-merchantable and classified as brush. The midpoint of each class was used when recording data and reporting results. Trees in the 10-cm class were called saplings and those above classed as merchantable.

The study was conducted over a period of six days in May and June, 1986. During this period, detailed information was gathered by diameter class and species on 1499 trees. More general production and time data were collected on an additional 283 trees.

Site and System Description

The study site was located on Vancouver Island, 22 km west of Port Alberni, B.C. Table 1 gives stand and terrain information. Understory was salal and thick huckleberry. Species composition, by volume, was 29% balsam fir, 27% western red cedar, 21% western hemlock, 15% Douglas-fir, 4% yellow cedar, and 4% white pine.

TABLE 1. Stand Description.

Slope - Average	± 10%
- Aspect	North
Terrain	Rolling
Exposed Rock	1-10% of Area
Underbrush	Heavy
Obstacles	Some Windfalls
No. Trees per Hectare	353
Estimated Volume, m^3	
- Gross/ha	633
- Net/ha	554
- Gross/tree	1.10

All falling was done by the same faller. He had 17 years falling experience and FERIC considers him to have been skilled and efficient. He used a Stihl Model 056 chain saw with an 81-cm bar.

Trees were felled parallel to the haul road to facilitate grapple yarding. After falling, two bucking techniques were monitored during this study. First was conventional limbing and bucking whereby all trees were hand processed at the stump. This included measuring (Figure A), limbing, bucking, and topping according to bucking and grading rules issued by the company. Second was selective bucking where most trees were mechanically processed at the roadside and only oversize material (greater than 60-cm butt diameter) was bucked at the stump.

FIGURE A. Handfaller Measuring Tree.

Results and Discussion

Summary statistics for individual time elements are given in Table 2, by bucking technique. These were computed using observations made on both measured and non-measured trees. Subsequent tables are based on the 1499 measured trees only and show the influence of tree diameter and species on productivity and cost.

TABLE 2. Handfalling--Observed Time and Percentage Time Distribution Summary.

	Conventional Bucking		Selective Bucking	
	Min/Tree	%	Min/Tree	%
Productive Time				
Move	0.30	17.4	0.22	21.8
Brush	0.13	7.5	0.07	6.9
Cut	0.42	24.3	0.37	36.6
Wedge	0.04	2.3	0.03	3.0
Limb/Buck	0.37	21.4	0.05	5.0
Buck Windfalls	0.03	1.7	0.01	1.0
Subtotal	1.29	74.6	0.75	74.3
Non-Productive Time				
Fuel & Oil	0.06	3.4	0.04	4.0
File Chain	0.05	2.9	0.01	1.0
Saw Repairs	0.04	2.3	0.04	3.9
Other	0.29	16.8	0.17	16.8
Subtotal	0.44	25.4	0.26	25.7
Total	1.73	100.0	1.01	100.0
Total Productive Time (min)	725.5	74.8	922.0	74.6
Total Non-Productive Time (min)	244.6	25.2	313.8	25.4
Total	970.1	100.0	1235.8	100.0
Number of Trees				
Merchantable (15.0 cm dbh+)	291	52	617	51
Sapling (5.0-14.9 cm dbh)	227	40	487	40
Snag	44	8	116	9
Total	562	100	1220	100
No. Trees per Productive Hour	46.5		79.4	
No. Trees per Total Hour	34.8		59.2	
No. Trees per 6.5-Hour Shift	226.2		384.8	

1. Overall Results

Non-productive time includes all delays no matter what their duration. "Other" delay time includes such items as reconnaissance, rest breaks, visitors, and waiting for the wind to subside.

The percent of productive time was about the same for both conventional- and selective-bucking techniques. Moving, cutting, and limbing/bucking were the main productive time elements in the conventional-bucking system, while moving and cutting were the main productive time elements in the selective-bucking system. The number of trees cut per productive hour was 46.5 in the conventional-bucking system and 79.4 in the selective-bucking system.

Moving accounted for 17% of the time per tree with the conventional-bucking technique, and 22% with the selective-bucking technique. In addition to moving from tree to tree, move time also included walk-in and walk-out times, (at lunch and at the beginning and end of each shift). Table 3 shows the time spent in each of these phases. FERIC observed that much of the moving time was not determined by the next adjacent tree, but more by the falling pattern (trees were felled parallel to the haul road), tree lean, and topography.

TABLE 3. Move Time Phases.

Phase	Conventional Bucking		Selective Bucking	
	Min	%	Min	%
Tree-to-Tree	132.1	79	211.7	80
Walk-In and Walk-Out	34.3	21	54.4	20
Total	166.4	100	266.1	100

The percent of time spent brushing was about the same for both techniques. We observed that the underbrush, mainly huckleberry, affected the faller's ability to move freely. The huckleberry was very thick in places and averaged about 1.5 m in height. It tended to catch onto clothing and gear, and also reduced visibility.

Cutting time per tree was 24% of total time for the conventional-bucking technique and 37% for the selective-bucking technique. The 24% cutting time is consistent with that found in previous studies (Peterson 1986).

The limbing/bucking time difference of 0.32 min/tree highlights the main advantage of the selective-bucking technique. In the conventional-bucking technique, limbing/bucking time was the second largest productive time element. It accounted for 21% of the time per tree. When the selective-bucking technique was utilized, limbing/bucking time dropped to 5% of the time per tree. This time is also consistent with that found in a previous study (Peterson 1987).

"Other" delays accounted for a significant portion of the non-productive time. Table 4 summarizes the "Other" delays experienced. There were 297 occurrences timed, with an average time per occurrence of 1.3 min. The largest time category was "Rest Break" with a total of 183.4 min. The average time per break was 10.2 min.

TABLE 4. Summary of "Other" Delays.

Activity	Conventional Bucking		Selective Bucking	
	No.	Min	No.	Min
Fix or Get Wedges	4	1.3	15	5.2
Get Axe	6	4.8	7	4.4
Get or Move Fuel	17	17.1	37	32.4
Listen For or Assist Partner	2	1.8	2	9.6
Miscellaneous	5	2.4	35	21.7
Raingear, Clothing	1	0.8	3	2.6
Reconnaissance	47	22.3	78	22.3
Rest Break	10	95.6	8	87.8
Saw Stuck	4	2.9	2	0.7
Talk to Supervisor	3	13.9	7	24.0
Visitors	0	0	3	2.1
Wait for Wind	0	0	1	0.2
Total	99	162.9	168	213.0

For all observations, the minimum, mean, and maximum values and standard deviation were calculated for each falling phase. This information is shown in Tables 5 and 6. The time spent moving varied from a low of 0.04 min to a maximum of 5.83 min/occurrence. Cutting time ranged from a minimum of 0.04 min to a maximum of 5.45 min/occurrence. Limbing/bucking times ranged from 0.07 min to 8.67 min. The highest time differences occurred in the "Other" category where times ranged from a low of 0.09 min to a high of 24.06 min.

TABLE 5. Summary Statistics for Elements in the Handfalling Work Cycle--Conventional Bucking.

Falling Phase	No. of Observations	Minutes per Occurrence			
		Minimum	Mean	Maximum	Standard Deviation
Move	561	0.04	0.37	4.73	0.52
Brush	161	0.07	0.46	4.67	0.52
Cut	561	0.04	0.42	5.44	0.62
Wedge	44	0.10	0.52	1.31	0.32
Limb/Buck	144	0.07	1.45	8.67	1.15
Buck Windfalls	17	0.14	1.04	3.52	0.87
Fuel & Oil	22	0.79	1.43	1.90	0.30
File Chain	6	3.01	4.50	9.08	2.52
Saw Repairs	11	0.39	2.11	6.80	2.05
Other	98	0.09	1.66	24.06	3.87

TABLE 6. Summary Statistics for Elements in the Handfalling Work Cycle--Selective Bucking.

Falling Phase	No. of Observations	Minutes per Occurrence			
		Minimum	Mean	Maximum	Standard Deviation
Move	500	0.04	0.33	5.83	0.67
Brush	216	0.05	0.27	1.33	0.23
Cut	614	0.07	0.53	5.45	0.54
Wedge	71	0.12	0.54	2.08	0.41
Limb/Buck	30	0.13	2.00	5.69	1.39
Buck Windfalls	9	0.17	0.46	1.59	0.51
Fuel & Oil	21	0.64	1.53	2.28	0.50
File Chain	4	2.35	3.33	4.16	1.05
Saw Repairs	19	0.24	1.38	4.76	1.31
Other	119	0.07	1.33	15.97	3.15

2. Results by Diameter Class

Detailed cutting, wedging, and limbing/bucking time information by diameter class is given in Table 7. The information is shown graphically in Figure B for all species combined. Results of the statistical analysis by tree species will be covered in a separate publication.

Referring to Table 7, 714 of the 1499 trees observed were in the 10-cm diameter class, or the sapling class. As diameter increases, so does the cutting time. For both techniques, average cutting time per tree varied from 0.13 min for the sapling class to 4.78 min for the 150-cm class.

When comparing the totals of cutting, wedging, and limbing/bucking times (Figure B), the advantages of the selective-bucking technique are apparent. When compared to the conventional-bucking technique, the time is less for all diameter classes in which the technique applies (20 to 60 cm inclusive).

Tree volumes were derived from local volume tables calculated by FERIC. Tree diameters, heights, and species were noted and measured. The gross merchantable volume per tree, by diameter class, is shown in Table 8.

3. Falling Costs

Costs used in this section were estimated by FERIC. The operating labour cost of $294.62/day included the faller's IWA rate plus 35% for fringe benefits. Chain saw costs were estimated to be $25.00/day. Other costs such as crew transportation and supervision were not included.

Table 8 lists total falling costs per cubic metre and per tree by diameter class. The table is based on the actual cutting, wedging, and limbing/bucking times (Table 7), and fixed time (including delay time). Fixed times of 0.90 min/tree for the conventional-bucking system and 0.56 for the selective-bucking system were calculated from Table 2 and include all time except cutting, wedging, and limbing/bucking. This information is shown graphically in Figure C.

TABLE 7. Falling Phase Times by Diameter Class--All Species.

Diameter Class Midpoint (cm)	Minutes Per Tree									
	Conventional Bucking					Selective Bucking				
	No. of Observations	Cut	Wedge	Limb/ Buck	Total	No. of Observations	Cut	Wedge	Limb/ Buck	Total
10	227	0.13			0.13	487	0.13			0.13
20	98	0.28		0.02	0.30	213	0.26			0.26
30	68	0.40	0.06	0.37	0.83	131	0.42	0.06		0.48
40	52	0.61	0.14	1.08	1.83	94	0.57	0.09	0.01	0.67
50	29	0.81	0.17	1.42	2.40	41	0.89	0.17	0.01	1.07
60	9	1.05	0.15	1.65	2.85	20	1.26	0.14	0.66	2.06
70	4	1.43	0.04	1.50	2.97	6	1.37	0.40	1.48	3.25
80	1	1.65		5.33	6.98	2	1.67	0.58	1.64	3.89
90	3	1.91	0.09	1.64	3.64	1	0.96		2.05	3.01
100						1	2.76	0.22	3.98	6.96
110	2	3.02		3.50	6.52	2	3.36		3.81	7.17
120	2	4.36		5.64	10.00	1	4.37	0.94	2.06	7.73
130	2	4.15		2.76	6.91					
140										
150	2	4.44		3.82	8.26	1	5.45		4.31	9.76
TOTAL	499					1000				

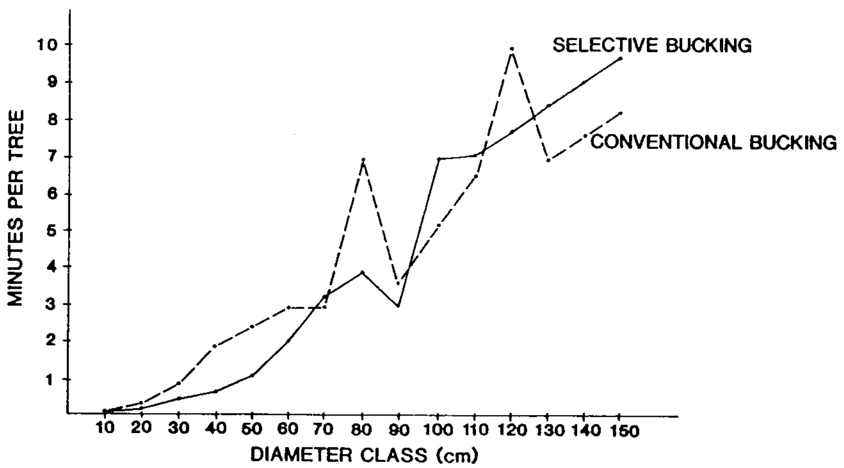

FIGURE B. Actual Cutting, Wedging, and Limbing/Bucking Times--All Species--By Bucking Technique.

TABLE 8. Falling Costs.

Diameter Class Midpoint (cm)	Gross Merchantable Volume Per Tree (m^3)	Conventional Bucking		Selective Bucking	
		$/m³	$/tree	$/m³	$/tree
10	0.06	14.00	0.84	9.50	0.57
20	0.15	6.53	0.98	4.47	0.67
30	0.47	3.02	1.42	1.81	0.85
40	1.01	2.22	2.24	1.00	1.01
50	1.71	1.58	2.71	0.78	1.34
60	2.66	1.16	3.08	0.81	2.15
70	3.47	0.91	3.17	0.90	3.12
80	4.18	1.55	6.46	0.87	3.65
90	6.72	0.55	3.72	0.44	2.93
100	10.77			0.57	6.17
110	13.00	0.47	6.08	0.49	6.34
120	14.28	0.63	8.94	0.48	6.80
130	11.02	0.58	6.40		
140	20.32				
150	24.87	0.30	7.51	0.34	8.46

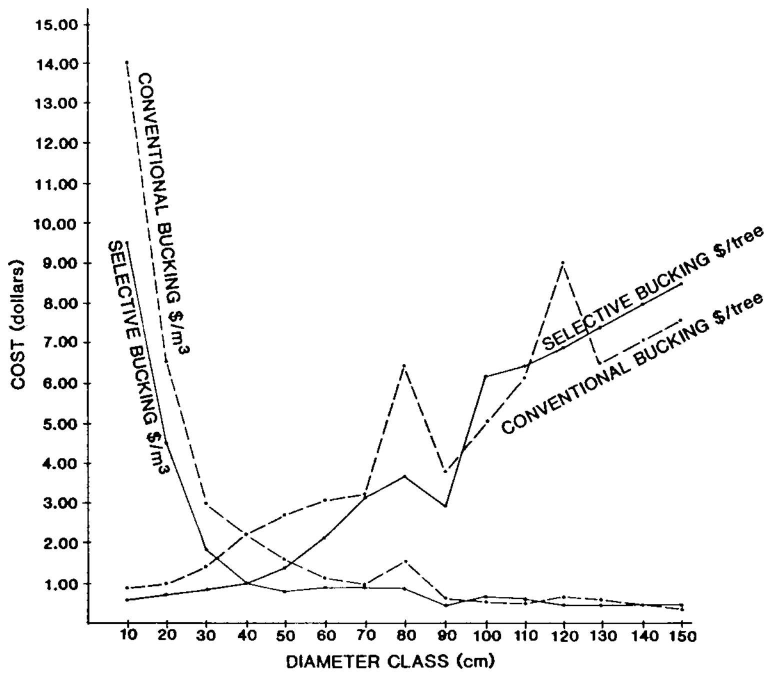

FIGURE C. Falling Cost per Cubic Metre and per Tree by Diameter Class and Bucking Technique--All Species.

In the conventional-bucking system, falling costs vary from a low of \$0.84/tree to a high of \$8.94/tree and a low of \$0.30/m³ to a high of \$14.00/m³. Costs in the selective-bucking technique vary from a low of \$0.57/tree to a high of \$8.46/tree and a low of \$0.34/m³ to a high of \$9.50/m³. In both techniques, the diameter class with the lowest cost per tree had the highest cost per cubic metre.

As shown in Figure C, falling costs per cubic metre drop rapidly as tree diameter increases. Small trees are expensive to cut and help justify the mechanization of falling in small-diameter stands.

Using the data in Table 2, the overall average tree volume of 1.10 m³, and a per-shift falling cost of \$319.62, average falling costs were calculated. In the conventional-bucking system, costs averaged \$1.41/tree or \$1.28/m³. The faller averaged 226 trees per shift, for a production of 249 m³. In the selective-bucking system, costs averaged \$0.83/tree or \$0.76/m³. The faller averaged 385 trees per shift, for a production of 423 m³.

4. Predicted Results

Regression analysis was done to derive expressions for predicting cutting, wedging, and limbing/bucking times as a function of tree-diameter class. Linear relationships between tree diameter and phase times were tested using the least-squares method. Times were stratified by species and falling technique. A variety of model specifications were tried when doing the statistical analysis. These included dbh, dbh^2, 1/dbh, $1/dbh^2$, and combinations of these. Diameter squared (dbh^2) was chosen because it offered maximum predictive power. Further discussions of statistical analysis will be covered in a separate publication.

Phase time observations were stratified by species and tested to determine if times varied by diameter class and species. At the 5% level of significance, the equations predicting cutting and limbing/bucking phase times varied by diameter class only, not by species. Wedging time proved to be unpredictable by diameter class and species. The results for the cutting and limbing/bucking phases are shown in Tables 9 and 10, and graphically in Figure D. Predictions were only made up to the 70-cm diameter class as there were insufficient samples for accurate predictions after this point. As seen in Figure D, the selective-bucking line is significantly lower up to the 60-cm diameter class. This is because no time is spent limbing and bucking. After the 50-cm diameter class, the effect of bucking the bottom one or two logs on oversize trees becomes apparent. The effect of leaving the top merchantable section for processing at the roadside is also shown by the shorter limbing/bucking time for 60- and 70-cm diameter classes (selective bucking).

TABLE 9. Regression Equations--All Species.

System	Dependant	Sample Size	r^2	Standard Error (min)	Prediction Equation
Conventional Bucking	Cutting Time	261	0.64	0.18	$(18.14 + 0.0253 * dbh^2)/100$
	Limbing/Bucking Time	119	0.19	0.63	$(66.88 + 0.0312 * dbh^2)/100$
Selective Bucking	Cutting Time	504	0.56	0.24	$(14.99 + 0.0285 * dbh^2)/100$
	Limbing/Bucking Time	18	0.31	0.74	$(22.18 + 0.0325 * dbh^2)/100$

Example: Cutting and limbing/bucking time for a 50-cm diameter tree in the conventional system is:

Cutting = $(18.14 + 0.0253 * 50^2)/100$ = 0.81
Limbing/Bucking = $(66.88 + 0.0312 * 50^2)/100$ = 1.45

Total = 2.26 min

TABLE 10. Predicted Cutting and Limbing/Bucking Phase Times--All Species.

Diameter Class Midpoint (cm)	Cutting		Limbing/Bucking		Total*	
	Conventional Bucking (min)	Selective Bucking (min)	Conventional Bucking (min)	Selective Bucking (min)	Conventional Bucking (min)	Selective Bucking (min)
10	0.21	0.18	0.70	0	0.91	0.18
20	0.28	0.26	0.79	0	1.07	0.26
30	0.41	0.41	0.95	0	1.36	0.41
40	0.59	0.61	1.17	0	1.76	0.61
50	0.81	0.86	1.45	0	2.26	0.86
60	1.09	1.17	1.79	1.39	2.88	2.56
70	1.42	1.54	2.20	1.82	3.62	3.36

* Total Time = Cutting + Limbing/Bucking

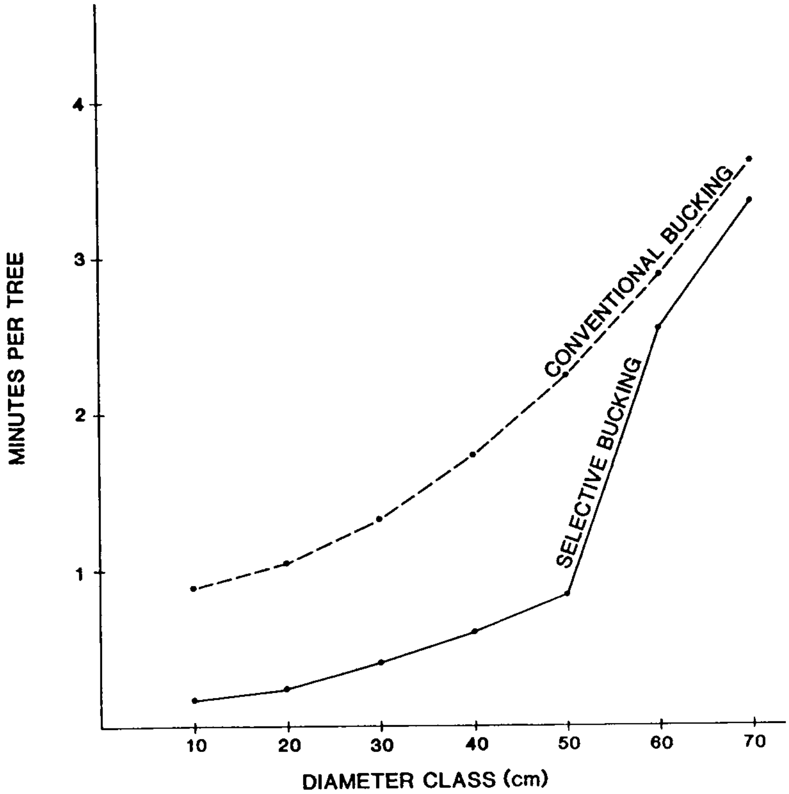

FIGURE D. Predicted Cutting and Limbing/Bucking Times--All Species--By Bucking Technique.

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