HARVESTING & PROCESSING

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FERIC

HARVESTING ECONOMICS: HANDFALLING SECOND-GROWTH TIMBER

J.T. Peterson*

This is the first report on a series of studies investigating the effect of tree size, species, and terrain on falling productivity and costs.

Three fallers were studied by FERIC in April 1985. The study site was located on the east coast of Vancouver Island, B.C., in a second-growth stand approximately 110 years old. Species composition was 60% Douglas-fir, 21% hemlock, 16% cedar, and 3% deciduous species.

The cost of falling proved to be very sensitive to tree diameter, varying from \$0.49/m³ for the 82.5-cm diameter class to \$21.50/m³ for the 12.5-cm diameter class. Falling costs averaged \$1.45 per tree or \$1.57/m³.

Introduction

Historically, loggers have known the average logging costs for each phase of their operation (falling, skidding, yarding, loading). 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 need, the Harvesting Economics Project was recommended by FERIC member companies in 1983, and a budget was established in 1984. Field work on the project started in 1985.

This is a report on the first of several falling studies to be conducted for the project. These studies will show average results and, more specifically, they will examine how productivity and cost vary not only with individual fallers but also with tree size, species, and terrain.

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

Keywords: Felling, Manual Felling, Productivity, Costs, Second-Growth

*Author: J.T. Peterson is a Group Supervisor, Evaluation and Silviculture, Western Division.

FOREST ENGINEERING RESEARCH INSTITUTE OF CANADA
INSTITUT CANADIEN DE RECHERCHES EN GENIE FORESTIER

143 Place Frontenac
Pointe Claire, Québec
Canada H9R 4Z7
(514) 694-1140

201-2112 West Broadway
Vancouver, B.C.
Canada V6K 2C8
(604) 732-3711

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Study Method and Procedures

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 (Figure A). Trees were classified into 10-cm diameter classes beginning at 7.5 cm. Trees smaller than 7.5-cm dbh were considered non-merchantable and classified as brush. The midpoint of each class was used when recording data and reporting results. Data were collected by detailed timing techniques utilizing timing boards and hand-held stop watches. Fallers were timed while at the tree. Walk-in and walk-out times were excluded. Unless otherwise noted, total time in this report refers to a 5.5-hour falling shift. Tree volumes were derived from the operational cruise done by MacMillan Bloedel Limited, Woodland Services, in April 1985, and compiled by Reid, Collins Associates Limited.

The study was conducted over a period of 23 days beginning in April 1985. During this period, detailed information was gathered by diameter class and species on 1746 trees. At the same time, as part of another study (Peterson 1986), more general production and time data were collected on an additional 5328 trees.

FIGURE A. Ribboning Trees to Identify Diameter Classes.

Site and System Description

The study site was located on the east coast of Vancouver Island, 5.3 km west of Buckley Bay, B.C. The stand (Table 1) was established after blowdown in approximately 1874. Understory consisted of sword fern and Oregon grape, with a few dense patches of conifer saplings. Species composition, by volume, was 60% Douglas-fir, 21% western hemlock, 16% western red cedar, and 3% deciduous species.

TABLE 1. Stand Description.

Cutting area, ha	10.3
Slope - range	0-52%
- average	23%
- aspect	East
Terrain	Rolling
Exposed Rock	None
Underbrush	Light
Obstacles	Some windfalls
No. stems per hectare	778
Estimated volume, m^3	
- gross/ha	713
- net/ha	665
- gross/tree	0.92

Observations were made on three fallers. Both Faller No. 1 and Faller No. 3 had five years experience, and Faller No. 2 had ten years experience. FERIC considered all three fallers to be skilled and efficient.

Normally the falling phase includes falling, measuring, limbing, bucking, and topping on all trees, but during this study a selective bucking system was utilized. Trees under 60-cm butt diameter were simply felled. Bucking was only done on trees with a butt diameter greater than 60 cm, with the bottom one or two logs hand bucked and the remainder of the tree left for roadside processing. According to operational cruise figures, 5% of the trees had butt diameters over 60 cm and required selective bucking.

Falling started at the east boundary of the block and progressed uphill to the west (Figure B). Trees were directionally felled parallel to the haul road (Figure C) to facilitate grapple yarding. No effort was made to point tops in one direction. Husqvarna Model 2100 chain saws were used. One faller used a 91-cm bar, while the others used 81-cm bars.

Results and Discussion

Summary statistics for individual time elements are given in Table 2. These were computed using observations made on measured and non-measured trees. The results are reported for individual fallers and all fallers combined. Subsequent presentations are based on the 1746 measured trees and show the influence of tree diameter and species on productivity and cost.

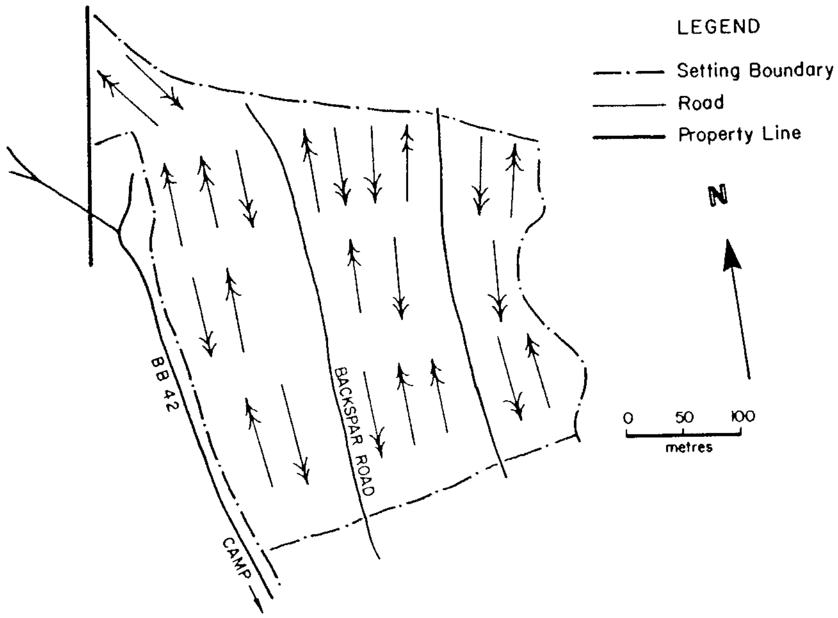

FIGURE B. Falling Pattern.

FIGURE C. Trees Felled Parallel to Haul Road.

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.

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

	FALLER NO. 1		FALLER NO. 2		FALLER NO. 3		COMBINED FALLERS	
PHASE	HOURS	%	HOURS	%	HOURS	%	HOURS	%
Productive Time								
Move[1]	17.4	20.0	15.2	19.3	2.1	19.6	34.7	19.7
Brush	5.7	6.6	8.1	10.2	0.8	7.5	14.6	8.3
Cut[2]	39.2	45.1	27.0	34.3	4.6	43.0	70.8	40.1
Limb & buck	4.3	4.9	3.2	4.1	0.4	3.8	7.9	4.5
Buck windfalls	0.6	0.7	0.5	0.6	0.1	0.9	1.2	0.7
Subtotal	67.2	77.3	54.0	68.5	8.0	74.8	129.2	73.3
Non-Productive Time								
Fuel & oil	6.0	6.9	4.1	5.2	1.1	10.3	11.2	6.3
File chain	1.7	1.9	2.6	3.3	0.4	3.7	4.7	2.7
Saw repairs	3.7	4.2	3.6	4.6	0.2	1.9	7.5	4.2
Other	8.4	9.7	14.5	18.4	1.0	9.3	23.9	13.5
Subtotal	19.8	22.7	24.8	31.5	2.7	25.2	47.3	26.7
Total	87.0	100.0	78.8	100.0	10.7	100.0	176.5	100.0
No. Trees								
Merchantable (17.5 cm dbh+)	2 927	75.2	2 083	75.8	331	77.0	5 341	75.5
Sapling (7.5-17.4 cm dbh)	613	15.7	424	15.4	63	14.6	1 100	15.5
Snag	355	9.1	242	8.8	36	8.4	633	9.0
Total	3 895	100.0	2 749	100.0	430	100.0	7 074	100.0
No. Trees per Productive Hour	58.0		50.9		53.8		54.7	
No. Trees per Total Hour	44.8		34.9		40.2		40.1	
No. Trees per Shift	246.4		192.0		221.1		220.6	

[1] Excludes walk-in and walk-out time.
[2] Includes wedging time.

The fallers averaged slightly over 70% productive time once they were in the stand. Cutting time was the main productive time element. Trees cut per productive hour ranged from 50.9 to 58.0 (14% variance). Productivity per total hour ranged even further at 28% and reflects the differences in delay time between the fallers.

Time spent moving between trees was fairly constant for the three fallers. It averaged approximately 20% of total time. FERIC observed that many move times were not determined by the next adjacent tree, but more by the falling pattern, tree leans, and topography.

Limbing and bucking time accounted for only 4.5% of the total time. This is because of the selective bucking system utilized. Bucking occurred only on trees with a butt diameter greater than 60 cm, and only the bottom one or two logs were bucked. The remainder of the tree was left for roadside processing. Current FERIC studies on conventional falling and bucking techniques show that the limbing and bucking time is in the 15 to 25% range.

Brushing time varied from 6.6% (Faller No. 1) to 10.2% (Faller No. 2). Faller No. 2's work area included some dense patches of young conifer saplings (2- to 5-cm diameter) which took time to clear.

Another major difference for Faller No. 2 was in the "Other" delay category (Table 3). The percentage of time spent in this phase was almost double that of the other two fallers. He lost more time because of wind, and spent more time on reconnaissance and rest breaks.

TABLE 3. Summary of "Other" Delays.

ACTIVITY	FALLER NO. 1 (min)	FALLER NO. 2 (min)	FALLER NO. 3 (min)	COMBINED FALLERS (min)
Fix or cut wedges	12.8	38.0	8.8	59.6
Get axe	11.7	7.6	1.0	20.3
Hang-ups	17.3	37.2	1.9	56.4
Listen for or assist partner	27.1	46.3	25.6	99.0
Miscellaneous	9.6	39.3	10.4	59.3
Move spare saw	17.6			17.6
Rain gear, clothing	2.3	24.7		27.0
Reconnaissance	77.3	138.0	2.5	217.8
Rest break	178.9	308.7	10.6	498.2
Saw stuck	4.0	21.0		25.0
Talk to supervisor	25.7	53.4		79.1
Unknown	53.9	22.1		76.0
Visitors	52.8	17.4		70.2
Wait wind	12.8	117.2	—	130.0
Total	503.8	870.9	60.8	1435.5

The minimum, maximum, and mean values and the standard deviation were computed for each falling stage to show the range of values observed in the study. This information is shown in Table 4.

TABLE 4. Summary Statistics for Elements in the Handfalling Work Cycle.

		MINUTES			
FALLING PHASE	NUMBER OBSERVATIONS	MINIMUM	MAXIMUM	MEAN VALUE	STANDARD DEVIATION
Move	4324	0.03	6.44	0.46	0.43
Brush	1531	0.04	9.56	0.56	0.77
Cut	5651	0.03	7.05	0.67	0.61
Limb & Buck	286	0.12	6.71	1.64	1.02
Buck windfall	76	0.20	4.47	0.84	0.85
Fuel & oil	175	0.93	7.88	3.24	1.32
File chain	19	5.21	16.68	11.48	3.93
Saw repairs	104	0.15	31.37	4.14	6.48
Other	462	0.05	25.10	3.23	4.72

2. Results by Species and Diameter Class

Detailed cutting and limbing/bucking time information by species and by diameter class is given in Table 5 for the 1746 measured trees. The information is shown graphically in Figure D.

TABLE 5. Cutting Time and Gross Merchantable Volume by Diameter Class and Species.

	CEDAR				DECIDUOUS				DOUGLAS FIR			
DIAMETER CLASS MIDPOINT (cm)	TREE COUNT	CUT TIME/ TREE (min)	LIMB/ BUCK (min)	GROSS MERCH. VOLUME (m^3/tree)	TREE COUNT	CUT TIME/ TREE (min)	LIMB/ BUCK (min)	GROSS MERCH. VOLUME (m^3/tree)	TREE COUNT	CUT TIME/ TREE (min)	LIMB/ BUCK (min)	GROSS MERCH. VOLUME (m^3/tree)
12.5												
22.5	31	0.31	0.06	0.19	1	0.38		0.36	111	0.42	0.04	0.32
32.5	35	0.53	0.04	0.46	1	0.39		0.88	94	0.59	0.06	0.65
42.5	28	0.88	0.07	0.94	1	0.49		1.50	77	0.84	0.04	1.31
52.5	7	1.34	0.07	1.66					55	1.17	0.21	2.23
62.5	7	1.17	0.22	3.07	1	0.75		3.00	21	1.63	0.51	3.40
72.5	1	2.18		4.50					14	1.72	0.69	4.33
82.5	2	3.65		7.90					2	2.34	1.26	7.02
Total	111				4				374			

	HEMLOCK				ALL SPECIES			
DIAMETER CLASS MIDPOINT (cm)	TREE COUNT	CUT TIME/ TREE (min)	LIMB/ BUCK (min)	GROSS MERCH. VOLUME (m^3/tree)	TREE COUNT	CUT TIME/ TREE (min)	LIMB/ BUCK (min)	GROSS MERCH. VOLUME (m^3/tree)
12.5					1056*	0.22		0.04
22.5	87	0.40	0.03	0.23	229	0.40	0.04	0.27
32.5	58	0.53		0.92	187	0.56	0.04	0.70
42.5	50	0.95	0.12	1.61	155	0.88	0.07	1.33
52.5	5	0.79	0.67	2.90	67	1.16	0.23	2.22
62.5					28	1.45	0.42	3.20
72.5	1	1.22		6.53	16	1.72	0.60	4.48
82.5					4	2.99	0.63	7.46
Total	201				690			
				GRAND TOTAL	1746			

*Species was not identified on the smallest size class.

Referring to Table 5, 1056 of the 1746 trees observed were in the 7.5- to 17.4-cm diameter class, or in the sapling class. The average cutting time for this class was 0.22 minutes. The data show that as diameter increases so does the cutting time.

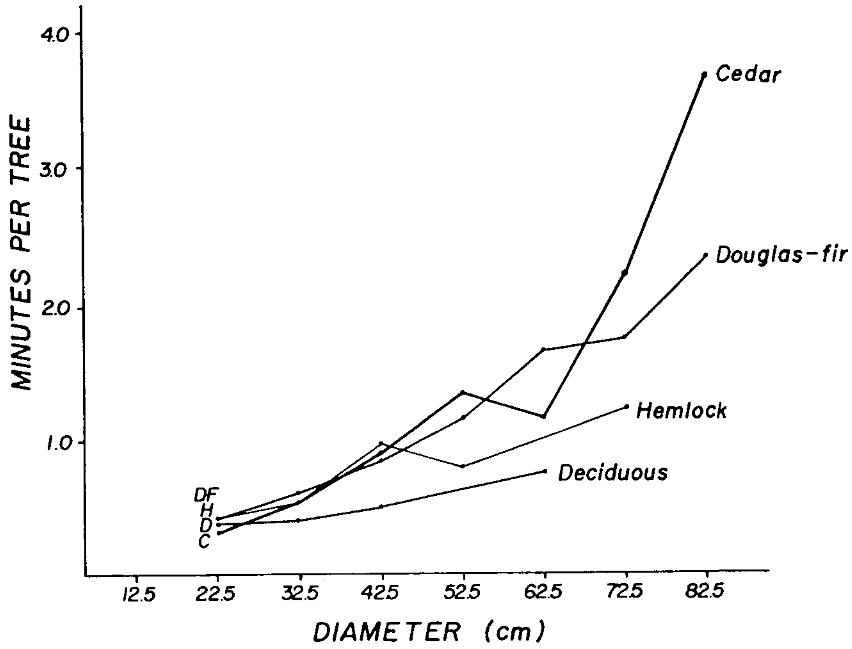

FIGURE D. Actual Cutting Time by Diameter and Species.

Cutting time per tree varied from 0.22 minutes for the sapling class (all species), to 2.99 minutes for the 82.5-cm class. Generally, cedar and Douglas-fir took the longest times, followed by hemlock, and deciduous species. In coastal stands, cedar has the largest butt flare, which could account for the longer cutting time.

Regression analysis was done to derive expressions for predicting cutting time as a function of tree diameter class. A variety of models were tried. These included dbh, dbh^2, 1/dbh, $1/dbh^2$, and combinations of these. Diameter only was chosen because it offered simplicity of use and maximum predictive power. Linear relationships between tree diameter and cutting times were tested using the least squares method. Cutting times were stratified by species and by faller. The analysis showed that cutting time varied between fallers when tested at the 5% level of signficance.

Cutting time observations were stratified by species and tested to determine if cutting time varied by species. At the 5% level of significance, the equations predicting cutting time for each species were found to be different. This indicates that separate equations should be used for different species. The results for all fallers combined are shown in Table 6, and graphically in Figure E. The actual results follow the estimated figures closely until the 72.5-cm class. The sample size was small for the 72.5- and 82.5-cm diameter classes, so predictions of falling time for trees this size may not be accurate.

TABLE 6. Predicted Cutting Times and Regression Equations.

DIAMETER CLASS MIDPOINT (cm)	MINUTES PER TREE			
	CEDAR	DOUGLAS-FIR	HEMLOCK	ALL SPECIES
22.5	0.22	0.61	0.36	0.33
32.5	0.57	0.89	0.61	0.61
42.5	0.92	1.16	0.85	0.89
52.5	1.26	1.44	1.09	1.18
62.5	1.61	1.71	1.34	1.46
72.5	1.95	1.99	1.58	1.74
82.5	2.30	2.26	1.82	2.02

SPECIES	SAMPLE SIZE	r^2	STANDARD ERROR	CUTTING TIME EQUATION
Cedar	108	0.59	0.40	-0.5519 + 0.0345 (Diameter)
Douglas-fir	360	0.54	0.36	-0.0027 + 0.0274 (Diameter)
Hemlock	195	0.26	0.38	-0.1822 + 0.0243 (Diameter)
All Species	663	0.50	0.37	-0.3056 + 0.0283 (Diameter)

Example: Cutting time for a 52.5-cm Douglas-fir is:
-0.0027 + 0.0274 (52.5) = 1.44 minutes

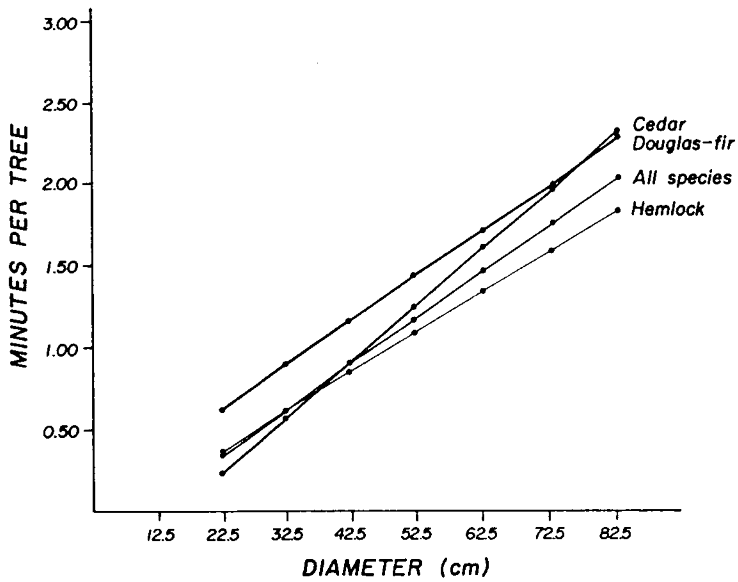

FIGURE E. Estimated Effect of Diameter on Cutting Time (by Species).

3. Falling Costs by Species and Diameter Class

The gross merchantable volumes shown in Table 4 were derived from MacMillan Bloedel Limited's operational cruise information. A volume was calculated for the 12.5-cm class assuming utilization to a 10-cm top diameter and a 2.5-m length.

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

Table 7 lists total falling costs per tree and per cubic metre by diameter class and species, exclusive of travel time and supervision. The table is based on actual cutting times (Table 4), plus actual limbing and bucking times (Table 4), and fixed time (including delay time). Fixed time (0.83 minutes per tree) is calculated from Table 2 and includes all time except cutting and limbing and bucking. It is the sum of all time elements not influenced by tree size. This information is shown graphically in Figures F, G, and H.

TABLE 7. Total Falling Cost per Tree and per Cubic Metre by Species and Diameter.

DIAMETER CLASS MIDPOINT (cm)	CEDAR		DOUGLAS-FIR		HEMLOCK		DECIDUOUS		ALL SPECIES WEIGHTED AVG	
	$/TREE	$/m³	$/TREE	$/m³	$/TREE	$/m³	$/TREE	$/m³	$/TREE	$/m³
12.5									0.86	21.50
22.5	0.98	5.16	1.30	4.06	1.03	4.48	0.99	2.75	1.04	3.85
32.5	1.16	2.52	1.21	1.86	1.12	1.22	1.00	1.14	1.17	1.67
42.5	1.46	1.55	1.40	1.07	1.56	0.97	1.08	0.72	1.46	1.10
52.5	1.84	1.11	1.81	0.81	1.43	0.49			1.82	0.82
62.5	1.82	0.59	2.44	0.72			1.30	0.43	2.21	0.69
72.5	2.47	0.55	2.66	0.61	1.68	0.26			2.58	0.58
82.5	3.67	0.46	3.63	0.52					3.65	0.49

Weighted average costs per tree vary from a low of $0.86 to a high of $3.65 per tree. Weighted average costs per cubic metre vary from a low of $0.49 to a high of $21.50. The diameter class with the lowest falling cost per tree ($0.86) had the highest cost per cubic metre ($21.50). In Table 6 some diameter classes had the same or similar costs per tree but dissimilar costs per cubic metre. This apparent discrepancy is explained by the difference in gross merchantable volume between species.

The cost per cubic metre for falling drops quickly as diameter class increases. Small trees are expensive to cut and are part of the reason for mechanization of falling in small-diameter stands. Falling costs, as with cutting times, were generally highest for cedar and Douglas-fir. They were followed by hemlock and deciduous species.

Using the data in Table 2, the overall piece average of 0.92 m^3 per tree and a per shift falling cost of $319.62, costs averaged $1.45 per tree or $1.57/$m^3$. The fallers averaged 220.6 trees per shift, for a production of 203 m^3 per shift. Saplings, snags, and merchantable trees were included in the computation of average tree size.

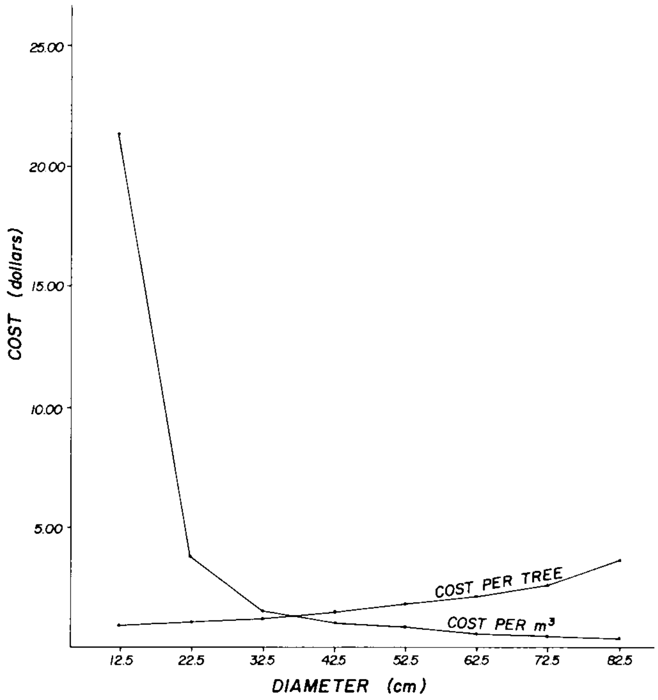

FIGURE F. Falling Cost per Tree and per Cubic Metre by Diameter--All Species.

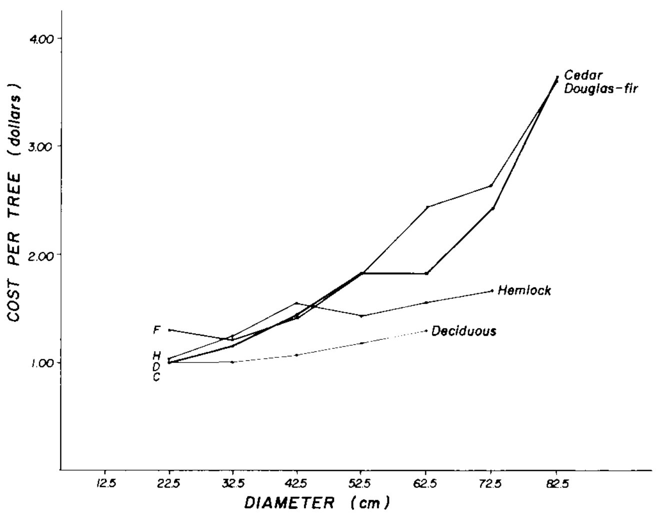

FIGURE G. Falling Cost per Tree by Diameter--By Species.

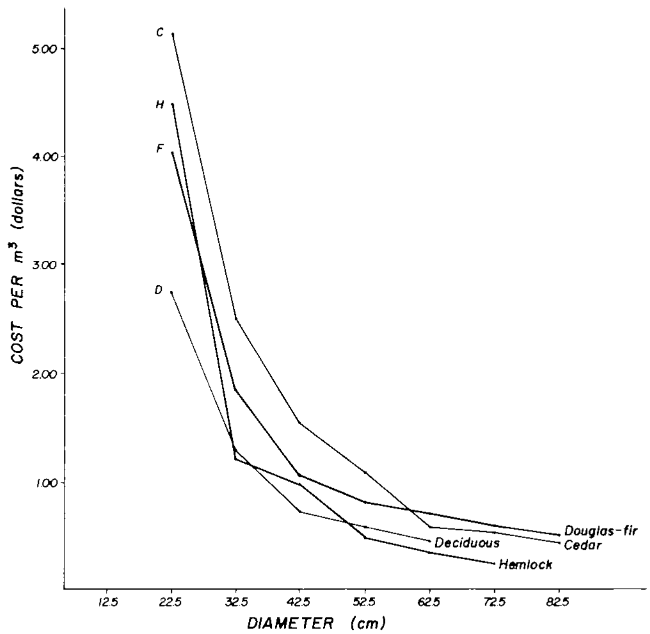

FIGURE H. Falling Cost per Cubic Metre by Diameter--By Species.

Conclusions

Roadside processing of trees allowed the use of a selective bucking system. This reduced the time normally spent limbing and bucking from over 15% to 4.5 percent. The fallers averaged 221 trees per shift, for a production of 203 m^3. Falling costs averaged $1.45 per tree or $1.57/$m^3$.

The detailed study results highlight the cost sensitivity associated with different tree species and diameter classes. The falling cost for the 12.5-cm diameter class at $21.50/$m^3$ was more than 43 times as expensive as the 82.5-cm class at $0.49/$m^3$.

Study results show that there is a correlation between species, diameter class, and cutting time. Generally, cedar and Douglas-fir took the longest time, followed by hemlock and deciduous species.

Regression equations allow the calculation of estimated weighting factors to adjust for changes in species and diameter class. This information is useful to logging engineers, logging foremen, and others when budgeting and planning their operations. Regression formulas developed from study data can be used to predict falling costs for trees smaller than 87.5-cm dbh.

Future studies will include the effect of brushiness and terrain. In addition, they will add to the database for species and diameter effect.

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