A FOREST MANAGEMENT AND LOGGING PLAN FOR THE IMP LAKE TRACT IN GOGEBIC COUNTY, MICHIGAN

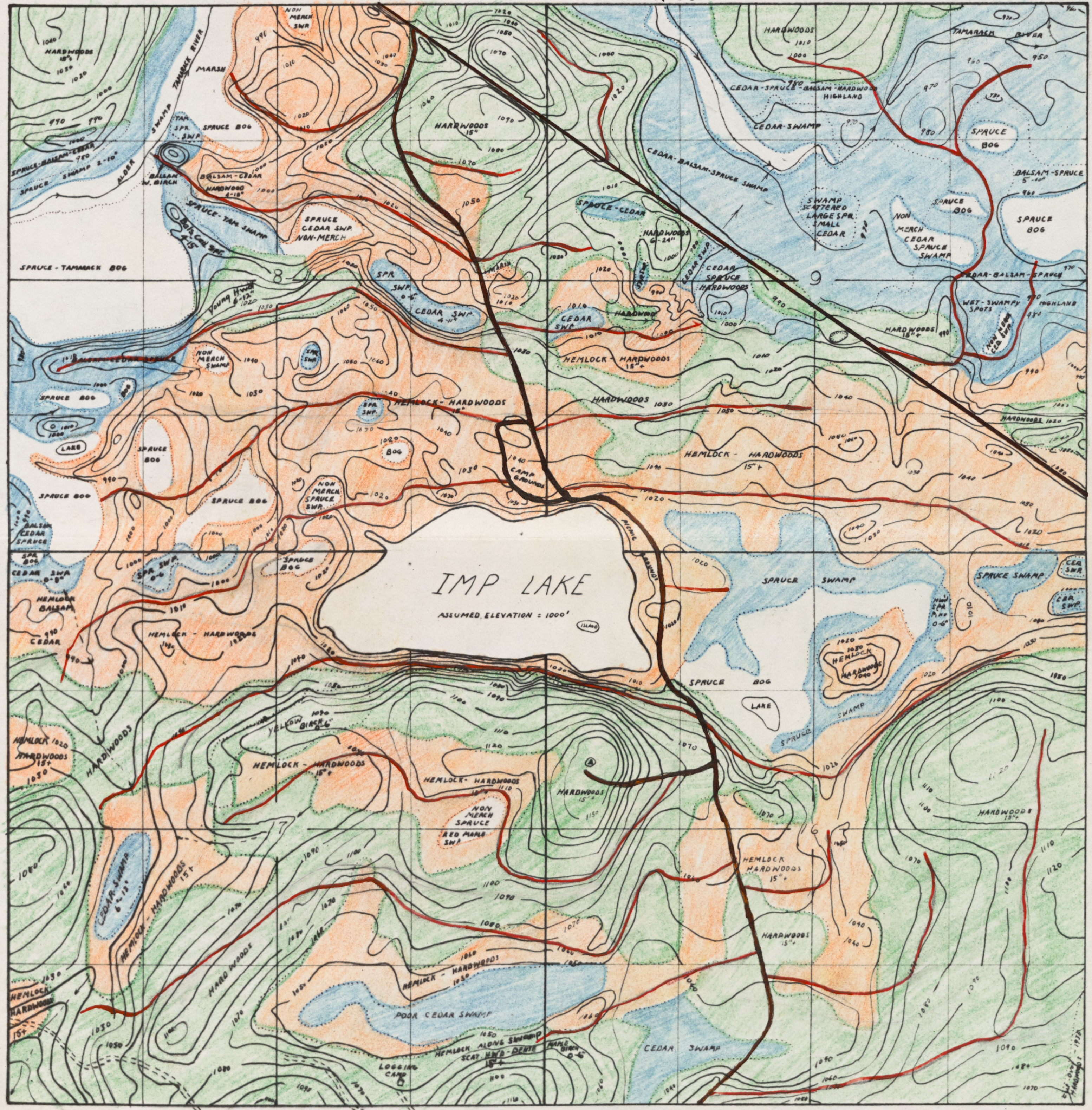
Carl G. Heczko

1946

CONTOUR AND TYPE MAP
OF
SECTIONS 8,9,16,17 T44N R38W
GOGEBIC CO., MICHIGAN

Hemlock - Hardwood
Hardwood
Spruce - Balsam - Cedar
Non - Merchantable

15 Chains
CONTOUR INTERVAL = 10'
TYPE LINE - ....
Branch Road
Main Road



MAPPED BY Frank Murray
TRACED BY William L. Kier
AUGUST 10 1944

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School of Forestry and Conservation
University of Michigan

A FOREST MANAGEMENT AND LOGGING PLAN FOR THE IMP LAKE TRACT IN GOGEBIC COUNTY, MICHIGAN

By
Carl G. Heczko

. Forest management — Michigan — Gogebic County

. Logging — Economic aspects — Michigan - Gogebic County

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Ann Arbor, Michigan
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PREFACE

During the past decades lumbermen have slashed through the virgin forests of our country as rapidly as possible, removing the forest products very much like miners exploiting some valuable mineral. The possibility of a second crop on the area never seemed to occur to them. It can be said that these men did not even believe that trees actually grew. They thought that trees had been created and were waiting to be cut down. Why should they bother to make management plans for forest areas when there was an abundance of land already forested which could be purchased at a low price?

After the valuable whitepine forests were removed from Michigan, the lumbermen that did not move westward began to cut the less valuable hardwoods and hemlocks, because these species were then coming into demand to supplement the dwindling supply of white pine. At this point, with an ever-increasing demand for forest products, they should have realized that even these less valuable trees would soon be as scarce as the white pine. However clear-cutting, followed by fires, continued at an alarming rate. As the virgin forests were becoming extinct, lumbermen began to notice that some of the cut-over and burned-over areas, that had been restocked by natural means, were in condition to be cut again. This was mostly true in pulpwood species such as aspen and jack pine that grow fast, but hardwood slash areas that had escaped serious fire damage were also once again assuming a merchantable appearance.

A few broad-minded companies began to realize that they could not continue to liquidate their holdings and expect to buy more virgin forests for future operations. The time had come when they must either so plan their logging operations as to maintain a perpetual yield or they must go out of business. At long last they perceived that if nature alone can produce continuous forest crops, certainly man, with a little foresight, could help to produce more valuable crops and in a shorter period of time.

Lumbermen have always had the idea that to make the most profit from logging a certain tract of land, everything that was of merchantable size had to be cut. Very few of them collect any cost data on their operations which would show them what type of timber was worth enough to cover the cost of cutting and still provide a fair profit. It is the general belief that the cost per M. b.f. of logging small timber is the same as that of logging large trees. However the board-foot volume of small logs is low and therefore more logs are required per M. b.f. and the cost rises correspondingly. There is a definite diameter at which value and production costs balance, and it is unprofitable to cut trees below this diameter limit. This report will show that by removing only the larger trees, logging can still be carried on at a profit and with the added advantage of having a continuous source of forest products.

The writer wishes to thank Professor Donald M. Matthews for the time he spent in ironing out the difficulties that arose and for his suggestions and invaluable assistance throughout the work on this problem. Acknowledgment is also given to Frank Murray, from whom most of the forest data used was received. Finally the writer wishes to express his appreciation for the assistance offered by his wife, Leah Naugle Heczko, in the final preparation of this thesis.

Carl G. Heczko

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A FOREST MANAGEMENT AND LOGGING PLAN
FOR THE IMP LAKE TRACT IN GOGEBIC COUNTY, MICHIGAN

Introduction

Management of northern hardwood and hemlock forests has seldom been given serious thought by lumbermen. The main reason for this is the slow rate of growth of this timber as compared to that in the southern states. Heavy taxation in the past has also been a cause of rapid liquidation of forest holdings. Though the growth of these northern species is slow due to the shorter growing season, the increased value of the products tends to offset this. Then too, these forests are closer to the main markets than the average southern forest, and thus transportation costs are lower. Yield taxes have been passed by many states to replace the general property tax on forest land. These factors should encourage more forest owners to manage their holdings on a sustained yield basis such as outlined in this thesis.

The area taken for this study is located in Gogebic County of Northern Michigan and consists of sections 8, 9, 16, and 17 in township 44 north, range 38 west. These four sections of land are a part of the Ottawa National Forest, but for the purpose of this thesis it can be assumed that they are owned by one company. A crop will be taken off the area every year, so this will be a small operation, but the same plan could be carried out on a larger scale just as well. The data used for this study was obtained from Frank Murray, Manager of University Forest Properties, who cruised and mapped this area during the summer of 1944.

The trees on this area will be cut according to the selection method, that is, only the oldest or largest trees in the stand will be taken plus such small trees that should be removed as thinnings. After several years another cut will be made, and this will be repeated after like intervals forever. Since the cut consists chiefly of large trees, the logs will be of more value than if the entire stand were cut. The trees taken in a single cutting may occur singly or in groups. The stand is never completely cleared off, and the small openings made in the stand will be seeded in by trees surrounding the opening. By this method, the stand is not bothered much by wind-throw and there is no need for slash disposal. Such light cuttings as will be made favor the reproduction of sugar maple, yellow birch and hemlock that are now on the area. In general, the composition of the new stands will not be materially different from that of the original stand. There are three major types on this area: hardwood, hemlock-hardwood, and a spruce-cedar-balsam type.

The most profitable use of the hardwood and hemlock timber produced in this area is for saw-logs. Chemical wood and fire wood are also in demand in some sections, and good use can be made of tops and cull trees where this is the case. The balsam fir and spruce will be sold as pulpwood. The cedar has a number of uses, such as posts, poles, railroad ties, and mine cribbing. Some of the swamp areas have tamarack on them. This can be used for mine timber.

The production of saw-logs requires a long rotation, at least 120 years. Growth is estimated to be 0.2 inch in diameter a year. Immature stands contain considerable board-foot volume at 60 years, but the trees are too small and of too low quality to be profitably converted into lumber.

With the exception of trees wounded in logging operations, rot is not serious in trees under 150 years in age. Much of the windbreakage in mature trees is traceable to trunk rots. Basswood and yellow birch are more susceptible to decay than theother trees, and their wood rots more rapidly once they are infected. Fomes connatus and Fomes igniarius are considered the chief cause of butt rot in maple and birch. Hemlock is affected with Fomes Pini, Polyporus Schwienitzie and Armillaria mellea. Poria subacida is considered the cause of 90 per cent of the butt rot in balsam fir and is thought also to be the cause of butt rot in white cedar.[1] Polyporus balsameus also causes the butt rot in white cedar. Most of the damage to cedar occurs on hemlock knolls and along the edges of swamps, making the cedar unmerchantable except for mine cribbing. The cedar in the swamps is fairly sound. The only satisfactory control of the rots is by removing over-mature, infected, and injured trees and by the prevention of damage to the remaining trees in logging.

The spring cankerworm, Paleacrita vernata, a defoliator, strikes periodically and causes some damage chiefly to the suppressed trees. The favorite host trees arethe elms and

[1]Baxter, D. V., Pathology in Forest Practice, John Wiley and Sons, Inc., New York, 1943.

basswoods, but they also attack other hardwoods. The spruce budworm, Cacoecia fumiferana, is a powerful defoliator of fir and spruce, causing the most damage in pure stands. By controlling the composition of the stand the spread of epidemics of these insects can be retarded.

The cruise data contained only the trees 10 inches d.b.h. and larger, and these by two-inch classes. It is taken for granted that there are enough trees in the smaller diameter classes below 10 inches to fill into the larger diameter classes as they are cut. The data in Table 2 represents an average acre and gives the number of trees per acre and their volume by size classes. The volume is net volume, a deduction for decay having been made by the cruiser.

Basal Area Percentage Control

Normal yield table data arranged in form so that it is comparable to all-age forest conditions can be used to analyze the growing stock conditions in an all-age forest, to determine the cut during the first cycle, and to predict cuts during subsequent cycles. It is not required to have available yield tables or detailed growth date for the actual species or groups of species that occur in any particular forest area in order to apply the principle of basal area percentage control to natural forest conditions. A study of the percentage distribution of basal area through the different age groups in all-age normal yield tables shows that species of similar habit of growth have apprixi-mately the same percentage distribution of basal area for any definite rotation and cutting cycle, regardless of what the site conditions or total basal area may be. This fact makes it possible to use European yield-table data for comparable species as the basis of control when dealing with a forest composed of species for which no satisfactory yield data are available. In this problem the normal yield table for oak, site II, as presented by Roth[1] was used as a basis of control. Using this information, basal area per acre was plotted over average diameter and a basal area curve drawn as shown in Fig. 1.

To determine the number of cycles which will be included in the range of diameters of cruise data, the minimum size of timber in the cruise is subtracted from the average maximum diameter of timber that is to be grown, and this is divided by the product of the cycle and annual increment. In this case it is as follows: $\frac{22'' - 10''}{20 \text{ yrs.} \times 0.2''} = 3$ cycles. Thus the trees in this cruise data must be divided over three cutting cycles. Since the annual increment and the length of cutting cycle is known, the diameter range in each cycle group and the probable average diameter of the trees in the group can easily be determined. From the basal area curve of the control table being used, the quantity of basal area in sq. ft. which one fully stocked acre of trees of the diameters indicated would carry is read. This data is tabulated, and the percentage of basal area which should be allocated to each cyclic age group is determined. For a harvest crop of 22-inch timber, on a cycle of 20 years, with a

[1]Roth, Filibert, Forest Regulation, 2nd. ed., Ann Arbor, Michigan, 1925.

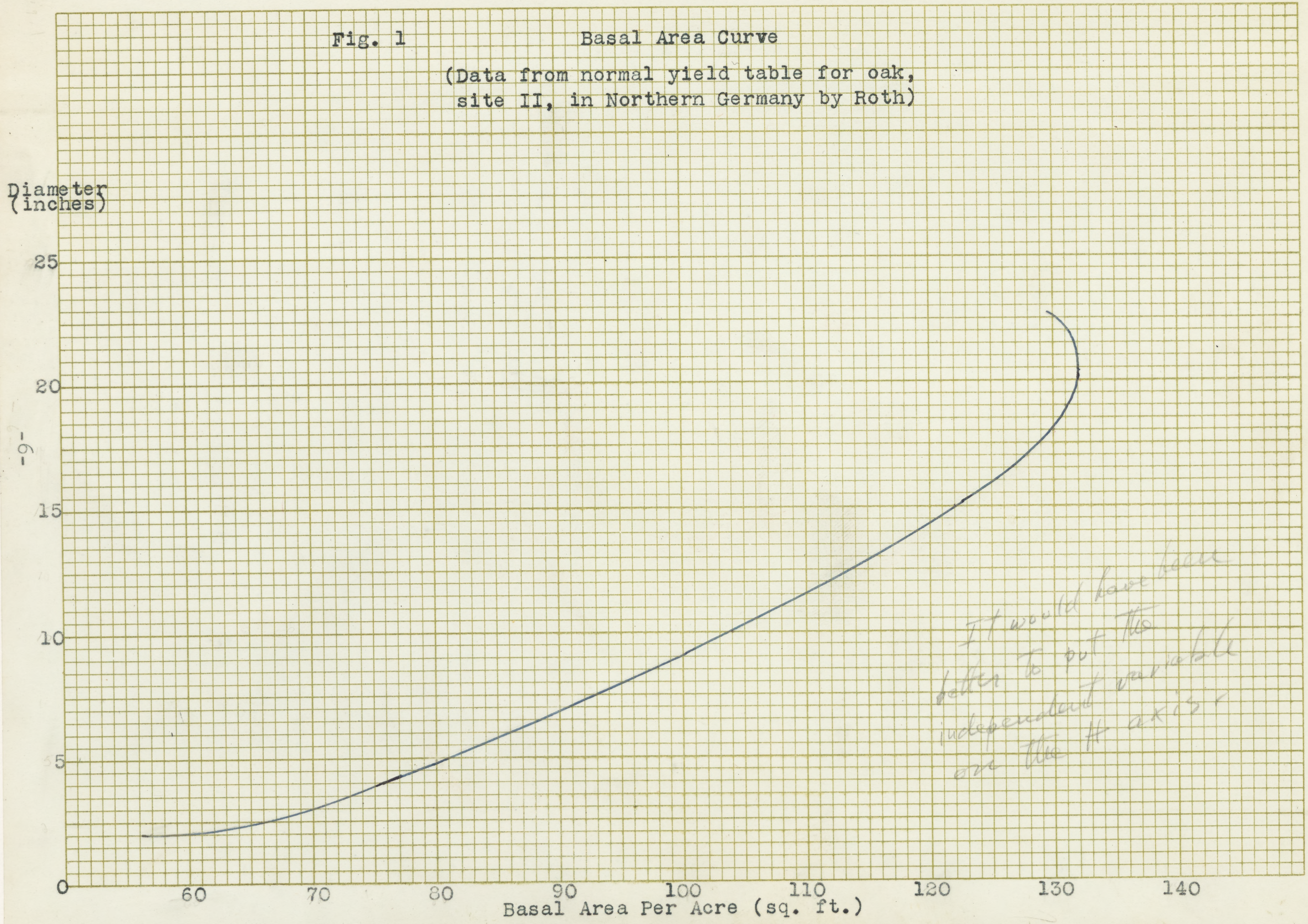


Fig. 1 Basal Area Curve

(Data from normal yield table for oak, site II, in Northern Germany by Roth) mean annual increment of 0.2 inch, and with cruise data to a 10-inch diameter, the tabulation is as follows:

Table 1

Basal Area Control Table

Age Group	D.B.H. inches		Basal Area, in sq. ft. (from curve)	Basal Area Per Cent per Group
	Range	Average		
I	10 - 14	12	114	30.6
II	14 - 18	16	126	33.9
III	18 - 22	20	132	35.5
Total			372	100.0

The above table shows that 35.5 per cent of the basal area in the cruise data will come out when the oldest group is cut. The annual harvest cut which can be taken from the forest will come from one-twentieth of the total area. This can be calculated from the data in the following stand table representing average conditions on the area. (Table 2)

Using the stand table data, the basal area per d.b.h. class and the volume per d.b.h. class were calculated. The basal area column was totaled and this total multiplied by the basal area per cent found in each group in the control table. According to this table, 35.5% of the total basal area will be removed in the first harvest cut. Adding cumulatively the basal area column, starting at the bottom, until 35.5% of the total basal area in the column is included will give the approximate diameter limit of the harvest cut and the number of trees in this group. The volume

Table 2

Stand and Stock Table (Hardwood Type)

Average Acre

Diameter	No. of trees	B.A. per dia. class sq. ft.	Vol. ft b.m.	% vol. per dia. class	Vol. in ft. b.m. per sq. ft. of B.A.
10	3.6	1.96	104	1.4	50
12	7.9	6.20	366	5.0	60
14	9.6	10.25	747	10.1	70
16	9.6	13.40	1150	15.6	86
18	9.8	17.30	1738	23.6	100
20	5.6	17.20	1250	17.0	102
22	3.4	9.00	943	12.8	104
24	2.2	6.92	703	9.6	101
26	0.4	1.48	168	2.3	113
28	0.2	0.86	128	1.8	150
30	0.1	0.49	59	0.8	120
Total	52.4	80.05	7356	100.0	

in and above this diameter limit, as determined from the stand table, will be the average volume per acre which can be taken in the harvest cut of the first cycle. The total harvest cut per year will be this quantity multiplied by one-twentieth of the total area in this type. The entire stand can be classified by this basal area percentage method and the volume in each age group determined. Following is such a classified stand and stock table for a typical acre of the hardwood type.

Table 3

Classified Stand and Stock Table

(Hardwood Type)

Age Group	% Basal Area	Actual Basal Area sq. ft.	No. of trees	Diameter Range inches	Average Diameter inches	Volume b.f.
I	30.6	24.45	25.6	10 - 16	13.2	1717
II	33.9	27.10	16.2	16 - 20	17.5	2670
III	35.5	28.40	10.6	20 +	22.2	2969
Total	100.0	80.05	52.4			7356

A reasonably accurate determination of the cut that can be taken on any cutting cycle may be made by this procedure. Following is an illustration of how the figures in the above table were computed. The control table indicates that 35.5 per cent of the basal area may be removed in the harvest cut. The stand table of the actual area shows that the total basal area is 80.05 sq. ft. per acre. Therefore 35.5 per cent of 80.05, or 28.40 sq. ft. of basal area, may be removed in the initial cut. Adding cumulatively from the bottom of the basal area column of the stand table shows that the basal area of trees 22 inches and over in diameter totals 18.75 sq. ft. As a cut of 28.40 sq. ft. is allowable, the difference, or 9.65 sq. ft., can come from the 20-inch class.

The 20-inch class contains 12.20 sq. ft. of basal area, 5.6 trees, and 1250 b.f. board measure. Therefore $\frac{9.65}{12.20}$, or 79 per cent, of the basal area, of the number of trees, and of the volume can be removed from the 20-inch class. The following calculations will show the allowable average cut per acre:

Cut	No. of trees	Volume in ft. b.m.
20"	.79 x 5.6 = 4.3	.79 x 1250 = 968
22"	3.4	943
24"	2.2	703
26"	0.4	168
28"	0.2	128
30"	0.1	59
Total	10.6	2969

For practical purposes this means a cut of 10 or 11 trees per acre and a volume of about 3 M b.f. per acre. The same thing was done for each of the other age groups. The average diameter figure for each group is obtained by dividing the basal area of the group (28.40 in group III) by the number of trees in the group (10.6 in group III) and by looking up the corresponding figure in a basal area table.

Besides the volume obtained in removing the harvest cut, an additional volume can be removed from the smaller diameter classes as thinnings. As a conservative measure, thinnings should be estimated on the volume basis of the smallest trees in each group. The average diameter of group II trees is 17.5 inches. Growth in 20 years will amount to 20 x 0.2" or 4 inches. Therefore in 20 years this group will average (17.5 + 4) or 21.5 inches in diameter. The number of trees in group II that should be carried forward is equal to the basal area of group III divided by the basal area of a 21.5-inch tree. This equals 28.4 ÷ 2.52 or 11.2 trees.

The total cut, including thinnings, can now be determined.

Harvest cut		= 2969 b.f.
Thinnings, Group II = 16.2 trees - 11.2 = 5, 16" trees		
	5 trees @ 120 b.f. =	600 b.f.
Group I = 25.6 trees - 16.2 = 9.4, 10" trees		
	9.4 trees @ 29 b.f. =	272 b.f.
Total cut per acre		= 3841 b.f.

For the second cycle the total cut is calculated as follows:

Harvest cut	11.2 trees @ 278 b.f. =	3110 b.f.
Thinnings (Same as in first cut)		= 872 b.f.
Total cut per acre		= 3982 b.f.

The same procedure must now be carried out for the hemlock-hardwood type. The same control table as was used for the hardwood type will be used. Table 4 is a stand and stock table of an average acre of the hemlock-hardwood type. By using this stand table the data can be classified in the same manner as that used in the hardwood type. Table 5 is the classified stand and stock table for the hemlock-hardwood type on a 20-year cutting cycle and a mean annual increment of 0.2 inch.

Table 4

Stand and Stock Table (Hemlock-Hardwood Type)

Average Acre

Diameter	No. of trees	B.A. per dia. class sq. ft.	Vol. ft. b.m.	% vol. per dia. class	Vol. in ft. b.m. per sq. ft. of B.A.
10	3.8	2.07	108	1.1	52
12	5.9	4.63	308	3.0	66
14	9.8	10.48	882	8.5	84
16	10.4	14.52	1387	13.5	95
18	9.7	17.15	1916	18.6	111
20	6.6	17.40	1543	15.1	107
22	3.7	9.77	1157	11.3	115
24	4.2	13.20	1540	15.0	116
26	2.0	7.37	993	9.6	135
28	0.6	2.56	336	3.3	131
30	0.2	0.98	105	1.0	107
Total	56.9	97.13	10275	100.0	

Table 5

Classified Stand and Stock Table

(Hemlock-Hardwood Type)

Age Group	% Basal Area	Actual Basal Area sq. ft.	No. of trees	Diameter Range inches	Average Diameter inches	Volume b.f.
I	30.6	29.63	28.4	10 - 16	13.8	2483
II	33.9	33.00	17.5	16 - 20	18.7	3591
III	35.5	34.50	11.0	20 +	24.0	4201
Total	100.0	97.13	56.9			10275

The average diameter of Group II trees from Table 5 is 18.7 inches. Growth in 20 years will equal 20 x 0.2" = 4 inches. Therefore 18.7 + 4 = 22.7 inches. The number of trees in Group II to carry forward is 34.5 ÷ 2.81 = 12.3. The total cut, including thinnings, can now be determined as follows:

Harvest cut		= 4201 b.f.
Thinnings, Group II = 17.5 trees - 12.3 = 5.2 trees		
	5.2 @ 133 b.f. =	692 b.f.
Group I = 28.4 trees - 17.5 = 10.9 trees		
	10.9 @ 28 b.f. =	310 b.f.
Total cut per acre		= 5203 b.f.

For the second cycle the total cut is calculated as follows:

Harvest cut	12.3 trees @ 313 b.f.	= 3845 b.f.
Thinnings (Same as in first cycle)		= 1002 b.f.
Total cut per acre		= 4847 b.f.

By multiplying these cuts per acre by one-twentieth of the area in that type, the average cut per year can be determined for this type. Table 6 shows the distribution of the area according to forest types and non-merchantable land. The total merchantable area is 2560 acres minus 356 acres, or 2204 acres. On a 20-year cutting cycle this would mean an annual cutting area of about 110 acres.

Table 6

Acreage by Forest Types

Type	Acres				
	Section 8	Section 9	Section 16	Section 17	Total
Hardwood	142	141	354	317	954
Hemlock-Hardwood	245	178	167	199	789
Cedar, Spruce, and Balsam Fir	90	247	59	65	461
Non-merchantable (Lake, roads, camp ground, and bogs)	162.5	73.5	61	59	356
Total					2560

Volume on the Area

From the cruise sheets of the area the net volume of the saw-log material was calculated for trees 20 inches and over in diameter. The cedar and pulpwood was tallied down to 6 inches. During the first cycle only one-twentieth of the volume will be taken. It was decided that during the first cutting cycle only one-third of the cedar posts tallied and one-half of the tie-cuts tallied would be taken. Since no growth data or cruise data by diameter sizes was given for the cedar, it was decided to leave the remainder behind for future cuts. All of the cedar poles tallied and all of the pulpwood will be taken. Following are tables of the different species on the area and the volume that will be removed each year.

Table 7

Volume on Area of Trees 20 Inches or More in Diameter

(In M b.f.)

Species	Hemlock-Hardwood Type	Hardwood Type	Cedar, Spruce and Fir Type	Total on Area	Annual Cut
Hard Maple	230.97	1277.61	6.70	1515.28	75.764
Yellow Birch	601.86	581.98	37.81	1221.65	61.083
Hemlock	3040.94	423.37	63.62	3527.93	176.397
Soft Maple	32.36	16.89	8.94	58.19	2.909
Basswood	36.30	408.80	0.0	445.10	22.255
Black Ash	2.80	6.70	0.0	9.50	0.475
White Pine	27.46	27.95	52.07	107.48	5.374
Elm	38.52	153.38	0.0	191.90	9.595
Combined Total				7077.03	353.852

Table 8

Volume on Area of Cedar 6 Inches or More in Diameter

(By number of pieces)

Product	Hemlock-Hardwood Type	Hardwood Type	Cedar, Spruce and Fir Type	Total on Area	Annual Cut
Posts	11498	2299	31700	45497	758
Poles	1630	386	3964	5980	299
Tie-cuts	3701	980	7473	12154	304

Table 9

Volume on Area of Pulpwood 6 Inches or More in Diameter

(Cords)

Species	Hemlock-Hardwood Type	Hardwood Type	Cedar, Spruce and Fir Type	Total on Area	Annual Cut
Spruce	385	243	1832	2460	123
Balsam Fir	204	69	761	1034	52
Combined Total				3494	175

Machine Rates

Since the annual cut will not be large enough to keep the logging equipment busy the full 235 working days a year, it is assumed that other work will be found for it, either by renting it out to other loggers or by taking contracts to log on other property for the remainder of the year. The Forest Service has timber land in the vicinity on which cutting contracts may be received. In this way, costs can be determined as if the equipment were to be used during the full year.

Either teams or caterpillar tractors can be used on the skidding operation. Costs of production must be compared to determine which will be cheaper to use. First the machine rates used were computed under conditions of larger operations, but costs would still be similar on this small operation.

The following scale of wages will be used in this problem:

Truck driver.......	$0.80	per	hour
Helper............	0.70	"	"
Teamster..........	0.70	"	"
Barn Boss..........	0.70	"	"
Blacksmith.........	0.85	"	"
Tractor operator...	0.85	"	"
Hooker.............	0.70	"	"
Sawyers............	0.80	"	"
Forester...........	225.00	"	month

<u>D-4 Tractor Equipped with Winch</u>

I. Fixed Cost per Hour

Initial cost of tractor.............	$2700.00	
Winch...............................	660.00	
Total initial cost..................	3360.00	
Average annual depreciation $= \frac{\$3360}{5 \text{ yrs.}}$	672.00	
Average annual interest @ 6% on the average interest bearing investment (where average interest bearing investment $= \frac{I + R}{2} + \frac{A.A.Dep.}{2} = \frac{3360 + 0}{2} + \frac{672}{2} = 2016) = 2016 \times .06$	120.96	
Average annual personal property tax @ 2% $= 2016 \times .02$	40.32	
Average annual insurance @ 2% $= 2016 \times .02$	40.32	
Average annual repair parts and repair labor	540.00	
Total annual fixed charge	1413.60	
Total fixed cost per hour on the basis of 2000 hours a year $= \frac{1413.60}{2000}$		$0.707

II. Operating cost per hour

Operator @ 85¢ per hour + 22% for Workmen's Compensation, Social Security, etc.	$ 1.037	
Hooker @ 70¢ per hour + 22%	0.854	
Diesel Fuel Oil, 1.2 gal. per hour @ 10.5¢	0.126	
Gasoline, 1 gal. per day @ 16.9¢ ÷ 8	0.021	
Lubricating oil, 1 gal. per day @ 71¢ ÷ 8	0.088	
Grease, 0.5 lb. per hour @ 17¢	0.085	
Cable and rigging	0.250	
Total operating cost per hour		$2.461
Total hourly cost		$3.168
Total average cost per minute		5.28¢

Team

I. Fixed cost per day

Initial cost of team and harness	$ 566.00
Estimated trade-in value after 5 yrs.	-100.00
Amount to be depreciated	466.00
Average annual depreciation = $\frac{\$466}{5 \text{ yrs.}}$	93.20
Average annual interest @ 6% on the average interest bearing investment (where average interest bearing investment = $\frac{566 + 100}{2} + \frac{93.20}{2} =$ 379.60) = 379.60 x .06	22.70
Allowances for taxes and insurance or other provisions for risk @ 4% = 379.60 x .04	15.18
Average annual repairs to harness and team	20.00
Average annual depreciation and interest on barns and stable	9.40

Total annual fixed charge $ 160.48

Total fixed cost per day on the basis of 235 work days a year = $\frac{160.48}{235}$ $0.68

II. Operating cost per day

Teamster @ 70¢ per hour + 22% for Workmen's Compensation, Social Security, etc. 6.83

Barn Boss @ 70¢ per hour + 22%, pro-rated over 10 teams for 235 work days a year 1.06

Blacksmith @ 85¢ per hour + 22%, half of which is charged to the 10 teams .41

A. Cost of feed

Oats, 10 bu. @ 60¢ for 10 teams	$ 6.00
Hay, 5 bales @ $1.20 for 10 teams	6.00
Bran, 17 lbs. @ 3¢ for 10 teams	.51
Cost of feed per day for 10 teams	12.51

Cost of feed per day per team on basis of 235 work days per year = $\frac{12.51 \times 365}{10 \times 235}$ 1.94

Total operating cost per day 10.24

Total daily cost $10.92

Average cost per hour = 10.92 ÷ 8 $ 1.35

Average cost per minute = 1.35 ÷ 60 2.27¢

Comparison of Production Costs of Tractor and Team

W. S. Bromley's studies of production time for teams and D-2 tractors were used in this problem. Following are the figures used:

		Tractors	Teams
A.	Speed "out" after load (in minutes per 100 ft.)	0.361	0.527
B.	Speed "in" with load (in minutes per 100 ft.)	0.417	0.534
C.	Speed round trip (in minutes per 100 ft.)	0.778	1.061
D.	Average load per turn (a D-4 tractor can haul 1.4 times the load of a D-2) = 2.4 x 1.4	300 b.f.	146 b.f.[1]
E.	Average fixed time per turn (in minutes)	4.28	4.30
F.	Average variable time per M b.f. per 100 ft. = (C ÷ D) x 1000 (minutes per 100 ft.)	2.59	7.27
G.	Average fixed time per M b.f. (in minutes) = (E ÷ D) x 1000	14.26	29.46

Calculation of basic costs of skidding

		Tractors	Teams
H.	Cost of operating per minute (from machine rate tables for teams and tractors)	5.28¢	2.27¢
I.	Average variable cost per M per 100 ft. (F x H)	13.70¢	16.50¢
J.	Average fixed cost per M (G x H)	75.30¢	66.87¢

Bromley's studies were made in small timber, and his teams skidded only 91 b.f. per trip. However there is a tendency among teamsters to skid only one log at a time, even when they could skid larger loads. Therefore in this problem, where the logs will be large, the teams will skid larger loads. The load can be determined by setting up a ratio between what teams and tractors did on a ground skidding job of tree-length southern pine. This information

[1] Bromley used 91 b.f., but 146 b.f. was substituted in this study as explained below.

was found in Appendix "B" of Cost Control in the Logging Industry by D. M. Matthews.[1] According to this chart, a team will skid 158 b.f. per trip in 16-inch tree-length logs. A D-4 tractor will skid 325 b.f. If the D-4 will skid 300 b.f. of 16-foot logs in this problem, the load for the teams can be determined by the following ratio: $\frac{158}{325} = \frac{x}{300}$. A value of 146 b.f. is found to be the average load for a team in this size timber.

This gives the teams a smaller fixed cost per M b.f. than the tractors. However the variable cost of the teams is greater. Therefore teams may be used profitably up to that skidding distance where the sum of the fixed and variable costs for them equals the sum of the fixed and variable costs of the tractors. The graph in Figure 2 shows this point to be at 300 feet. Teams should thus be used on distances up to 300 feet and tractors for distances beyond 300 feet. Whether teams or tractors will be used for skidding will depend on how far apart the roads and landings are spaced.

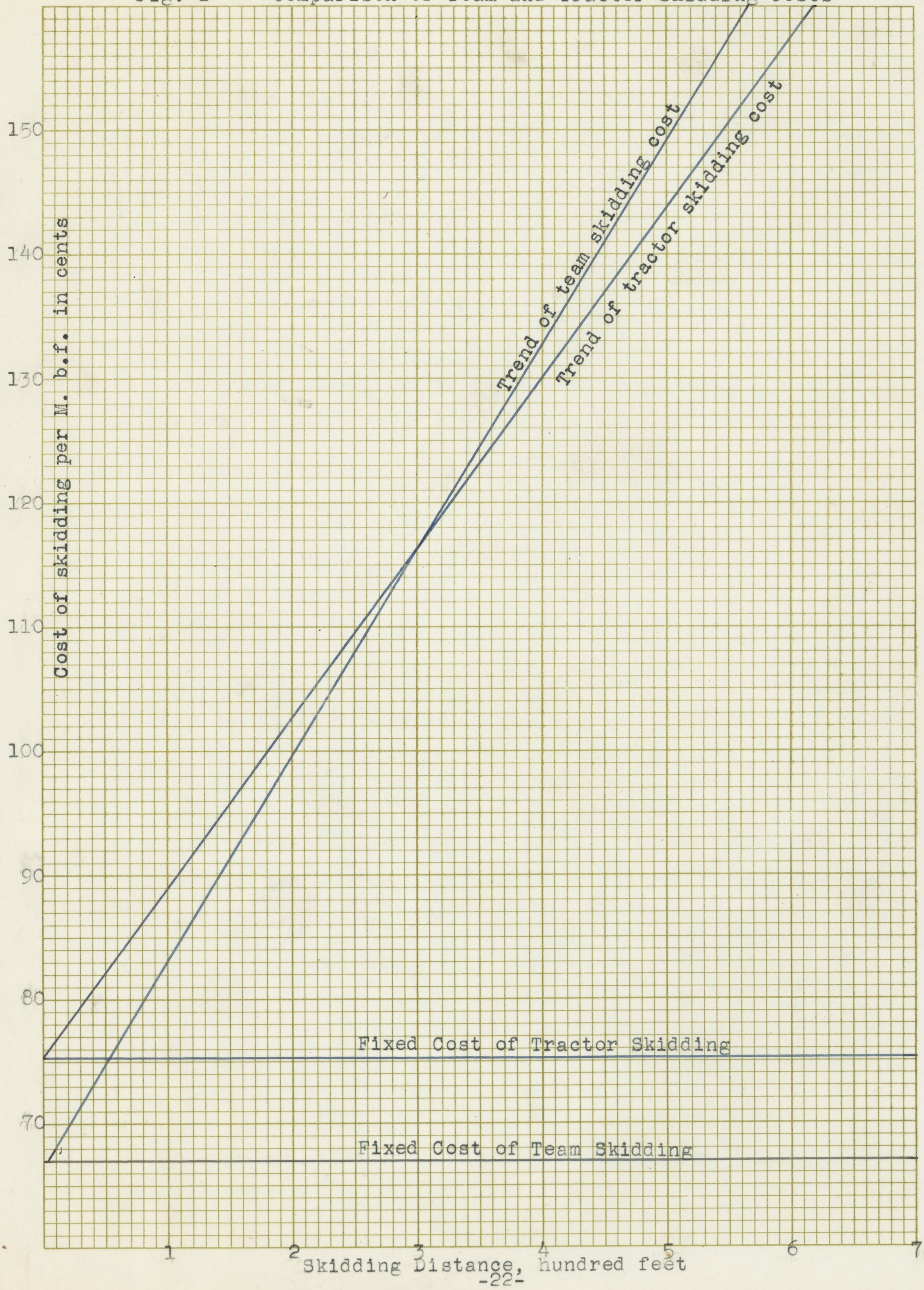
Before a spacing figure for roads can be determined, the road standard must be known, and this depends on the cost of hauling per mile. The cost of hauling can be determined as follows:

Machine Rate for One and One-Half Ton Truck

The following figures are for the Lake States Region and are based on a 2000-hour year and a 3-year life.

[1] Matthews, D. M., Cost Control in the Logging Industry, 1st ed., McGraw-Hill Book Co., New York, 1942.

Fig. 2 --- Comparison of Team and Tractor Skidding Costs



I. Fixed cost per hour			
Registration (licenses)	$ 55.00		
Public Liability $50,000/100,000 plus $25,000 Property Damage Insurance	52.20		
Collision ($50 deductible)	40.00		
Fire and theft	32.00		
Annual cost of licenses and insurance (Michigan data)	$ 179.20		
Average cost per hour of licenses and insurance = $\frac{179.20}{2000}$		$0.090	
Original cost of truck	$1800.00		
Third axle unit	656.00		
Gross investment	2456.00		
Less tires (charged to mileage)	-435.00		
Net investment	2021.00		
Less wrecking value	-300.00		
Amount to be depreciated	$1721.00		
Average hourly depreciation		0.287	
Average hourly interest @ 6% on average interest bearing investment ($\frac{2021 + 300}{2} + \frac{574}{2}$ = 1447) = 1447 x .06 ÷ 2000		0.043	
Driver's wages @ 80¢ per hour + 22% for workmen's compensation, social security, etc.		0.976	
Total fixed cost per hour			$1.396
II. Operating cost per hour			
Oil @ 30¢ per qt. (10 qts. every 50 hours)		$0.060	
Repairs, average of $400 per year		0.200	
Greasing and general maintenance		0.040	

Fuel (average)	$0.400	
Tires, $435 ÷ 1000 hours	0.435	
Total operating cost per hour		$1.135
Hauling cost per hour		$2.531

Determination of the Economic Service Standard for Interior Roads

It does not pay to construct interior roads of very high standard unless the volume to be moved over them is rather large. As a rule, however, loggers usually construct roads of too low a standard to be economical. A classification of woods roads commonly used in Michigan and Wisconsin is as follows:

Class I (Strip Road) - Average round trip speed 2 m.p.h., made by piece cutter or trucker. Cost included in piece rate of cutting or trucking.

Class II (Poor Haul Roads) - Brushed out, stumps cut low, hand graded. Average round trip speed is 4 m.p.h. Cost to construct in heavy soil - $150 per mile. Cost to construct in sand or gravel - $75 per mile.

Class III (Fair to good haul roads) - Machine graded, drainage provided, dirt surfaced, fair alignment and gradients. Average round trip speed is 10 m.p.h. Cost to construct in heavy soil - $300 per mile.

Class IV (Good haul road comparable to the average township road) - good alignment and gradient, smooth and well-maintained dirt surface. Average round trip speed is 16 m.p.h. Cost to construct in heavy soil - $500 per mile.

It will be assumed that roads similar to the foregoing can be constructed at the costs indicated. The truck machine rate will be used to determine the hauling cost per mile on each class of road.

Hauling and Road Construction Costs

By the use of the following formula, the hauling cost per round trip mile can be determined for each road standard.

$$\text{Hauling cost} = \frac{2\ H.C.}{m.p.h. \times L}$$

where H.C. = hourly cost of operating truck = $2.53

m.p.h. = round trip speed in miles per hour

L = load in M b.f. = 2.5 M

The hauling and construction costs for the different road standards are as follows:

Table 10

Hauling and Road Construction Cost

Road Standard	Round Trip Speed	Hauling Cost per M b.f.		Road Construction Cost	
		Per Mile	Per Sta.	Per Mile	Per Sta.
II	4	50.7¢	0.97¢	$150	$2.84
III	10	20.2	0.38	300	5.68
IV	16	12.7	0.24	500	9.47
IV	20	10.1	0.19		
IV	30	6.8	0.13		

By assuming that skidding will be direct, without the use of landings, the skidding and hauling costs can be compared for each standard of road and a decision made as to which would be the most economical. The following formula[1] gives the sum of the road construction, variable skidding, and the hauling costs per M b.f. on interior roads:

$$\text{Total cost per M} = 2C\frac{S}{4} + H\frac{D}{2}$$

where C = 13.7¢, variable cost of skidding per station (with tractor)

D = 1 mile, maximum length of interior road

S = Spacing of roads in 100 ft. (Varies according to road standard)

H = Hauling cost per M b.f. per mile (Varies according to road standard)

Calculation of Road Spacing for Each Road Standard

Proper branch road spacing is dependent upon balancing the cost of road construction with the variable cost of skidding or draying and the volume of timber to be removed. The spacing of the roads of different standards can be determined by the following formula[1]:

$$S = \sqrt{\frac{.33R}{V.C.}}$$

where S = Spacing of roads (in hundreds of feet)

R = Cost of road construction per mile (in cents)

V = Volume cut per acre (in M b.f.)

C = Variable cost per M b.f. of skidding 100 ft. (in cents)

Following are the calculations for determining the proper road spacing to use for each road standard:

[1] Matthews, D.M., Cost Control in the Logging Industry, 1st. ed., McGraw-Hill Book Co., New York, 1942.

Standard II (4 M.P.H.), $S = \sqrt{\frac{.33 \times 15000}{4 \times 13.7}} = \sqrt{90.3} = 9.5$ stations

Standard III (10 M.P.H.), $S = \sqrt{\frac{.33 \times 30000}{4 \times 13.7}} = \sqrt{180} = 13.4$ stations

Standard IV (16 M.P.H.), $S = \sqrt{\frac{.33 \times 50000}{4 \times 13.7}} = \sqrt{301} = 17.4$ stations

By substituting these figures in the total cost formula, the proper road standard can be determined.

$$\text{Cost} = 2C\frac{S}{4} + H\frac{D}{2}$$

Standard II (4 M.P.H.) $= (2 \times 13.7 \times \frac{9.5}{4}) + (50.7 \times \frac{1}{2})$

$= 65 + 25.3 = 90.3¢$

Standard III (10 M.P.H.) $= (2 \times 13.7 \times \frac{13.4}{4}) + (20.2 \times \frac{1}{2})$

$= 91.8 + 10.1 = 101.9¢$

Standard IV (16 M.P.H.) $= (2 \times 13.7 \times \frac{17.4}{4}) + (12.7 \times \frac{1}{2})$

$= 119 + 6.3 = 125.3¢$

It is evident from the foregoing cost comparison that a Standard II road will be the most economical to adopt when the volume to be removed is only 4 M per acre and when the maximum haul is one mile. ~~This road will cost $150~~ a mile to build.

Determination of the Actual Economic Spacing of the Branch Roads When Landings Are to be Used

A trial calculation is run to determine the spacing of roads if landings are to be spaced 12.5% of the road spacing. The formula[1], $S = \sqrt{\frac{17.25\ r}{V.C.}}$, will be used

where S = road spacing (in station of 100 ft.)

[1]Matthews, D. M., Cost Control in the Logging Industry, 1st. ed., McGraw-Hill Book Co., New York, 1942.

r = road construction cost per station of 100 Ft.

V = volume to be cut per acre in M b.f.

C = cost of skidding per M per station in cents

The calculation is as follows:

$$S = \sqrt{\frac{17.25 \times 284}{4 \times 13.7}} = \sqrt{\frac{4900}{54.8}} = \sqrt{89.4} = 9.5 \text{ stations}$$

The cost of skidding and roads under this road spacing will equal 2 pcs[1] where

p = average skidding distance in % of road spacing

c = variable cost of skidding per station

s = spacing of roads in hundreds of feet.

Cost of skidding and roads = 2 x .2525 x 13.7 x 9.5

= 65.7¢ per M.

Loading will be done with an "A" frame jammer and at an estimated set-up cost of $5.00. The cost of landings per M b.f. is equal to $\frac{L}{.0287\ S^2V}$ [1] where

L = Cost of a landing in cents

S = Road spacing in stations

V = Volume of cut in M b.f.

The calculation is as follows:

$$\text{Cost} = \frac{500¢}{.0287 \times 9.5^2 \times 4} = \frac{500}{10.26} = 48.7¢ \text{ per M b.f.}$$

The ratio of skidding and road costs to landing costs equals $\frac{65.7}{48.7}$, or 1.4 to 1. From column 11 of Table 4 in Cost Control in the Logging Industry[1], this ratio calls for landings spaced 60% of road spacing. From this same table, the correct road spacing formula for a 60% spacing of landings is seen to be, $S = \sqrt{\frac{14.3\ r}{V.C.}}$.

[1]Matthews, D. M., Cost Control in the Logging Industry, 1st. ed., McGraw-Hill Book Co., New York, 1942.

$$S = \sqrt{\frac{14.3 \times 284}{4 \times 13.7}} = \sqrt{74.2} = 8.6 \text{ stations}$$

This shows that roads should be spaced 860 feet apart and landings 60% of this or 516 feet apart along the roads.

The graph on team and tractor skidding costs (Fig. 2) shows that teams should be used for skidding up to distances of 300 feet and tractors on distances over that. Since this is a small area both types of skidding cannot be used. However loading will be done with a team, and this same team can skid the logs closest to the landing while waiting for a truck to return for a load. The rest of the timber will be skidded with the tractor.

Estimate of Logging Costs

Now that the spacing of the roads has been determined, the actual costs of logging can be calculated.

Cost of Skidding

Fixed cost	= \$0.755 per M b.f.
Variable cost (pes for a z value of 60%) = 0.304 x 13.7 x 8.6	= 0.358 " " "
Cost of skidding	= 1.113 " " "

Cost of Landings

Cost calculated by the formula,

$$\frac{L}{0.138\ S^2V} = \frac{\$5.00}{0.138 \times 8.6^2 \times 4} =$$

$$\frac{5.00}{40.8} = 0.122 \text{ per M b.f.}$$

Cost of Road Construction

The cost of roads could be determined by multiplying the cost of roads per station by the constant, 4.356, and dividing this product by the product of the volume cut per acre and the road spacing as measured in units of 100 feet. This is shown by the formula, $\frac{4.356 \times 1}{V.S.}$. This would give the road cost per M. However the area worked on in this problem has a mixture of several types, and some of the cost of road construction should also go to the pulpwood and cedar being taken off the area. Therefore it will be easier to treat road construction costs as fixed per acre costs and spread these costs over the woods products according to the value of the product after all other costs have been deducted. County roads divide up the area very well and will be used as the main haul roads. This will be done later on in the problem.

Cost of Loading

An "A" frame jammer costs about $200 to construct and has an expected life of about 4000 hours. A team will be used on the cross-haul. Loading time is 15 minutes per M.

Jammer cost per M = $\frac{\$200}{4000 \text{ hrs.}} \times \frac{15 \text{ min.}}{60 \text{ min.}}$	= $0.013 per M b.f.
Team cost = 2.27¢ x 15 min.	= 0.341 " " "
Two hookers @ 85.4 ¢ per hr. = .854 x $\frac{15}{60}$ x 2	= 0.427 " " "
Standby charge of truck = $1.396 x $\frac{15}{60}$	= 0.349 " " "
Cost of loading	= $1.130 " " "

Cost of Hauling

Hauling on interior roads at 4 m.p.h., an average distance of one-half mile = ($0.507 x ½)
= $0.254 per M b.f.

[1] Matthews, D. M., Cost Control in the Logging Industry, 1st ed., McGraw-Hill Book Co., New York, 1942.

Hauling on county gravel road at 16 m.p.h. an average distance of 1.25 miles = (0.127 x 1.25) = \$0.159 per M b.f.

Hauling on paved highway at 30 m.p.h. an average distance of 8 miles = (0.068 x 8) = 0.544 " " "

Cost of hauling = \$0.957 " " "

Cost of Unloading

Logs will be dumped into pond at Watersmeet, Michigan. If logs are to be decked at the mill yard, mill-paid employees will do this. The only cost to unloading will be the standby charge of truck and driver. Delays at the mill average about 15 minutes per load. The cost per M is as follows: $\frac{\$1.396}{2.5\text{ M}} \times \frac{15\text{ min.}}{60\text{ min.}}$ = \$0.140 per M b.f.

Cost of Felling, Bucking, and Swamping

Swamping will be done by the felling and bucking crews, and the cost is included in their wages. The following felling and bucking times were taken from the O.P.A. time and price charts of September 1943. A weighted average has to be determined for trees 20 inches and over in diameter. This can be determined by multiplying the time per diameter class by the number of trees in that class, taking a summation of these products, and dividing by the number of trees cut. Following is the calculation as determined on a sample of one acre.

Table 11

Calculation of Felling and Bucking Time

D.B.H.	No. of trees per dia. class in sample acre	Felling and Bucking time per M in hours	Product of columns 2 and 3
20	5.6	2.57	14.40
22	3.4	2.52	8.57
24	2.2	2.54	5.58
26	0.4	2.61	1.04
28	0.2	2.68	0.54
30	0.1	2.73	0.27
Total	11.9		30.40

The average time for felling and bucking a thousand board feet is 30.40 ÷ 11.9 or 2.55 hours.

2.55 hours x (80¢ + 22% for Social Security, Workmen's Compensation, etc.) = $2.49 per M b.f.

Thus the total production cost per M board feet of sawtimber, exclusive of fixed per acre costs, is as follows:

Skidding	$1.113
Landings	0.122
Loading	1.130
Hauling	0.957
Unloading	0.140
Felling and Bucking	2.490
Total	$5.952 per M b.f.

The cost of production of pulpwood and of cedar products must now be determined so that the fixed per acre costs may be proportionally divided according to the value of the product.

Cost of Production of Pulpwood

No definite management plan has been set up for the spruce, balsam fir, and cedar type, as not enough information was available on this type. Cedar was tallied according to number of posts, poles and tie-cuts, and pulpwood, according to the number of cords on the area. The pulpwood cut included all trees 6 inches and over. One-third of the cedar posts, one-half of the tie-cuts, and all of the poles will be cut. By leaving two-thirds of the posts and one-half of the tie-cuts, enough timber will be left on the area to insure cuts at future cutting cycles. The cedar poles are by far the most valuable of the cedar products, and enough small cedar trees will be left to produce more cedar poles in the future. Of the four sections under management, about 460 acres are of the spruce, balsam fir, and cedar type.

Cutting Costs

The cutting costs obtained for pulpwood are on a stick rate basis. They are as follows: 7¢ for everything up to an 8-inch top diameter, 14¢ for 8 inches and up to 12 inches, and 21¢ for everything 12 inches and over. These prices also included piling the pulp sticks and swamping roads to the piles. The cruise data, however, had all the spruce and balsam fir totaled up in cords, so a proportional price for cutting pulpwood must be determined on a per cord basis. The percentage of sticks of each diameter class in an average cord was found, and also the number of sticks per cord.

By multiplying the number of sticks per diameter class that would be needed to make a cord by the percentage of such diameter classes in an average cord, the number of sticks of each diameter in a cord can be found. If this number is now multiplied by the cutting cost per stick for that diameter class and the resulting products totaled, the cutting and piling cost per cord will be determined. Following are the calculations:

Table 12

Determination of the Cutting and Piling Cost Per Cord

Top Dia. of Sticks (inches)	No. of Sticks Per Cord	% of dia. Class in Ave. Cord	No. sticks Per dia. Class in Ave. Cord	Cutting Cost Per Stick	Wtd. Cost Per Cord
4	100	18.8	18.8	$0.07	$1.32
5	75	17.5	13.1	0.07	0.92
6	55	16.5	9.1	0.07	0.64
7	40	13.3	5.3	0.07	0.37
8	32	11.1	3.6	0.14	0.50
9	25	9.5	2.4	0.14	0.33
10	20	5.3	1.1	0.14	0.15
11	17	3.8	0.6	0.14	0.09
12	15	3.1	0.5	0.21	0.10
13	12	1.1	0.1	0.21	0.03
Total		100.0	54.6		$4.45

The pulpwood will be loaded on drays and hauled by tractor to the landing, where it will be loaded on trucks. A tractor can pull two drays, each containing a cord, and trucks can haul a two-cord load. The costs are as follows:

Loading Drays

15 min. per cord = 15 min. x 2 cords x 2 men at $0.854 = $0.854

Draying with Tractor

Average skidding distance is ps or .304 x 8.6 sta. = 2.6, or 3 stations.

Total turn time =
Fixed time = 4.28 min.
Variable time = 3 x .778 = 2.34 min.
6.62 min.

Cost of draying 2 cords = 6.62 x 5.28¢ = 0.350

Hauling

In hauling cedar and pulpwood, a helper will ride with the driver at all times. This will increase the fixed cost per hour to $2.25. The driver and helper will both load and unload the truck.

Loading and unloading truck = 1.0 hr. @ $2.25 = $2.25

Hauling on branch roads at 4 m.p.h.

$$= \frac{2 \text{ H.C. x distance}}{\text{m.p.h.}}$$

$$= \frac{2 \times \$3.385 \times 0.5 \text{ miles}}{4} = 0.847$$

Hauling on county gravel road at

$$16 \text{ m.p.h.} = \frac{2 \times 3.385 \times 1.25}{16} = 0.528$$

Hauling on paved highway at 30 m.p.h.

$$= \frac{2 \times 3.385 \times 8 \text{ miles}}{30} = 1.81$$

Total hauling cost for 2 cords = $5.435

The skidding, hauling and loading cost of 2 cords = $6.639

The skidding, hauling and loading cost of 1 cord = $3.319

Cutting cost at $4.45 + 22% for social security, Workmen's Compensation, etc. = $5.420

Cost of production per cord, exclusive of fixed per acre costs = $8.739

Cost of Production of Cedar Poles

The cedar poles are the most valuable product of the spruce-cedar-fir type. It has been decided to cut all of the poles tallied on the area since they are trees that have reached their maximum value. Sixty per cent of the poles on the area are 25 feet long, and forty per cent average 40 feet in length. Following are the cost calculations:

The tractor will skid an average of 4 poles per trip, so the cost of skidding is $\frac{6.62 \text{ min.} \times 5.28¢}{4 \text{ poles}}$ = $0.087

A truck can haul about 25 poles on a load. Loading time is 30 minutes per load. The truck helper and one other man will serve as hookers in loading.

Cost of extra hooker = $\$0.854 \times \frac{30 \text{ min.}}{60 \text{ min.}}$ = $0.427

Jammer cost = $\frac{\$200 \times 30 \text{ min.}}{4000 \times 60 \text{ min.}}$ = 0.025

Cost of team = 2.27¢ x 30 min. = 0.681

Standby charge on the truck = $\frac{\$2.25 \times 30 \text{ min.}}{60}$ = 1.125

Unloading = $\frac{\$2.25 \times 20 \text{ min.}}{60 \text{ min.}}$ = 0.750

Hauling on interior roads = $\frac{2 \times \$3.385 \times .5 \text{ mi.}}{4 \text{ m.p.h.}}$ = 0.847

Hauling on county gravel road = $\frac{2 \times \$3.385 \times 1.25 \text{ mi.}}{16 \text{ m.p.h.}}$ = 0.528

Hauling on paved highway = $\frac{2 \times \$3.385 \times 8 \text{ mi.}}{30 \text{ m.p.h.}}$ = 1.810

Cost of hauling, loading and unloading per load = $6.193

Cost of hauling, loading, and unloading per pole = $\frac{\$6.193}{25}$ = $0.248

Cost of logging, exclusive of cutting costs = $0.335

Cutting cost of 25-ft. poles @ 1½¢ a linear foot

= 25 x .015 + 22% for Social Security, Workmen's Compensation, etc. = $0.457

∴ Cost of production of 25-ft. pole, exclusive of fixed per acre cost = $0.792

Cutting cost of 40-ft. poles @ 1½¢ a linear foot

= 40 x .015 + 22% = $0.732

∴ Cost of production of 40-ft. pole, exclusive of fixed per acre cost = $1.067

Cost of Production of Cedar Posts

The skidding, hauling, and loading costs of cedar posts can be figured as they were for pulpwood. There are an average of 40 posts to a cord. By taking only one-third of the cedar posts shown on the tally sheet, it was estimated that enough trees would be left behind to produce poles for future crops. The costs per post are as follows:

Skidding, loading, and hauling cost = $3.319 ÷ 40 = $.083

Cutting cost @ 9¢ + 22% for Social Security, Workmen's Compensation, etc. = .110

Cost of production per post, exclusive of fixed per acre cost = $.193

Cost of Production of Cedar Tie-Cuts

The pulpwood costs for skidding, hauling, and loading on a per cord basis can also be used for the tie-cuts. There are an average of 20 tie-cuts to the cord. Only one-half of the tie-cuts totaled on the tally sheets will be cut during the first cutting cycle. The cost per tie-cut is as follows:

Skidding, loading, and hauling cost = $3.319 ÷ 20	= $0.166
Cutting cost @ 16¢ + 22% for Social Security, Workmen's Compensation, etc.	= $0.195
Cost of production per tie-cut, exclusive of fixed per acre costs	= $0.361

Fixed Per Acre Costs

Certain costs like that of roads, administration, and camp buildings, that were not apportioned before must now be taken into consideration. These costs will be distributed among the products according to the value of the product after production costs have been deducted. These fixed per acre costs are made with the assumption that work will continue on other property after the annual cut is removed from this tract. The share of these fixed per acre costs that will be born by the timber on this tract will depend on the percentage of the working days in each year that are spent in logging this tract. The time required to remove the annual cut off this tract must now be determined. In order to get the most value out of a piece of machinery, it must be kept busy as many days as possible in a year. Only one tractor will be required in this problem, and all production will be based on the output of this one tractor. Therefore the time required to complete the logging of the annual crop on this tract will depend on how long it will take to skid and dray all of the forest products to the landings.

Production of tractor

The average skidding distance is "ps", where "p" is the percentage that average skidding distance to landings is of actual road spacing, and "s" is the road spacing in hundred feet. "p" is found in Table 4 of "Cost Control in the Logging Industry"[1] under the landing spacing of 60% of road spacing and is 0.304. Therefore ps = 0.304 x 8.6 = 2.6, or about 300 feet is the average skidding distance.

Fixed time of skidding per turn	= 4.28 minutes
Variable time per turn, 3 x .778	= 2.34 "
Total turn time	= 6.62 minutes

Turn time per M b.f. $= \frac{6.62}{0.3\ M} =$ 22 minutes

Production of tractor per 8-hour day $= \frac{8\ hrs.\ x\ 60}{22}$

$= 21.8$, or 22 M.

If draying pulpwood and cedar, the tractor can make $\frac{8\ x\ 60}{6.62}$ or 73 trips per day. The time required to complete all of the skidding is equal to $\frac{\text{total volume}}{\text{volume skidded per day}}$.

Time to skid the saw-timber $= \frac{354\ M}{22\ M}$	= 16.0 days
Time to dray the pulpwood $= \frac{175\ cords}{73\ x\ 2\ cords}$	= 1.2 days
Time to dray the cedar posts and tie-cuts $= \frac{\frac{758\ posts}{40} + \frac{304\ ties}{20}}{73\ x\ 2\ cords} = \frac{34.2\ cords}{146}$	= 0.2 days
Time to skid the cedar poles $= \frac{299}{73\ x\ 4\ poles}$	= 1.0 day
Time required to do the skidding and draying	= 18.4 days

[1] Matthews, D. M., Cost Control in the Logging Industry, 1st. ed., McGraw-Hill Book Co., New York, 1942.

Production of trucks

The number of trips that a truck can make per day can be calculated as follows:

$$\text{Round trip travel time} = 2\left(\frac{1 \text{ mile}}{10 \text{ m.p.h.}} + \frac{2.5 \text{ miles}}{16 \text{ m.p.h.}} + \frac{8 \text{ miles}}{30 \text{ m.p.h.}}\right)$$

$$= 1.046 \text{ hours}$$

$$\text{No. of trips} = \frac{8 \text{ hours}}{1.046 + \frac{2.5 \text{ M b.f.} \times 15 \text{ min.}}{60 \text{ min.}} + \frac{15 \text{ min.}}{60 \text{ min.}}}$$

$$= \frac{8}{1.046 + 0.625 + 0.250} = \frac{8}{1.921} = 4.1, \text{ or}$$

4 trips per day.

A truck can haul 2.5 M b.f. on a load; therefore, it can haul 2.5 x 4 or 10 M b.f. per day. To determine the number of truck days required to haul all of the saw-timber, the total annual cut must be divided by the daily production of one truck, which is as follows: $\frac{354 \text{ M b.f.}}{10 \text{ M b.f.}} = 35.4$ truck days.

The number of trips that a truck can make per day when hauling pulpwood is as follows:

$$= \frac{8}{1.046 + 1 \text{ hr.}} = \frac{8}{2.046} = 3.9, \text{ or 4 trips per day.}$$

At four trips a day with a load of 2 cords, a total of 8 cords can be hauled by each truck per day. Therefore it will take $\frac{175 \text{ cords}}{8 \text{ cords}} = 22$ truck days to haul all the pulpwood. It will take $\frac{\frac{758 \text{ posts}}{40} + \frac{304 \text{ tie-cuts}}{20}}{8 \text{ cords}} = \frac{34.2 \text{ cords}}{8} = 4.3$ truck days to haul all the cedar posts and tie-cuts.

The number of trips that a truck can make per day when hauling cedar poles is as follows: $\frac{8 \text{ hours}}{1.046 + \frac{30 \text{ min.}}{60} + \frac{20 \text{ min.}}{60}}$

$$= \frac{8}{1.046 + 0.5 + 0.33} = \frac{8}{1.876} = 4.2, \text{ or 4 trips per day.}$$

If a truck can haul 25 poles on a load, then at four trips per day, it can haul 100 poles per day. Therefore it will take $\frac{299 \text{ poles}}{100} = 3$ truck days to haul all the cedar poles.

35.4 truck days to haul saw-timber

22.0 truck days to haul pulpwood

4.3 truck days to haul cedar posts and tie-cuts

3.0 truck days to haul cedar poles

64.7 truck days required to haul all the forest products.

The number of trucks required to keep up with the production of one tractor will be $\frac{64.7}{19} = 3.4$, or 3. Three trucks will be used on this operation.

It was determined that 19 days would be required to do all the skidding and draying with a tractor and by adding on another five days for breakdowns and delays, the total time on this operation would be equal to 10% of the 235 work days in a year. Therefore 10% of the annual fixed per acre costs should be apportioned to the products removed from this tract.

Following are the annual fixed per acre costs:

Number of miles of interior road needed on the tract = $\frac{2560 \text{ acres}}{8.6 \times 12.1} = 24.6$ miles. Since the area will be cut over in 20 years, only about 1¼ miles of road should be built on the area each year. However roads will also have to be built on property that will be logged after the work on this tract is completed. Since the work on this tract will take only 10% of the annual work time, 10 times 1¼ or 12.5 miles of road will have to be built.

Annual road construction cost = 12.5 x $150	= $1875
Annual cost of repairs to roads will be assumed	= 1000
Camp buildings (main camp on tract) = $\frac{\$5000}{10 \text{ yrs.}}$	= 500
Camps on other areas logged each year	= 2500

Small tools, drays, etc. = $\frac{\$4000}{2 \text{ yrs.}}$ = = $2000

Administration:

Forester @ $2700 + 22% for Social Security, Workmen's Compensation, etc. = 3294

Foreman @ $2160 + 22% = 2635

Clerk @ $2160 + 22% = 2635

Total fixed per acre costs =$16439

10% of $16439, or $1644 is the amount of fixed per acre costs allotted to this tract annually.

Stumpage Values

Prices for the timber products were obtained from O.P.A. price sheets of September 1943. The price used for hardwoods, hemlock, and pine was the woods-run figure with the veneer left in. These estimates will be conservative, as by restricting the cut to trees 20 inches and larger in diameter, the product should be better than average woods-run. Rough pulpwood prices were used, and a price for 10-inch tie-cuts was used as an average. As stated before, 60% of the poles are of 25-foot length and 40% are of 40-foot length, class one grade. Following are the tables of these price figures.

Table 13

Prices of Hardwood Logs

(Per M.)

Species	Grade				
	No. 1	No. 2	No. 3	Woods-Run	
				Veneer-in	Veneer-out
Hard Maple	$ 80	$29	$22	$32	$24
Soft Maple	55	27	20	30	22
Yellow Birch	110	38	27	48	32
White Birch	60	--	--	24	21
Basswood	75	31	21	40	26
Ash	50	25	22	28	23
Soft Elm	50	25	22	28	23
Rock Elm	35	24	22	28	--
Beech	45	26	22	27	23
Cherry	55	27	20	30	22
Cottonwood	40	26	23	28	24
Red Oak	60	29	21	36	22

Table 14

Prices of White Pine Logs

(Per M.)

Species	Prime	No. 1	No. 2	Woods-Run
White Pine	$40	$33	$28	$30

Table 15

Prices of Softwood and Aspen Logs

(Per M.)

Species	Woods-Run Grade
*Hemlock	$24
Norway Pine	30
Jack Pine	26
Spruce	28
Balsam Fir	28
Tamarack	25
Cedar	20
Aspen	24

*Add $2.00 if peeled

Table 16

Prices of Tie-Cuts

(Per Piece)

Diameter (in inches)	White Oak	Hard Maple, Red Oak, Beech, Cherry	Hemlock, Elm, Larch, Pine, Spruce	Aspen, Cedar, Balm of Giliad
9	$ .70	$ .60	$ .55	$ .50
10	.90	.80	.67	.57
11 +	1.05	.95	.83	.78

Table 17

Prices of Pulpwood and Posts

Species	Rough	Peeled
Balsam Fir (per cord)	$11.00	$14.00
Spruce (per cord)	14.00	17.00
Cedar Posts (each)	.30	---

Table 18

Prices of Northern White Cedar Poles

(Per Pole)

Length	Class	Price
25 feet	7	$ 3.45
40 feet	1	14.85
	2	13.70
	3	12.45
	4	11.55
	5	10.65
	6	9.25
45 feet	1	18.00
	2	14.55
	3	13.55
	4	12.40
	5	12.20
50 feet	1	20.00
	2	17.00
	3	14.30
	4	13.85
	5	12.75
55 feet	1	24.00
	2	19.10
	3	16.75
	4	15.25
	5	15.00
60 feet	1	29.00
	2	24.50
	3	19.60
	4	17.50

By subtracting the cost of production of each product from the selling price, the surplus, exclusive of fixed per acre cost deductions, will be determined. These individual surpluses will be totaled and the percentage of each determined. By multiplying these percentages times the total fixed per acre cost, the amount that should be allotted to each product will be determined. Subtracting this from the surplus will give the stumpage value for that species and product. Following are the calculations as described above:

Table 19*

Stumpage Value of Annual Cut

(20-year cutting cycle)

Species (1)	Selling Price (2)	Total Volume Cut Per Year (3)	Gross Value (4)	Production Cost Per Unit + 20% Margin (5)	Total Production Cost (6)
Hard Maple	$32.00[1]	75.764[1]	$2425	$ 7.14 [1]	$ 542
Yellow Birch	48.00[1]	61.083[1]	2970	7.14 [1]	442
Hemlock	24.00[1]	176.397[1]	4240	7.14 [1]	1261
Soft Maple	30.00[1]	2.909[1]	87	7.14 [1]	21
Basswood	40.00[1]	22.255[1]	890	7.14 [1]	159
Black Ash	28.00[1]	0.475[1]	13	7.14 [1]	3
White Pine	30.00[1]	5.374[1]	161	7.14 [1]	38
Elm	28.00[1]	9.595[1]	269	7.14 [1]	69
Cedar Posts	0.30[2]	758. [2]	227	0.232[2]	176
Cedar Poles 25'	3.45[2]	180. [2]	622	0.950[2]	171
Cedar Poles 40'	14.85[2]	119. [2]	1767	1.280[2]	152
Cedar Tie-Cuts	0.57[2]	304. [2]	173	0.433[2]	132
Spruce Pulpwood	14.00[3]	123. [3]	1722	10.50 [3]	1292
Balsam Fir Pulpwood	11.00[3]	52. [3]	572	10.50 [3]	546

*Continued on next page

[1] Unit is M b.f.
[2] Unit is piece
[3] Unit is cord

Col. 1 --- Species cut on area
Col. 2 --- O.P.A. log price per unit
Col. 3 --- Annual cut, from Tables 7, 8, and 9.
Col. 4 --- Col. 2 x Col. 3
Col. 5 --- From Cost and Production Sheets + 20% for margin
Col. 6 --- Col. 3 x Col. 5

Table 19 (Cont.)

Stumpage Value of Annual Cut

(20-year cutting cycle)

Species (1)	Surplus Before Fixed Per Acre Cost Deductions (7)	% Surplus Per Species (8)	Fixed Costs (9)	Total Stumpage (10)	Stumpage Per Unit (11)
Hard Maple	$1883	16.9	$278	$1605	$21.20 [1]
Yellow Birch	2528	22.7	374	2154	35.30 [1]
Hemlock	2979	26.7	438	2541	14.40 [1]
Soft Maple	66	0.6	10	56	19.20 [1]
Basswood	731	6.6	109	622	28.00 [1]
Black Ash	10	0.1	2	8	16.80 [1]
White Pine	123	1.1	18	105	19.50 [1]
Elm	200	1.8	30	170	17.70 [1]
Cedar Posts	51	0.5	8	43	0.057 [2]
Cedar Poles 25'	455	4.1	67	388	2.15 [2]
Cedar Poles 40'	1618	14.5	238	1380	11.60 [2]
Cedar Tie-Cuts	41	0.4	7	34	0.112 [2]
Spruce Pulpwood	430	3.8	62	368	2.99 [3]
Balsam Fir Pulpwood	26	0.2	3	23	0.442 [3]
Total	$11141	100.0	$1644	$9497	

[1]Unit is M b.f.
[2]Unit is piece
[3]Unit is cord

Col. 1 --- Species cut on area
Col. 7 --- Col. 4 - Col. 6
Col. 8 --- Percentage of total surplus by species
Col. 9 --- $1644 x Col. 8

Col. 10 --- Col. 7 - Col. 9
Col. 11 --- Col. 10 ÷ Col. 3

Estimate of Personnel Required

An estimate must now be made of the number of sawyers needed to keep one tractor supplied with logs. An average time of 2.55 manhours (from Table 11) is required to produce one M b.f. of logs. Therefore it will take $\frac{354 \text{ M} \times 2.55 \text{ hrs.}}{8 \text{ hrs.}}$, or 113 man days to do the felling and bucking of the saw-timber. One man can cut 1.5 cords of pulpwood a day. There are 175 cords of pulpwood to be cut, plus 34 cords of posts and ties, or a total of 209 cords. Therefore it will take $\frac{209 \text{ cords}}{1.5}$, or 140 man days to cut the pulpwood, cedar posts, and cedar ties. One man can cut 25 cedar poles per day. Therefore $\frac{299 \text{ poles}}{25}$, or 12 man days will be required to cut the cedar poles. This will be a total of 265 man days required for the cutting of the annual crop of this tract. The number of men required for the cutting, in order to keep production up for one tractor, is equal to $\frac{265}{19}$, or 14.

Unless the logging on this tract is done during the winter months, the forest products on the spruce-cedar-balsam fir type cannot be removed along with the saw-timber. The swamp areas are unfavorable for logging during the summer months, so the timber products from these areas must be removed during the winter. Felling and bucking should begin at least two weeks before skidding and hauling start, so as to allow the tractor a wider skidding range and to avoid crowded conditions in any one part of the woods. If the tractor did all of the close skidding first, it could not produce enough to keep the trucks busy when it had only long skidding distances left. During the winter months, heavy snows will cover the logs if the felling and bucking crews get too far ahead of skidding, making it hard to find all the logs and causing a loss.

Men for the different jobs will be hired as the work progresses. Following is a list of men needed:

Sawyers	14
Dray loaders	4
Truck drivers	3
Hookers	3
Swampers	2
Tractor operator	1
Teamster	1
Blacksmith-Mechanic	1
Forester	1
Foreman	1
Clerk	1
Cook	1
Cook's helper	1
Bull cook	1

Forest Taxation

A timber owner in Michigan who plans to operate his holdings on a perpetual yield basis is confronted with the payment of land and timber taxes. There is a choice of either operating under the general property tax and paying a given amount of tax each year, based on the assessed valuation of the property, or of taking advantage of the Forest Crop Law. Land adequately stocked with immature forest trees and capable of supporting a thrifty forest stand, or essential to the proper development of a forest property and not used for other purposes, can be classified under this law. Property entered under this law pays an annual specific tax of 5 cents per acre and a yield tax of 10 per cent on all forest products cut. If the property is entered under the law, the owner must get permission from state tax assessors to cut merchantable forest products. No exclusive hunting and fishing privileges can be granted on the area.

Probably in most cases the amount of tax paid by the owner of forest property would be less under the Forest Crop Law. However, if the period of return is short and a valuable harvest is taken, it may pay to keep the property under the general property tax. A comparison must be made to determine which method of taxation is better for any particular piece of property. Table 20 gives the calculation used to determine the value of the timber on the entire property.

The table shows the value of the timber on the entire property to be $353,240. The land can be assumed to have a value of $5 per acre, or a total value of $5 x 2560 acres, or $12,800 for the whole tract. These two values added together give a total valuation of $366,040. Tax collectors usually appraise a property at about 75% of its true value, which would be $214,530 in this case. The Michigan general property tax rate is now 15 mils per dollar of assessed

Table 20

Value of All Merchantable Timber on the Tract

Species	Total Merchantable Volume	Stumpage Value Per Unit[4]	Total Stumpage
Hard Maple	4081[1]	$21.20	$86,600
Yellow Birch	2627[1]	35.30	92,800
Hemlock	6536[1]	14.40	94,000
Soft Maple	256[1]	19.20	4,920
Basswood	766[1]	28.00	21,450
Elm	260[1]	17.70	4,600
Black Ash	56[1]	16.80	940
White Pine	146[1]	19.50	2,840
Spruce Pulpwood	2460[2]	2.99	7,360
Balsam Fir Pulpwood	1034[2]	0.442	460
Cedar Posts	45497[3]	0.057	2,590
Cedar Tie-Cuts	12154[3]	0.112	1,360
Cedar Poles	5980[3]	5.57	33,320
Total			$353,240

[1]Unit is M b.f.
[2]Unit is cord
[3]Unit is piece
[4]From Table 19

valuation. This would give an annual tax of $\frac{\$214,530 \times .015}{2560}$, or $1.25 per acre of property.

The formula, $I = \frac{L - S}{y}(1.0p^n - 1)$, developed by Professor D. M. Matthews, gives the value of the income per acre at which taxes over any given period would be the same under either method of taxation. In this formula I is estimated income per acre at the next harvest, L is the tax per acre under the general property tax, S is the specific annual land tax per acre under the Forest Crop Law, y is the percentage of yield taken under the Forest Crop Law, p is the interest rate, and n is the period of deferment of income. Since in this problem the income that will be obtained per acre is known, "n" can be solved for, and the period of years over which the two taxes will amount to the same determined.

$$\text{Income per acre per cycle} = \frac{\$9497}{1/20 \times 2560} = \frac{\$9497}{128} = \$74.20$$

$$\$74.20 = \frac{1.25 - .05}{.10}\left(\frac{1.06^n - 1}{.06}\right)$$

$$\$74.20 = 12\left(\frac{1.06^n - 1}{.06}\right)$$

$$\frac{1.06^n - 1}{.06} = 6.18$$

$$1.06^n - 1 = .3708$$

$$1.06^n = 1.3708$$

From a table of compound interest factors, a value of 5 years will be found for "n".

Since the cutting cycle under this plan is equal to 20 years, the property should be placed under the Forest Crop Law. This can be proven by the following calculations:

The General Property Tax, in 20 years, will accumulate to $\$1.25\frac{(1.06^{20} - 1)}{.06} = \$1.25 \times 36.7856 = \$46.00$

Under the Forest Crop Law, the specific tax will amount to $\$0.05\frac{(1.06^{20} - 1)}{.06}$ = \$1.84

The yield tax will be 10% of \$74.20 = 7.42

Thus the total tax per acre for 20 years under the Forest Crop Law = \$9.26

This shows that the accumulated sum of taxes under the General Property Tax is much more than under the Forest Crop Law and that it would be to the timber owner's advantage to place his property under the Forest Crop Law.

Valuation of the Property

Present Capital Value of Income

1st cycle:

$$c_o = \frac{a(1.0p^n - 1)}{.0p \times 1.0p^n} = \frac{\$9497(1.06^{20} - 1)}{.06 \times 1.06^{20}}$$

$$= \$9497 \times 11.4699 \qquad = \$108,900$$

2nd cycle:

$$c_o = \frac{\$9497 - (\$9497 \times 10\%) - (\$.05 \times 2560)}{.06 \times 1.06^{20}}$$

$$= \frac{\$9497 - \$1078}{.06 \times 3.2071} = \frac{\$8419}{.192426} \qquad = \underline{43,750}$$

Total capital value before deduction of 1st cycle taxes = $152,650

Capital Value of 1st Cycle Taxes

General Property Tax (declining over 20 years)

$$c_o = \frac{\$214,530 \times .015}{20}\left[\frac{1.06^{20}\left[(20 \times .06) - 1\right] + 1}{.06^2 \times 1.06^{20}}\right]$$

$$= 160.9 \times 142.15 \qquad = \$22,850$$

Specific land tax (increasing over 20 years)

$$c_o = \frac{.05 \times 2560}{20}\left[\frac{1.06^{20} - 20(.06) - 1}{.06^2 \times 1.06^{20}}\right]$$

$$= 6.4 \times 87.23 \qquad = \underline{558}$$

Capital value of 1st cycle taxes = -$23,408

Present worth of property = $129,292

Alternative Cutting Plan

Since there is so much difference in taxes between forest land under the general property tax and forest land under the Forest Crop Law, it would be advantageous to cut over the tract as quickly as possible and to put all land under the Forest Crop Law.

Instead of cutting over only one-twentieth of the area each year and spending the rest of the time cutting on other property, it would be better to complete the cutting on this operation first. The length of time that will be required to go over the tract if only one tractor is used for skidding must be determined. It was previously determined that a tractor could skid about 22 M b.f. of logs per 8-hour day and make 73 trips per day if draying pulpwood or cedar. The time required to skid and dray all of the forest products allocated to one cutting cycle must now be determined.

Time to skid all the saw-timber $= \frac{7077\text{ M}}{22\text{ M}} = 322$ days

Time to dray all the pulpwood $= \frac{3494\text{ cords}}{73 \times 2\text{ cords}} = 24$ days

Time to dray all the posts and ties

$$= \frac{\frac{15{,}166\text{ posts}}{40} + \frac{6077\text{ ties}}{20}}{73\text{ trips} \times 2\text{ cords}} = \frac{683\text{ cords}}{146} = 5\text{ days}$$

Time to skid all the poles $= \frac{5980\text{ poles}}{73 \times 4\text{ poles}}$

$$= \frac{5980}{292} = \underline{21\text{ days}}$$

Time required to complete all skidding and draying $= 372$ days

Since there are only 235 workable days in a year, it can be assumed that two years will be required to cut over the tract and that half of the crop will be removed each year. If this is done, 10 x \$9497 or \$94970 will be the amount of annual return from the property for two years of every 20 in the cutting cycle.

Valuation of Property Under Alternative Plan

Capital Value of Incomes:

Present worth of incomes during the 1st cycle

$$= \frac{\$94,970\ (1.06^2 - 1)}{.06 \times 1.06^2}$$

$$= \$94,970 \times 1.8334 \qquad = \$174,100$$

Present worth of incomes during subsequent cycles after the 10% yield tax was deducted

$$= \frac{(90\% \times \$94,970)\ \frac{1.06^2 - 1}{.06 \times 1.06^2}}{(1.06^{20} - 1)}$$

$$= \frac{\$85,400 \times 1.8334}{(3.2071 - 1)} = \frac{\$156,700}{2.2071} \qquad = 70,800$$

Capital value of property after allowing for a 10% yield tax in subsequent cycles, but before allowance for specific land taxes and the general property tax =\$244,900

Capital value of general property and specific land tax:

Present worth of general property tax during 1st 2 yrs.

$$\text{P.W. of tax during 1st yr.} = \frac{\$214,530 \times .015}{1.06}$$

$$= \frac{\$3218}{1.06} = \$3035$$

$$\text{P.W. of tax during 2nd yr.} = \frac{\$107,265 \times .015}{1.06^2}$$

$$= \frac{\$1609}{1.1236} = 1430$$

Present worth of specific land tax beginning in 2nd yr.

$$\text{P.W. of tax during 2nd yr.} = \frac{.05 \times 1280 \text{ acres}}{1.06^2}$$

$$= \frac{64}{1.1236} = \$\ 57$$

P.W. of subsequent taxes coming after

$$\text{the 2nd yr.} = \frac{.05 \times 2560 \text{ acres}}{.06 \times 1.06^2}$$

$$= \frac{128}{.06742} = \underline{1900}$$

Present worth of general property and specific land taxes = -$ 6,422

Present worth of property = $238,478

Conclusion

The previous calculations show that the present worth of the property will be much more if the property is cut over in two years instead of twenty. This is mainly due to the fact that much of the heavy property tax is evaded by logging the property quickly and by entering the forest land under the crop law tax. Some of the increase in present value of the property was also due to the fact that the cyclic income was received sooner and that part of it did not have to be discounted over the length of the cutting cycle.

To receive more accurate information on the productive possibilities of the stand during the second cycle, another cruise should be made of the tract a few years after cutting. This should be made to show the actual number of trees still left on the area and a knowledge of how fast the trees that were left after the first cut were growing. It might be assumed that the mean annual growth should be greater in the future, as the stand has been released and there is more room for the trees to grow. Virgin stands are usually stagnant stands. Since no information as to annual growth and diameter of trees is on hand for the spruce-cedar-balsam fir type, this date should be determined and an estimate made of how much can be taken off the area in the future, and to what size it would be most profitable to grow the material. This second cruise of the area should be made to include smaller diameter trees, as the present data does not give much information on the reproduction. It can only be assumed that there are more young trees there to fill into the places occupied at present by the larger trees. After this information is received, a better plan can be made for future production.

REFERENCES

Baxter, D. V., Pathology in Forest Practice, John Wiley and Sons, Inc., New York, 1943.

Chapman, H. H. and D. B. Demeritt: Elements of Forest Mensuration, 2nd. ed., J. B. Lyon & Co., Albany, New York, 1936.

Fairchild, Fred R., Forest Taxation in the United States, Misc. Publication No. 218, Washington, D. C., 1935

Graham, S. A., Principles of Forest Entomology, 2nd. ed., McGraw-Hill Book Co., New York, 1939.

Hawley, R. C., The Practice of Silviculture, 4th. ed., John Wiley and Sons, Inc., New York, 1937

Matthews, D. M., Cost Control in the Logging Industry, 1st. ed., McGraw-Hill Book Co., New York, 1942.

Matthews, D. M., Management of American Forests, 1st. ed., McGraw-Hill Book Co., New York, 1935.

Roth, Filibert, Forest Regulation, 2nd. ed., Ann Arbor, Michigan, 1925.

Westveld, R. H., Applied Silviculture in the United States, John Wiley and Sons, Inc., New York, 1939.

Zon, Raphael and R. D. Garver, Selective Logging in the Northern Lake States, U. S. Department of Agriculture, Tech. Bull. 164, 1930.