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PROVISIONAL AERIAL STAND VOLUME TABLES FOR SELECTED FOREST TYPES IN CANADA

by
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ABSTRACT

Data from 1,933 field-measured sample plots in Quebec, Ontario, Northwest Territories and Alberta were used to construct aerial stand volume tables for 10 cover types by regression analysis. The tables, in which volume is predicted from stand height and canopy density, are sufficiently accurate for the determination of preliminary stand volume estimates.

RÉSUMÉ

Ayant en main les données sur 1,933 places-échantillons qu'on avait établies entre 1951 et 1958 dans le Québec, l'Ontario, les Territoires du Nord-Ouest et l'Alberta, l'auteur a construit des tables de volumes de peuplements en se servant de photographies aériennes récentes qu'il a interprétées par l'analyse des régressions. Dix types de peuplements furent traités et les tables, qui prédisent les volumes à partir de la hauteur du peuplement et la densité du couvert, sont considérées par l'auteur comme étant suffisamment précises pour servir à faire des estimations provisoires.

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Provisional Aerial Stand Volume Tables for Selected Forest Types in Canada

by

G. M. BONNOR[1]

INTRODUCTION

The construction and use of aerial stand volume tables has become increasingly important in the last two decades, primarily due to improvements in aerial photographic techniques. The tables are based on the relationship between variables which can be measured or interpreted on aerial photographs and stand volume. They are used to estimate stand volumes from the photographs either directly or in conjunction with local field data to produce local volume tables.

The stand characteristics most commonly used to estimate stand volume from aerial photographs are: crown closure (canopy density), crown count, crown diameter and tree height (Spurr 1948). For construction of the tables, photo measurements of the independent variables are commonly used (Moessner *et. al.* 1951, Allison and Breadon 1958, Roger *et. al.* 1959); however, ground measurements (Nyyssonen 1955) or a combination of photo and ground measurements (Gingrich and Meyer 1955) have also been used.

The dependent variable, volume, is expressed in cubic feet or board feet, total volume or merchantable volume, depending on the required use of the tables. For construction of the tables, volume is usually determined by the application of field measurements to volume tables.

Stratification of the forest area into cover types by means of aerial photographs is usual and, if properly carried out, has the effect of reducing regression variance. Stratification by density, height, species, species groups, volume classes or site are common schemes. Moessner (1963) made a study of a number of photo and map stratification schemes; findings indicated that in volume estimating, photo volume classes offer the best means of stratification. Bickford (1953) in a similar study compared volume class stratification with stand size stratification and also found the former to be more efficient. Kendall and Sayn-Wittgenstein (1961) in a test of the effectiveness of air photo stratification included some continuous variables more commonly found in regression equations. They found a stratification by cover type, height and canopy density to give the most precise volume estimates. Macpherson (1962) found a two-way stratification by cover type and volume class to give good volume predictions.

Of the parameters used to estimate stand volume from aerial photos, average stand height appears to be the best single variable (Hanks and Thomson 1964,

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Nyyssonen 1955, Gingrich and Meyer 1955), although Morris (1957) assumed that the estimation of age and stand density would give more accurate volume estimates than height. Other parameters commonly used are canopy density and average crown diameter. Moessner *et. al.* (1951) found that, of the three parameters mentioned, canopy density showed the poorest over-all correlation with volume, but they included canopy density because of its value in stands of below medium density. Bickford (1953), however, dealing with the same variables, found canopy density to give the best volume estimates.

The precision of stand volume tables varies a great deal, depending on the homogeneity of the area sampled and the methods used in constructing the tables. The standard error of estimate, expressed in per cent of the mean volume, is often used to indicate the precision of the tables. Duffy and Meyer (1962) reported a low standard error of estimate of $\pm 17\%$ for a table for lodge pole pine stands in Alberta; Hanks and Thomson (1964), on the other hand, reported standard errors of estimate in excess of $\pm 65\%$ for Iowa hardwoods.

THE STUDY

This report deals with the construction of stand volume tables for cover types in the Subalpine, Boreal and Great Lakes-St. Lawrence Regions of Canada (Rowe 1959). The basis for the tables is data from 1,933 sample plots, collected during the period 1951-1958. Further details of the sampling are given in Table 1.

TABLE 1. LOCATION AND COMPOSITION OF SAMPLE PLOTS

Location	Latitude and	Longitude	Forest Region	Major Species*	No. of Plots
Matane, P.Q.	49	67	Boreal	bF,wB,bS,wS	150
Sault-au-Cochon, P.Q.	49	69	Boreal	bS,wP,rP	39
St. Maurice, P.Q.	47	73	Gt. Lakes-St. Lawrence	bS,jP	111
Lièvre, P.Q.	47	75	Gt. Lakes-St. Lawrence	yB,bF,bS, jP,hM,Be	465
Algonquin, Ontario	46	78	Gt. Lakes-St. Lawrence	wP,rP,jP	382
Dorset, Ontario	45	79	Gt. Lakes-St. Lawrence	hM,Be	47
Nipigon, Ontario	48	88	Boreal	tA,jP,bS	199
Peace River, Alberta	59	112	Boreal	wS,bPo	164
Slave River, N.W.T.	61	113	Boreal	wS,bPo	148
Kananaskis, Alberta	51	115	Subalpine	lP,wS	228
				Total	1933

*for list of abbreviations, see Appendix 1.

The tables are based on the relationship between total cubic foot volume per acre (V), for trees four inches d.b.h. and up, and canopy density (C) and average stand height (H). Regression analyses were used to evaluate this relationship. All parameters were obtained from ground measurements.

METHOD

The collection and compilation of basic data incorporate methods which may be challenged by statisticians and mensurationists. These sources of error will be dealt with separately. Also, because of the lengthy period over which the data were assembled and the large number of people working on the project, there was some variation in the method of collecting and compiling the data. However, the general procedure was as follows.

At the start of each field season, the cover types to be sampled were chosen. Following the selection of suitable sampling areas and stands, plot locations were subjectively established to provide a wide range of height, canopy density and site classes.

Sample plots were established in the selected locations. The square sample plots covered 1/4 or 1/5 acre. For each plot, the following information was recorded: site class, plant indicators, disturbances, soil moisture and texture, parent material, topography; forest section and region, drainage area, photo no., plot no., plot size, date; height class, canopy density class, cover type and age class. Further, a complete tally of trees was made by species, in one inch diameter classes, for trees four inches in diameter at breast height and over. Also, the height of five to ten trees was measured, and 30-60 readings with a modification of the Moosehorn (Robinson 1947) were obtained for the determination of canopy density.

In the office, height-diameter curves were constructed by 10 foot mean height classes for each location and for each species. The plot volume as well as the average heights weighted by volume were then obtained by the application of the diameter tallies to local volume tables prepared from the height-diameter curves and form class volume tables (Anon. 1948). Also, the basal area for each species within each plot was calculated. Lastly, from the readings with the Moosehorn, canopy density (per cent crown cover) was calculated for each plot.

By application of the basal area figures for each plot to the sub-type classification used by the Department of Forestry and Rural Development, the sub-type of each plot was determined. A total of 151 sub-types were represented by the 1933 plots. To provide a sufficient number of plots for the subsequent analyses, the plots were combined into 13 cover types, each containing at least 50 plots.

ANALYSES AND INTERPRETATION

The variables included in the first regression analysis were:

$Y = V$ (volume per acre)

$X_1 = H$ (stand height, in feet)

$X_2 = C$ (canopy density, in per cent)

$X_3 = HC$

$X_4 = HC^2$

$X_5 = \frac{1}{C}$

$X_6 = C^2$

$X_7 = \frac{H}{C}$

A step-wise multiple regression analysis (Brown)[2] was carried out for each cover type and for the combined data. Only the three variables showing the best correlation with stand volume were included in the evaluation of the regression analyses. Cover types and results of the analyses are shown in Table 2.

[2]Brown, D. M. 1961. Least Squares Linear Regression Analysis for 1 Dependent and 24 Independent Variables. Department of Forestry and Rural Development of Canada. Statistical Research Service, Forest Entomology and Pathology Branch. File No. 06-01-001.

TABLE 2. RESULTS OF FIRST SERIES OF REGRESSION ANALYSES

Cover Type	No. of Plots	Best 3 Variables	Standard Error cu. ft.	Standard Error % of volume
100 (All plots)	1933	H $\frac{1}{C}$ HC^2	995	33
101 Intolerant hardwoods	87	H HC^2 C	766	20
102 Tolerant hardwoods	338	HC C H	541	21
103 Intolerant hardwoods + softwoods	69	H C^2 HC	672	20
104 Tolerant hardwoods + softwoods	51	HC C^2 H	661	37
105 Jack pine	249	H $\frac{H}{C}$ HC	443	21
106 Black spruce	168	HC C^2 $\frac{H}{C}$	449	25
107 White spruce	242	H $\frac{H}{C}$ C	827	18
108 Red and white pine	127	HC $\frac{H}{C}$ C^2	459	14
109 Balsam fir	101	HC^2 C $\frac{H}{C}$	997	31
110 Pine-Spruce	86	$\frac{1}{C}$ H C^2	893	27
111 Spruce-Balsam	108	HC HC^2 C^2	918	27
112 Pine-Intolerant hardwoods	108	HC $\frac{H}{C}$ H	611	18
113 Lodgepole pine	199	HC C H	519	19

The "Best 3 Variables" are listed in order of importance. The standard errors of estimate compare favourably with those obtained by other researchers (Hanks and Thomson 1964). However, the lack of any trend in the variables selected lead to the conclusion that there is little difference between the variables, and that any three variables that include height and canopy density will give a fit almost as good as the combinations in Table 2. For this reason, and to produce greater uniformity between regression equations, another series of regression analyses was calculated, using three selected variables. The variables selected were H, C and HC, corresponding to the variables of the "Australian" equation (Spurr 1952). The standard errors of estimate obtained by the use of these variables were approximately the same as those shown in Table 2, and it was decided to use H, C and HC in the volume equations.

The last series of tests investigated the possibility of combining some of the cover types without a significant loss of accuracy. Basic to this approach was the calculation of a regression equation common to all 1,933 plots. The error in total plot volume, had this equation been used, was then calculated for each cover

TABLE 3. RELATIVE ERROR IN VOLUME PREDICTION USING A COMMON REGRESSION

Cover Type		Difference between field estimated volume and predicted volume (in % of field estimated volume)
101	Intolerant hardwoods	+ .4
102	Tolerant hardwoods	+29
103	Intolerant hardwoods + softwoods	− 5.4
104	Tolerant hardwoods + softwoods	+83
105	Jack pine	+30
106	Black spruce	+ 2.6
107	White spruce	−10
108	Red and white pine	− 8.1
109	Balsam fir	−16
110	Pine-Spruce	−14
111	Spruce-Balsam	−19
112	Pine-Intolerant hardwoods	− 8.5
113	Lodgepole pine	−25

type and expressed in per cent of total plot volume for that cover type. In Cover Type 105, for example, the sum of all plot volumes is 512,012 cu. ft. Using the common regression, the estimated total volume is 666,462 cu. ft. The difference expressed in per cent of the sum of all plot volumes is 30%. These errors, called relative errors, are shown in Table 3.

This approach was based on the assumption that cover types having similar relative errors in volume estimation could be combined and new equations calculated for the selected combinations. The error is relative only to the common equation and is removed when separate equations are calculated. The figures in Table 3 indicate that a number of combinations are possible (101, 106; 102, 105; 103, 108, 112; 109, 110, 111). However, allowing for the fact that sample data such as these do not completely reflect the relationships within populations, it was decided that such combinations should also be silviculturally meaningful. For example, Table 3 shows that cover types 102 (tolerant hardwoods) and 105 (jack pine) have similar relative errors. A combination of these two cover types, however, would not be silviculturally meaningful.

Taking the above considerations into account, it was decided to combine cover types 109, 110 and 111 into one cover type (114, mixed softwoods) and cover types 103 and 112 into another cover type (115, intolerant hardwoods + softwoods).

The regression coefficients and standard errors of estimate were then calculated (Table 4), and stand volume tables were constructed from the equations (Appendix II). In the tables, the range of the sample plot data is blocked by a heavy line.

TABLE 4. STAND VOLUME TABLE REGRESSION EQUATIONS

Cover Type	Regression Equation	Standard error of estimate (cu. ft.)	Standard error of estimate (% of vol.)	No. of Plots
101 Intolerant hardwoods	V = 824.274 + 8.11249 H −52.9139C + 1.18962 HC	661	20	87
102 Tolerant hardwoods	V = 2309.65 − 32.7908 H −53.2246C + 1.18467 HC	535	21	338
104 Tolerant hardwoods + softwoods	V = −4844.11 + 89.2225 H +85.2487C − 1.11417 HC	662	37	51
105 Jack pine	V = −1467.76 + 35.8816 H −16.8047C + .817067 HC	454	21	249
106 Black spruce	V = −877.070 + 29.5130 H −13.6464C + .887888 HC	454	25	168
107 White spruce	V = −1103.17 + 53.9385 H −7.26820C + .585915 HC	832	18	242
108 Red and white pine	V = −7476.08 + 114.278 H +85.2758C − .568079 HC	462	14	127
113 Lodgepole pine	V = 1710.75 − 38.7005 H −48.7927C + 2.29914 HC	668	19	199
114 Mixed softwoods	V = −5282.70 + 106.799 H 76.8578C − .614612 HC	995	30	295
115 Intolerant hardwoods + softwoods	V = −5983.88 + 112.174 H +62.2359C − .495664 HC	656	20	177

It should be noted that the equation for cover type 107, white spruce, which contains plot data from Quebec, Northwest Territories and Alberta, has a relatively low standard error, indicating that the relationship between volume, canopy density and height is not significantly affected by regional differences.

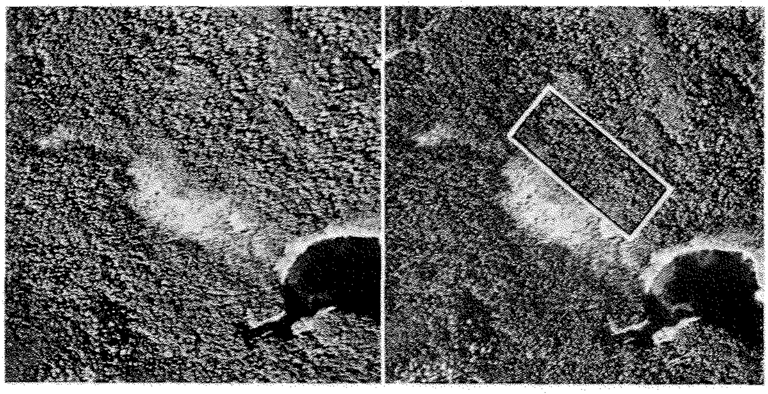
The stereograms in Table 5 illustrate three of the sub-types and cover types for which the tables were constructed. The data accompanying each stereogram were obtained from ground measurements. The information in the table therefore provides the user with some indication of the appearance on aerial photographs of ground-measured stand characteristics.

SOURCES OF ERROR

The choice of stand characteristics, the collection of sample plot data and the compilation methods have all contributed to weaknesses in the regression equations and volume tables. These sources of error should be explained, in order that better use be made of the tables.

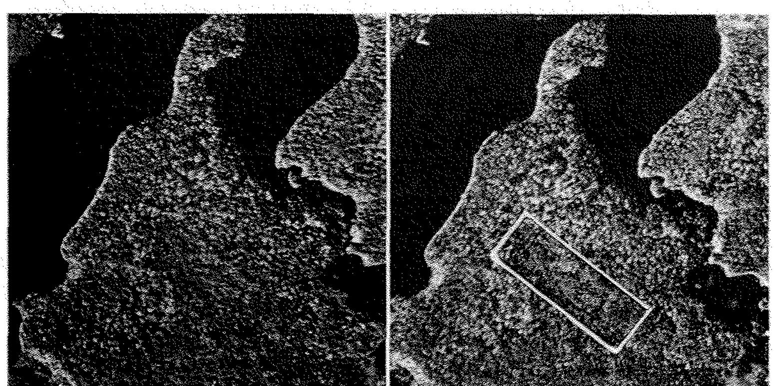
The plot selection method described previously is extremely subjective. Within each cover type, the plots were selected, not located at random, to provide a wide range of height, canopy density and site classes. The samples therefore could yield information about the population which is biased. However, from a practical point of view the method affords a better-than-average coverage of the desired classes.

TABLE 5. STEREOGRAMS ILLUSTRATING THREE COVER TYPES



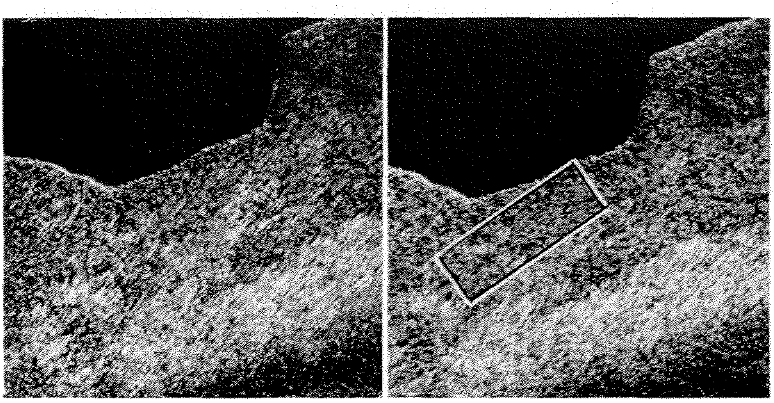
Cover type: black spruce (106)
Estimated volume: 2173 cu.ft/ac.

Canopy density: 37%
Stand height: 57 ft.
Actual volume: 1963 cu.ft/ac.



Cover type: mixed softwoods (114)
Estimated volume: 2615 cu.ft/ac.

Canopy density: 60%
Stand height: 47 ft.
Actual volume: 1969 cu.ft/ac.



Cover type: tolerant hardwoods (102)
Estimated volume: 2876 cu.ft/ac.

Canopy density: 89%
Stand height: 73 ft.
Actual volume: 2347 cu.ft/ac.

Another potential source of error is the use of average height weighted by volume (MacAndrews 1955). In theory the use of this variable in aerial stand volume tables is improper, since knowledge of stand volume prior to the determination of this average height is necessary. In the application of most stand volume tables, however, average stand heights are estimated and an experienced photo interpreter could produce estimates of average height weighted by volume as accurate as those of other average heights. Average height weighted by volume is generally close to the average height of dominants and codominants for a given stand (MacAndrews 1955).

Concerning Moosehorn readings, current research[3] indicates that 100-300 Moosehorn readings are necessary to obtain canopy density estimates within 5 per cent canopy density of the actual canopy density, with a probability level of .95. The much smaller number of readings obtained in the sample plots therefore has produced inaccurate canopy density values. However, the large number of sample plots may have reduced the effect of this inaccuracy on the regression analyses. The research project referred to above also indicates that the Moosehorn does not yield biased canopy density estimates.

The use of ground measurements eliminates one source of bias common to methods in which photo measurements of stand characteristics are used, namely the personal bias of the photo interpreter. For the same reason, another source of bias is introduced: in the application of the tables, canopy density is measured on aerial photos, and we have no assurance that this photo-measured characteristic is the same as the ground-measured canopy density.

CONCLUSIONS

The results of the regression analyses support the findings by some other researchers, namely that both height and canopy density are useful variables in the estimation of stand volume. Some cover types show evidence of decreasing volume with height and/or canopy density at the outer limits of the tables (cover types 101, 102, 104). This tendency results largely from the fact that there were few plots in these classes and that the plots were given little weight in the regression analyses; it may also be in part attributed to over-maturity associated with hardwood stands. The successful combination of several species and species groups into one cover type indicate that, for the rough estimation of stand volume, only a few cover types are necessary, and makes easier the job of the photo interpreter, who does not have to distinguish between as many species.

While the stand volume tables presented in this study suffer from certain shortcomings, it is believed that they will find a useful application in the field of preliminary volume estimates. The tables will be useful in the initial, rough estimation of individual stand volumes and in the stratification of stands by volume classes (Moessner 1963). Also, they will provide a framework for the construction of local volume tables.

[3]Department of Forestry and Rural Development, Forest Management Research and Services Institute, Project 33-11-S2.

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APPENDIX I

SPECIES NAMES AND ABBREVIATIONS

Common Name	Abbreviation	Latin Name
Eastern white pine	wP	*Pinus strobus* L.
Red pine	rP	*Pinus resinosa* Ait.
Jack pine	jP	*Pinus banksiana* Lamb.
Lodgepole pine	lP	*Pinus contorta* Dougl. var. *latifolia* Engelm.
Black spruce	bS	*Picea mariana* (Mill.) BSP
White spruce	wS	*Picea glauca* (Moench) Voss.
Balsam fir	bF	*Abies balsamea* (L.) Mill.
Tamarack	tL	*Larix laricina* (Du Roi) K. Koch
Eastern white cedar	eC	*Thuja occidentalis* L.
Eastern hemlock	eH	*Tsuga canadensis* (L.) Carr.
Trembling aspen	tA	*Populus tremuloides* Michx.
Largetooth aspen	lA	*Populus grandidentata* Michx.
Balsam poplar	bPo	*Populus balsamifera* L.
White birch	wB	*Betula papyrifera* Marsh.
Yellow birch	yB	*Betula alleghaniensis* Britt.
Sugar maple	sM	*Acer saccharum* Marsh.
Red maple	rM	*Acer rubrum* L.
Ash	As	*Fraxinus americana* L.
Basswood	Ba	*Tilia americana* L.
Beech	Be	*Fagus grandifolia* Ehrh.
Cherry	Ch	*Prunus serotina* Ehrh.
Elm	E	*Ulmus americana* L.
Ironwood	I	*Ostrya virginiana* (Mill.) K. Koch
Oak	O	*Quercus alba* L. and *Quercus rubra* L.

APPENDIX II

AERIAL STAND VOLUME TABLES

Cover Type 101

Intolerant Hardwoods

Canopy Density in Per Cent	Stand Height, in feet 40	50	60	70	80	90	100
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet						
40	936	1492	2050	2606	3164	3720	4277
50	882	1558	2234	2910	3586	4262	4938
60	829	1624	2419	3214	4009	4804	5598
70	776	1690	2603	3517	4431	5345	6259
80	722	1755	2788	3821	4854	5886	6919
90	669	1821	2973	4124	5276	6428	7580

Basis: 87 plots

Location: Lièvre, P.Q. (2 plots)
Algonquin, Ont. (1 plot)
Nipigon, Ont. (14 plots)
Peace River, Alta. (41 ")
Slave River, N.W.T. (29 ")

Regression equation: $V = 824.274 + 8.11249H - 52.9139C + 1.18962HC$

Standard error of estimate: $\pm 20\%$

*Average species composition**:
bPo 85%
tA 12%
other 3%

*by basal area, expressed in per cent of total basal area.

Cover Type 102

Tolerant Hardwoods

Canopy Density in Per Cent	Stand Height, in feet 40	50	60	70	80
	Volume per acre of trees 4" d.b.h. and over in total cubic feet				
20	881	790	699	608	517
30	823	850	878	905	933
40	764	910	1056	1202	1348
50	706	970	1235	1499	1764
60	648	1031	1414	1796	2179
70	589	1091	1592	2093	2595
80	531	1151	1771	2390	3010
90	473	1211	1949	2688	3426
100	414	1271	2128	2984	3841

Basis: 338 plots

Location: Lièvre, P.Q. (285 plots)
Algonquin, Ont. (8 ")
Dorset, Ont. (45 ")

Regression equation: V = 2309.65 − 32.7908H − 53.2246C + 1.18467HC

Standard error of estimate: ±21%

Average species composition:

sM	58%
Be	19%
yB	17%
other	6%

Cover Type 104

Tolerant Hardwoods plus Softwoods

Canopy Density in Per Cent	Stand Height, in feet: 40	50	60	70	80
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet				
40	352	799	1245	1692	2138
50	759	1094	1429	1764	2099
60	1166	1389	1613	1837	2060
70	1572	1684	1797	1909	2022
80	1979	1980	1981	1982	1983
90	2386	2275	2165	2054	1944

Basis: 51 plots

Location: Lièvre, P.Q. (46 plots)
Algonquin, Ont. (5 ")

Regression equation: $V = -4844.11 + 89.2225H + 85.2487C - 1.11417HC$

Standard error of estimate: $\pm 37\%$

Average species composition:

yB 56%
bF 17%
sM 10%
Other softwoods 12%
Other hardwoods 5%

Cover Type 105

Jack Pine

Canopy Density in Per Cent	Stand Height, in feet 30	40	50	60	70	80
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet					
20	—	285	807	1330	1852	2374
30	—	444	1048	1652	2256	2860
40	—	603	1288	1974	2660	3345
50	—	761	1529	2296	3063	3831
60	71	920	1769	2618	3467	4316
70	148	1079	2010	2940	3871	4802
80	225	1238	2250	3263	4275	5288

Basis: 249 plots

Location: St. Maurice, P.Q. (62 plots)
Lièvre, P.Q. (44 ")
Algonquin, Ont. (105 ")
Nipigon, Ont. (38 ")

Regression equation: $V = -1467.76 + 35.8816H - 16.8047C + .817067HC$

Standard error of estimate: $\pm 21\%$

Average species composition:
jP 93%
other 7%

Cover Type 106

Black Spruce

Canopy Density in Per Cent	Stand Height, in feet: 30	40	50	60	70
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet				
10	138	522	906	1290	1674
20	268	741	1214	1686	2159
30	398	960	1521	2082	2644
40	528	1178	1828	2479	3129
50	658	1397	2136	2875	3614
60	788	1616	2443	3271	4099
70	918	1834	2751	3668	4584
80	1048	2053	3058	4064	5069

Basis: 168 plots

Location: Matane, P.Q. (1 plot)
Sault-au-Cochon, P.Q. (30 plots)
St. Maurice, P.Q. (7 ")
Lièvre, P.Q. (31 ")
Algonquin, Ont. (6 ")
Nipigon, Ont. (93 ")

Regression equation: $V = -877.070 + 29.5130H - 13.6464C + .887888HC$

Standard error of estimate: $\pm 25\%$

Average species composition:
bS 94%
other 6%

Cover Type 107

White Spruce

Canopy Density in Per Cent	Stand Height, in feet 50	60	70	80	90	100	110	120
	Volume per acre of trees 4" d.b.h. and over in total cubic feet							
20	2034	2691	3347	4004	4660	5317	5974	6630
30	2254	2970	3685	4400	5115	5830	6546	7260
40	2475	3249	4022	4796	5570	6344	7117	7891
50	2695	3527	4360	5192	6024	6857	7689	8522
60	2915	3806	4697	5588	6479	7370	8261	9152

Basis: 242 plots

Location: Peace River, Alta. (123 plots)
Slave River, N.W.T. (119 ")

Regression equation: V = −1103.17 + 53.9385H − 7.2682OC + .585915HC

Standard error of estimate: ±18%

Average species composition:

wS 98%
other 2%

Cover Type 108

Red and White Pine

Canopy Density in Per Cent	Stand Height, in feet: 50	60	70	80
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet			
60	1650	2452	3254	4056
70	2219	2964	3709	4056
80	2788	3476	4164	4852
90	3356	3988	4619	5251

Basis: 127 plots

Location: Algonquin, Ont. (127 plots)

Regression equation: $V = -7476.08 + 114.278H + 85.2758C - .568079HC$

Standard error of estimate: $\pm 14\%$

Average species composition:

rP	54%
wP	35%
hardwoods	7%
other softwoods	4%

Cover Type 113

Lodgepole Pine

Canopy Density in Per Cent	30	40	50	60	70
	Volume per acre of trees 4" d.b.h. and over in total cubic feet				
20	953	1026	1099	1172	1245
30	1155	1458	1761	2063	2366
40	1357	1890	2422	2955	3488
50	1559	2321	3084	3846	4609
60	1761	2753	3746	4738	5730
70	1962	3185	4407	5630	6852

Stand Height, in feet (column headings 30–70)

Basis: 199 plots

Location: Kananaskis, Alta. (199 plots)

Regression equation: V = 1710.75 − 38.7005H − 48.7927C + 2.29914HC

Standard error of estimate: ±19%

Average species composition:

lP 97%
other 3%

Cover Type 114

Mixed Softwoods

Canopy Density in Per Cent	Stand Height, in feet: 40	50	60	70	80
	Volume per acre of trees 4″ d.b.h. and over in total cubic feet				
10	3	518	1525	2532	3538
20	35	980	1925	2870	3815
30	557	1441	2325	3208	4092
40	1080	1902	2724	3547	4369
50	1603	2364	3124	3885	4646
60	2126	2825	3524	4223	4922
70	2648	3286	3924	4562	5199
80	3171	3747	4324	4900	5476
90	3694	4209	4724	5238	5753
100	4216	4670	5123	5577	6030

Basis: 295 plots

Location: Matane, P.Q. (149 plots)
Sault-au-Cochon, P.Q. (9 ")
St. Maurice, P.Q. (42 ")
Lièvre, P.Q. (48 ")
Algonquin, Ont. (5 ")
Nipigon, Ont. (17 ")
Kananaskis, Alta. (25 ")

Regression equation: $V = -5282.70 + 106.799H + 76.8578C - .614612HC$

Standard error of estimate: $\pm 30\%$

Average species composition:

bF	52%	jP	8%
bS	14%	lP	7%
wS	11%	other	8%

Cover Type 115

Intolerant Hardwoods plus Softwoods

Canopy Density in Per Cent	Stand Height, in feet 50	60	70	80
	Volume per acre of trees 4" d.b.h. and over in total cubic feet			
20	374	1396	2419	3442
30	748	1721	2694	3668
40	1123	2046	2970	3893
50	1497	2371	3245	4119
60	1872	2696	3521	4345
70	2246	3021	3796	4571
80	2621	3346	4071	4797
90	2996	3671	4347	5022
100	3370	3996	4621	5248

Basis: 177 plots

Location: Lièvre, P.Q. (9 plots)
Algonquin, Ont. (125 ")
Dorset, Ont. (2 ")
Nipigon, Ont. (37 ")
Kananaskis, Alta. (4 ")

Regression equation: $V = -5983.88 + 112.174H + 62.2359C - .495664HC$

Standard error of estimate: $\pm 20\%$

Average species composition:

tA 28%
wP 23%
rP 17%
wB 10%
bF 5%
other softwoods 12%
other hardwoods 5%

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