HARVESTING & PROCESSING
Technical Note TN-111 November 1987

HARVESTING ECONOMICS: HANDFALLING COASTAL OLD-GROWTH TIMBER

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Summary and Conclusions

This is the third report in a series of studies investigating the effect of tree size, species, and terrain on falling productivity and costs. The report gives the results of one faller as he worked in three separate sites on the east coast of Vancouver Island, British Columbia.

There was a wide range of variables encountered between the three stands studied. For example, slopes ranged from 5 to 80%, average tree size from 1.0 to 2.1 m^3/tree, and species composition from almost no Douglas-fir in one stand to almost all Douglas-fir in another. When falling production and costs are averaged, the effects of these different variables are often missed. This report highlights the effect of many of these variables on falling productivity and costs.

When all three stands were combined, the faller averaged 119 trees/shift and production was 182 m^3/shift. When comparing stands, the trees felled per shift ranged from 110 to 130, and production ranged from 116 to 225 m^3/shift.

The average falling cost for all stands combined was \$2.69/tree or \$1.76/m^3. The cost of \$1.76/m^3 appears reasonable at first glance; however, it includes average stand costs that range from \$1.42/m^3 to \$2.75/m^3 and diameter-class costs as high as \$25.38/m^3. This information can alert the logging planner to the actual costs likely to be encountered and aid him in searching for the most cost-effective way to handle problems.

The production sensitivity associated with varying diameter classes is highlighted in the study results. The average cutting time per tree ranged from a low of 0.17 minutes for the 12.5-cm diameter class to a high of 9.43 minutes for the 162.5-cm diameter class. Generally, cutting and limbing/bucking times increased as diameters increased.

The smallest diameter class had the highest cost per cubic metre. Costs ranged from \$25.38/m^3 in the 12.5-cm diameter class to \$0.29/m^3 in the 172.5-cm diameter class. Costs per tree ranged from \$1.57 in the 12.5-cm diameter class to \$13.19 in the 162.5-cm diameter class.

Keywords: Felling, Manual Felling, Productivity, Costs, Old Growth

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 ISSN 0381-7741

Introduction

Historically, loggers have known the average logging costs for each phase of their operation. A shortcoming of average costs is that they are a mixture of high and low costs. Although an average cost may seem satisfactory, a closer inspection may reveal individual costs that are not acceptable. The Harvesting Economics Project was initiated in 1983 to provide detailed costs on individual logging phases.

This is the third report on several falling studies conducted for the Harvesting Economics Project. The group of falling studies shows average results, as well as how productivity and costs vary with individual fallers, tree size, species, and terrain.

Specific data from each study will be saved in a central file and be used in a predictive model for estimating marginal and aggregate costs of harvesting.

Data in this report have been obtained through on-site, detailed measurements of faller productivity on three separate sites. 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 Approach and Procedures

Data were collected utilizing 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-hour shift. To gather data by diameter size (diameter at breast height or dbh), individual standing trees were measured with D-tapes and premarked by ribboning. Trees were classified into 10-cm diameter classes beginning at 7.5-cm dbh. 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 results. Trees in the 12.5-cm class were called saplings and those above classed as merchantable.

Tree volumes were derived from local volume tables calculated by FERIC. Tree diameters, heights, and species were noted and measured by FERIC in each stand.

Three different old-growth stands were studied over a period of three months beginning in January 1986. During this period, detailed information by diameter class and species was gathered on 565 trees. More general time and production data were collected on an additional 100 trees.

Site and System Description

The three sites studied are all located on the east coast of Vancouver Island, B.C. Table 1 gives comparative stand and terrain information.

Stand No. 1 was located 33 km west of Parksville, B.C. Understory consisted of huckleberry, Oregon grape, and salal. Species composition, by volume, was 91% Douglas-fir, 6% western hemlock, and 3% western red cedar.

TABLE 1. Stand Descriptions.

	Stand No. 1	Stand No. 2	Stand No. 3
Slope - Average	20%	80%	5%
- Aspect	East	Northeast	Southeast
Terrain	Rolling	Gullied	Rolling
Exposed Rock	1-10% of Area	None	None
Underbrush	Light	Medium	Light
Obstacles	Some windfalls	Some windfalls	Some windfalls
No. Trees per Hectare	397	716	476
Estimated volume, m^3			
- gross/ha	814	1146	476
- gross/tree	2.05	1.60	1.00

Stand No. 2 was located 7 km west of Nanoose Bay, B.C. Understory consisted of devils club, horsetails, Oregon grape, salal, skunk cabbage, and sword fern. Species composition, by volume, was 42% western red cedar, 34% western hemlock, 22% deciduous species, and 2% Douglas-fir.

Stand No. 3 was located 15 km west of Buckley Bay, B.C. Understory consisted of huckleberry and salal. Species composition, by volume, was 78% balsam fir, 12% western hemlock, 7% western red cedar, and 3% Douglas-fir.

All felling was done by the same faller. He had six years falling experience and FERIC considers him to have been skilled and efficient. He used a Husqvarna Model 2100 chain saw with a 81-cm bar. Trees were directionally felled parallel to the haul road to facilitate grapple yarding. After felling (Figure A), trees were measured (Figure B), limbed, bucked (Figure C), and topped according to bucking and grading rules issued by the company.

FIGURE A. Handfaller Cutting Tree.

FIGURE B. Handfaller Measuring Tree.

FIGURE C. Handfaller Bucking Tree.

Results and Discussion

Summary statistics for individual time elements are given in Tables 2 to 5. These were computed using observations made on a total of 665 measured and non-measured trees. Subsequent presentations are based on the 565 measured trees only and show the influence of tree diameter and species on productivity and cost.

1. Overall Results

The faller averaged 59% productive time in Stand No. 1, 64% in Stand No. 2, and only 44% in Stand No. 3 (Table 2). The lower productive time in Stands No. 1 and 3 resulted from losing over 7 hours for wind. Cutting, limbing/bucking, and moving were the main productive time elements. Trees cut per productive hour ranged from 28.4 to 40.9 (44% difference). The production per total hour ranged ±9%, or from 16.9 to 20.0 trees. The lower variance in trees felled per total hour is explained mainly by the higher delay times experienced in Stands No. 1 and 3.

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

Identification	Stand No. 1		Stand No. 2		Stand No. 3		Combined	
	Min/Tree	%	Min/Tree	%	Min/Tree	%	Min/Tree	%
Productive Time								
Move	0.50	14	0.38	13	0.26	8	0.37	11
Brush	0.09	2	0.10	3	0.08	2	0.09	3
Cut	0.73	21	0.79	26	0.53	16	0.69	21
Wedge	0.06	2	0.08	3	0.05	1	0.07	2
Limb/Buck	0.69	19	0.47	16	0.52	16	0.55	17
Buck Windfall	0.04	1	0.08	3	0.02	1	0.05	1
Subtotal	2.11	59	1.90	64	1.46	44	1.82	55
Non-Productive Time								
Fuel/Oil	0.14	4	0.14	5	0.12	3	0.13	4
File Chain	0.14	4	0.14	4	0.03	1	0.11	3
Saw Repairs	0.14	4	0.18	6	0.03	1	0.12	4
Other	1.02	29	0.63	21	1.71	51	1.10	34
Subtotal	1.44	41	1.09	36	1.89	56	1.46	45
Total	3.55	100	2.99	100	3.35	100	3.28	100
Productive Minutes	413.2		470.6		322.5		1206.3	
Non-Productive Minutes	283.0		271.9		418.7		973.6	
Total	696.2		742.5		741.2		2179.9	
Number of Trees								
Merchantable (17.5 cm+ dbh)	164		156		131		451	
Sapling (7.5 - 17.4 cm dbh)	11		90		76		177	
Snag	21		2		14		37	
Total	196		248		221		665	
No. Trees Per Productive Hour	28.4		31.8		40.9		33.1	
No. Trees Per Total Hour	16.9		20.0		17.8		18.3	
No. Trees Per 6.5-Hour Shift	109.9		130.0		115.7		119.0	

Moving time accounted for 24% of the productive time in Stand No. 1, 20% in Stand No. 2, and 18% in Stand No. 3. In addition to moving from tree-to-tree, moving time also includes walk-in and out times, (walk-in at start of shift, walk-out and in at lunch time, and walk-out at end of shift). Table 3 shows the breakdown of these phases. FERIC observed that moving times often were not determined by the next adjacent tree, but by the falling pattern (trees felled parallel to haul road), tree lean, and topography.

TABLE 3. Moving Time.

Phase	Stand No. 1		Stand No. 2		Stand No. 3	
	Min	%	Min	%	Min	%
Tree-to-Tree	73.4	75	56.8	61	42.7	75
Walk-in & Out	24.2	25	36.7	39	14.0	25
Total	97.6	100	93.5	100	56.7	100

Time spent brushing varied little between the three areas and the understory did not appear to hamper the faller's productivity in any significant way.

Cutting time varied from 35% of productive time in Stand No. 1 to 42% in Stand No. 2, with Stand No. 3 at 36%. Wedging time was fairly constant in all three areas.

Limbing/bucking time was the second largest productive time element. It accounted for 33% of the productive time in Stand No. 1, 25% in Stand No. 2, and 36% in Stand No. 3. FERIC observed that because of the steep slope in Stand No. 2, some trees slid away after being felled and were not bucked. Also, many trees were not topped because they either broke or were buried by other trees. These trees would be processed later after being yarded to the roadside. In addition, there was a higher volume of cedar in Stand No. 2, much of which was decadent. Many of these trees broke up when they hit the ground and only produced one log when processed. The limbing/bucking times in the three areas were consistent with those found in another handfalling study (Peterson 1987). In that study, conventional limbing/bucking time in an old-growth stand accounted for 29% of the faller's productive time.

Non-productive time includes all delays, no matter what their duration. "Other" delay time includes such items as reconnaissance, rest breaks, visitors, and wait for wind. Table 4 summarizes these delays. Wait for wind was the major delay activity in Stand No. 1 and Stand No. 3. More time was lost for reconnaissance and rest breaks in Stand No. 2, probably because of the steeper slope (80% in Stand No. 2 versus 20% in Stand No. 1 and 5% in Stand No. 3).

TABLE 4. Summary of "Other" Delays.

Activity	Stand No. 1		Stand No. 2		Stand No. 3	
	No.	Min	No.	Min	No.	Min
Cut Burl	1	0.5	1	12.7	-	-
Fix or Get Wedges	-	-	3	1.2	6	3.1
Get Axe	6	2.4	5	2.4	4	2.5
Get or Move Fuel	4	4.4	13	14.9	4	3.2
Listen for or Assist Partner	-	-	1	15.8	1	0.5
Miscellaneous	1	1.3	1	31.0	3	2.9
Move Spare Saw	1	1.1	-	-	-	-
Raingear, Clothing	4	2.9	1	0.6	1	1.0
Reconnaissance	41	16.2	52	35.0	37	20.6
Rest Break	10	16.7	7	31.9	5	20.1
Saw Stuck	3	5.6	5	4.7	4	7.0
Talk to Supervisor	2	4.7	3	4.0	-	-
Visitors	2	11.4	2	1.8	2	0.9
Wait for Wind	3	133.2	-	-	7	315.8
Total	78	200.4	94	156.0	74	377.6

The minimum, mean, and maximum 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 5. Moving time ranged from a low of 0.05 minutes to a high of 15.08 minutes/move. Brushing time varied from a low of 0.03 minutes to 4.15 minutes/occurrence. There was a range of 11.66 minutes in the cutting phase, 5.30 minutes in the wedging phase, and 7.65 minutes in the limbing/bucking phase. The largest time difference occurred in the saw-repair category (18.13 minutes).

2. Results by Species and Diameter Class

Falling phase times by diameter class and species are given in Tables 6, 7, and 8 for the sample of 565 measured trees. This information is shown graphically in Figures D, E, F, and G. One hundred and sixty one of the 565 trees observed were in the 7.5- to 17.4-cm class (sapling class). The average cutting time for this class was 0.18 minutes. The results show that as diameter increases so does the processing time.

Cutting times for hemlock and Douglas-fir were very similar in Stand No. 1 (Figure D). When wedging and limbing/bucking times are added, hemlock took longer to process. This is because of the longer limbing/bucking times in hemlock for size classes 42.5 cm and over. In Stand No. 2, hemlock generally took longer to process, followed by Douglas-fir in the smaller classes and then cedar (Figure E). In Stand No. 3, hemlock again took longer to process, followed next by Douglas-fir and then balsam (Figure F). FERIC believes the longer processing times for hemlock reflect the fact that it is a shade-resistant species with many limbs.

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

Falling Phase	Number of Observations			Minimum (min)			Mean (min)			Maximum (min)			Standard Deviation (min)		
	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3
Move	176	193	160	0.09	0.07	0.05	0.55	0.48	0.35	7.37	15.08	4.72	0.88	1.29	0.51
Brush	48	57	49	0.03	0.07	0.05	0.37	0.45	0.38	2.38	4.15	2.21	0.45	0.57	0.38
Cut	196	248	221	0.06	0.07	0.07	0.73	0.81	0.55	2.10	11.72	9.43	0.46	1.43	0.84
Wedge	20	18	22	0.12	0.13	0.14	0.52	1.15	0.49	1.90	5.40	1.36	0.47	1.21	0.35
Limb/Buck	115	59	96	0.16	0.16	0.11	1.18	1.98	1.19	4.03	7.76	4.87	0.59	1.51	0.84
Buck Windfalls	8	15	14	0.22	0.33	0.09	1.04	1.22	0.32	2.35	4.01	1.34	0.60	1.00	0.32
Fuel & Oil	11	12	8	1.12	1.65	1.71	2.49	2.83	3.27	5.81	5.21	6.74	1.29	0.90	1.53
File Chain	5	6	2	4.45	2.46	3.55	5.55	5.93	3.72	6.69	9.39	3.88	0.74	2.73	0.17
Saw Repairs	4	18	2	0.34	0.28	0.66	6.87	2.47	3.74	16.28	18.41	6.83	6.10	5.26	3.09
Other	76	91	73	0.09	0.08	0.11	0.92	1.54	1.28	10.20	15.82	15.55	1.43	2.85	2.40

TABLE 6. Falling Phase Time by Diameter Class and Species--Stand No. 1.

Diameter Class Midpoint (cm)	Douglas-fir					Hemlock					Cedar					All Species				
	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)
12.5																11*	0.20			0.20
22.5						16	0.26		0.08	0.34						16	0.26		0.08	0.34
32.5	9	0.51	0.03	0.71	1.25	14	0.43		0.54	0.97						23	0.46	0.01	0.61	1.08
42.5	35	0.73	0.12	0.76	1.61	6	0.60		1.14	1.74	1	0.71			0.71	42	0.71	0.10	0.79	1.60
52.5	25	0.88	0.02	0.98	1.88	2	0.88		1.74	2.62						27	0.88	0.02	1.04	1.94
62.5	17	1.05	0.05	1.11	2.21											17	1.05	0.05	1.11	2.21
72.5	16	1.46	0.19	1.13	2.78	1	1.31		4.03	5.34						17	1.45	0.18	1.30	2.93
82.5	3	1.67	0.06	1.75	3.48											3	1.67	0.06	1.75	3.48
92.5	2	1.75		1.91	3.66											2	1.75		1.91	3.66
Total	107					39					1					158				

*Species was not identified on the smallest size class.

TABLE 7. Falling Phase Times by Diameter Class and Species--Stand No. 2.

Diameter Class Midpoint (cm)	Douglas-fir					Hemlock					Cedar				
	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)
12.5															
22.5	2	0.30		0.08	0.38	21	0.27		0.04	0.31	16	0.38	0.18		0.56
32.5	4	0.61	0.34	0.59	1.54	15	0.56	0.02	1.09	1.67	17	0.53	0.13	0.26	0.92
42.5	4	0.61		1.41	2.02	5	0.68	0.17	0.95	1.80	5	0.61	0.16	0.85	1.62
52.5						3	1.19	0.15	2.11	3.45	3	0.93	0.56	2.04	3.53
62.5						1	1.24		2.04	3.28					
72.5						1	1.71		4.50	6.21	4	1.44		1.31	2.75
82.5						1	3.97		3.78	7.75	1	1.59		3.64	5.23
92.5											2	2.94		1.60	4.54
102.5											1	3.36		2.95	6.31
112.5															
122.5											3	4.54	1.80	5.20	11.54
132.5															
142.5											2	5.42		4.84	10.26
152.5															
162.5															
172.5											2	9.04	1.44	2.86	13.34
Total	10					47					56				

Diameter Class Midpoint (cm)	Balsam					Deciduous					All Species				
	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)
12.5											82*	0.19			0.19
22.5	2	0.14		0.08	0.38	10	0.26			0.26	51	0.30	0.06	0.02	0.38
32.5	1	0.32	0.34	0.59	1.54	5	0.49			0.49	42	0.54	0.09	0.55	1.18
42.5				1.41	2.02	5	0.63	0.33		0.96	19	0.63	0.17	0.77	1.57
52.5						6	0.77			0.77	12	0.92	0.18	1.04	2.14
62.5	2	1.41		2.57	3.98	5	1.03	0.33		1.06	9	1.23	0.01	1.09	2.33**
72.5						2	0.87			0.87	7	1.48	0.04	1.48	3.00
82.5						2	1.57			1.57	4	2.17		1.86	4.03
92.5											2	2.94		1.60	4.54
102.5						1	1.43			1.43	2	2.40		1.48	3.88
112.5															
122.5											3	4.54	1.80	5.20	11.54
132.5															
142.5											2	5.42		4.84	10.26
152.5															
162.5															
172.5											2	9.04	1.44	2.86	13.34
Total	5					36					237				

* Species was not identified on the smallest size class.

** Includes one spruce (diameter class 62.5 cm) with a cut time of 1.85 min and a limb/buck time of 2.60 min.

TABLE 8. Falling Phase Times by Diameter Classes and Species--Stand No. 3.

Diameter Class Midpoint (cm)	Douglas-fir					Hemlock					Balsam					All Species				
	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)	No. Ob.	Cut (min)	Wedge (min)	Limb/ Buck (min)	Total (min)
12.5																68*	0.17			0.17
22.5						13	0.28		0.05	0.33	15	0.33		0.16	0.49	28	0.31		0.11	0.42
32.5						9	0.67	0.06	1.00	1.73	24	0.51	0.05	0.56	1.12	33	0.55	0.05	0.68	1.28
42.5	1	0.61		1.25	1.86	4	0.89	0.06	1.92	2.87	20	0.67	0.04	0.97	1.68	25	0.70	0.04	1.13	1.87
52.5						2	0.95		1.23	2.18	5	0.90		1.44	2.34	7	0.91		1.38	2.29
62.5	1	1.37	1.03	1.27	3.67	1	1.93	1.08	4.15	7.16	2	1.66	0.56	1.88	4.10	4	1.66	0.81	2.29	4.76
72.5	1	3.05		1.63	4.68	1	1.94		1.85	3.79						2	2.50		1.74	4.24
82.5						1	6.25	1.36	4.87	12.48	1	1.24		2.63	3.87	2	3.75	0.68	3.75	8.18
92.5																				
102.5																				
112.5																				
122.5																				
132.5																				
142.5																				
152.5																				
162.5	1	9.43		4.35	13.78											1	9.43		4.35	13.78
Total	4					31					67					170				

*Species was not identified on the smallest size class.

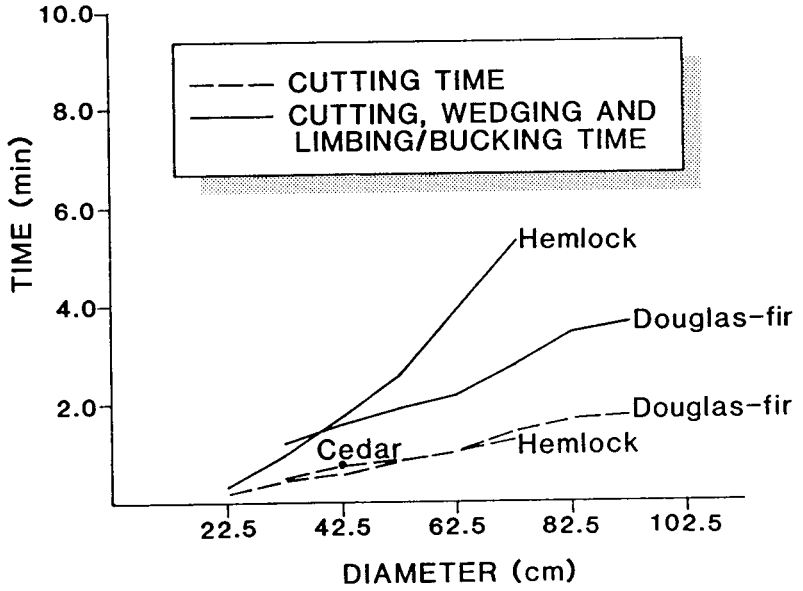

FIGURE D. Diameter Effect, by Species--Stand No. 1.

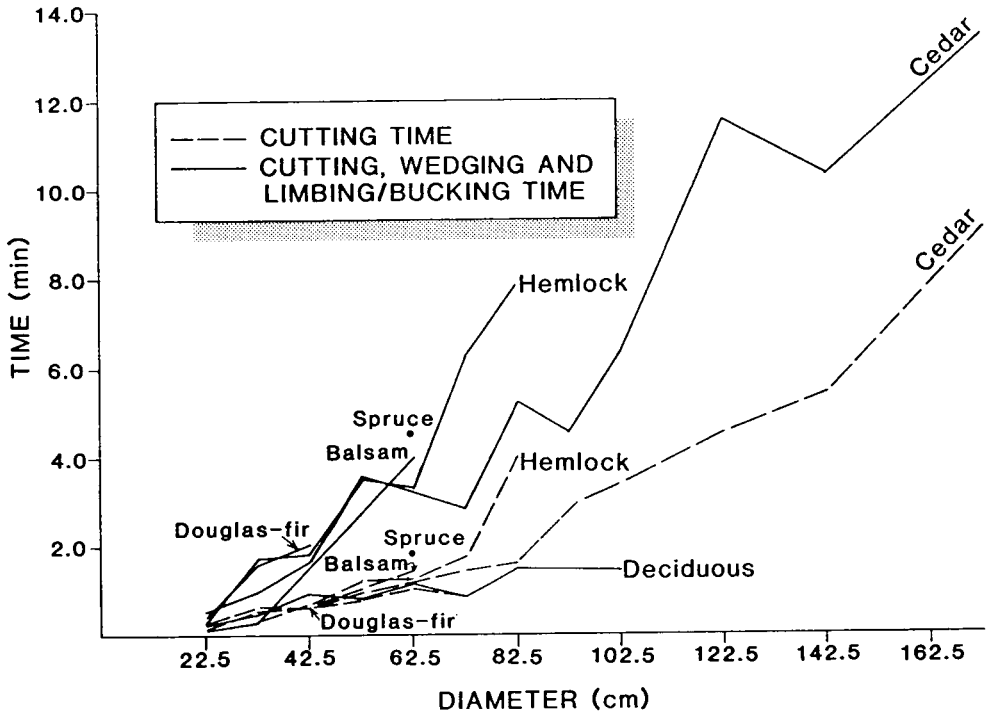

FIGURE E. Diameter Effect, by Species--Stand No. 2.

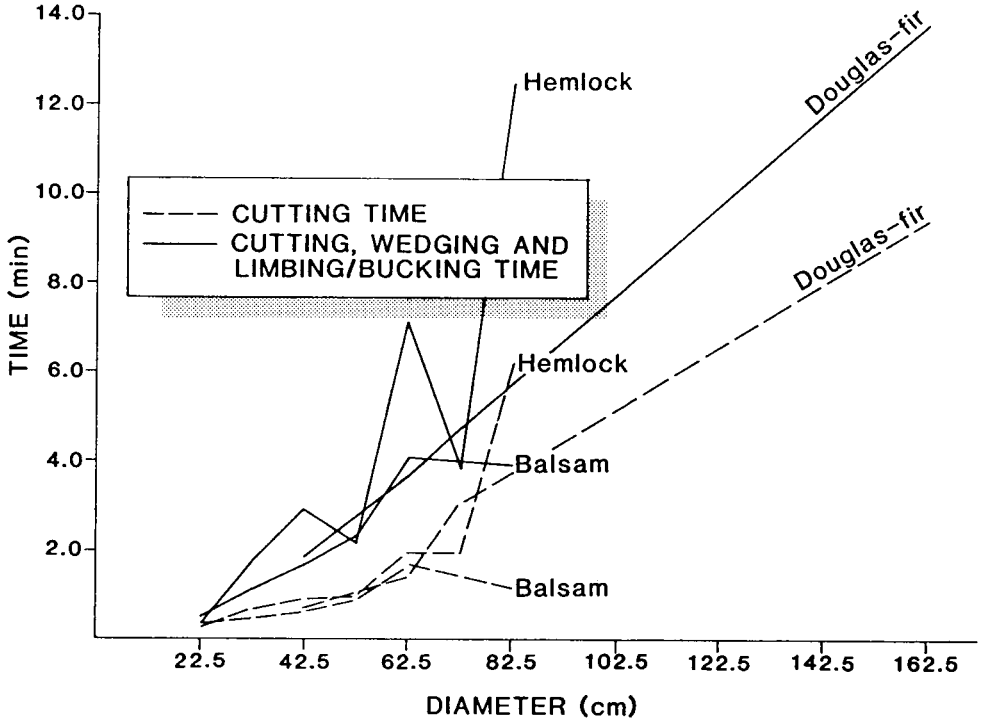

FIGURE F. Diameter Effect, by Species--Stand No. 3.

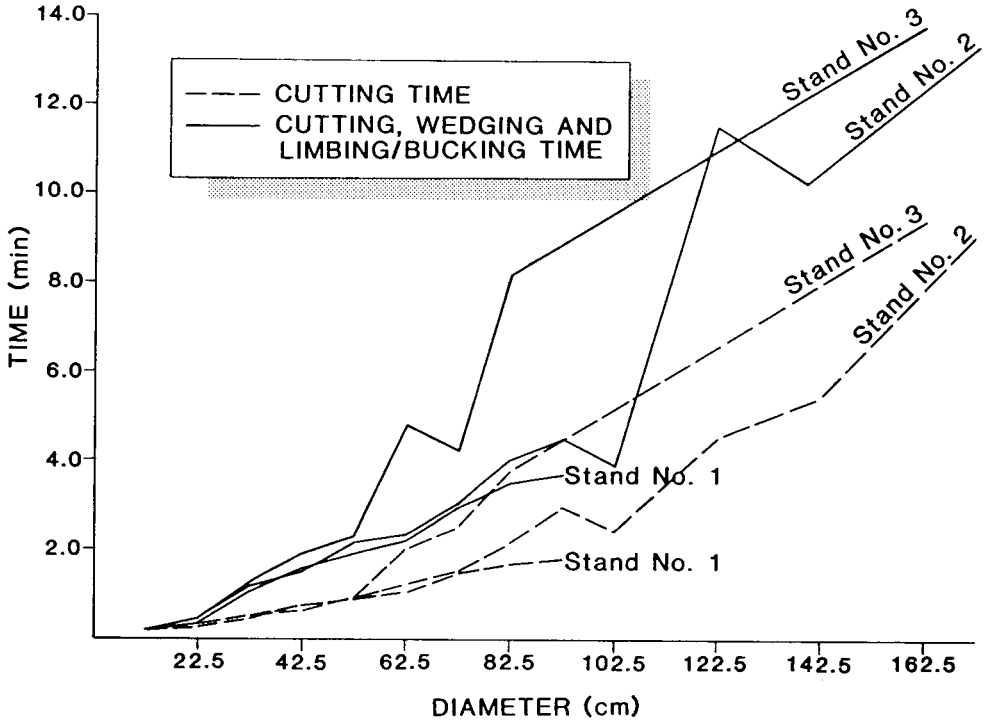

FIGURE G. Diameter Effect, by Stand--All Species.

When comparing cutting times for all species (Figure G), there was little variance between the three stands in the smaller diameter classes. There were insufficient samples in the larger diameter classes (82.5 cm+) to make reliable statements about the differences shown. Cutting time per tree varied from a low of 0.17 minutes for the sapling class (Stand No. 3) to 9.43 minutes for the 162.5-cm class (Stand No. 3). When wedging and limbing/bucking times were added, Stand No. 3 took longer in most cases because of the higher proportion of hemlock.

The gross merchantable volumes for the trees observed are shown in Table 9. They are derived from local volume tables calculated by FERIC.

3. Falling Costs by Species and Diameter Class

The direct falling costs presented in this section were estimated by FERIC, based on an operating labour cost of $294.62/day which includes 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 10 lists total falling costs per tree by diameter class and species. Table 11 lists the same information on a per-cubic-metre basis. The tables are based on actual cutting and limbing/bucking times (Tables 5, 6, and 7) plus fixed time (including delay time). Fixed times of 2.13 minutes for Stand No. 1, 1.73 minutes for Stand No. 2, 2.30 minutes for Stand No. 3, and 2.04 minutes for all stands combined were calculated from Table 2 and include all time except cutting and limbing/bucking. They are the sum of all time elements not influenced by tree size. This information is shown graphically in Figure H.

Costs per tree in Stand No. 3 are consistently higher than those of the other two stands in all diameter classes. In most cases, this results from the higher limbing/bucking times experienced in each diameter class because of the greater percentage of hemlock/balsam. Costs per tree in Stand No. 2 are consistently lower until the 82.5-cm diameter class. FERIC believes that the higher number of decadent cedar trees (which produced only one log per tree) and the steep terrain (trees slid away and were not bucked) account for this lower cost.

In the smallest diameter class (12.5 cm), there was a significant difference ($5.75) in the cost per cubic metre between the three stands. Stand No. 2 was the lowest at $19.63/$m^3$, and Stand No. 3 the highest at $25.38/$m^3$. This difference reduces to $1.23/$m^3$ in the 22.5-cm diameter class, and to $0.22/$m^3$ in the 82.5-cm diameter class. This highlights the cost sensitivity associated with falling small-diameter trees.

The per-cubic-metre falling cost quickly drops as diameter class increases. Looking at the combined cost per cubic metre for all species (Table 11), there is a $20.54/$m^3$ range over the four smallest diameter classes (12.5 to 42.5 cm). This range reduces to $0.67/$m^3$ in the following four diameter classes (52.5 to 82.5 cm).

TABLE 9. Gross Merchantable Volume by Diameter Class and Species.

Diameter Class Midpoint (cm)	Volume per Tree, m^3														
	Balsam		Cedar		Deciduous	Douglas-fir			Hemlock			Spruce	All Species			
	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Combined
12.5													0.08	0.08	0.08	0.08
22.5	0.26	0.34		0.17	0.19		0.18		0.30	0.26	0.29		0.30	0.21	0.31	0.25
32.5	0.65	0.83		0.45	0.58	0.75	0.51		0.73	0.65	0.77		0.74	0.55	0.81	0.68
42.5		1.61	0.90	0.92	1.18	1.39	1.10	1.44	1.43	1.26	1.56		1.39	1.12	1.59	1.39
52.5	2.14	2.70		1.60	2.09	2.28			2.44	2.14	2.74		2.29	2.34	2.72	2.37
62.5		4.19			3.37	3.45		3.17		3.36	4.44	2.51	3.45	3.15	4.00	3.44
72.5				3.77	5.08	4.95		4.36	5.68	4.92	6.66		4.99	3.77	5.52	4.67
82.5		8.54		5.36	7.28	6.80				6.88	9.51		6.80	6.70	9.02	7.25
92.5				7.26		9.04							9.04	7.26		8.15
102.5				9.53	13.41									11.47		11.47
112.5																
122.5				15.34										15.34		15.34
132.5																
142.5				22.99										22.99		22.99
152.5																
162.5									25.33						25.33	25.33
172.5				38.40										38.40		38.40

TABLE 10. Total Falling Cost per Tree by Species and Diameter Class.

Diameter Class Midpoint (cm)	$/Tree														
	Balsam		Cedar		Deciduous	Douglas-fir			Hemlock			Spruce	All Species			
	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Combined
12.5													1.91	1.57	2.03	1.73
22.5	1.53	2.29		1.73	1.63		1.73		2.03	1.67	2.16		2.03	1.68	2.23	1.90
32.5	1.68	1.76		2.07	1.82	2.75	2.40		2.54	2.77	3.26		2.62	2.31	2.89	2.58
42.5		3.23	2.33	2.62	1.94	2.97	3.08	3.41	3.17	2.76	4.19		2.98	2.57	3.39	3.01
52.5	4.68	3.80		3.85	2.05	3.27			3.90	4.12	3.67		3.32	3.03	3.76	3.31
62.5		4.79			2.26	3.52		4.05		4.11	6.87	5.07	3.52	3.32	5.13	3.69
72.5				3.67	2.13	3.87		5.72	6.13	6.51	4.99		4.00	3.85	5.36	4.06
82.5		5.06		5.71	2.71	4.55				7.77	11.00		4.55	4.72	8.04	5.40
92.5				5.14		4.75							4.75	5.14		4.95
102.5				6.59	2.59									4.60		4.60
112.5																
122.5				9.41										9.41		9.41
132.5																
142.5				9.83										9.83		9.83
152.5																
162.5									13.19						13.19	13.19
172.5				11.18										11.18		11.18

TABLE 11. Total Falling Cost per Cubic Metre by Species and Diameter Class.

Diameter Class Midpoint (cm)	$/m														
	Balsam		Cedar		Deciduous	Douglas-fir			Hemlock			Spruce	All Species			
	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 1	Stand No. 2	Stand No. 3	Stand No. 2	Stand No. 1	Stand No. 2	Stand No. 3	Combined
12.5													23.88	19.63	25.38	22.71
22.5	5.88	6.74		10.18	8.58		9.61		6.77	6.42	7.45		6.77	8.00	7.19	7.55
32.5	2.58	3.33		4.60	3.14	3.67	4.71		3.48	4.26	4.23		3.54	4.20	3.57	3.83
42.5		2.01	2.59	2.85	1.64	2.14	2.80	2.37	2.22	2.19	2.69		2.14	2.29	2.13	2.17
52.5	2.19	1.41		2.41	0.98	1.43			1.60	1.93	1.34		1.45	1.29	1.38	1.40
62.5		1.14			0.67	1.02		1.28		1.22	1.55	2.02	1.02	1.05	1.28	1.06
72.5				0.97	0.42	0.78		1.31	1.08	1.32	0.75		0.80	1.02	0.97	0.88
82.5		0.59		1.07	0.37	0.67				1.13	1.16		0.67	0.70	0.89	0.73
92.5				0.71		0.53							0.53	0.71		0.62
102.5				0.69	0.19									0.40		0.40
112.5																
122.5				0.61										0.61		0.61
132.5																
142.5				0.43										0.43		0.43
152.5																
162.5									0.52						0.52	0.52
172.5				0.29										0.29		0.29

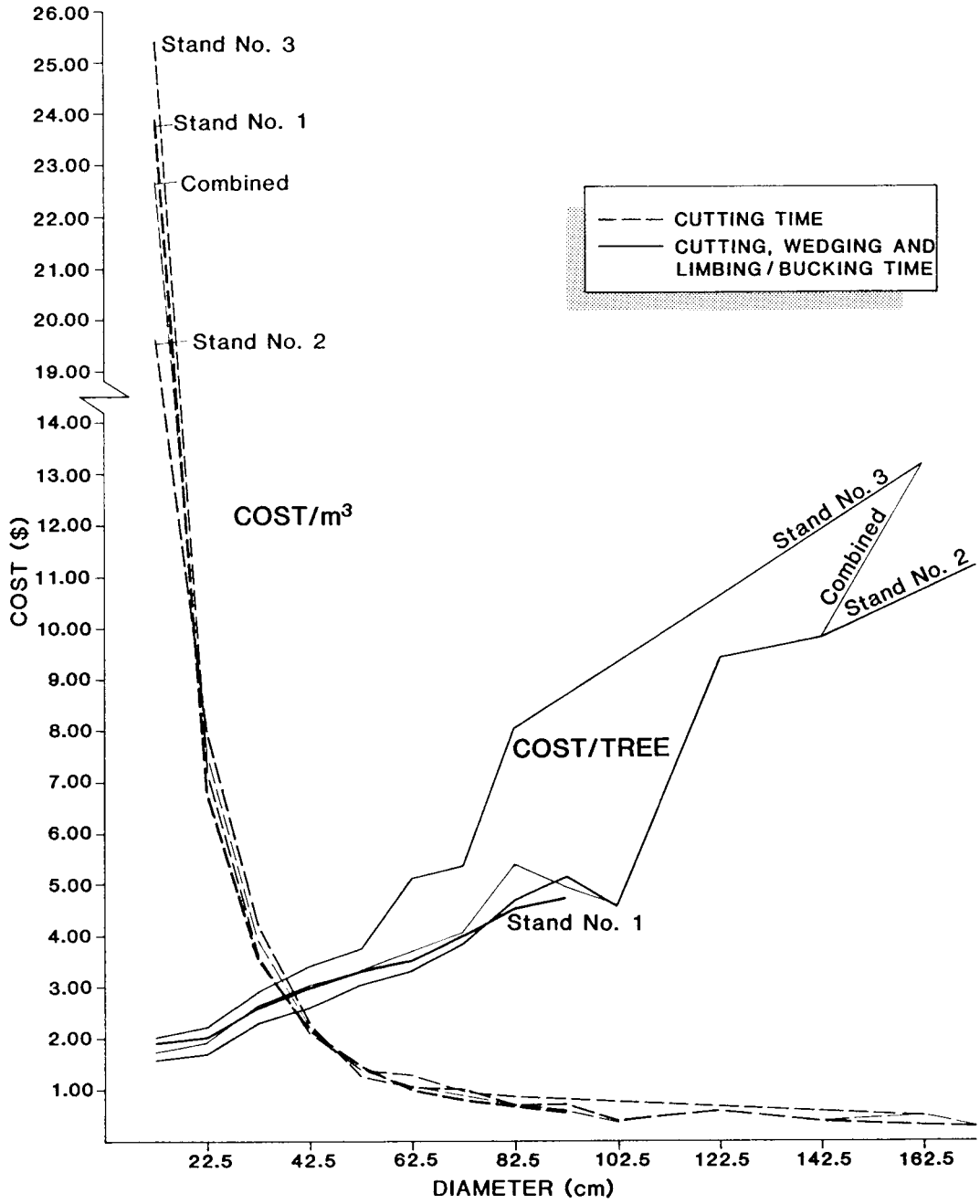

FIGURE H. Falling Cost per Tree and per Cubic Metre by Stand and by Diameter--All Species.

Using the overall tree average data in Table 2, and a per-shift falling cost of $319.62, average stand costs were derived and are shown in Table 12. There were differences of $0.46/tree and $1.33/m³ between the three stands studied.

TABLE 12. Average Costs by Stand.

Stand No.	m^3/Tree	Avg Total Min/Tree	Cost/Tree	Cost/m^3
1	2.05	3.55	$2.91	$1.42
2	1.60	2.99	$2.45	$1.53
3	1.00	3.35	$2.75	$2.75
Combined	1.53	3.28	$2.69	$1.76

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. A variety of model specifications were tried for the statistical analysis. These included specifications by dbh, dbh^2, 1/dbh, $1/dbh^2$, and combinations of these. In the example presented here, a combination of diameter and diameter squared was used because it offered maximum predictive power. Linear relationships between tree diameter and phase times were tested using the least squares method.

For example purposes, only the results from Stand No. 3 are shown here (Table 13). Cutting, wedging, and limbing/bucking time observations were stratified by species and tested to determine if times vary by diameter class. No significant correlation was found between wedging time and diameter class. At the five-percent level of significance, the equations predicting cutting and limbing/bucking times for each species were found to be different. This indicates that separate equations should be used for different species. The results for all species combined (Stand No. 3) are shown graphically in Figure I. The sample size was small for diameters greater than 52.5 cm, so predictions of falling phase times after this size may not be accurate. Further discussions and results of statistical analysis for all stands will be covered in a separate publication.

TABLE 13. Predicted Phase Times and Regression Equations--Stand No. 3.

Phase	Species	Sample Size	r^2	Standard Error	Equation
Cut	Balsam	66	0.60	0.20	$57.90-2.31(dbh)+0.0601(dbh^2)$
	Douglas-fir*				
	Hemlock	31	0.96	0.24	$39.16-1.50(dbh)+0.0586(dbh^2)$
	All Species	102	0.92	0.31	$13.33-0.097(dbh)+0.037(dbh^2)$
Limb/ Buck	Balsam	50	0.37	0.45	$0.56+1.35(dbh)+0.0259(dbh^2)$
	Douglas-fir*				
	Hemlock	19	0.65	0.76	$-54.81+5.22(dbh)-0.0048(dbh^2)$
	All Species	74	0.59	0.59	$-63.20+4.71(dbh)-0.0086(dbh^2)$

* Sample Size was too small to make accurate predictions.

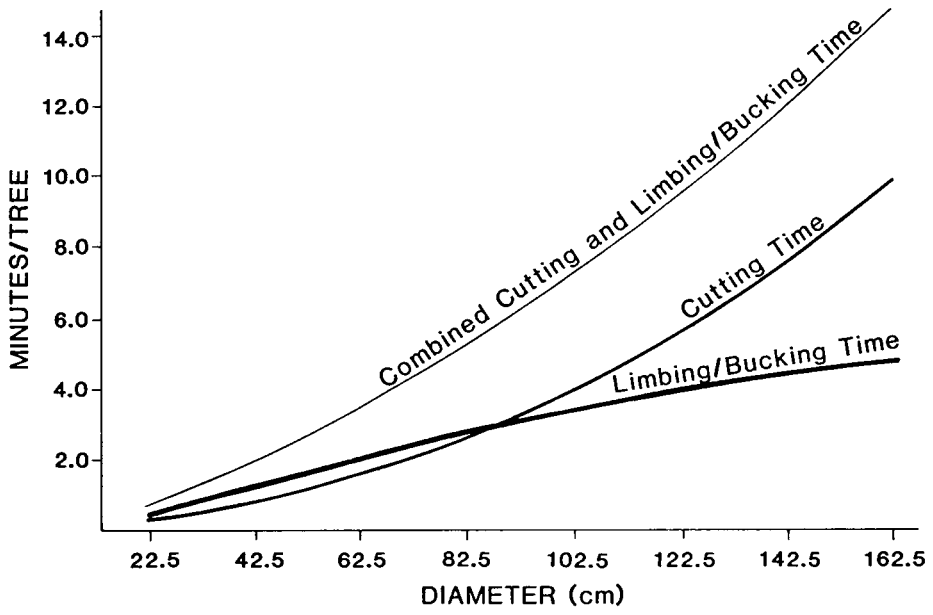

FIGURE I. Predicted Cutting and Limbing/Bucking Times, All Species--Stand No. 3.

REFERENCE

Peterson, J.T. 1987. Harvesting economics: handfalling old-growth timber--conventional versus selective-bucking techniques. Forest Engineering Research Institute of Canada. Technical Note No. TN-106. Vancouver, B.C.

ACKNOWLEDGEMENTS

The author wishes to thank the faller and staff of MacMillan Bloedel Ltd., Northwest Bay Division, for their help and cooperation. Technical assistance by FERIC employees P.D. Forrester, E.J. Phillips, and S.R. Webb is also acknowledged.