AERIAL VOLUME TABLES BY FOREST TYPE ON THE DUNBAR FOREST EXPERIMENT STATION, MICHIGAN

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Wayne William Gaskins

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This is to certify that the

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Wayne William Gaskins

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Paul O. Gaiser
Major professor

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AERIAL VOLUME TABLES BY FOREST TYPE ON THE DUNBAR FOREST EXPERIMENT STATION, MICHIGAN

by

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A THESIS

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INTRODUCTION

The desire of the timber owner for more accurate and less expensive timber estimates is always present. This demand has been partially met by the use of aerial photographs as an aid to the ground survey party in readily interpreting land and timber features. A major part of the expense of a timber cruise is due to the length of time field parties must spend in obtaining a representative sample measure of the standing timber even with the ground use of the aerial photograph. Timber estimates made from measurable features on an aerial photograph offer possibilities for a saving in timber survey work. At present only a few volume tables are designed for use with the aerial photograph. This lack of aerial volume tables that give more than a very broad volume estimate presents a challenge as to how such volume tables should be constructed for local use, upon what variables the volume estimations in the table should be based, their ease and rapidity of application, and their accuracy.

This study was designed to develop a method of aerial volume table construction and includes construction of local aerial volume tables for two forest types on the Dunbar Forest Experiment Station. The aerial volume tables were designed to give the estimated volume for a fifth-acre plot by forest types. These estimated volumes are dependent upon the average crown diameter and crown density variables which are easily measured on the aerial photograph.

The data for this study were gathered on the Dunbar Forest Experiment

Station, sixteen miles south of Sault Ste. Marie, Michigan.*

* Measurements were made during the period from June to September, 1947.

REVIEW OF LITERATURE

The use of aerial photographs was at one time thought to be just an aid in delineating the type boundaries of standing timber, and they were used merely to supply supplementary information for timber cruises that were carried out by ordinary ground methods (18), (20), and (27).

Following such a limited use of aerial photographs, aerial volume tables were developed for volume estimation based upon features discernible on the photograph. As indicated in the work of Moir (24), Wilcox (43), and Craig (7), these aerial volume tables were adequate only for large general surveys involving thousands of acres. Chase (6) has prepared aerial volume tables of this type. The estimate obtained by using this type of volume table for a timber cruise involving only a few hundred or thousand acres would produce completely inadequate results.

At the present time there is a need for aerial volume tables that will give more accurate volume estimates. Spurr (34) points out that there are only six variables of trees and stands that may be distinguished or measured on the aerial photograph. They are: species or cover type; rather broad site classes; crown density per unit area; number of tree crowns per acre; tree height; and crown diameter. Therefore the aerial volume tables must be based on one or more of these variables. Rogers (26) suggests that volumes may be estimated from photographs by measuring the density of individual tree crowns, size of individual tree crown, and/or tree height.

Aerial volume tables should be constructed on variables that can

by rapidly and easily determined from the aerial photograph. The measurement of the crown density variable can be more easily and accurately estimated with Moessner's (22) density scale. Sisam (32) states that "... visible crown diameters may be used directly in determining volumes" from aerial photographs.

The author considered the investigations of Spurr (34) and Sisam (32), and Moessner's (22) work on the crown density variable in the selection of the variables upon which these aerial volume tables were constructed.

METHOD OF PROCEDURE

Field Procedure

The measurements considered necessary for each tree were recorded in tabular form; they were: diameter breast high outside bark to the nearest one-tenth inch, the average visible crown diameter measured below the crown (two measurements of crown diameter at right angles were taken and measured to the nearest foot), the total height of the tree in feet, the crown class (dominant, codominant, or intermediate), and for approximately every ten trees measured, the diameter breast high inside bark and diameter outside bark at 2.25 feet above half the height of the tree were taken for form quotient determination.

The equipment used in the field included a diameter tape, one-hundred foot steel tape, Swedish bark gauge, Abney level, climbing spurs, safety belt, and a steel pin sharpened on one end to hold the end of the tape while measuring crown diameters without the aid of a field assistant.

Sample trees for measurement were selected by walking through the forest type. Trees four inches or over in diameter breast high were measured. Only those trees in the dominant, codominant, or intermediate crown classes were considered to form the crown which might appear on the aerial photograph. Trees with an intermediate crown class were included because of the possible influence they might have upon the texture (6) (2) of the forest canopy as seen on the photograph. Two hundred sample trees were measured for species having a wide range of diameters; one hundred sample trees were measured for species having a small range of diameters.

Fifth-acre plots were selected in a given type and marked by fifth-acre circles on the aerial photograph.

Office Procedure

A method of utilizing the density of crown cover in square feet per acre for the forest type in acre-volume determination is to establish an aerial volume table based on average crown diameter and the crown density on a plot rather than the individual tree basis (34). In order to utilize the density scale by Moessner (22), it was necessary to calculate the number of square feet for each of his crown density percentages (Table I).

Each sample tree was given the volume indicated by the correct form class volume table of the species (4).

The sample trees measured were grouped into one-inch diameter classes (4.6 to 5.6 inches, 5.6 to 6.6 inches, etc.). All additional measurements taken on each sample were grouped by diameter classes, and the mean of each was computed. This tabular form presents the actual sample or field average for d.b.h., crown diameter (feet), total height (feet), and total volume (cubic feet), by one-inch d.b.h. classes.

The next step in aerial volume table construction was to obtain curved values for the total tree height, crown diameter, and cubic foot volume, as shown by constructing curves of each of these dependent variables over d.b.h.

A correlation must be established between the average crown diameter and the average tree volume in order to use the crown diameter as one of the variables in crown density-crown diameter aerial volume tables.

Table I

Relation of Crown Density and Crown Area

Crown Density Percentage	Square Feet of Crown per Fifth-Acre Plot
5%	435.6
15%	1306.8
25%	2178.0
35%	3049.2
45%	3920.4
55%	4791.6
65%	5662.8
75%	6534.0
85%	7405.2
95%	8276.4

This correlation was shown by constructing a curve using the curved crown diameter values as the independent variable and the curved cubic-foot volumes as the dependent variable. A good correlation was established for the species studied for this report. From each curve, a volume table based on the one-foot crown diameter classes giving cubic volume by crown diameter was made which gave the cubic volume for a given crown diameter by individual trees.

In order that the volume can be given on a fifth-acre plot basis rather than by the individual tree, the maximum number of trees in one crown diameter class for each of the plot density percentages was determined. To do this, it was necessary to know the area of one tree crown of each one-foot crown diameter class (Table II), then to divide the square-foot area occupied by one crown into the square-foot area necessary to give the desired percentage of cover on a fifth-acre plot, assuming all the trees on the plot have the same crown diameter and area (Table I). This gave the number of trees, all of the same crown diameter, needed for the desired crown density (Table III). The number of trees needed to give a particular crown density was then multiplied by the volume per tree. The results gave a volume table for one species on a fifth-acre plot basis. This volume table gave the volume based on the variables, one-foot crown diameters, and crown density percentages.

In order to make the table more applicable to the varying crown diameters in a forest, each single foot crown diameter class was grouped into two-foot crown diameter classes. This was accomplished by averaging the volumes for the two one-foot crown diameters. The resulting aerial volume table is for a single species by two-foot crown diameter classes and the same crown density percentages as used on Moessner's crown

Table II

Relation of Crown Diameter and Crown Area

Crown Diameter (Feet)	Area of Crown (Square Feet)
4	12.57
5	19.64
6	28.27
7	38.48
8	50.27
9	63.62
10	78.54
11	95.03
12	113.10
13	132.73
14	153.94
15	176.72
16	201.06
17	226.98
18	254.47
19	283.53
20	314.16
21	346.36

Table III

Number of Trees per One-Fifth Acre Plot

Density Percentage	Diameter of Crown (Feet)																	
	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
5%	34.7	22.1	15.4	20.2	8.7	6.8	5.5	4.6	3.8	3.3	2.8	2.5	2.2	1.9	1.7	1.5	1.4	1.2
15%	104.0	66.6	46.2	33.9	26.0	20.5	16.6	13.8	11.6	9.8	8.5	7.4	6.5	5.8	5.1	4.6	4.2	3.8
25%	173.3	110.9	77.0	56.6	43.3	34.2	27.7	22.9	19.2	16.4	14.1	12.3	10.8	9.6	8.6	7.7	6.9	6.3
35%	242.6	155.3	107.8	79.2	60.7	47.9	38.8	32.1	27.0	23.0	19.8	17.2	15.2	13.4	12.0	10.8	9.7	8.8
45%	311.9	199.7	138.6	101.9	78.0	61.6	49.9	41.2	34.7	29.5	25.5	22.2	19.5	17.3	15.4	13.8	12.5	11.3
55%	381.3	244.0	169.5	124.5	95.3	75.3	61.0	50.4	42.4	36.1	31.1	27.1	23.8	21.1	18.8	16.9	15.2	13.8
65%	450.6	288.4	200.3	147.1	112.6	89.0	72.1	59.6	50.1	42.7	36.8	32.0	28.2	24.9	22.2	20.0	18.0	16.3
75%	520.0	332.8	231.1	169.8	130.0	102.7	83.2	68.8	57.8	49.2	42.4	37.0	32.5	28.8	25.7	23.0	20.8	18.9
85%	587.3	377.1	261.9	192.4	147.3	116.4	94.3	77.9	65.5	55.8	48.1	41.9	36.8	32.6	29.1	26.1	23.6	21.4
95%	658.6	421.5	292.7	215.0	164.6	130.1	105.4	87.1	73.2	62.4	53.8	46.8	41.2	36.5	32.5	29.2	26.3	23.9

density scale (22). This would constitute the completed volume table if the type were made up of a single species.

If the volume table is used to give the volume for a forest type made up of two or more species, each species is handled exactly as has been described in the previous paragraphs, but after the last step it is necessary to combine the species aerial volume tables. This is done by weighting the volumes as given by the per cent of occurrence of the species concerned. The relative abundance of each species on a plot is determined by taking a check plot in the field. By averaging the number of each species that occur on the sample field plots of the type, a trend of occurrence, in per cent, by diameter class is determined. The percentages of the various species occurring by one-inch d.b.h. classes are then curved to give a more constant increase or decrease as shown in Figure 12. By correlating with a curve, the per cent of stocking for each species by d.b.h. classes in the type, the weight of every part of each individual species volume table in the final type aerial volume table was determined. The percentages of species abundance are given by d.b.h. classes. To apply these percentages to the crown diameter variable in the final aerial volume table, the curve of crown diameter to d.b.h. was used. This provided each one-foot crown diameter class with a value or percentage of abundance by species in the type. The percentages of abundance by species in two-foot crown diameter classes is determined by calculating the mean of the two one-foot crown percentages. Multiply the resulting percentage of abundance for each species crown diameter class by the proper volume of that species in the type as already determined. The unit volumes given in each of the resulting single species volume tables are added together to make the combined species volume table. This volume

table is applicable to the forest type for which it was designed and will give the cubic-foot volume per fifth-acre plot according to crown density per cent and two-foot crown diameter classes.

AERIAL VOLUME TABLES FOR THE DUNBAR FOREST

Field data were collected on the Dunbar Forest Experiment Station, Sault Ste. Marie, Michigan. The white spruce-balsam fir and the black spruce types were selected as the two forest types for this study.

The data for each species were grouped into one-inch diameter classes, and curved values were determined from the curves in Figures 1 through 9 of the plotted field values. The average of the d.b.h. classes, crown diameter, total tree height, and cubic-foot volume for the field data and curved values for each species are given in Tables IV, V, and VI. The cubic-foot volume of each tree was obtained from species form-class volume tables prepared by the Canadian Forest Service (4). Curves of volume over crown diameter are shown in Figures 10, 11, and 13. The curved volumes are given in Table VII by one-foot crown diameter classes for each species. The number of trees of each one-foot crown diameter class needed to give the fifth-acre density percentages, as listed in Table III, were multiplied by the cubic-foot volume of the crown diameter for each species as given in Table VII. The resulting values give the volume in cubic feet by one-foot crown diameter classes and crown density percentages as used with Moessner's crown density scale (22). The one-foot crown diameter classes are combined to form two-foot crown diameter classes. These aerial volume tables, Tables VIII, IX, and X, give the cubic-foot volume on a fifth-acre basis, assuming a single species constitutes the forest type. The black spruce volume table, Table X, is the completed aerial volume table for this species in pure stands.

The white spruce and balsam fir volume tables, Tables VIII and IX, give the volume for each of the species on a fifth-acre, as pure types. Since the two species comprise a type, it is necessary to determine the abundance of the white spruce and balsam fir by d.b.h. classes in the forest type by field check plots. Fifth-acre plots were measured in the type, and the abundance percentages of both species are arranged by one-inch d.b.h. classes in Table XI. The curved values for the percentage of abundance to d.b.h. classes were obtained from Figure 12. These curved abundance percentage values were also included in Table XI. The curves for crown diameter by d.b.h. classes, Figures 4 and 5, are used to change the abundance percentage for each d.b.h. class to its respective crown diameter class. The curved values of abundance percentage for white spruce and balsam fir are given in Table XII for the type by one- and two--foot crown diameter classes. The actual cubic-foot volume that each species occupies on a fifth-acre, as given in Tables XIII and XIV, was determined by multiplying the assumed, or pure type, volume of the species for one--fifth acre, Tables VIII and IX, by the abundance percentage for each species as it occurred in the forest type. The final volume table for this two species type was obtained by adding the volumes given for both species in Tables XIII and XIV. This table, Table XV, is an aerial volume table giving the total volume in cubic feet on a fifth-acre of the white spruce-balsam fir type. It is applicable in this forest type on and around the Dunbar Forest Experiment Station.

FIGURE 1 - WHITE SPRUCE HEIGHT CURVE

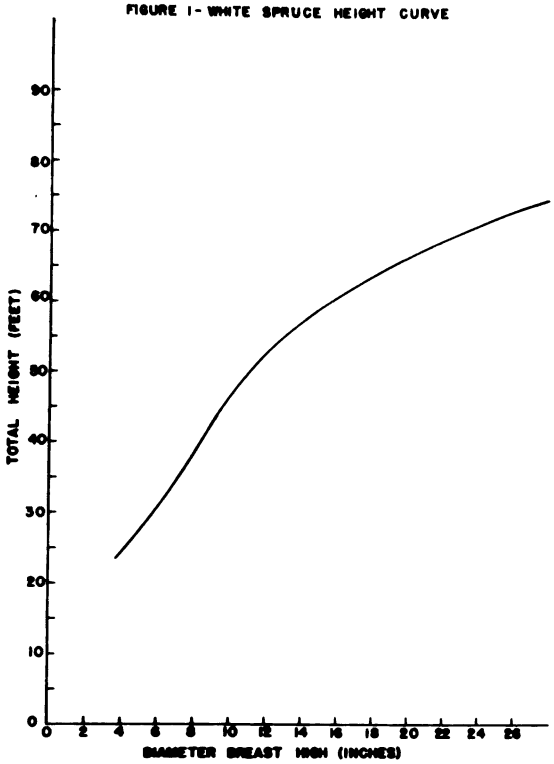


FIGURE 2 - BALSAM FIR HEIGHT CURVE

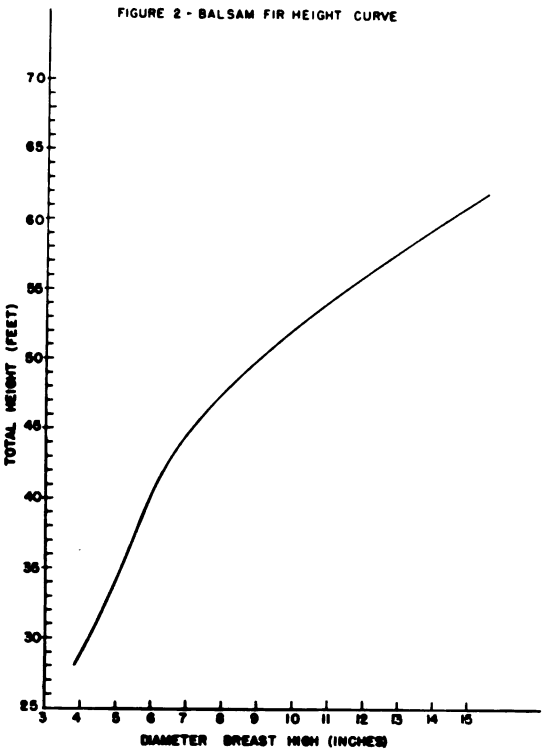
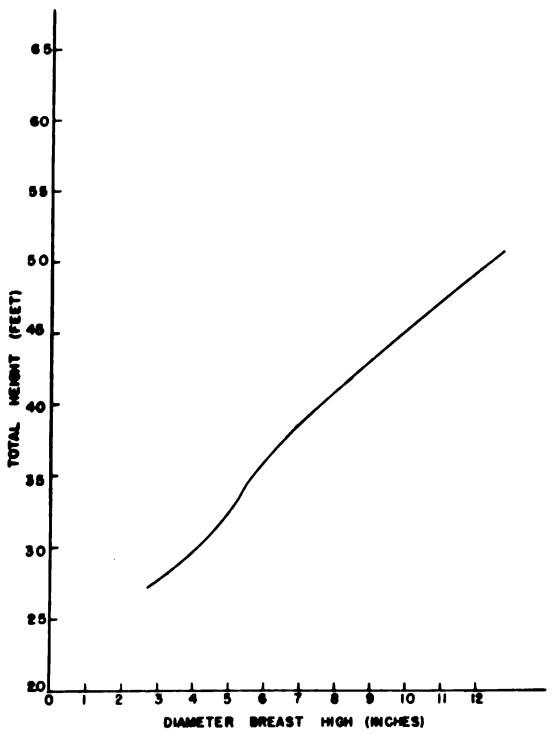


FIGURE 3 - BLACK SPRUCE HEIGHT CURVE



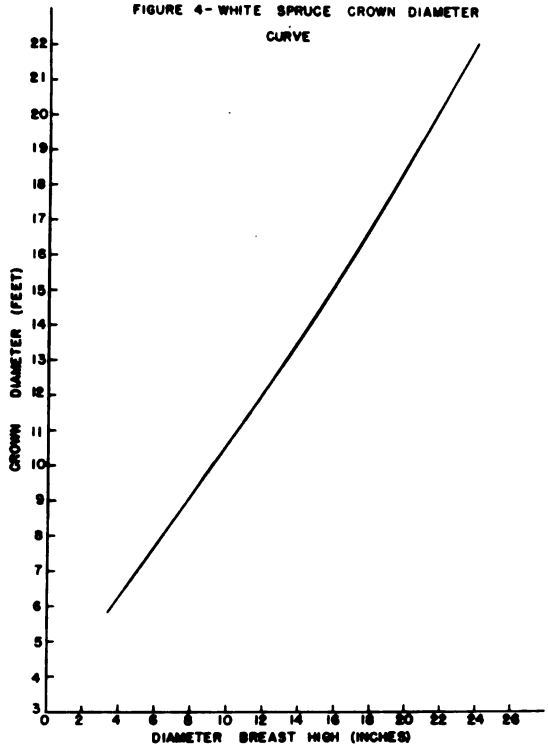


FIGURE 4- WHITE SPRUCE CROWN DIAMETER CURVE
CROWN DIAMETER (FEET)
DIAMETER BREAST HIGH (INCHES)

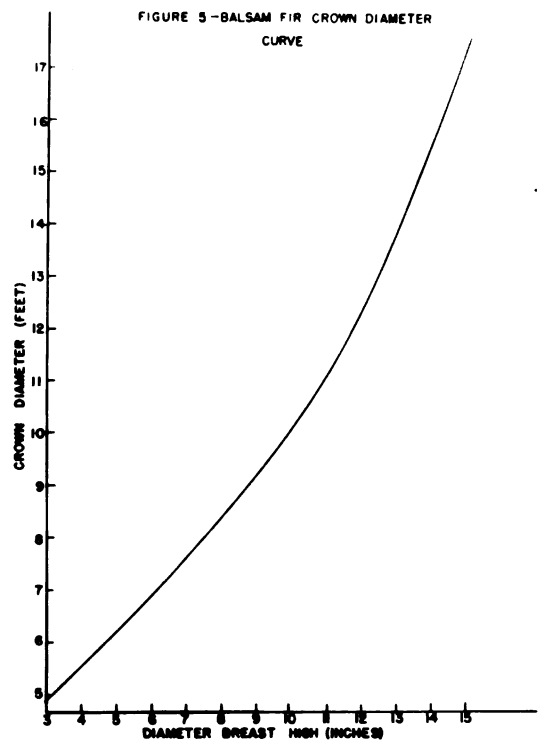


FIGURE 5 -BALSAM FIR CROWN DIAMETER CURVE
CROWN DIAMETER (FEET)
DIAMETER BREAST HIGH (INCHES)

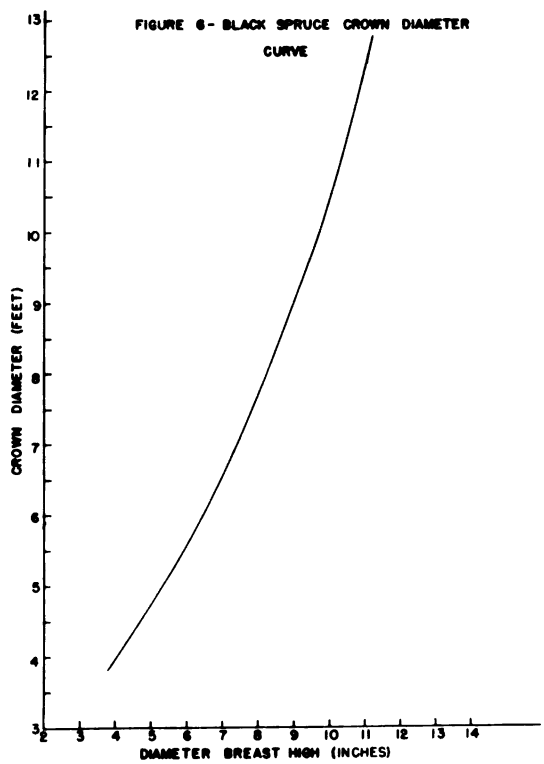


FIGURE 6- BLACK SPRUCE CROWN DIAMETER CURVE
CROWN DIAMETER (FEET)
DIAMETER BREAST HIGH (INCHES)

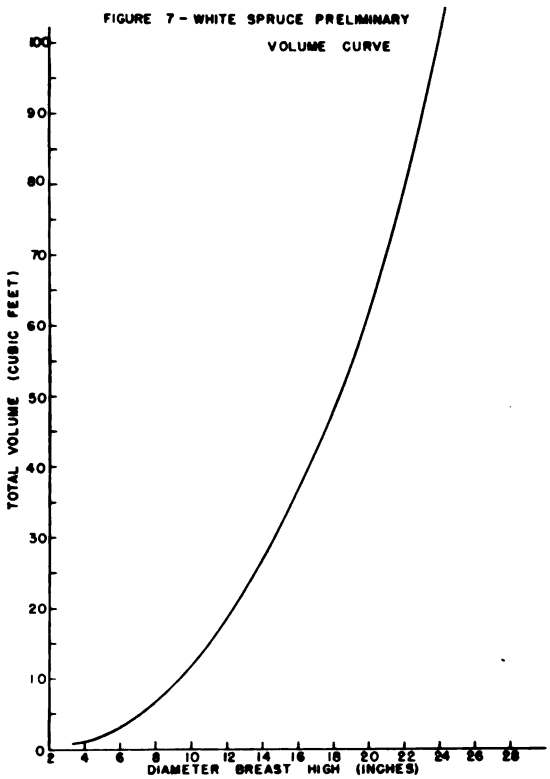


FIGURE 7 - WHITE SPRUCE PRELIMINARY VOLUME CURVE
TOTAL VOLUME (CUBIC FEET)
DIAMETER BREAST HIGH (INCHES)

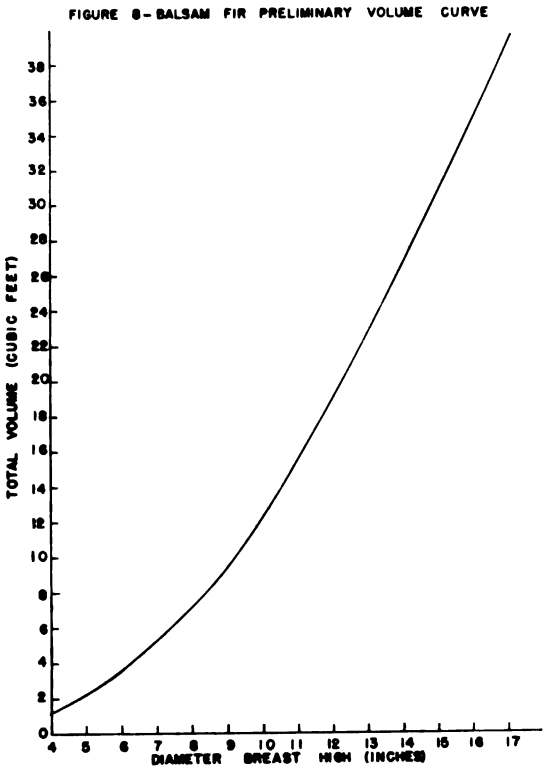


FIGURE 8 - BALSAM FIR PRELIMINARY VOLUME CURVE
TOTAL VOLUME (CUBIC FEET)
DIAMETER BREAST HIGH (INCHES)

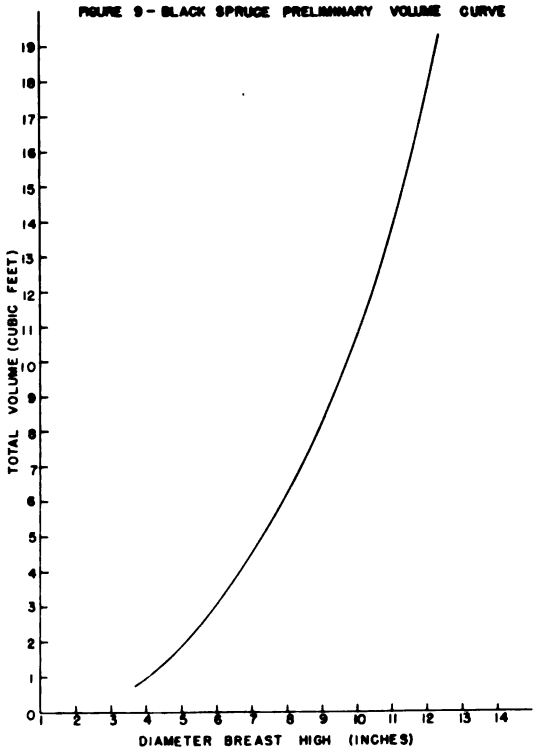


FIGURE 9 - BLACK SPRUCE PRELIMINARY VOLUME CURVE
TOTAL VOLUME (CUBIC FEET)
DIAMETER BREAST HIGH (INCHES)

FIGURE 10 - WHITE SPRUCE VOLUME CURVE

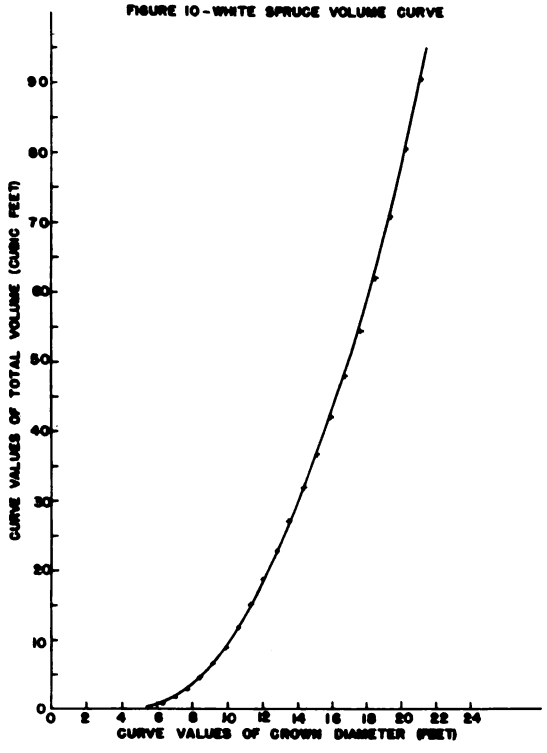
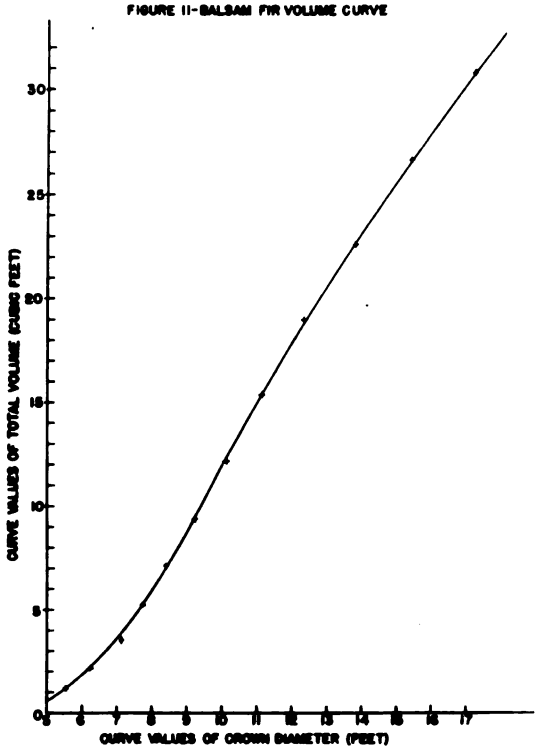


FIGURE 11 - BALSAM FIR VOLUME CURVE



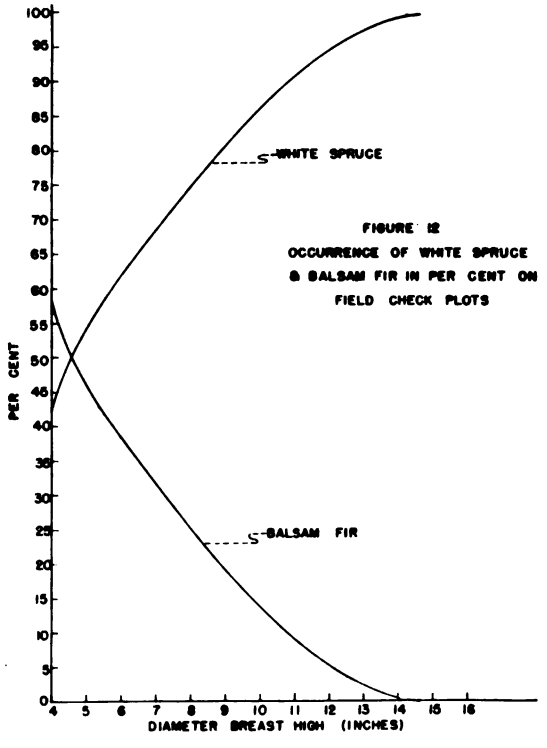


FIGURE 12
OCCURRENCE OF WHITE SPRUCE & BALSAM FIR IN PER CENT ON FIELD CHECK PLOTS

FIGURE 13 - BLACK SPRUCE VOLUME CURVE

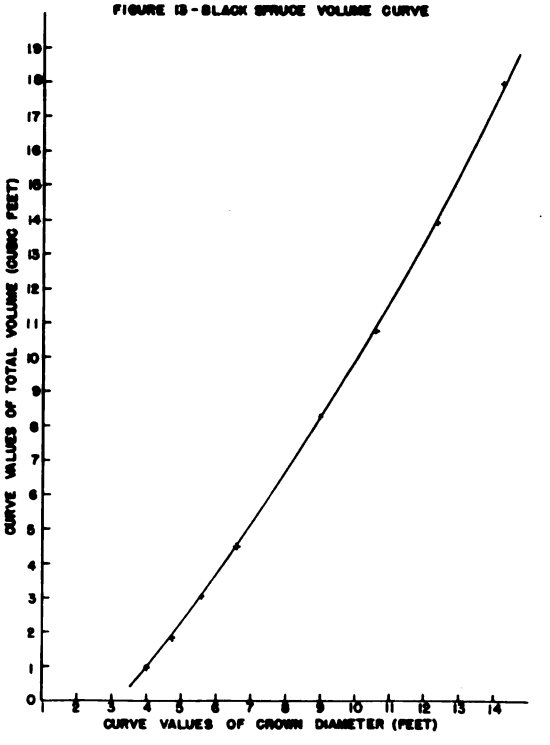


Table IV

Field Data and Curved Values for White Spruce*

D.B.H. Class (Inches)	D.B.H. Class Field Average (Inches)	Number of Sample Trees	Crown Diameter (Feet)		Total Height (Feet)		Total Volume (Cubic Feet)	
			Field Average	Curved Values	Field Average	Curved Values	Field Average	Curved Values
4	4.1	9	6.3	6.30	25.4	25.5	0.98	0.98
5	5.1	31	7.0	7.03	29.0	28.7	1.81	1.75
6	6.1	19	8.5	7.74	31.5	32.0	2.93	2.94
7	7.0	16	9.2	8.45	33.8	35.7	4.03	4.65
8	8.0	12	8.8	9.15	42.8	39.5	6.83	6.70
9	9.0	10	8.5	9.89	44.2	43.9	8.80	8.90
10	10.0	21	10.4	10.60	50.2	47.7	12.27	11.75
11	11.0	25	11.4	11.34	51.5	51.1	15.56	15.00
12	12.0	12	11.8	12.04	57.7	53.8	19.75	18.70
13	13.1	11	12.8	12.78	57.5	56.2	23.69	22.75
14	14.1	9	14.3	13.54	54.9	58.4	25.50	27.00
15	14.9	8	14.2	14.31	56.3	60.2	30.53	31.80
16	15.8	6	14.7	15.10	57.7	61.8	34.93	36.90
17	17.0	6	15.2	15.89	62.7	63.4	42.27	42.30
18	17.9	2	17.5	16.74	61.0	64.9	46.60	48.20
19	18.8	2	21.8	17.58	56.0	66.4	48.30	54.75
20	20.2	1	15.0	18.44	66.0	67.7	65.70	62.40
21	----	0	----	19.30	----	68.9	-----	71.25

* Picea glauca

Table V

Field Data and Curved Values for Balsam Fir*

D.B.H. Class (Inches)	D.B. H. Class Field Average (Inches)	Number of Sample Trees	Crown Diameter (Feet)		Total Height (Feet)		Total Volume (Cubic Feet)	
			Field Average	Curved Values	Field Average	Curved Values	Field Average	Curved Values
4	4.2	16	5.7	5.5	29.0	29.0	1.39	1.18
5	5.0	19	5.9	6.2	35.0	34.0	2.34	2.18
6	6.1	32	7.1	7.1	38.1	40.3	3.49	3.56
7	7.1	42	7.7	7.6	47.7	44.5	5.63	5.25
8	7.9	41	8.1	8.4	46.9	47.5	7.13	7.18
9	9.1	24	9.5	9.2	49.5	50.0	9.53	9.40
10	10.1	17	10.2	10.1	52.5	52.0	12.41	12.20
11	10.9	8	10.8	11.1	53.4	54.0	15.64	15.40
12	12.0	2	12.8	12.3	42.5	55.8	14.50	18.95
13	12.9	1	13.0	13.8	63.0	57.6	24.00	22.65
14	14.3	1	17.5	15.4	55.5	59.3	27.00	26.68
15	----	0	----	17.2	----	61.0	-----	30.78

* Abies balsamea

Table VI

Field Data and Curved Values for Black Spruce*

D.B.H. Class (Inches)	D.B.H. Class Field Average (Inches)	Number of Sample Trees	Crown Diameter (Feet)		Total Height (Feet)		Total Volume (Cubic Feet)	
			Field Average	Curved Values	Field Average	Curved Values	Field Average	Curved Values
4	4.2	13	4.2	3.97	29.92	29.75	1.2	0.97
5	5.2	21	5.3	4.74	32.45	32.50	2.0	1.88
6	6.1	23	5.2	5.57	37.07	36.15	3.3	3.05
7	7.2	15	6.7	6.55	39.63	38.75	4.7	4.53
8	8.0	16	7.8	7.70	40.41	40.95	6.2	6.24
9	8.8	6	8.8	8.98	41.25	43.10	8.0	8.30
10	9.7	1	9.5	10.52	40.50	45.25	9.9	10.80
11	10.8	4	12.0	12.25	46.62	47.35	13.3	13.97

* Picea mariana

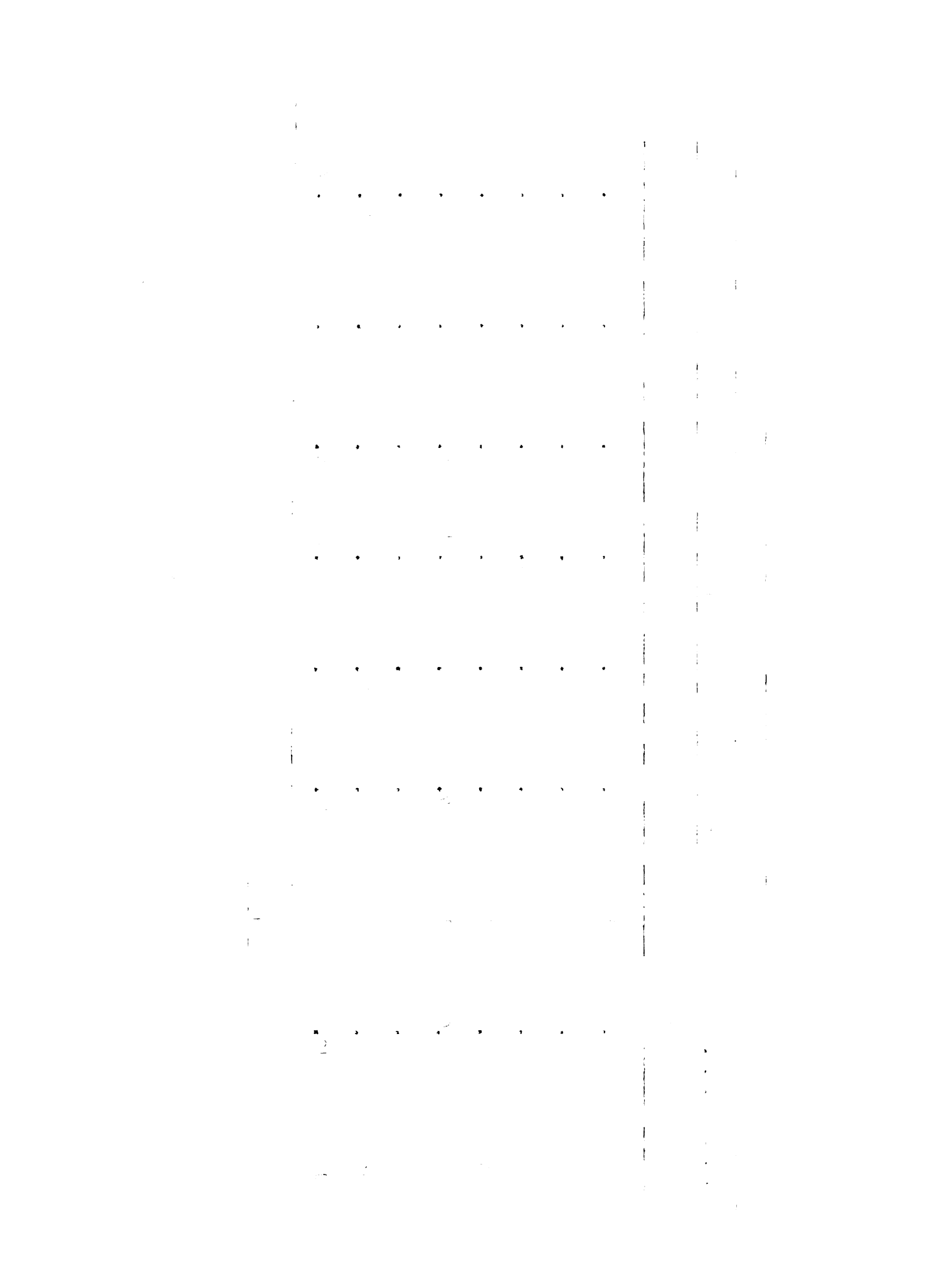


Table VII

Cubic-Foot Volume by Crown Diameter Classes

Crown Diameter Class (Feet)	Volume (Cubic Feet)		
	White Spruce	Balsam Fir	Black Spruce
4	---	---	0.9
5	---	---	2.3
6	0.6	1.8	3.7
7	1.8	3.6	5.2
8	3.5	5.8	6.7
9	6.1	8.7	8.3
10	9.4	12.0	9.9
11	13.4	15.1	11.7
12	18.3	18.0	13.5
13	23.8	20.7	15.5
14.	29.8	23.3	---
15	36.5	25.7	---
16	43.4	28.1	---
17	50.9	30.3	---
18	59.2	---	---
19	68.7	---	---
20	79.2	---	---
21	90.8	---	---

Table VIII

White Spruce Aerial Volume Table

Cubic Feet per One-Fifth Acre

(White Spruce Only)

Crown Density (Per Cent)	Crown Diameter Classes (Feet)							
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	18 - 19	20 - 21
5%	14.70	35.96	56.67	74.04	87.34	96.09	101.84	109.92
15%	44.37	108.02	170.48	222.76	261.70	288.66	308.92	338.84
25%	74.04	180.08	283.62	370.84	434.56	478.68	519.05	559.26
35%	102.72	252.32	397.43	520.75	613.42	670.87	726.18	781.64
45%	133.29	324.38	510.57	668.55	785.10	863.43	929.87	1008.02
55%	167.90	396.44	624.38	817.55	957.96	1053.45	1136.99	1228.94
65%	192.48	463.50	738.19	966.59	1132.32	1245.64	1344.12	1452.82
75%	222.15	540.73	852.00	1114.35	1307.01	1438.21	1550.77	1681.74
85%	251.73	612.79	965.14	1263.34	1481.36	1628.23	1757.89	1906.12
95%	281.31	684.85	1078.95	1412.34	1655.71	1822.96	1965.02	2126.54

Table IX

Balsam Fir Aerial Volume Table

Cubic Feet per One-Fifth Acre

(Balsam Fir Only)

Crown Density (Per Cent)	Crown Diameter Classes (Feet)				
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15
5%	34.42	55.19	67.73	68.35	64.74
15%	103.80	165.73	203.79	205.83	194.11
25%	173.18	276.27	339.09	342.54	322.32
35%	242.38	387.10	475.15	486.05	451.69
45%	311.27	497.65	610.46	617.62	582.34
55%	381.05	608.18	796.52	755.23	710.55
65%	450.26	718.73	882.58	892.84	839.92
75%	519.14	829.56	1018.64	1024.42	969.41
85%	588.84	940.10	1153.94	1167.03	1098.78
95%	658.04	1051.14	1290.00	1304.64	1228.15

Table X

Black Spruce Aerial Volume Table

Cubic Feet per One-Fifth Acre

(Black Spruce Only)

Crown Density (Per Cent)	Crown Diameter Classes (Feet)				
	4 - 5	6 - 7	8 - 9	10 - 11	12 - 13
5%	41.77	57.56	57.60	54.22	51.23
15%	125.32	173.44	172.88	163.16	154.25
25%	208.75	288.88	288.15	271.52	256.70
35%	292.28	404.96	403.76	380.46	360.50
45%	375.82	520.84	519.04	488.82	462.85
55%	459.28	636.66	634.31	597.76	565.98
65%	542.81	752.28	749.59	706.70	669.10
75%	626.39	868.17	865.20	815.64	771.45
85%	709.82	983.80	980.47	924.00	874.58
95%	793.35	1099.42	1095.75	1032.94	977.70

Table XI

Percentage Abundance of White Spruce and Balsam Fir

Field Check Plots

D.B.H. (Inches)	Abundance Percentage From Field Plots		Abundance Percentage From Field Plots(Curved)	
	White Spruce	Balsam Fir	White Spruce	Balsam Fir
4	42.4%	57.6%	42.5%	57.5%
5	58.4%	41.6%	54.3%	45.7%
6	66.7%	33.3%	61.8%	38.2%
7	71.4%	28.6%	68.7%	31.3%
8	65.5%	34.5%	75.2%	24.8%
9	75.0%	25.0%	81.2%	18.8%
10	90.5%	9.5%	86.7%	13.3%
11	91.7%	8.3%	91.4%	8.6%
12	89.5%	10.5%	95.0%	5.0%
13	100.0%	-----	97.8%	2.2%
14	100.0%	-----	99.6%	0.4%
15	100.0%	-----	100.0%	----
16	100.0%	-----	100.0%	----

Table XI

Percentage Abundance of White Spruce and Balsam Fir

Field Check Plots

D.B.H. (Inches)	Abundance Percentage From Field Plots		Abundance Percentage From Field Plots(Curved)	
	White Spruce	Balsam Fir	White Spruce	Balsam Fir
4	42.4%	57.6%	42.5%	57.5%
5	58.4%	41.6%	54.3%	45.7%
6	66.7%	33.3%	61.8%	38.2%
7	71.4%	28.6%	68.7%	31.3%
8	65.5%	34.5%	75.2%	24.8%
9	75.0%	25.0%	81.2%	18.8%
10	90.5%	9.5%	86.7%	13.3%
11	91.7%	8.3%	91.4%	8.6%
12	89.5%	10.5%	95.0%	5.0%
13	100.0%	-----	97.8%	2.2%
14	100.0%	-----	99.6%	0.4%
15	100.0%	-----	100.0%	----
16	100.0%	-----	100.0%	----

Table XII

Percentage of Abundance of White Spruce and Balsam Fir

One- and Two-Foot Crown Diameter Classes

Crown Diameter (Feet)	White Spruce			Balsam Fir		
	D.B.H. Classes (Inches)	Percentage of Abundance		D.B.H. Classes (Inches)	Percentage of Abundance	
		One-Foot Crown Diameter Classes (Per Cent)	Two-Foot Crown Diameter Classes (Per Cent)		One-Foot Crown Diameter Classes (Per Cent)	Two-Foot Crown Diameter Classes (Per Cent)
6	4	42.5	48.4	4 & 5	51.6	44.9
7	5	54.3		6	38.2	
8	6 & 7	65.2	70.2	7 & 8	28.0	23.4
9	8	75.2		9	18.8	
10	9	81.2	85.1	10	13.3	11.0
11	10 & 11	89.0		11	8.6	
12	12	95.0	96.4	12	5.0	4.3
13	13	97.8		12.5	3.6	
14	14 & 15	99.8	99.9	13	2.2	1.3
15	16	100.0		14	0.2	
16	17	100.0	100.0			
17	18	100.0				
18	19 & 20	100.0	100.0			
19	21	100.0				
20	22	100.0	100.0			
21	23	100.0				

Table XIII

White Spruce Aerial Volume Table

Regulated by Abundance of the Species on the Field Check Plots

(Cubic Feet)

Crown Density (Per Cent)	Crown Diameter Classes (Feet)							
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	18 - 19	20 - 21
5%	7.11	25.24	48.23	71.37	87.25	96.09	101.84	109.92
15%	21.47	75.83	145.08	214.74	261.44	288.66	308.92	338.84
25%	35.83	126.42	241.36	357.49	434.12	478.68	519.05	559.26
35%	49.72	177.13	338.21	502.00	612.81	670.87	726.18	781.64
45%	64.51	227.71	434.49	644.48	784.31	863.43	929.87	1008.02
55%	81.26	278.30	531.35	788.12	957.00	1053.45	1136.99	1228.94
65%	93.16	325.38	628.20	931.79	1131.19	1245.64	1344.12	1452.82
75%	107.52	379.59	725.05	1074.23	1305.70	1438.21	1550.77	1681.74
85%	121.84	430.18	821.33	1217.86	1479.88	1628.23	1757.89	1906.12
95%	136.15	480.76	918.19	1361.49	1654.05	1822.96	1965.02	2126.54

Table XIV

Balsam Fir Aerial Volume Table

Regulated by Abundance of the Species on the Field Check Plots

(Cubic Feet)

Crown Density (Per Cent)	Crown Diameter Classes (Feet)				
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15
5%	15.45	12.91	7.45	2.94	0.84
15%	46.61	38.78	22.42	8.85	2.52
25%	77.76	64.65	37.30	14.73	4.19
35%	108.83	90.58	52.27	20.90	5.87
45%	139.76	116.45	67.15	26.56	7.57
55%	171.45	142.31	87.62	32.47	9.24
65%	202.17	168.18	97.08	38.39	10.92
75%	233.09	194.12	112.05	44.05	12.60
85%	264.39	219.98	126.93	50.18	14.28
95%	295.46	245.97	141.90	56.10	15.96

Table XV

Local Volume Table for White Spruce - Balsam Fir Type

Dunbar Forest

One-Fifth Acre Aerial Cruising Plot

Cubic Feet per One-Fifth Acre

Crown Density (Per Cent)	Crown Diameter Classes (Feet)							
	6 - 7	8 - 9	10 - 11	12 - 13	14 - 15	16 - 17	18 - 19	20 - 21
5%	22.56	38.15	55.68	74.15	88.09	96.09	101.84	109.92
15%	68.08	114.61	167.50	223.59	263.96	288.66	308.92	338.84
25%	113.59	191.07	278.66	372.22	438.31	478.68	519.05	559.26
35%	158.55	267.71	390.48	522.90	618.68	670.87	726.18	781.64
45%	204.27	344.16	501.64	671.04	791.88	863.43	929.87	1008.02
55%	252.71	420.61	618.97	820.59	966.24	1053.45	1136.99	1228.94
65%	295.33	493.56	725.28	970.18	1142.11	1245.64	1344.12	1452.82
75%	340.61	573.71	837.10	1118.28	1318.30	1438.21	1550.77	1681.74
85%	386.23	650.16	947.26	1268.04	1494.16	1628.23	1757.89	1906.12
95%	431.61	726.73	1060.09	1417.59	1670.01	1822.96	1965.02	2126.54

APPLICATION OF AERIAL VOLUME TABLES

An aerial volume table is a means by which volume estimates can be made in photocruising a forest type. These volume estimates are limited by the accuracy of the volume table and the ability of the photocruiser to take the necessary measurements from the photographs for the photocruise.

In order to use the aerial volume tables in this study for rapid volume estimation, the following general procedure should be observed and followed. First, type lines separating the different forest types are drawn on the photographs. Fifth-acre sample plots are drawn to scale on the photograph for the line-plot method of mechanical sampling. The plots may be measured and plotted directly on the photograph or by locating the plots on the photograph by the use of a slotted templet. This templet is designed to correct for land elevation changes occurring within the limits of a single photograph (12). The average crown diameter of each plot is determined from the photograph by measuring several of the visible crowns occurring within the sample plot. The crown density per cent of each sample plot on the photograph is estimated by ocular comparison of the crown density of each sample plot to the crown density scale (22). The average crown diameter and estimated crown density per cent are the two variables needed to obtain the estimated volume on each plot from the volume table. Each sample plot established on the photograph within the type is photocruised in a similar manner in order that the desired per cent of sample is obtained.

The type boundaries are reproduced on a base map from the photographs

for the determination of the forest type area by the use of a grid or planimeter.

Volumes of as many photo sample plots as deemed necessary should be field checked to assure the most nearly correct volume estimate for the sample. The difference between the photo estimated volume and the field checked volume is used as a correction factor. This correction factor is applied to the estimated volume of all the photo plots to correct for possible human error in photo interpretation.

The estimated volume of the entire forest type is determined by multiplying the total number of acres in the type by the average volume per acre of the photocruise plots in the type.

SUMMARY AND RECOMMENDATIONS

This study was undertaken to develop a method of local aerial volume table construction and to construct volume tables for the white spruce-balsam fir and the black spruce types on the Dunbar Forest Experiment Station. The completed tables for both forest types, Tables X and XV, are designed for area volume estimation based upon crown diameter and crown density variables.

Measurements taken of individual trees in the field were: d.b.h. outside bark to the nearest one-tenth inch, the average crown diameter, total height, crown class, and for approximately every ten trees measured, the diameter inside bark at 2.25 feet above half the height of the tree. The abundance of each species on fifth-acre plots was also determined and listed by one-inch d.b.h. classes.

The steps used in the construction of pure and mixed forest type volume tables are:

A. Pure Type Volume Table (one species):

1. Group the measurements taken from sample trees by one-inch d.b.h. classes and compute the mean of each.
2. Plot the total tree height, crown diameter, and cubic-foot volume over d.b.h. for each one-inch d.b.h. class.
3. Plot the cubic volume over the crown diameter using the curved values determined in step 2.
4. Determine the number of stems in each crown density percentage by dividing the total square-foot area of a fifth-acre by the square feet in each one-foot crown class.

5. Determine the area of crown cover necessary to constitute the units of crown density per cent for a fifth-acre as used in these volume tables.

6. Divide the results of step 5 by the results of step 4 to determine the number of crowns in each density per cent on a fifth-acre.

7. Multiply results of step 6 by the volume of a tree according to each one-foot crown diameter class as determined in step 3. This results in an aerial volume table that gives the cubic-foot volume per fifth-acre. Estimates are on crown density per cent and one-foot crown diameter classes.

8. Convert the one-foot crown diameter classes determined in step 7 into two-foot crown diameter classes. This results in the completed aerial volume table for a pure forest type. It gives the cubic-foot volume by two-foot crown diameter classes and crown density percentage classes.

B. Mixed Type Volume Table (more than one species):

Steps 1 through 8 are identical to those followed in the construction of the pure type volume table.

9. From field check plots, determine the abundance by number of stems of each species by d.b.h. classes.

10. Prepare percentage of abundance over d.b.h. class curves for each species occurring in the type.

11. Modify the fifth-acre volume estimates for each species to correspond to the abundance of the species on a fifth-acre of the forest type. The result is an aerial volume table which gives the cubic-foot volume estimate for a fifth-acre

of a mixed forest type by two-foot crown diameter and crown density classes.

With the aid of aerial volume tables the length of time needed for timber cruising can be reduced. Although much of the timber cruise can be carried on from measurements obtained from the aerial photographs, timber estimators should not forget that the aerial photograph is only the means to an end "...it is neither the end itself, nor the perfect means...."(2). Therefore, a knowledge of both the area and the forest types being cruised are beneficial to the photocruiser in making better volume estimates, and adequate field checks must be made to produce a volume estimate that will be both economical and accurate.

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