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A COMPARISON OF SELECTIVE LOGGING AND CLEAR CUTTING IN THE HARDWOOD - HEMLOCK FORESTS OF THE NORTHERN LAKE STATES

Presented as Partial Fulfillment of the Requirements for the Degree of Master of Forestry. May 26,1947

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FOREWORD

At the 1939 summer meeting of the Society of American Foresters held in Milwaukee, Wisconsin, the main subject for discussion was the Lake States forestry problem. At this meeting two lumbermen among the speakers presented opposing views on the practicability of selective logging, each bringing forth his own arguments and reasons why this system of cutting was or was not practical for his operation. Such differences are typical of the wide spread controversy among loggers and foresters on this subject..

It is the object of this paper to point the way toward the proper decision in regards to a system of partial cutting by a careful examination of the factors involved. Although the case presented here is a theoretical one, based upon a theoretical stand, every effort has been made to choose data typical or reasonable for the Great Lakes area (especially the Upper Peninsula of Michigan). Properly chosen artificial data should not detract from the value of such a report because the varied nature of logging operations prevents any data from being applied universally. The real value, then, of any comparative study of liquidation versus selective logging lies not in the proof that clear cutting is economically superior (or vice versa) but in the procedure worked up to arrive at the conclusion (especially in the handling of certain key items such as fixed costs) and the statement that one system of cutting works to advantage for a certain type of stand and under certain specific conditions and methods of operation.

The author wishes to extend his thanks to the faculty members of the School of Forestry and Conservation, several of whom have given him valuable assistance and especially to Professor D. M. Matthews, under whose supervision this paper was prepared, and Frank Murray, who provided invaluable aid both in the form of data and his knowledge of logging operations in this area, without which help it would have been impossible to complete several sections of this paper.

J. W. Meteer

May 26, 1947

I. INTRODUCTION

Through broad and diversified usage, the term selective logging has come to hold a variety of meanings. In it's strict sense it refers to a partial cutting of a certain volume per acre-usually above a specified diameter limit. In addition, overmature and inferior trees are removed that will not live until the next cutting or will interfere with the growth of more vigorous growing stock. In this manner it serves as a stand improvement measure at the same time merchantable value is removed. In this paper the term selective logging is taken to mean as outlined above and at no time to include the rather common practice of "culling" the woods-selecting the prime trees and leaving an assortment of cull, inferior, and overmature trees, from which the harvesting of a second cut is very doubtful.

The high point in the controversy of selective logging versus a rapid liquidation operation is the old story that production is cut down and costs are raised. For example one operator stated, "We cannot get good answers to the things we must know before taking what may be a very costly step. How will selective logging affect costs in cutting, road building, hauling, camps, marketing, and overhead? What are the new risks in fire, windfall, and damage to Hemlock? What can I be sure of with respect to counter balancing these with gains in growth, better yield in logs, and longer use of conversion facilities?"[1] This paper attempts to

1. Journal of Forestry. Proceedings, Meeting SAF. October, 1939

answer some of these questions by studying stands of the type common to the Lake States and examining the factors concerned with selective logging. These factors can be subdivided into two broad classes; 1)value-returns and 2)costs, both of which are subject to variations with the intensity of cutting. It is the ascertainment of the most favorable combinations of these factors - plus the economic consideration of fitting the total annual cut to the capacity of conversion facilities, or vice versa - that determines the cutting limit at which the lumberman is to operate.

One of the most common forest types in the upland old-growth forests of the Northern Great-Lakes States is the mixed hardwood-hemlock. Eastern hemlock (Tsuga canadensis), sugar maple (Acer saccharum), and yellow birch (Betula lutea) are the main species, with ash, basswood, elm, and occasionably beech and white pine of lesser importance. Volumes normally range from 5 to 15 M ft. per acre. Stand table A (table I) shows the composition of what might be considered a typical hardwood-hemlock stand (adapted from cruise data from Iron County Michigan). Lesser species (ash, elm, and basswood) have been omitted from this table because of their relative insignificance and in order to facilitate computations and simplify data. The hardwoods follow the same trends in value-returns and costs per tree diameter class and it is reasonable to assume that the exclusion of the minor species would have no appreciable effect upon the results of this study.

Values must necessarily be computed on a mill tally basis. Accepted overrun percentages for the Scribner Decimal C log rule (table III) for hemlock, maple, and birch were applied to the log scale volume to obtain mill tally volumes.

TABLE I

Stand Table A. Mixed Hardwood-Hemlock, Upper Michigan.

Scribner Decimal C Log Rule (Cull eliminated in the cruise)

	Maple			Birch			Hemlock		
		Volume			Volume			Volume	
DBH	No. Trees	Log Scale	Mill Tally	No. Trees	Log Scale	Mill Tally	No. Trees	Log Scale	Mill Tally
10	4.28	132	187	2.64	78	106	5.42	108	177
12	3.78	237	325	2.12	93	123	4.15	189	294
14	3.64	364	480	2.08	150	194	4.02	358	527
16	3.52	550	711	2.18	214	271	2.18	289	405
18	3.40	755	950	2.01	360	447	1.55	308	415
20	2.65	762	938	1.58	364	444	.63	167	218
22	1.82	634	765	.80	227	274	.46	151	192
24	1.06	401	478	.84	224	262	.43	169	211
26	.72	326	382	.20	70	83	.27	131	161
28	.16	87	100				.29	168	204
30+	.18	123	140				.16	113	135
	25.21	4371	5456	14.45	1780	2204	19.56	2151	2939

Combined Stand Table

10	12.34	318	470
12	10.05	519	742
14	9.74	872	1201
16	7.88	1053	1387
18	6.96	1423	1812
20	4.86	1293	1600
22	3.08	1012	1231
24	2.33	794	951
26	1.19	527	626
28	.45	255	304
30+	.34	236	275
	59.22	8302	10599

TABLE II

Stand Table B. Mixed Hardwood-Hemlock, Upper Michigan..

Scribner Decimal C Log Rule (Cull eliminated in the cruise)

	Maple			Birch			Hemlock		
		Volume			Volume			Volume	
DBH	No. Trees	Log Scale	Mill Tally	No. Trees	Log Scale	Mill Tally	No Trees	Log Scale	Mill Tally
10	2.86	65	92	2.64	78	106	3.82	116	190
12	2.52	136	186	2.12	93	123	3.75	190	295
14	2.43	241	320	2.08	150	194	4.52	530	680
16	2.35	367	474	2.18	214	271	4.38	657	920
18	2.27	504	634	2.01	360	498	4.52	1060	1430
20	1.77	509	627	1.58	364	445	2.72	794	1032
22	1.27	423	512	0.80	227	274	1.76	615	780
24	0.71	268	320	0.84	224	262	1.45	484	605
26	0.48	218	260	0.20	70	083	0.96	478	587
28	0.11	58	67				0.45	227	275
30	0.12	82	93				0.25	198	237
	16.89	2,871	3,585	14.45	1,780	2,178	28.58	5,349	7,031

Combined Stand Table

10	9.32	259	388
12	8.39	419	604
14	9.03	921	1194
16	8.91	1238	1665
18	8.80	1924	2562
20	6.07	1603	2026
22	3.83	1265	1566
24	3.00	976	1187
26	1.64	766	930
28	.56	285	342
30	.37	280	330
	59.92	9,936	12,794

TABLE III

Percent of net overrun, Scribner Decimal C log rule

DBH	Maple	Birch	Hemlock
10	41.8	35.8	64.8
12	37.2	32.6	55.7
14	33.0	29.6	47.4
16	29.1	26.7	40.2
18	25.7	24.3	34.8
20	23.0	22.2	30.1
22	20.8	20.5	26.8
24	19.1	19.2	24.8
26	17.0	17.7	22.9
28	15.2	16.2	21.2
30	13.6	14.8	19.7

II VALUE RETURN FACTORS 1/

Lumber Values as Affected by species and diameter class.

On the lumber market certain species and high grades are at a premium. Birch and Maple are both high value species and command good prices. Hemlock is normally in less demand and producers are at a disadvantage when they handle this species.

Each log saws out only a small percentage of the high grade knot-free lumber that brings top prices. Such lumber is sawn from the outer circumference of the log and large logs yield a higher percentage of clear lumber than do the small. Again hemlock is at a disadvantage, sawing out but little more of the higher grade lumber at 30 inches than at 10. As the larger trees saw out more high grade lumber (with the exception of hemlock), it is necessary- in order to obtain a true picture of the potential value to be derived from a stand- to compute the value per M ft. and the value per acre for each diameter class.

Lumber prices used in this study (table IV) were those of late 1941 and 1942. Present-day prices (1947) are definitely not normal and would give exaggerated values. An examination of prices at the 1940 level showed them to be little above the late depression years, being almost identical with the 1937 prices. The author feels that as prices return to normal they should approach those used here.

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1. Value returns are expressed as the lumber sale value per M bd. ft. mill tally of lumber produced.

TABLE IV

Lumber prices, Dollars per M ft. b.m..

Lumber Grade	Maple	Birch	Hemlock
FAS	94.00	115.00	
SELECTS	79.00	100.00	
#1Com	58.00	67.00	
#2Com	44.00	46.00	
#4Com	26.00	29.00	
MERCH			41.50
#3Com			37.50
#4Com			31.75

Accepted lumber-grade returns from the different tree diameters are entered for each species in columns A,B,C,D, and E of tables V (a)(b)(c). The weighted value per M per DBH class in column G was obtained by adding the products of "% of grade times price of grade". Of special significance is the fact that maple ranges from $32.12 per M ft. b.m. to $55.77 from the low to the high diameters and birch ranges from $38.16 to $62.19, while hemlock prices are practically constant at from $39.58 to $39.69 per M. The value per acre of all diameters was then obtained by multiplying the mill tally volume by the value per M ft. Values per acre for each species were then entered in columns C,D, and E of table VI and added to get column F. The weighted value per M for trees of each DBH class for the entire stand was calculated in column G. The hemlock in this stand and its constant value per diameter class has severely reduced the effect of the much higher value returns in the upper diameters of maple and birch.

TABLE V (a)

Grade returns-Maple -per DBH class

	A	B	C	D	E	F	G	H
	FAS	Sel	#1Com	#2Com	#3Com	Mill-Tally Vol./Ac.	Value Per	Value Per
	Prices per M bm							
	$94.00	79.00	58.00	44.00	26.00	Mbm	Mbm	Acre
DBH	%of grades from each Dbh Class							
10		1.2	9.6	13.5	75.7	.187	$32.12	$6.00
12	0.9	2.1	12.3	15.3	69.4	.325	34.37	11.15
14	2.3	3.2	15.1	16.0	63.4	.480	36.82	17.70
16	4.1	4.2	17.7	16.1	57.9	.711	39.52	28.10
18	5.2	5.2	20.3	15.9	52.8	.950	42.01	39.90
20	7.5	6.0	23.1	15.7	47.7	.938	44.47	41.70
22	9.1	7.1	25.5	15.3	43.0	.765	46.77	35.80
24	10.9	8.1	27.6	14.6	38.8	.478	49.12	23.45
26	12.6	9.2	29.7	13.7	34.8	.382	51.34	19.60
28	14.2	10.2	31.9	12.7	31.0	.100	53.42	5.34
30	16.0	11.2	33.9	11.5	27.3	.140	55.77	7.80
								236.54

Explanation.
G. Sum of (% of grade x price per grade) for each DBH class.
H. F x G

(b) Birch

	A	B	C	D	E	F	G	H
	FAS	Sel	#1Com	#2Com	#3Com	Mill-Tally Vol./Ac.	Value Per	Value Per
	Prices per M bm							
	$115	100	67	46	29	Mbm	Mbm	Acre
DBH	% of grades from each Dbh Class							
10	1.3	1.2	9.0	22.5	66.0	.106	$38.16	$4.04
12	3.1	2.1	13.0	19.4	61.9	.123	41.22	5.07
14	4.8	3.2	15.9	17.5	58.0	.194	44.20	8.56
16	6.6	4.2	18.0	16.8	53.7	.271	47.16	12.75
18	8.3	5.2	19.5	16.7	49.7	.447	49.87	22.40
20	10.0	6.0	20.8	16.8	45.7	.344	52.39	23.50
22	12.1	7.1	22.4	16.9	40.9	.274	56.63	15.21
24	14.5	8.1	24.3	16.9	35.4	.262	59.07	15.50
26	16.2	9.2	26.6	16.9	30.2	.083	62.19	5.18
28	18.1	10.2	29.1	17.0	24.5			
30	20.0	11.2	31.6	17.0	19.0			
								112.21

TABLE V (continued)

(c) Hemlock

DBH	A Merch.	B #3Com.	C #4Com.	F :Mill Tally :Vol Per Ac: Mbm	G :Value :Per M:	:Value :Per :Acre
	Prices Per Mbm					
	$41.50	37.50	31.75			
	% of Grades from each DBH Class:					
10	60.8	35.4	3.8	.177	$39.67	$7.00
12	60.9	34.6	4.5	.294	39.66	11.60
14	61.0	33.8	5.2	.527	39.60	20.85
16	61.3	32.9	5.8	.405	39.58	16.00
18	61.8	32.1	6.1	.415	39.56	16.40
20	62.5	31.0	6.5	.218	39.58	8.62
22	63.1	30.2	6.7	.192	39.64	7.60
24	63.6	29.4	7.0	.211	39.62	8.35
26	64.4	28.6	7.0	.161	39.63	6.37
28	65.0	27.9	7.1	.204	39.67	8.10
30	65.7	27.1	7.2	.135	39.69	5.36

TABLE VI

Weighted Average, Values for Entire Stand

DBH	A :No. :Trees	B :Volume :M.Tally	C :Value Per Acre :Maple	D :Birch	E :Hemlock	F :Total	G :Ave.Value Per M: :Mill Tally :
10	14.34	470	$6.00	$4.04	$7.00	$17.04	$36.20
12	11.05	742	11.15	5.07	11.60	27.82	37.60
14	9.74	1204	17.70	8.56	20.85	47.11	39.20
16	7.88	1387	28.10	12.75	16.00	56.85	41.00
18	6.96	1812	39.90	22.40	16.40	78.70	43.40
20	4.86	1600	41.70	23.50	8.62	73.82	46.20
22	3.08	1231	35.80	15.21	7.60	58.61	47.60
24	2.33	951	23.45	15.50	8.35	47.30	49.70
26	1.19	626	19.60	5.18	6.37	31.15	49.80
28	0.45	304	5.34	-	8.10	13.44	44.20 *
30	0.34	275	7.80	-	5.36	13.16	47.80 *
	62.22	10599	236.54	112.21	116.25	465.00	

Explanation:
- A and B. From stand table.
- C, D, and E. From table V a,b, andc.
- F. Sum of C,D, and E - each DBH.
- G. F / B.
- * These values fall because of the higher percent of hemlock in these classes.

Intensity of Cutting

From table VI, it is evident that higher value returns per M ft. bm. lie in the upper diameter classes. The operator that can confine his cutting to the upper classes will naturally turn out a product of higher value. Thus a weighted average of the value per M cut on an acre varies inversely with the degree of cutting. As an operator logs further into his lower DBH classes he takes volume of a lower value and decreases his log-run value returns. Table VII was constructed to show the volume and values per M to be taken in cutting to various diameter limits. In columns A,B,C, D,E, and F the woods scale and mill tally volumes (and their percentages) are computed for cuttings of each diameter and up. Columns G and H show the value and percent in each DBH class and above. From these figures columnI was developed showing the weighted value per M mill tally for the portion of the stand above each diameter. Thus a cut of 22% (of log scale volume) will take 4.31 trees 24 inches and over in DBH, 1.812 M and produce 2.156 M ft. of lumber valued at $48.80 per M; 48% takes 12.25 trees 20 in. and up, 4.043 Mp and produce 4.190 M ft. of lumber worth $47.60 per M; while a 100% cut takes 62.22 trees 10 in. and up, and 8.302 M which will produce 10.599 M ft. of lumber valued at $43.80

TABLE VII

Results of cutting to specified DBH classes

	A	B	C	D	E	F	G	H	I
DBH	Trees Each DBH & Up		Log Scale Vol. Each DBH & Up		M. Tally Vol. Each DBH & up		Value Per Acre Each DBH & Up		Value PerM M. Tally DBH & Up
	No.	%	Bd. Ft.	%	Bd. Ft.	%	Dollars	%	
10	59.34	100	8302	100	10599	100	$465.00	100	$43.80
12	46.88	78	7984	96	10129	95	447.96	96.5	44.20
14	36.83	63	7465	89	9386	88	420.14	90.5	44.80
16	27.09	46	6593	78.5	8186	77	373.03	80	45.60
18	19.21	32	5540	66	6799	64	316.18	68	46.60
20	12.25	21	4117	49	4987	47	237.48	51	47.60
22	7.39	12	2824	34	3387	32	163.66	35	48.25
24	4.31	7	1812	22	2156	20	105.05	23	48.80
26	1.98	3	1018		1205		57.75		48.00
28	.79	1.3	491		579		26.60		
30	.34	0.5	236		275		13.16		

Explanation:
A,B,C,D,E, and F. Computed from stand table.
G and H. Computed from table VI (columnF)
I. G / E.

Composition of the Stand

It has been previously mentioned that the presence of low value species such as hemlock have a decided effect in lowering the value of a cut. It provides a significant comparison to drop the hemlock (which makes up about 27% of the stand) from the computations of stand A and observe the actual effect upon the values. Following identical calculations, results are obtained in tables VIII and IX (which are counterparts of tables VI and VII)

TABLE VIII

Value Per M Each DBH Class

DBH	No. Trees Per Ac	Volume Per Ac M.Tally	Total Value Per Acre	Weighted Average Value Per M
10	6.92	293	$10.04	$34.35
12	5.90	448	16.22	36.20
14	5.72	674	26.26	38.80
16	5.70	982	40.85	41.60
18	5.41	1448	64.75	44.70
20	4.23	1305	60.90	46.60
22	2.62	1039	51.01	48.20
24	1.90	740	38.95	52.60
26	0.92	465	24.78	53.30
28	0.16	100	5.34	53.40
30	.18	140	7.80	55.75

TABLE IX

Results of Cutting to Specified DBH Limits

DBH	Trees Each DBH & Up No.	%	Log Scale Vol: Each DBH & Up Bd. Ft.	%	M. Tally Vol.: Each DBH & Up Bd. Ft.	%	Value Per Acre: Each DBH & Up Dollars	%	Value Per M: M. Tally DBH & Up
10	39.66	100	6087	100	7634	100	$346.90	100	$45.65
12	32.74	82	5877	97	7341	96	336.86	97	45.90
14	26.84	68	5547	91	6893	90	320.64	92	46.60
16	21.12	53	5033	83	6219	80	294.38	85	47.30
18	15.42	36	4269	70	5237	68	253.53	73	48.40
20	10.01	25	3154	52	3789	50	188.78	54	49.70
22	5.78	14	2092	34	2484	33	127.88	37	51.50
24	3.16	8	1231	20	1445	19	76.87	22	53.20
26	1.26		606		705		37.92		53.80
28	.34		210		240		.13.14		54.80
30	.18		123		140		7.80		55.75

As determined in table VI, values per M range from 36.20 for 10 in. trees to $47.80 for 30 inch trees. When hemlock is dropped from the calculations, the values range from $34.35 to $55.75 per M ft. Cuts of 100,48, and 22% bring values of $43.80, 47.50, and 48.80 per M respectively.. Dropping hemlock from the calculation, cuts of 100, 52, and 20% bring respective values of $45.65, 49.70, and $53.20 per M ft.

To further portray the effect of hemlock in the stand, a comparison of the value returns is computed for stand B (table II) in which hemlock comprises 54% of the volume. The results are shown in tables X and XI. Here the value per M ranges from $37.50 per M for 10 inch trees to $44.20 per M for 30 inch trees. Cuts of 100%, 52%, and 25% bring values of $42.60, 44.60, and 45.50 per M respectively. These above - illustrated effects of hemlock on the values returned from the stand are shown graphically in figure I.

TABLE X

Value Per M Each DBH Class

DBH	No. Trees Per Ac.	Volume Per Ac M.Tally	Total Value Per Acre	Weighted Average Value Per M
10	9.32	388	$14.53	$37.40
12	8.39	604	23.15	38.30
14	9.03	1194	46.86	39.20
16	8.91	1665	67.85	41.35
18	8.80	2562	108.05	42.20
20	6.07	2026	88.05	43.50
22	3.83	1466	70.01	44.80
24	3.00	1187	55.15	46.45
26	1.64	930	42.11	45.30
28	0.56	342	14.50	42.40
30	.37	330	15.60	44.20

TABLE XI

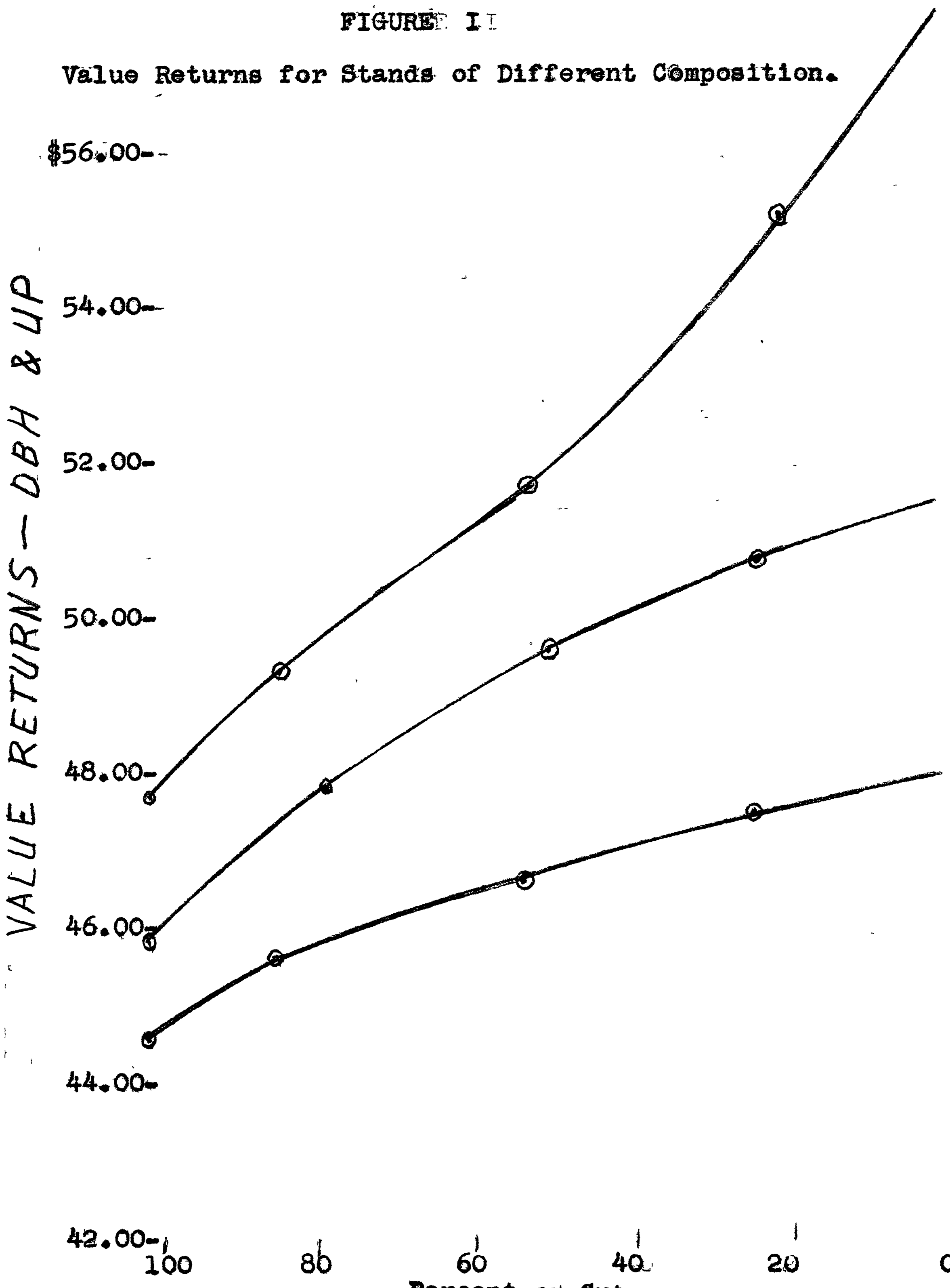
Results of Cutting to Specified DBH Limits

DBH	Trees Each DBH & Up No.	Trees Each DBH & Up %	Log Scale Vol. Each DBH & Up Bd. Ft.	Log Scale Vol. Each DBH & Up %	M. Tally Vol. Each DBH & Up Bd. Ft.	M. Tally Vol. Each DBH & Up %	Value Per Acre Each DBH & Up Dollars	Value Per Acre Each DBH & Up %	Value Per M: M. Tally DBH & Up
10	59.92	100	9936	100	12794	100	$544.86	100	$42.60
12	50.60	84	9677	97	12406	97	530.33	97	42.95
14	42.21	71	9258	93	11802	92	507.18	93	43.00
16	33.18	55	8337	84	10608	83	460.32	84	43.60
18	24.27	40	7099	71	8943	69	392.47	72	43.90
20	15.47	26	5175	52	6381	50	284.42	52	44.60
22	9.40	16	3572	35	4355	34	196.37	36	45.10
24	5.57	9.5	2307	23	2789	22	126.36	23	45.50
26	2.57		1331		1602		71.21		44.55
28	0.93		565		672		29.10		43.35
30	.37		280		330		14.60		44.20

These effects of hemlock upon the stand as illustrated in the cases above are shown graphically in figure I.

FIGURE I

Value Returns for Stands of Different Composition.



Another factor affecting value returns is the volume distribution in the DBH classes. Greater concentrations of volume (of the more valuable birch and maple) in the higher diameters will naturally increase value returns per acre as well as the value per M for cuts in the upper portion of the stand. Conversely, when upper classes run heavy to hemlock, values in these classes fall. Such a condition exists in stand B (table II) and this influence can be seen in table X where the weighted value per M shows a decrease above 24 inches and in table XI where the value per M decreases for cuts above 24 inches.

Growth and its Influence on Future Cuts

As a partial cutting presupposes at least a second cut, it is essential to know when this cut can be made and what volume it will return. Growth data on stands logged selectively are a necessary prerequisite to such calculations. Unfortunately such data are generally lacking and many operators must work with inadequate and possibly inaccurate information. Total net growth in virgin stands may be very light, nil, or even negative; and lacking positive data on accelerated growth brought about by the opening up of the stand in selective logging, the tendency has often been to underestimate the true growth rate following partial cutting. In the absence of growth figures following selective logging, the best substitute is data supplied by growth studies from specially selected trees in virgin stands. Table XII is made up from such a study by Frank Murray, made from selected trees in virgin stands for the express purpose of making growth predictions for the residual portion of proposed partial cuts in the Upper Peninsula of Michigan.

TABLE XII [1]

Diameter Growth, Inches in Ten Years

DBH	Sugar Maple	Yellow Birch	Hemlock
6	1.20	0.70	1.50
8	1.60	1.05	1.80
10	1.80	1.30	2.00
12	1.95	1.60	2.15
14	2.00	1.75	2.15
16	2.05	1.80	2.10
18	2.05	1.80	2.00
20	2.00	1.75	1.85
22	1.90	1.65	1.60
24	1.80	1.50	1.40
26	1.75		1.20
28	1.65		

The stands left after cutting to the 16, 18, 20, and 22 inch limits (only these are considered because they appear to be the most practicable) respectively are predicted forward by the Reynolds method of growth prediction. Results are shown in table XIII a,b,c, and d. This method entails the prediction forward of the number of trees per acre. To obtain the volumes in table XIII, the volume per tree of the original stand was applied to the trees predicted forward. This is a conservative procedure, in that the objects of selective logging are to produce a vigorous stand of well formed healthy trees which should produce much less cull and more average volume per tree than occurs in the normal virgin stand. This is, of course, altered by both the amount of cull in the original stand and the extent to which the stand improvement aspect is considered in the marking rules of the individual operator. It is to be noted that - in this paper - the stand is cut to a straight (inflexible) diameter limit. Actually -as selective logging has been defined- certain trees below that limit may be taken for stand improvement measures; especially when cutting in the

1. Murray, Frank; Material from private files. Note: Hemlock was not included in the original data and is an approximation.

upper DBH classes. (Some few operators choose to almost ignore the diameter limit marking rules and take trees the experienced marker judges cannot remain in the stand until the next cut.) The stand in this paper was not handled by a flexible diameter limit because it would be impossible to correctly estimate the residual stand without the actual marking (which data is not available to the author).

TABLE XIII

Growth Predictions. (a) Cut 16 inches and Up

DBH	Maple No. Trees	Maple Vol. Log Scale	Birch No. Trees	Birch Vol. Log Scale	Hemlock No. Trees	Hemlock Vol. Log Scale	Total No. Trees	Total Vol. Log Scale
	Residual Stand						Residual Stand	
10	4.28	132	2.64	78	5.42	108	12.34	470
12	3.78	237	2.12	93	4.15	189	10.05	742
14	3.64	364	2.08	150	4.02	358	9.74	1201
	11.70	733	6.84	321	13.59	655	32.13	2413
	Stand 20 Years Hence						Stand 20 Years Hence	
10	5.38	167	2.56	75	5.00	100	12.94	342
12	2.95	186	2.14	94	5.40	248	10.49	528
14	2.58	258	1.94	140	5.04	449	9.56	847
16	3.70	577	1.90	187	3.93	520	9.53	1284
18	3.55	787	1.65	297	4.10	8;0	9.30	1894
20	0.11	38	-	-	0.52	137	0.63	175
	18.27	2013	10.19	793	23.99	2264	52.45	5070
	Stand 30 Years Hence						Stand 30 Years Hence	
10	5.87	182	2.57	76	4.90	98	13.34	356
12	3.29	207	2.09	92	5.00	230	10.38	529
14	2.89	289	1.94	139	5.02	446	9.85	874
16	2.58	403	1.90	187	5.02	666	9.50	1256
18	3.59	796	1.89	340	4.13	816	9.61	1952
20	3.55	1234	1.47	280	4.34	150	9.36	2664
22	0.22	83	-	-	0.48	162	0.70	245
	21.99	3194	11.86	1114	28.89	3568	62.74	7876

TABLE XIII (continued)

(b) Cut 18 inches and Up

DBH	Maple: No. Trees	Maple: Vol. Log Scale	Birch: No. Trees	Birch: Vol. Log Scale	Hemlock: No. Trees	Hemlock: Vol. Log Scale	Total: No. Trees	Total: Vol. Log Scale
	Residual Stand						Residual Stand	
10	4.28	132	2.64	78	5.42	108	12.34	318
12	3.78	237	2.12	93	4.15	189	10.05	519
14	3.64	364	2.08	150	4.02	358	9.74	872
16	3.52	550	2.18	214	2.18	289	7.88	1053
	15.22	1283	9.02	535	15.77	944	40.01	2762
	Stand 20 Years Hence							
10	5.38	167	2.56	75	5.00	100	12.94	342
12	2.95	186	2.14	94	5.40	248	10.49	528
14	2.58	258	1.94	140	5.04	449	9.56	847
16	3.70	577	1.92	189	3.93	520	9.55	1286
18	3.55	787	2.04	367	4.10	810	9.69	1964
20	3.41	1200	1.77	336	2.60	687	7.78	2223
22	0.22	77					0.22	77
	21.79	3252	12.37	1201	26.07	2814	60.23	7267
	Stand 30 Years Hence							
10	5.87	182	2.57	76	4.90	98	13.34	356
12	3.29	207	2.09	92	5.00	230	10.38	529
14	2.89	289	1.94	139	5.02	446	9.85	874
16	2.58	403	1.90	187	5.02	666	9.50	1256
18	3.59	796	1.93	346	4.13	816	9.65	1958
20	3.35	1234	2.02	383	4.48	1180	9.85	2797
22	3.42	1200	1.59	449	2.42	792	7.43	2441
24	0.11	42					0.11	42
	25.10	4353	14.04	1672	30.97	4228	70.11	10253

TABLE XIIII (continued)

(c) Cut 20 inches and Up

DBH	Maple Residual Stand No. Trees	Maple Residual Stand Vol. Log Scale	Birch No. Trees	Birch Vol. Log Scale	Hemlock No. Trees	Hemlock Vol. Log Scale	Total Residual Stand No. Trees	Total Residual Stand Vol. Log Scale
10	4.28	132	2.64	78	5.42	108	12.34	318
12	3.78	237	2.12	93	4.15	189	10.05	519
14	3.64	364	2.08	150	4.02	358	9.74	872
16	3.52	550	2.18	214	2.18	289	7.88	1053
18	3.40	755	2.01	360	1.55	308	6.96	1423
	18.62	2038	11.03	895	17.32	1252	46.97	4185
Stand 10 Years Hence								
10	4.80	149	2.59	76	5.40	108	12.79	333
12	3.64	238	2.14	94	5.42	249	11.20	581
14	3.70	370	1.95	140	3.86	342	9.51	852
16	3.64	268	2.05	201	3.99	532	9.68	1301
18	3.40	750	2.06	370	2.39	472	7.85	1592
20	3.42	1200	1.81	344	1.66	438	6.89	1982
22	0.10	35					0.10	35
	22.70	3310	12.60	1225	22.72	2142	58.02	6676
Stand 20 Years Hence								
10	5.38	167	2.56	75	5.00	100	12.94	342
12	2.95	186	2.14	94	5.40	248	10.49	528
14	2.58	250	1.94	140	5.04	449	9.56	839
16	3.70	577	1.92	189	3.93	520	9.55	1286
18	3.55	787	2.06	370	4.10	810	9.71	1967
20	3.41	1200	2.03	386	2.70	712	8.14	2298
22	3.52	1230	1.63	460	1.55	510	6.70	2200
24	0.09	34					0.09	34
	25.18	4431	14.28	1714	27.72	3349	67.18	9494

TABLE XIII (continued)

(d) Cut 22 inches and Up

DBH	Maple Residual Stand No. Trees	Maple Residual Stand Vol. Log Scale	Birch No. Trees	Birch Vol. Log Scale	Hemlock No. Trees	Hemlock Vol. Log Scale	Total Residual Stand No. Trees	Total Residual Stand Vol. Log Scale
10	4.28	132	2.64	78	5.42	108	12.34	318
12	3.78	237	2.12	93	4.15	189	10.05	519
14	3.64	364	2.08	150	4.02	358	9.74	872
16	3.52	550	2.18	214	2.18	289	7.88	1052
18	3.40	755	2.01	360	1.55	308	6.96	1423
20	2.65	762	1.58	300	0.63	167	4.86	1229
	21.27	2800	12.61	1195	17.95	1419	51.83	5414
	Stand 10 Years Hence							
10	4.80	149	2.59	76	5.40	108	12.79	333
12	3.64	238	2.14	94	5.42	249	11.20	581
14	3.70	370	1.95	140	3.86	342	9.51	852
16	3.64	568	2.05	201	3.99	532	9.68	1301
18	3.40	750	2.06	370	2.39	472	7.84	1592
20	3.42	1200	2.00	380	1.70	448	7.12	2028
22	2.75	964	1.39	394	0.59	194	4.73	1552
	25.35	4239	14.18	1655	23.35	2345	62.88	8239
	Stand 20 Years Hence							
10	5.38	167	2.56	75	5.00	100	12.94	342
12	2.95	186	2.14	94	5.40	248	10.49	528
14	2.58	258	1.94	140	5.04	449	9.56	857
16	3.70	577	1.92	189	3.93	520	9.55	1286
18	3.55	787	2.06	370	4.10	810	9.71	1967
20	3.41	1200	2.09	397	2.71	714	8.21	2311
22	4.64	1620	2.00	566	1.80	592	8.44	2778
24	2.63	955	1.15	306	0.47	185	4.25	1446
	28.84	5750	15.86	2137	28.45	3618	73.15	11505

Table XIII shows the following information in regards to cuttings of different intensity:

16" limit - Residual stand returns to original volume in slightly over 30 yrs., which is a net growth of 206 bd. ft. per acre per yr.

18" limit - Residual stand returns to original volume in slightly over 20 yrs, which is net growth of 225 bd. ft. per acre per yr.

20" limit - Residual stand returns to original volume in slightly over 15 yrs, which is a net growth of 255 bd.ft. per acre per yr.

22" limit - Residual stand returns to original volume in 10 yrs. which is a net (periodic) growth of 283 bd. ft. per acre per year.

Since any growth prediction is only a mechanical procedure attempting to simulate the actual growth of a stand, it is obvious that the stand tables in table XIII are merely approximations. They are, however, of considerable value in that they indicate the approximate period of time it takes for the stand to return to its original volume. It is to be noted that the proportion of hemlock in the stand has increased. In this particular stand the reasons lie largely in the fact that this species is more heavily concentrated in the lower diameter classes; thus cutting to a straight diameter limit serves to increase the percent of hemlock in the residual stand (compare total volumes each species, table I and volume each species in the residual stand table XIII). This is a problem of theindividual stand only and the situation might be reversed in stands of different composition. In a stand of this type, the solution to this problem can be found in establishing differential marking rules for each species in order to favor the more valuable species in the make-up of the residual stand(and second cut).

The important question now is the determination of values returned from future cuts. Normally the value of the stand (at the end of the above - prescribed periods) will be equal to or greater than the values returned from the original stand. Although the increase in hemlock in the above illustration (table XIII) will tend to lower the average value per M, the increase in volume(and value) brought about by better growing stock and less cull should serve to counter such a loss. Better yet, if hemlock were cut to a limit only one class lower than the rest of the stand, the second cut would be definitely of higher value.

Assuming the second cut to be equal in value to the first, values returned from an acre of timberland are as follows:

DBH Limit	Now	10 Yrs.	15 Yrs.	20 Yrs.	30 Yrs.
10	$465.00	---	---	---	---
16	373.03	---	---	---	$373.03
18	316.18	---	---	$316.18	---
20	237.48	---	237.48	---	237.48
22	163.66	$163.66	---	163.66	163.66

The Size of the Operation and the Total Values

Below is an analysis of the different cuttings in relation to the size of the area necessary to sustain them.

DBH Limit	Cutting 1,800 acres yearly Yield (Mill Tally)	Area Required Yrs
10	10,599 Bd. Ft. Per Ac.	54,000 Ac. to cut for 30
16	8,186	54,000 Ac. to cut forever
18	6.799	36,000 Ac. "
20	4,987	27,000 Ac.
22	3,387	18,000 Ac.

Many lumbermen who are at present operating on a liquidation basis feel they cannot afford to cut production. The number of acres required to produce a constant production of 20,000 M annually (Mill Tally) are as follows:

DBH Limit	Ac. Per Yr.	Area Required
10	1,870	56,000 Ac. to cut for 30 yrs.
16	2,450	73,500 Ac. to cut forever
18	2,950	59,000
20	4,080	61,000
22	6,100	61,000

III COST FACTORS

Cost computations are perhaps the single most important tool available to the timber producer. With correct interpretation and breakdown of his costs the logger can have at hand a useful and essential evaluation of his business.

In the lumber industry (especially) a large number of factors, many of which are particularly variable and hard to evaluate, play upon cost determination. It is necessary, then, that the various cost elements be properly classified. Such a classification is as follows:

Class A. Direct costs. These are variable per M, usually with tree size, and include activities connected with the handling of timber.

Class B. Fixed per M.

Class C. Fixed per acre or fixed in total.

Costs are never the same for any two operations because of the varied nature of stand composition, equipment, logging chance, and logging methods. Costs that follow will apply only to the operation for which they are computed. However, the procedures are generally applicable to any similar operation.

Direct Logging Costs

Felling and bucking. Although the piece-rate system of payment for felling and bucking has begun to fall into disfavor , this system is still a widespread practice in the Northern Lake States. In table XIV (a), (b), and (c), stand data for the three species is worked up into the number of lineal feet per M (column C) and the cost of producing one M ft. was obtained for each DBH (column

F) on the basis of payment at the rate of $0.035 per lineal ft for birch and maple and $0.03 for hemlock. The inequities of the piece-rate system are plainly evident in column F. Of course these costs will average out to a log-run figure per M that may be entirely equitable in itself; but when partial cuttings are made, cutters stand to lose and are prone to resent any change that will prevent them from making the high wages that go with cutting small trees. Hourly wages have been considered to be a more fair method of payment. Although it requires more time and labor to cut the smaller trees, the range in costs for the different diameters is not as great as under the piece-rate system. Payment on the basis of volume produced serves the part of stabalizing costs for the operator, but penalizes the worker in the lower diameter limits.

It is to be noted that the cost per M of felling and bucking for each size class is directly related to the number of logs and volume per tree. Under selective logging the reduction of cull and improved quality of growing stock should result in an appreciable reduction of costs in the second cut.

TABLE XIV

Cost of felling and bucking

(a) Maple

DBH	A Volume Per Tree Log Scale	B Merch. Length Per Tree	C Lineal Feet Per M	D No.16 ft. Logs Per Tree	E No.16 ft. Logs Per M	F Fell&Buck Cost Per M Log Scale
10	31	16	518	1	32.2	18.10
12	63	23	364	1.43	22.7	12.70
14	100	26	260	1.62	16.2	9.10
16	156	31	198	1.93	12.4	6.92
18	222	32	144	2.00	9.0	5.04
20	288	35	121	2.18	7.6	4.23
22	348	32	92	2.00	5.8	3.22
24	378	30	79	1.87	5.0	2.76
26	452	30	66	1.87	4.1	2.31
28	542	31	57	1.93	3.6	1.99
30	682	35	51	2.18	3.1	1.79

(b) Birch

DBH	A	B	C	D	E	F
10	29	16	550	1	34.6	19.22
12	44	18	410	1.12	25.5	14.32
14	72	19	264	1.19	16.5	9.25
16	98	20	204	1.25	12.8	7.13
18	180	26	145	1.59	9.0	5.07
20	230	28	122	1.70	7.6	4.27
22	284	28	99	1.65	6.2	3.46
24	267	20	75	1.25	4.7	2.65
26	335	20	60	1.25	3.7	2.10
28	-	-	-	-	-	-
30	-	-	-	-	-	-

Explanation:

A. From stand table, Volume/No. trees.
B. Compare A with volume table and interpolate to height.
C. Solve for x in: B:A :: x:one M bd. ft.
D. B/16 ft.
E. Solve for x in: D:A :: x:one M bd. ft.
F. Cxpiece-rate

TABLE XIV (Continued)

(c) Hemlock

DBH	A	B	C	D	E	F
10	20	12	600	0.75	37.4	18.00
12	46	17	370	1.06	23.1	11.10
14	89	24	269	1.50	16.9	8.06
16	133	30	225	1.87	14.1	6.75
18	198	34	172	2.12	10.7	5.16
20	265	39	147	2.44	9.2	4.40
22	329	41	125	2.56	7.8	3.74
24	394	41	104	2.54	6.5	3.12
26	485	41	85	2.56	5.3	2.55
28	580	41	71	2.56	4.4	2.13
30	710	41	58	2.56	3.6	1.74

(d) Total cost all species

DBH	Weighted Cost Per M Log Scale
10	18.30
12	12.40
14	8.70
16	6.91
18	5.10
20	4.24
22	3.40
24	2.82
26	2.34
28	2.08
30	1.79

Skidding. Logs are ground skidded to landings by 35 H.P. winch-equiped caterpillar tractors; one swamper working with each tractor. The tractor machine rate is listed below.

	Hourly rate
Ownership Cost	
Depreciation over 10,000 hrs.	$0.40
Interest,taxes,insurance,storage,etc.	.11
Direct Operating Costs	
Fuel,lube,grease,service andmaintenance labor, and repairs	.74
Direct Labor Cost	
Driver and swamper	1.30
	$2.55 Per hour
	or $0.0426 Per min.

In the absence of actual time study data it is necessary to use average data or that computed (and adjusted) from other studies.

The author does not feel that the use of such data will impair the value of this study because logging costs can vary so greatly under various circumstances. The cost data used here appear reasonable for this area and as long as such is the case, they serve their purpose in presenting the effect of tree size upon the logging operation.

Tractor loads are subject to great variation depending first on log size and after that on equipment and methods and effeciency of logging. For example one crew may follow different systems of bunching and load heavier than another. There is always a tendency to underload the smaller logs because of the difficulty in acquiring a full load. Some tractors may operate with only two tongs or with no winch. Horses usually skid only one log at a time. All of these factors may combine to alter the cost differential between DBH classes, increasing - or decreasing as the case may be - the cost of logging small trees.

In column A of table XV is the average load hauled by a winch-equiped 35 horse power tractor with four tongs. This data is adapted from time studies made on 25 horse power tractors in the Upper Penunsula of Michigan by W.S. Bromely[1] of the University of Michigan. Itwas necessary to adjust the data to fit the larger tractors. This table adjusts the load from a log size (top Dib) basis to a tree size basis. Table XVI was constructed to show the variable cost per Mft.per 100 ft. of skidding distance, based on an estimate by the Caterpillar Tractor Company that 0.85 minutes is a reasonable average to haul and return 100 ft. of skidding distance (use of second

1. Bromely, W.S. Ground Skidding with a D-2 Tractor compared with the Average Team on an Operation in Northern Michigan. Mimeographed, 1941. Tables 4 and 9.

gear on the haul and third gear on return). Each DBH class retains this cost relationship (column E table XVI (a)) as long as the skidding distance is constant. However, it has been determined - that - to obtain minimum costs - road spacing (and consequently skidding distance) should vary as different volumes are cut per acre. The variable skidding costs are thus computed, not for each DBH class, but for the volumes cut at the limits of each DBH and up. This computation is partially completed in column G of table XVI (a) and completed in column I after the correct skidding distance has been obtained in the section on road costs.

TABLE XV

Average load, 35 H.P. tractor.

	A	B	C	D	E	F	G	H
			Maple		Birch		Hemlock	
Top Dib log	No.16' Logs Hauled	DBH	Ave. Top Dib, Log each DBH	No.16' Logs Hauled	Ave. Top Dib, Logs each DBH	No.16' Logs Hauled	Ave. Top Dib, Logs each DBH	No. 16' Logs Hauled
8	4.0	10	8.0	4.0	8.0	4.0	8.0	4.0
10	3.6	12	9.4	3.7	9.8	3.6	10.0	3.6
12	3.1	14	11.2	3.3	11.7	3.2	11.3	3.3
14	2.5	16	13.0	2.8	13.6	2.5	13.0	2.8
16	1.9	18	15.0	2.1	15.2	2.2	14.8	2.2
18	1.5	20	17.0	1.7	17.2	1.8	16.7	1.8
20	1.1	22	19.0	1.3	19.2	1.3	18.4	1.4
22	1.0	24	21.0	1.1	21.5	1.0	20.3	1.1
24	1.0	26	23.1	1.0	23.6	1.0	22.3	1.0
26	1.0	28	25.0	1.0	-	-	24.3	1.0
28	1.0	30	27.0	1.0	-	-	26.3	1.0

Explanation:
A. Adapted from Bromely's publication.
C,E,&G. Computed from tableXIV, column D on basis of a 2 inch taper per 16 ft. log .
D,F,&H. Computed from column A.

TABLE XVI

Variable Skidding Costs

(a) Cost per M per 100 ft. of skid distance.

	A	B	C	D	E	F	G	H	I
	Maple			Birch			Hemlock		
DBH	Volume Per Turn	No. Turns Per M	VarCost Per M Per100'	Volume Per Turn	No. Turns Per M	VarCost Per M Per100'	Volume Per Turn	No. Turns per M	Var.Cost Per M Per 100'
10	124	8.05	$0.291	116	8.62	$0.312	106	9.45	$0.342
12	163	6.15	.222	140	7.15	.258	156	6.40	.232
14	203	4.93	.178	193	5.18	.188	186	5.10	.185
16	226	4.42	.160	196	5.11	.185	199	5.03	.182
18	230	4.36	.158	237	4.22	.153	214	4.90	.177
20	224	4.46	.161	244	4.10	.149	196	5.10	.185
22	226	4.42	.160	259	3.86	.140	180	5.56	.201
24	223	4.49	.162	235	4.25	.154	170	5.87	.211
26	243	4.10	.148	268	3.73	.135	190	5.27	.190
28	282	3.55	.126	-	-	-	226	4.42	.160
30	314	3.18	.115	-	-	-	277	3.61	.130

Explanation:
A,D,&G. Vol. per tree ; # logs per tree : x : #logs per turn.
B,E,&F. 1M ft. ÷ A,D,&G.
C,F,&I. ($0.0426 x 0.85 min.) = $0.0362 per turn x B,E,&H.

(b) Cost per M for total skid distance.

	A	B	C	D	E
DBH	Total Cost Per M Per 100'	Cost Per Acre Per 100' DBH&up	Cost Per M Per 100' DBH & up	Ave. Skid Distance in 100' Sta. DBH & up	Var. Skid Cost Per M DBH & up
10	$0.0311	$1.439	$0.173	2.57	$0.442
12	.233	1.34	.168	2.66	.444
14	.183	1.22	.163	2.80	.456
16	.171	1.06	.161	3.01	.484
18	.160	0.88	.159	3.30	.526
20	.162	.651	.158	3.82	.603
22	.162	.443	.157	4.62	.725
24	.166	.280	.155	5.78	.895
26	.155	.148	.146		
28	.147	.067	.136		
30	.122	.029	.122		

Explanation:
A. Weighted average of all species (sum ofcost per M x vol. per ac. each species) / total vol. per ac. each DBH.
B. Cost per M x vol. per ac. each species added for each DBH and up.
C. B / total vol. per acre each DBH and up.
D. Average skidding distance; developed in section on road costs.
E. CxD.
Note: Volumes are log scale.

The actual hauling of the logs is classified as variable skidding time, while the hooking, unhooking, and delay times are classed as fixed.. Fixed time also varies with tree or log size, as it takes more time to assemble a load of small logs than it does a load of large. Fixed skidding costs are computed in table XVII (basic data in column A is adapted from the same source as the data in preceding table). Fixed costs for stationary and slow moving machinery are charged at the same machine rate whether standing still or moving.. The operating costs may fall slightly, but the reduction proves to be practically negligible.

TABLE XVII

Fixed Skidding Costs

DBH	A Fixed Time Per Turn Minutes	B Average No. Turns Per M	C Fixed Time Per M Minutes	D Fixed Cost Per M Log Scale
10	6.8	8.56	58.2	$2.45
12	6.2	6.40	39.7	1.69
14	5.7	5.0	28.5	1.22
16	4.6	4.72	21.7	0.93
18	3.7	4.24	15.7	.67
20	3.0	4.68	14.0	.60
22	2.5	4.46	11.1	.47
24	2.3	5.1	11.7	.49
26	2.1	4.3	9.0	.38
28	2.1	4.1	8.6	.36
30	2.1	3.4	7.1	.30

Explanation:
A. Adapted from basic data.
B. Computed from table XVI.
C. Adapted from basic data.
D. C x $0.426 per minute.

vantageous to quick loading. If it is necessary to do this short yarding during the actual loading the time of loading is, of course, increased and truck standing time adds a cost to the yarding; whereas, if the truck is not present loader time is the only cost chargeable to yarding the logs into position. The control of the above-mentioned factors is largely a matter of planning. When hauling all size classes the fixed time is practically constant as an average for the stand. Breaking down this data for each DBH class would present inaccurate results because of the omission of the element of planning, which would change truck schedules for different loading times. Thus, the fixed time between loads is estimated to be 12 minutes between each load for all size classes.

Unloading costs are constant per load. The truck turn around and standing time of 5 minutes sets the cost.

Loading costs are compiled for loading on 1½ ton light (Ford or Chevrolet) trucks at 0.8 minutes per log in table XVIII.

TABLE XVIII

Loading Cost

DBH	A Logs Per M	B Logs Per Load	C Volume Per Load	D Load Time: One Load	E Truck Cost: Per M	F Loader Cost Per M	G Total Cost: Per M
10	34.5	30	870	24	$0.77	$1.36	$2.13
12	23.4	26	1100	20.7	.54	0.98	1.52
14	16.5	22	1340	17.6	.39	.73	1.12
16	12.9	18	1400	14.4	.32	.62	0.94
18	9.5	15	1580	12.0	.25	.50	.75
20	8.0	12.6	1580	10.0	.22	.46	.68
22	6.1	10.7	1760	8.55	.18	.38	.56
24	5.2	9.8	1840	7.85	.17	.35	.52
26	4.4	9.0	2050	7.2	.14	.31	.45
28	4.1	8.5	2070	6.8	.13	.30	.43
30	3.4	8.0	2350	6.4	.11	.26	.37

Explanation:
- A. Computed from table XIV, columns E.
- B. Based on reasonable estimates.
- C. From columns A and B.
- D. Computed at rate of 0.8 minutes per log.
- E. D plus load & unload time x fixed truck rate of $0.0233 / Load
- F. D plus 12 minutes x machine rate of $0.033 / Load
- G. E plus F.

Loading and unloading. Logs are loaded by semi-portable "A" frame jammers powered by gasoline engines and manned by a three man crew. Landings are picked from open spots in the woods and construction costs are negligible (in line with common practice in the region). The machine rate is as follows:

	Hourly rate
Ownership Cost	
Depreciation,etc. (10,000 hrs.	$0.031
Direct Operating Costs	
Fuel,oil, grease, etc.	.30
Cable, rigging, and repairs	.15
Direct Labor Cost	
Three operators	1.50
	$1.981 Per hour
	or $0.033 per min.

It is necessary to assume that an operation is so planned and coordinated that skidding progresses at a rate suffecient to keep the loader supplied with logs and that trucks are available for loading at proper intervals so that an undue amount of idle time is not charged to the loading operation.

The elements of loading cost are 1) fixed loader time between loads when logs are yarded closer to the jammer, 2) variable time which involves the actual loading of logs (it takes approximately the same time to load a large log as a small, thus variable time is contingent upon the number of logs of each size a truck can haul), and 3) the truck standing time during (and sometimes waiting for) the process of loading.

On a well planned smooth running operation the trucks should move right in and right out with their load and there should be little, if any, stand-still time other than that involved in the actual loading of the logs. Fixed jammer time per load (between loads) is dependent upon the interval between trucks and/or upon the amount of yarding or bunching required to ready the logs for effecient loading. Tractors quite often drop their loads at positions not wholly ad-

Hauling. Timber is hauled to the mill on 1½ ton light trucks. The trucks take the following route out of the woods: Out secondary branch roads (average haul of one mile) to the main haul road for an average haul of six miles, thence onto a county highway and to the mill in twelve miles. Trucks can make the following average round trip speeds: Secondary roads 7mph, main haul roads 10 mph, and highways 25 mph.

The truck machine rate is as follows:

Fixed Cost	Hourly rate
Depreciation (over 5,000 hrs.) (net investment less trade in $900)	$0.18
Interest, license, insurance, storage, etc.	.62
Driver's wages	.60
Total Fixed Cost	$1.40 per hour
or	$0.0233 per min.
Operating Cost	
Tires ($350 for 1,000 hrs.)	$0.35
Repairs, grease, maintenance, etc.	.10
Gas and oil	.50
Total Operating Cost	$0.95 per hour
Total Hauling Cost	$2.35 per hour

Fuel costs are sometimes considered as a separate item independent of the machine rate on the contention that they are not constant per hour at different speeds. However they are near enough to be considered so for practical purposes.

Hauling costs are computed in table XIX by the following formula: Haul cost per M per mile of haul $= \frac{\text{2 x Hourly haul cost}}{\text{Round trip speed x load}}$ plus $\frac{\text{Fixed time per load x Hourly fixed cost}}{\text{LOAD}}$.

The fixed (truck standing time) per load can vary greatly on different operations with individual drivers and the supervision. A portion of this time has already been figured into loading cost. Drivers may stop to talk and smoke and trucks must be serviced at frequent intervals (often during the working day) and are periodically laid up for tire changing, minor repairs, and adjustments.

This time, although not occurring on every load, should average out to about five minutes per load. (Major repairs, of course, are not chargeable against fixed time.

TABLE XIX

Hauling Cost.

DBH	A: Wood Roads: HC Per M Per Mile	B: Main Roads: HC Per M Per Mile	C: Highways: HC Per M: Per Mile	D: Total Op: Cost Per: M	E: Fixed Cost: Per M	F: Total Cost: Per M
10	$0.77	$0.54	$0.217	$6.61	$0.133	$6.74
12	.61	.428	.171	5.23	.106	5.34
14	.50	.35	.140	4.28	.087	4.37
16	.48	.336	.134	4.11	.083	4.19
18	.424	.298	.119	3.62	.070	3.70
20	.424	.298	.119	3.63	.070	3.70
22	.382	.267	.107	3.26	.066	3.33
24	.364	.256	.102	3.12	.063	3.18
26	.326	.229	.092	2.80	.057	2.86
28	.323	.227	.091	2.77	.056	2.83
30	.285	.200	.08	2.44	.049	2.49

Explanation.
A. 2 x $2.35 / 7 x load.
B. 2 x $2.35 / 10 x load.
C. 2 x $2.35 / 25 x load.
D. A plus (B x 6) plus (C x 12).
E. 5 min. x $0 .0233 / Load.
F. D plus E.
Volumes are log scale.

Logging Costs Fixed Per M

Woods supervision and general woods expense. General woods expense and supervision are often calculated on a per acre basis. This procedure is perfectly correct when applied to a given set of conditions; however, when considering several plans involving different cuts, a particular area-volume-cost relationship does not hold true. If the volume per acre cut is reduced by 50% the company has at least two choices of plans; 1) to continue cutting the same acreage, taking a reduction in production or 2) to increase the cutting area so as to keep production at the same level. When production is curtailed the scope of woods operations is reduced in like manner. Camps are smaller, crews are smaller, less trucks and tractors are needed as well as grease monkeys, mechanics, and storage facilities, and certain personnel can be eliminated. With the reduction in woods activities goes, naturally, a reduction in the items of supervision and woods expense. These costs are more directly related to the rate of production than to the acreage cut and it follows that they should be charged against production. These costs are constant at $2.00 per M.

Logging Costs Fixed Per Acre or in Total.

Fixed per acre costs are a definite controlling factor in selective logging and it is the evaluation of these costs that has created such a controversy on the merits of a partial cut. These costs may take on an entirely different nature in a selective logging or sustained yield operation than under a plan of forest liquidation; and it is necessary to examine them very closely in order to determine their application under the altered conditions brought about by logging selectively.

Road cost. One mile of main haul road taps 2,570 acres. At a cost of $800 per mile the fixed per acre charge is $0.312. This is a constant cost per acre regardless of the volume cut. Secondary roads, however, on properly planned operations do not incurr the same charge per acre for cuts of different intensity. Professor D.M. Matthews, in his work on minimum costs[1] has proven that by balancing skidding costs against road costs a minimum for the two in combination can be obtained. This balance is obtained by shifting the road spacing with different skidding costs and volume per acre cut. Table XIX is worked out for the volumes cut at each DBH and up by the road spacing formula as follows:

$$S = \sqrt{\frac{15.1\ r}{VC}}$$

where: S = Road spacing in 100 ft. stations
r = Road cost in 100 ft. stations or $400 per mile / 52.8 = $7.57
V = Volume cut per acre
C = Variable skid cost per M per 100'
15.1 = Constant factor to convert road costs to a per acre basis

Cost of roads per M = 4.365 r / VS

The spacing of landings influences skidding dictances in that, as the spacing is increased tractors have a longer diagonal haul, increasing the average skidding distance. Landings will be placed at intervals egual to approximately one half the road spacing. Since landings are spotted at open places in the woods with no formal attempt at special construction, this distance will vary. It does, however, establish a standard by which landing placement can be guided. Road construction crews should be instructed of this and in their process of moving trees, filling and cutting they can often open up good landing locations without extra cost. Jammers

1. Matthews, D.M. Cost Control in the Logging Industry. Mc Graw-Hill, 1942. Pg. 121.

can be moved at very slight cost by incoming trucks which mist go that direction anyway. With landings spaced as indicated above the average skidding distance is 0.289 x road spacing.

TABLE XX

Secondary Road Spacing and Cost.

	A	B	C	D	E	F	G
DBH	Volume: Per Ac: DBH&up	Var Skid: Cost Per: M Per100'	Volume: x Cost: (VC)	Rd.Space: 100 ft. Stations	Secondary Rd. Cost Per Ac D&up	Total Rd.: Cost Per Ac.D & up	Ave.Skid: Distance: 100' Sta.
10	8,302	$0.173	$1.44	8.9	$3.70	$4.01	2.57
12	7,984	.168	1.34	9.2	3.58	3.89	2.66
14	7,465	.163	1.22	9.7	3.40	3.71	2.80
16	6,593	.161	1.06	10.4	3.17	3.48	3.01
18	5,540	.159	0.88	11.4	2.90	3.21	3.30
20	4,117	.158	.65	13.2	2.50	2.81	3.82
22	2,824	.157	.44	16.0	2.06	2.37	4.62
24	1,812	.155	.28	20.0	1.65	1.96	5.78
26	1,018	.146	.15				
28	491	.136	.07				
30	296	.122	.03				

Explanation:
A. Table VII
B. Table XVI
C. A x B
D. $\sqrt{15.1 r / VC}$
E. 4.356r / D
F. E plus main haul road cost per acre ($0.312)
G. 0.289 x road spacing. This column is for use in computing skid costs in table XVI.
Note: Volumes are log scale.

Now suppose road spacing had not been changed. At the 20 inch limit the cost of skidding per M would be $0.409 instead of .603, a saving of 0.20 per M. The cost of roads, however, would be $o.956 per M instead of 0.657, an extra expence of $o.30.

<u>Logging Camps</u>. Camp construction is charged off on an acreage basis, the common type camp in this area costing about $3.00 per acre. Since camp location and spacing are usually determined on an area basis, according to the individual company's judgement of the

area one camp can economically best serve, this method of cost appraisal is correct. Camp costs will be charged that way in this paper. However, it is the personal belief of the author that with the rapid transportation of present day truck-haul logging, woods crews can be transported far enough from camp so that one camp producing 60,000 ft. per day (15,000 M per 250 day work year fron 1,800 acres) when clear cutting could still work over at least a large portion of the 3,600 acres necessary to sustain this production if the cut were only half (20 inches and up). Camp location, then, should be determined by minimum cost planning as in the case of branch road spacing. The camp cost per M as now computed, is double on a cut of 50% that for a cut of 100%. By incurring an extra cost in transporting woods crews, the camp cost per acre for selective logging can be reduced. These costs can be balanced to obtain a minimum combination. It should also be pointed out that if production is decreased (a 50% cut per acre with no increase in acreage) woods crews can be more than cut in half. This means a smaller camp and, although a large part of camp costs are fixed regardless of size, a reduction in cost. Further investigation into the possibilities set forth here might easily uncover a more equitable method of rating the costs of logging camps against selective logging.

Costs Fixed in Total

The fixed per acre classification of logging costs is frequently abused in that many of the so-called fixed per acre costs are incurred on a yearly basis and the total charged against the acreage cut. It follows that when reducing the cut per acre, if the acreage cut per year should be increased, the fixed per acre nature of these costs would decrease (providing such a change does not necessitate a change of total cost). If it is possible to sustain production at the clear cut level, then selective logging does not increase these costs per M.

Administrative and management expences. The woods operation must be charged with a portion of the administrative (front office personnel, legal services, and other overhead costs) and management expences(cruising, marking, management and forestry measures). These costs are computed in table XXI on two assumptions: Case I Under selective logging the acreage cut will be the same as under a clear cut plan. The costs per acre are $2.50 for clear cut and rising to $5.00 for selective logging(because of increased cost of marking and forestry measures). Case II Assuming the company has enough timber left to clear cut for 30 years, the area is to be handled on a cutting cycle basis for applying selective logging. It should be pointed out that cutting to a 10 year cycle means cutting 5400 acres per year. This means the operation would be so unwieldy as to be impractical. A practical limit must be set on the size of the compartment cut each year. In this case it will be 3,000 acres (see the discussion on logging camps). It can be seen that in the 10 or 15 year cycles the entire area cannot be covered at this rate. The adoption of either of these plans would mean the company could dispose of a portion of its property.

TABLE XXI

Administration and Management Cost.

(a) Case I

DBH	Volume Per Ac: Cut DBH & up	Acreage Cut: Per Year	Charge: Per Acre
10	8,302	1,800	$2.50
12	7,984	-	-
14	7,465	-	-
16	6,593	1,800	$5.00
18	5,540	1,800	5.00
20	4,117	1,800	5.00
22	2,824	1,800	5.00
24	1,812	-	-
26	1,018	-	-
28	491	-	-
30	236	-	-

(b) Case II

DBH & Up	A: CC or No. Compartments	B: Acreage Cut: Per Year	C: Adjusted Acreage Cut	D: Charge Per Acre
10	30	1,800	1,800	$2.50
12	-	-	-	-
14	-	-	-	-
16	30	1,800	1,800	5.00
18	20	2,700	2,700	3.33
20	15	3,600	3,000	3.00
22	10	5,400	3,000	3.00
24				
26				
28				
30				

Explanation.
- A, From growth predictions.
- B. Computed from A.
- C. Adjusted to practical limits.
- D. Pro-rated on basis of 16 inch class.

Taxes. It is the practice to let lands revert to the state for taxes following clear cutting. If the company owns enough land to clear cut for 30 years, then each year the cut on 1/30th of the original property must absorb the tax charges against the entire area. As the size of the property diminishes to zero the average tax for the entire period of operation is only one half what it would be the first year. The average tax charge then becomes 30 x tax per acre / 2.

Under the system of general property taxation tax rates vary extremely even between townships of a single county. At $0.50 per acre (not uncommon in the Upper Peninsula of Michigan) the tax charge becomes (30 x .50 / 2) or $7.50 per acre when clear cutting. Michigan and Wisconsin landowners have the choice of listing their lands under deferred tax laws if making partial cuttings. Most loggers, however, prefer the general property tax. Under selective logging cut-over lands are retained by the property owner and reassessed. The annual cut must still carry the charge of the entire tract. Assuming the tract is reassessed as cut, the first cut must carry the same total charge as when cutting selectively plus the taxes on the residual stand which start at zero and increase in the same manner the taxes on the original virgin stand decrease. The tax charge then becomes (Cutting Cycle x tax rate on virgin stands or $0.50 / 2) plus (CC x tax rate on residual stand / 2). Tax costs per acre will be computed on the same assumed cases as were administration and management expences (table XXII).

After the area is once cut over and it becomes static (as a whole) or regulated it will be reassessed at a value which will not be altered with each annual cut.

TABLE XXII

Tax Cost.

A		B	C	D	E		F
		CASE I			CASE II		
DBH & Up	Volume Per AC D & up	Assessed Value per AC Resid. Stand	Tax Per Ac Residual Stand	Tax Charge Per Ac	CC or	No. Compartments Adjusted	Ave Tax Charge Per Ac.
10	8,302	$5.00	$0.10	$7.50	30		$7.50
12	7,984	5.70	.11	-	-		-
14	7,465	6.90	.14	-	-		-
16	6,593	8.95	.18	10.20	30		10.20
18	5,540	11.40	.23	10.95	20		7.30
20	4,117	15.00	.30	12.00	15	18	7.20
22	2,824	18.00	.36	12.90	10	18	7.75
24	1,812	20.30	.40	-	-		-

Explanation:

B. Based on assessments of $25 per acre for virgin stands and $5.00 per acre after clear cutting.
C. Computed from B on basis of 20 mill levy.
D. (CC x $.50 / 2) plus (CC x Column C / 2)
E. Cutting cycle is adjusted to fit plan of not cutting over 3,000 acres per year (18 compartments)
F. (CC x $0.50 / 2) x (CC x Column C)
Note: Cutting 3,000 acres per year at the 20 and 22 inch limits it takes 18 years to cut over the property. The residual stand returns to original volume in 15 and 10 years respectively. Thus, the second cut will yield a greater return or acreage can be disposed of and a regulated stand still remain.

Stumpage Depletion

Stumpage prices are subject to great variation throughout the Lake States area. Depletion on this stand will be charged off at $8.50 per M log scale. Overrun decreases this by the amount shown as follows.

DBH & up	% Overrun	Stumpage
10	27.5	$6.67
12	27	6.70
14	26	6.75
16	24	6.86
18	23	6.90
20	21.5	7.00
22	20	7.10
24	19	7.15

Total Logging Costs

Total Logging costs are computed in the following two tables; Indirect or fixed costs in table XXIII and direct costs in XXIV.

TABLE XXIII

Total Indirect Logging Costs

(a) Case I

	A	B	C	D	E	F	G	H	I
DBH & Up	Cost Per Acre DBH & Up, Class C: Road	Camp	Admin & M'g't	Taxes	Total	Costs On Per M Basis	Fixed: Per M	Total All Fixed Costs, Per M: Log Scale	Mill Tally
10	$4.01	3.00	2.50	7.50	17.01	$2.05	2.00	$4.05	$3.18
12	3.89		-	-	-	-		-	-
14	3.71		-	-	-	-		-	-
16	3.48		5.00	10.20	21.68	3.29		5.29	4.26
18	3.13		5.00	10.95	22.16	4.00		6.00	4.88
20	2.81		5.00	12.00	22.81	5.55		7.55	6.22
22	2.37		5.00	12.90	23.27	8.22		10.22	8.51

(b) Case II

DBH	A	B	C	D	E	F	G	H	I
10	4.01	3.00	2.50	7.50	17.01	2.05	2.00	4.05	$3.18
12	3.89		-	-	-	-		-	-
14	3.71		-	-	-	-		-	-
16	3.48		5.00	10.20	21.68	3.29		5.29	4.26
18	3.13		3.33	7.30	16.84	3.40		5.40	4.38
20	2.81		3.00	7.20	16.11	3.90		5.90	4.85
22	2.37		3.00	7.75	16.12	5.70		7.70	6.40

Explanation:

A. Table XX
B. Section on Camp Cost.
C. Table XXI
D. Table XXII
E. Sum of A, B, C, and D.
F. E / Volume Per Ac. DBH & UP, Table VII.
G. Section on Woods Supervision and General Expense.
H. F plus G.
I. H reduced by overrun computed from table VII.

TABLE XXIV

Total Direct Logging Costs.

	A	B	C	D	E	F	G	H	I	J
DBH	Cost Per M, Log Scale				Total	Total	Cost	Var.	Total VarCost	
	Fell &	Fixed	Load &	Haul	Cost	Per Ac.	Per M	Skid	LogSc.	M. Tally
	Buck	Skid	Unload		Per M	Each DBH	DBH & up	Each	DBH & Up	
10	18.30	2.45	2.13	6.74	29.52	9.60	11.20	0.44	11.64	9.16
12	12.40	1.69	1.52	5.34	20.95	10.85	10.42	.44	10.86	8.56
14	8.70	1.22	1.12	4.37	15.41	13.43	9.70	.46	10.16	8.09
16	6.97	0.93	0.94	4.19	12.97	13.30	8.95	.48	9.43	7.60
18	5.10	.67	.75	3.70	10.22	14.55	8.25	.53	8.78	7.09
20	4.24	.60	.68	3.70	9.22	11.91	7.60	.60	8.20	6.75
22	3.40	.47	.56	3.33	7.76	7.87	6.81	.72	7.53	6.30
24	2.82	.49	.52	3.18	7.01	5.57	6.28	.89	7.17	6.05
26	2.34	.38	.45	2.86	6.03	3.18	5.69			
28	2.08	.36	.43	2.83	5.70	4.51	5.34			
30	1.79	.30	.37	2.49	4.95	1.17	4.95			

Explanation:

A. From Table XIV.
B. From Table XVII.
C. From Table XVIII.
D. From Table XIX.
E. Sum of A,B,C,andD.
F. E x volume per acre, each DBH.
G. Sum of F to each DBH / Volume per acre, each DBH and up.
H. From Table XVI. Computed separately because of the manner in which skidding costs were calculated.
I. G plus H.
J. I reduced by overrun computed from Table VII.

Direct Milling Costs

Direct costs of milling vary with the size of log handled and involve such items as sawing, boom and pond labor, power, and sawing supplies. These costs are high for small logs because of the longer time and more work involved in sawing one M ft. of lumber from small logs. Table XXV is a computation of these costs for typical band mills in the Lake States.[1]

TABLE XXV

Direct and Constant Milling Costs.

DBH	A Direct Cost Milling Per M Mill Tally	B Cost on Per Acre Basis	C Cost DBH & Up, Per Ac. Basis	D Cost Per M DBH & Up	E. Constant Per M	F Mill Mach. Dep. Constant Per M
10	$9.18	$4.30	$74.36	$7.00	$8.00	$0.70
12	8.60	6.38	70.06	6.92		
14	7.95	9.55	63.68	6.80		
16	7.40	10.25	54.13	6.62		
18	6.98	12.65	43.88	6.47		
20	6.66	10.65	31.23	6.26		
22	6.38	7.86	20.58	6.07		
24	6.15	5.86	12.72	5.90		
26	5.86	3.67	6.86			
28	5.65	1.71	3.19			
30	5.40	1.48	1.48			
		74.36				

Explanation:
A. Basic data adapted from USDA Tech. Bulletin #164;
B. A x Volume per acre, mill tally.
C. Sum of B, DBH and up.
D. C / Volume per acre, DBH and up.

Milling Costs Fixed Per M

Those costs of milling which remain constant involve the handling of sawn lumber and include mostly seasoning, finishing, and yard and selling expenses. These are shown in Column E of table XXV.

1. Adapted from the following publication: Zon, R. and Garver. Selective Logging in the Northern Hardwoods of the Lake States. USDA Technical Bulletin #164. 1930.

Milling Costs Fixed in Total

Insurance, general expences, administration and management, and mill depreciation are total yearly charges against production.

According to proper accounting procedures, the original cost of the mill (less scrap or sale value) is depreciated in equal annual amounts over the life of the mill. Major items of machinery which may have a life span shorter than the mill proper are depreciated seperately over their life span and when replacements are made, written off the books. Under clear cutting the mill will have a life span of 30 years. This assumption is based upon the premise that when the property is liquidated the owner must sell or scrap his mill and either quit business or move on to a new supply of timber. Many operators on a liquidation basis are forced (or will be) to do this because of the fast diminishing supply of available virgin timber in the Lake States. If the operation is of a more permanent nature the life of the mill may be at least doubled; greatly easing the burden of mill depreciation.

The life of major items of machinery is a function of production and when charged as such becomes a fixed per M cost. For this reason machinery depreciation is shown in table XXV while depreciation on the mill proper is fixed in total and charged in table XXVI. Table XXVI is constructed to show the costs that are charged in total against annual output for Case I and II.

TABLE XXVI

(a) Case I Costs Fixed In Total

DBH	A Volume Per Ac DBH &up	B Life of Mill Years	C Yearly Production Mill Tally	D Mill Dep Per M	E Insurance, Admin., M'g't, Gen.Exp., Etc.	F Total
10	16,599	30	19,000M	$0.15	$5.00	$5.15
12	-	-	-	-	-	-
14	-	-	-	-	-	-
17	8,186	60	14,700	0.09	6.45	6.54
18	6,799	60	12,000	0.12	7.90	8.04
20	4,987	60	9,000	0.15	10.50	10.65
22	3,387	60	6,100	0.23	15.60	15.83

(b) Case II

DBH	C	D	E	F
10	19,000	$0.15	$5.00	$5.15
12	-	-	-	-
14	-	-	-	-
16	14,700	0.09	6.45	6.54
18	18,400	.07	5.17	5.24
20	15,000	.09	6.30	6.39
22	10,200	.14	9.30	9.44

Explanation:

C. Based on the number of acres cut yearly from table XXI.
D. Based on $0.15 per M when clearcutting. Pro-rated for other limits on basis of columns B and C.
E. Based on $5.00 per M when clearcutting. Calculated same as column D.
F. D plus E.

Interest as a Cost

Interest has not been charged as a cost in this paper in spite of the contentions of many economists and foresters that it should be so treated. The author recognizes the concept of interest as the cost of the use of money tied up in a business, that interest is a link between capital and income, and also that a plan of operation producing 5 units of profit per 100 units of capital cannot arbitrarily be pronounced inferior to another that produces 6 units of profit but which may require 150 units of capital. Capital investments in a business enterprise, however, from the accounting standpoint are usually (not always)expenses in lump sums which are depreciated or depleted as costs. When these costs are charged against profit and loss and the enterprise still makes 6 units it would seem superior to the one producing five. Is it equitable, then, to introduce an interest charge which would in turn show the 5 units to be superior? In addition, the facts remain that very few forest owners recognize interest as a cost, the federal government does not permit its use for income tax purposes, accountants do not recognize it as a cost, and the profits developed in this paper are the same in actual dollars and cents regardless of the interest charged. So in accord with the above statements and in an endeavor to make this a practical comparison of selective logging and clear cutting by showing the profits as they would appear on the income sheets of an operating company, interest has been omitted as a cost.

Total Profits

The margin for profit and risk is computed in table XXVI for the various plans under consideration.

TABLE XXVII

Margin For Profit and Risk

(a) Case I

DBH	10	16	18	20	22
A. Value Per M, DBH & Up	43.80	45.60	46.60	47.60	48.25
<u>Logging Costs</u>					
B. Direct, DBH & UP	9.16	7.60	7.09	6.75	6.30
C. Indirect	3.18	4.26	4.88	6.22	8.51
D. Stumpage Depletion	6.67	6.86	6.90	7.00	7.10
	19.01	18.72	18.87	19.97	21.91
Surplus for Milling and Profit	24.79	26.88	27.73	27.63	26.34
<u>Milling Costs</u>					
E. Direct	7.00	6.62	6.47	6.26	6.07
F. Fixed Per M	8.70	8.70	8.70	8.70	8.70
G. Indirect	5.15	6.54	8.04	10.65	15.83
	20.85	21.86	23.21	25.61	30.60
Margin for Profit and Risk- - - - - - - - - -	3.94	5.02	4.52	2.02	-4.26

(b) Case II

	10	16	18	20	22
<u>Logging Costs</u>					
B. Direct, DBH and Up	9.16	7.60	7.09	6.75	6.30
C. Indirect	3.18	4.26	4.38	4.85	6.40
D. Stumpage Depletion	6.67	6.86	6.90	7.00	7.10
	19.01	18.72	18.37	18.60	19.80
Surplus for Millimg and Profit	24.79	26.88	28.23	29.00	28.45
<u>Milling Costs</u>					
E. Direct	7.00	6.62	6.47	6.26	6.07
F. Fixed Per M	8.70	8.70	8.70	8.70	8.70
G. Indirect	5.15	6.54	5.24	6.39	9.44
	20.85	21.86	20.41	21.35	24.21
Margin for Profit and Risk- - - - - - - - - -	3.94	5.02	7.82	7.65	4.24

Explanation:
- A. Table VII
- B. Table XXIV
- C. Table XXXIII
- D. From Section on Stumpage Depletion.
- E. Table XXV
- F. Table XXV
- G. Table XXVI

Note: Computed on a mill tally basis

IV INTERPRETATION OF RESULTS

For the stand and cost data presented here, partial cuts at 16 inches show the greatest profit per M for case I. As the data are computed for case II, cutting at the 18 inch limit shows the greatest profit , with limits of 16,18.20, and 22 inches all superior to clear cutting. This difference between the two cases is due to the fact that the operation (in case II) is so planned as to partially nullify the effect of the increasing fixed costs so common to partial cuttings.

Profit per M, however, is only oneindication of the relative merits of the plans under consideration. Following is a comparison of cutting at the different limits on an acreage and yearly basis.

As will be explained later, many elements go into the determination of the profit to be expected on the second cut. By conservatively estimating it to be the same as the first cut, the yearly profit below becomes a constant figure for the life of the stand (if on a sustained yield basis).

TABLE XXVIII

Profits on a Per Acre and Yearly Production Basis

(a) Case I

DBH	Volume Per Ac.D & Up M.Tally	Profit Per M	Profit Per Acre	Occurrence of Profit on Each Ac., Yrs	Total Yearly Profit
10	10,599	$3.94	$41.60	Once	$75,000
16	8,186	5.02	41.00	30	74,000
18	6,799	4.52	30.80	20	55,000
20	4,987	3.02	15.00	15	27,000
22	3,387	-4.26	-14.40	10	-26,000

TABLE XXVIII (continued)

(b) Case II

DBH	Volume Per Ac. D & Up M. Tally	Profit Per M	Profit Per Acre	Occurrence of Profit on Each Ac., Yrs	Total Yearly Profit	Acreage Cut Per Year
10	10,599	$3.94	$41.60	Once	$75,000	1800
16	8,186	5.02	41.00	30	74,000	1800
18	6,799	7.82	53.25	20	144,000	2700
20	4,987	7.65	38.20	15	114,000	3000
22	3,387	4.24	14.40	10	43,000	3000

Planning For The Second Cut

A selective logging type of operation can be initiated upon two basic presumptions: 1) For the purpose of achieving sustained yield. 2) To make one, two, or maybe three reduced cuts in an effort to prolong the operation; at the end of which time it is liquidated. The main factor here is the amount of property available for operation. If, as assumed in both cases I and II, the operation has suffecient acreage to cut for 30 years then cutting to the 16 inch limit means a 30 year cutting cycle and just fits the property. If, however, the company has only enough land to clear cut for 15 years and adopts the 16 inch limit cutting the same acreage, the area will be cut over in 15 years. At this point the decision must be made to: 1) acquire more land to fill out the area or 2) clear cut back over the area (which still has 15 years to grow to return to its original volume). It can be seen that in planning for selective logging, such factors as size of property, available timber of the required size to fill out a management unit, and length of cutting cycle must be considered as well as the financial returns and the necessity of meeting a given level of production.

The second cut ---Disadvantages. Obtaining a second cut means retaining partially stocked lands in ownership for the period of each cutting cycle before profits can be obtained from them. Carrying charges on these lands are often considered prohibitive. Taxes are an example; however, they are incurred on a yearly basis and are thus naturally suited to be rated against each year's production. Handled in this manner, they do not constitute a seperate carrying charge. In the Lake States, public forces responsible for fire protection have relieved forest owners from all but a small fire loss yearly and fire protection is not normally a great expense. Protection is not treated as a seperate item in this paper. Where the cost is large, it becomes an important carrying charge.

Operation on a long time basis involves waiting a period of years for the returns on any one acre of property. The risks naturally encountered in the lumber industry are multiplied several fold and for that reason a selective loggong plan must assure considerably greater profits than clear cutting. The greater risk involved with selective logging would tend to nullify the slight increase in profits per M for case I ; making the superiority of this case doubtful at least in the short-run.

The cost of logging cull trees that would be left in the woods under a clear cut plan has not been cumputed in this paper because in the Lake States many operators turn out such logs for the chemical wood market. Such trees would return a profit assuming reasonable utilization practices.

The second cut -- Advantages. As mentioned previously in Section II, the second cut should return a product of higher quality (less cull, more logs per tree, and less logs per M). Value returns would increase and variable costs of production would decrease. In addition, road costs should decrease, especially when working in the shorter cutting cycles. Main haul roads (although in this paper the charge was only against the first cut) might be built to a better service standard, treated as a capital cost, and depreciated over their probable life against later cuts. Secondary roads are charged against the first cut. They should cost only about one half to re-build for the second cut.

Proper accounting procedures require that stumpage be set up on the books as an asset. At $8.50 per M the stumpage account represents a debit balance of $70.50 per acre. On the first cut the depletion charge per M is the same whether clear cutting or selective logging. The stumpage account after the first cut retains a debit balance directly proportional to the residual volume per acre. Stumpage is replenisned in the case of clear cutting by new purchases and in the case of selective logging by growth. The cut after the property has been worked over once must - in the case of clear cutting - bear a charge of $8.50 per M (providing the cost has not changed). In the case of selective logging, second and later cuts would bear charges as follows; depending upon the volume cut per acre. After the original stumpage is depleted there would be no stumpage charge.

TABLE XXIX

Stumpage Depletion

DBH	Volume Per Ac. D & UP Log Scale	Percent of Vol. D & Up	Stumpage Account $ Per Ac	Stumpage Charge First Cut	Second Cut Stumpage Acc't	Second Cut Stumpage Charge	Third Cut Stumpage Acc't	Third Cut Stumpage Charge
10	8,302	100%	$70.50	$8.50	$70.50	$8.50	$70.50	$8.50
16	6,593	78.5			15.15	2.30	0	0
18	5,540	66			24.00	4.34	0	0
20	4,117	49			35.25	8.50	0	0
22	1,812	34			46.50	8.50	22.50	7.95

In cutting at all limits up to 22 inches the original cost of stumpage is depleted during the second cut. Growth, then, wipes out the stumpage depletion charge(which is no small point in favor of sustained yield); and the cost of growing timber replaces the cost of buying timber.

As a tract is cut clear the owner is required to make a new investment in timber and possibly mill. Virgin timber is becoming more scarce every year and many owners are finding no more available timber within economic hauling distance of their mill. Profits from clear cutting, thus, cannot be considered as net earnings until a portion is set aside to cover the cost of a new investment in property and mill. This has not been done in this paper.

The Economic Limit

A comparison of costs and values shows that -for this stand - the smallest tree to make a profit is the 14 inch class; trees of this size returning a profit of approximately $0.70 per M. When clear cutting his timber an operator must pay - from the profits of the larger trees - for the privilege of cutting trees 10 and12 inches in diameter. Logging selectively, these same trees are left in the woods until they can be cut at a profit. From this standpoint, cutting to the 14 inch limit takes 100 per cent of the value per acre.

The Effect of High Costs

It is especially significant to note the effect of changes in costs upon a selective logging operation. Variable costs normally retain their proportions from one class to the next and so higher costs accentuate the dollar difference between classes, thus favoring selective logging. Higher lumber prices, of course have the same effect. For example, if the piece rate for felling and bucking were reduced to $0.03 per lineal foot for birch and maple and $0.025 for hemlock the total variable cost per M (logging) for each limit would be as indicated in column A below. The margin

DBH	A	B
10	$7.30	$5.80
16	6.70	6.12
18	6.46	5.49
20	6.20	2.97
22	5.86	-3.01

for profit and risk then becomes as shown in column B (for case I). As originally computed, cutting at the 16 inch limit returned $1.08 more per M than clearcutting. With this reduction in costs the difference is only $0.32. An increase in fixed costs would have the same effect. It can be seen that the common belief that high costs (variable) impose conditions contrary to partial cutting is based on a fallacy.

CONCLUSION

From a study of the data presented here it appears that the items of fixed cost exert the most important influence upon selective logging. Upon comparing the results of the two cases it seems imperative that the selective logging operation be carefully planned in an effort to lower fixed costs. If a new operation, the planning becomes relatively easy. If an organization has been logging and milling for some years it may be necessary to completely reorganize - depending upon the extent to which production is lowered. If available timber is so limited as to preclude an increase in the acreage cut annually under selective logging, the scope of the operation is measurably reduced and those functions and expenses contributing to costs fixed per acre or fixed in total could in many instances (and should) be reduced accordingly. This means reorganization of management, items of overhead, and administration where possible, planning supervision and general expense to conform to production, and changing the aspects of depreciation and depletion. If, however, timber is available, the operation can be carried on at a higher level of production by increasing the acreage cut per year; and (as in case II) these critical costs do not bevome prohibitive.

One of the hardest conditions to meet is the mill owners common stipulation that production must be sustained at mill capacity. The trend toward smaller mills (quite common in the Lake States) solves this problem to some extent. Reducing production necessarily results in an increase in those costs fixed in total; however, it must be remembered that profits from other portions of the operation rise with selective logging and it is safe to lower production to the break-even point where the loss nullifies gain. Such an approach would establish a definite limit to which production can be lowered and might prove to mill owners that mill capacity is not as important consideration as many seem to believe. For example, in case I reducing production from 19,000 M to 15,000 M still nets the same yearly profit and down to 12,000 M still nets a greater profit per M. In case II, reducing production from 19,000 M down to 15,000 M still nets a much greater yearly profit and down to 10,000 M still nets a greater profit per M. It might be wise to approach this problem from another angle; why not adjust the mill capacity to fit woods production. This could be accomplished by converting a portion of the mill facilities to quality production (rather than concentrate on quantity) by improved utilization practices such as turning out small dimension stock from low grade lumber, slabs, and edgings or carrying the manufacturing process one step farther by turning out finished or semi-finished products such as maple flooring, special stock for furniture plants, or similar products.

In final analysis, the answer of whether to cut clear or partially lies in the conditions existing on the individual operation and their adaptability to new plans. Some, not subject to change (either because of natural causes or because impractical in the eyes of the owner), can preclude the possibilities of anything but clear cutting. The problem presented here has been an attempt, not to prove one system superior to the other, but to present an analysis of the conditions peculiar to the operation of either system and also to develop a method of analysis by which the advisability of selective logging can be determined for a given operation.

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