**United States
Department of
Agriculture**

Forest
Service

North Central
Forest Experiment
Station

Research
Paper **NC-222**

[illegible]

Volume Tables for Second-Growth Northern Hardwood Forests in Northeastern Wisconsin

Gayne G. Erdmann, Thomas R. Crow, and Robert R. Oberg

SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH
SUGAR MAPLE YELLOW BIRCH BASSWOOD WHITE ASH

North Central Forest Experiment Station
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108
Manuscript approved for publication June 18, 1982
1982

VOLUME TABLES FOR SECOND-GROWTH NORTHERN HARDWOOD FORESTS IN NORTHEASTERN WISCONSIN

Gayne G. Erdmann, *Silviculturist,*
Thomas R. Crow, *Principal Research Ecologist,*
and
Robert R. Oberg, *Forestry Research Technician,*
Marquette, Michigan

This paper presents formulas for determining the peeled cubic-foot volume of four important northern hardwood species: sugar maple (*Acer saccharum* Marsh.), American basswood (*Tilia americana* L.), yellow birch (*Betula alleghaniensis* Britton), and white ash (*Fraxinus americana* L.). Factors for converting cubic volume to board-foot and cordwood volumes are also provided. The equations are useful for quick estimates of volumes in even-aged, second-growth, northern hardwood stands in northeastern Wisconsin. Only a tree list by species and d.b.h. class is required when using our formulas, and no corrections are needed for differences in form quotient, bark volume, and species taper.

STUDY AREA

Measurements were taken from 125 trees in three 40-acre second-growth northern hardwood stands on the Argonne Experimental Forest in northeastern Wisconsin. The stands are primarily even-aged but have some scattered residuals left from the commercial clearcutting days. Two stands averaged 60 years in age. The third stand was about 70 years old and contained a higher proportion of small saw log trees.

The uncut portions of these three stands contained 483 trees 4.6 inches d.b.h. and larger per acre of which 64 percent were sugar maple, 13 percent basswood, 4 percent yellow birch, and 5 percent white ash. Other species included: hemlock (*Tsuga canadensis* (L.) Carr.), red maple (*Acer rubrum* L.), American elm (*Ulmus americana* L.), paper birch (*Betula papyrifera* Marsh.), black cherry (*Prunus serotina* Ehrh.), aspen (*Populus* spp.), and eastern hophornbean (*Ostrya virginiana* (Mill) K. Koch). Basal area stocking of all trees 4.6 inches d.b.h. and over averaged 129 square feet per acre. The stands also probably contained another 8 to 10 square feet per acre of basal area in saplings.

Site indices based on stem analysis were 65 feet at reference age 50 years for sugar maple and yellow birch and about 70 feet for basswood and white ash in the three stands. The stands are growing on a broad, level to gently rolling ridgetop, in coarse loamy Alfic Fragoithod soils primarily of the Iron River series. However, some small areas with thin sand and gravel layers in the substratum classify as Stambaugh. Small boulders are common on the surface and throughout the profile. Growing-season precipitation averages about 20 inches, but droughty periods are common in July and August.

METHODS

Fifty sugar maples, 34 basswoods, 26 white ashes, and 15 yellow birches, ranging from 4.6 to 20.0 inches d.b.h., were randomly selected from the three stands for constructing cubic-foot volume, cordwood volume, and Scribner board-foot volume tables. Most data were obtained from felled and sectioned trees, but some measurements were taken on a few large-diameter trees by using Swedish climbing ladders and bark gauges at the required sectioning points. Measurements for cubic-foot volumes included: diameters inside bark (d.i.b.) and outside bark (d.o.b.), bark thicknesses from a 1-foot stump to a 4.0-inch top at 8.3-foot intervals, and total tree heights to the nearest foot. Bark thickness was determined to the nearest 0.1 inch by taking four measurements at right angles on cross-sectional discs from the end of each section. In addition, measurements on saw log trees (9.6 inches d.b.h. and larger) included those needed to compute Scribner board-foot volumes to a variable merchantable top diameter that was limited by branches, defect, or other deformity, but not less than an 8.0-inch d.i.b. top. Cull volume was not estimated. Total cubic-foot volumes inside bark were computed for each tree over 4.6 inches d.b.h. using Smalian's formula for the stump, the stem in 8.3-foot (100-inch) lengths to a variable top d.i.b. of not less than 4.0 inches, the tip, and the branches to a 4.0-inch d.i.b. top.

Using Spurr's (1954) volume-line method, we constructed separate cubic-foot volume tables for sugar maple, basswood, yellow birch, and white ash (table 1). The sugar maple volume-line equations in table 2 were also used for calculating cubic-foot volumes of other less commonly associated species such as red maple and American elm. Merchantable cordwood and board-foot volumes can be derived from the total cubic-volume estimates by using appropriate converting factors for mean stand diameters (tables 3, 4, and 5). A cord was assumed to contain 79 cubic feet of solid wood in our cordwood computations.

EXAMPLE

For a simple example, we will use a 1-acre pure sugar maple stand containing only pulpwood and small saw log trees. The first step is to construct a stand table listing the number (N) of trees of each species by breast height diameter (D) classes. We usually separate the diameter classes into economic groupings for pulpwood-size trees (5- to 9-inch), small saw log trees (10- to 15-inch), and large saw log trees (over 16 inches).

The next step is to select the appropriate (sugar maple) volume-line equation for computing the total cubic-foot volume in pulpwood and small saw log trees (table 2).

$$V = -1.4702\,(N) + 0.1848\,(D^2N)$$

Then substitute the proper values for (N) and (D^2N) from the stand table (subtotal) summary into the formula for:

Volume in pulpwood trees

$V = -1.4702\,(144) + 0.1848\,(7{,}121) = 1{,}104$ cubic feet

Volume in saw log trees

$V = -1.4702\,(94) + 0.1848\,(13{,}764) = 2{,}405$ cubic feet

Table 1.—*Gross cubic-foot (peeled) volume in the entire stem of 60- to 70-year-old second-growth northern hardwoods on site index 65 land in northeastern Wisconsin*[1]

D.b.h. (inches)	Species Sugar maple	Basswood	White ash	Yellow birch
	Cubic feet			
5	3.2	2.5	2.6	4.4
6	5.2	4.6	4.6	6.3
7	7.6	7.1	7.0	8.5
8	10.4	10.0	9.8	11.1
9	13.5	13.3	12.9	14.1
10	17.0	17.0	16.3	17.4
11	20.9	21.1	20.2	21.1
12	25.1	25.6	24.4	25.1
13	29.8	30.4	29.0	29.4
14	34.8	35.7	33.9	34.1
15	40.1	41.3	39.2	39.2
16	45.8	47.3	44.9	44.6
17	51.9	53.7	50.9	50.3
18	58.4	60.5	57.3	56.4
19	65.2	67.7	64.1	62.9
20	72.4	75.3	71.2	69.7
21	80.0	83.2	78.7	76.8
22	88.0	91.6	86.6	84.3
23	96.3	100.3	94.8	92.1
24	105.0	109.5	103.4	100.3
25	114.0	119.0	112.4	108.9

[1] The entire stem plus all merchantable branchwood (to a variable top d.i.b. of not less than 4.0 inches and a minimum length of 100 inches) is included.

Thus, we calculate 1,104 cubic feet in pulpwood trees and 2,405 cubic feet in saw log trees, giving a gross peeled total cubic-foot volume of 3,509 cubic feet in this 1-acre stand. If total cubic-foot or cordwood volume estimates are needed, we can use the total (N) and (D^2N) values from the stand table summary to obtain the same results:

Volume in entire stand

$V = -1.4702\,(238) + 0.1848\,(20{,}885) = 3{,}509$ cubic feet.

Because $BA = D^2N \times 0.005454$, volume-line equations can also be expressed in terms of N and BA (table 2). For example, the equation for sugar maple, $V = 1.4702\,(N) + 0.1848\,(D^2N)$ would then be $V = 1.4702\,(N) + 33.88\,(BA)$. This form is ideal for a prism cruise in which BA and N are tallied by species. N and BA could be for the entire diameter range, could be divided into economic size classes (pulpwood, saw log), or could be the amount of wood to be removed in a sale.

Sugar Maple Stand Tables

Group	Diameter	D^2	Trees	D^2N	Total basal area ($BA = D^2N \times 0.005454$)
	Inches		*Number/acre*		
Pulpwood trees	5	25	38	950	5.2
	6	36	29	1,044	5.7
	7	49	23	1,127	6.1
	8	64	22	1,408	7.7
	9	81	32	2,592	14.1
		Subtotal	144	7,121	38.8
Small saw log trees	10	100	26	2,600	14.2
	11	121	18	2,178	11.9
	12	144	15	2,160	11.8
	13	169	12	2,028	11.1
	14	196	13	2,548	13.9
	15	225	10	2,250	12.3
		Subtotal	94	13,764	75.2
Total			238	20,885	114.0

Table 2.—*Total cubic-foot (peeled) volume formulas for the entire stems of 60-year-old second-growth northern hardwoods on site index 65 land for sugar maple at reference age 50*[1]

Species	Volume-line equations for a stand of trees[2]		Basis
			No. of trees
Sugar maple	$V = -1.4702\,(N) + .1848\,(D^2N)$	$V = -1.4702\,(N) + 33.88\,(BA)$	50
Basswood	$V = -2.3942\,(N) + .1942\,(D^2N)$	$V = -2.3942\,(N) + 35.61\,(BA)$	34
White ash	$V = -1.9425\,(N) + .1829\,(D^2N)$	$V = -1.9425\,(N) + 33.53\,(BA)$	26
Yellow birch	$V = -0.0045\,(N) + .1742\,(D^2N)$	$V = -0.0045\,(N) + 31.94\,(BA)$	15

[1] SI_{50} also 65 for yellow birch and about 70 for basswood and white ash.
[2] After Spurr's (1954) volume-line method.

Board-foot and cordwood volumes can be estimated by applying the proper conversion factors (from tables 3, 4, and 5) to the cubic-foot volumes for a specific mean stand diameter. Mean stand diameter is found by taking the square root of the sum of the products of D^2N divided by N from the stand table subtotals. Thus, the mean diameter for the pulpwood portion of the sugar maple stand is $\sqrt{\frac{7,121}{144}} = 7.0$ inches, while the saw log portion is $\sqrt{\frac{13,764}{94}} = 12.1$ inches. The mean diameter for the entire stand is $\sqrt{\frac{20,885}{238}} =$ 9.4 inches.

From table 3 we get a converting factor of 0.0099 for a pulpwood portion of the stand with a mean diameter of 7 inches. The cordwood volume for this portion of the stand is estimated by multiplying the total cubic-foot volume of 1,104 by 0.0099, resulting in 10.9 cords. Following the same procedures for the saw log portion of the stand with 12.1-inch average diameter, we get a 0.0107 converting factor and (0.0107 x 2,405 cubic feet) a 25.7 cord estimate, making a total stand estimate of 36.6 cords. Using 9.4 as the mean diameter of the entire stand and a 0.0105 converting factor with 3,509 cubic feet, we get an estimate of 36.8 cords—essentially the same amount we found by breaking the stand down into pulpwood and saw log components.

Table 3.—*Factors to convert total cubic-foot (peeled) volumes to peeled* cordwood volumes[1]

Mean stand d.b.h. (inches)	Species			
	Sugar maple	Basswood	White ash	Yellow birch
	Converting factors			
5	0.0077	0.0077	0.0077	0.0056
5.5	.0085	.0084	.0085	.0074
6	.0094	.0088	.0091	.0084
6.5	.0097	.0092	.0096	.0091
7	.0099	.0095	.0100	.0096
8	.0103	.0101	.0105	.0103
9	.0105	.0105	.0106	.0105
10	.0106	.0110	.0107	.0105
11	.0107	.0112	.0109	.0106
12	.0107	.0115	.0110	.0106
13	.0108	.0115	.0111	.0107
14	.0109	.0116	.0112	.0107
15	.0110	.0117	.0113	.0108
16	.0111	.0118	.0114	.0109
17	.0112	.0119	.0115	.0109
18	.0113	.0119	.0016	.0110
19	.0114	.0120	.0116	.0110
20	.0115	.0120	.0116	.0110

[1] Minimun top d.i.b. of 4.0 inches and minimum length of 8.3 feet (100 inches).

The converting factors in table 4 are handled like those in table 3. Thus, our 12.1-inch saw log stand would contain (0.0018 x 2,405 cubic feet) about 4.3 cords in peeled cordwood above an 8.0-inch d.i.b. top and in branchwood up to a minimum diameter of 4.0 inches d.i.b. and a minimum length of 8.3 feet.

Table 4.—*Factors to convert total cubic-foot (peeled) volumes above an 8-inch d.i.b. top on saw log trees to peeled cordwood volumes*[1]

Mean stand d.b.h. (inches)	Species			
	Sugar maple	Basswood	White ash	Yellow birch
	Converting factors			
10	0.0042	0.0050	0.0054	0.0040
10.5	.0036	.0041	.0043	.0032
11	.0030	.0033	.0035	.0025
11.5	.0025	.0027	.0031	.0021
12	.0018	.0023	.0028	.0019
12.5	.0013	.0021	.0027	.0018
13	.0010	.0019	.0027	.0016
14	.0008	.0017	.0025	.0013
15	.0007	.0014	.0023	.0011
16	.0006	.0012	.0020	.0010
17	.0007	.0011	.0018	.0008
18	.0010	.0010	.0017	.0008
19	.0018	.0010	.0016	.0008
20	.0028	.0010	.0015	.0008

[1] Minimun top d.i.b. of 4.0 inches and minimum length of 8.3 feet. Stem branchwood included.

Table 5.—*Factors to convert total cubic-foot (peeled) volumes to Scribner board-foot volumes*[1]

Mean stand d.b.h. (inches)	Species			
	Sugar maple	Basswood	White ash	Yellow birch
	Converting factors			
10	1.7	1.4	1.3	2.1
10.5	2.3	2.1	2.2	2.5
11	2.8	2.6	2.7	2.7
11.5	3.2	2.9	3.0	2.9
12	3.5	3.2	3.3	3.1
12.5	3.7	3.5	3.4	3.2
13	3.9	3.7	3.5	3.4
14	4.2	3.9	3.7	3.6
15	4.4	4.1	3.9	3.8
16	4.6	4.3	4.0	3.9
17	4.7	4.4	4.1	4.0
18	4.8	4.5	4.2	4.1
19	4.8	4.6	4.3	4.2
20	4.6	4.7	4.4	4.3
(No. of trees)	(50)	(34)	(26)	(15)

[1] Minimun top d.i.b. of not less than 8.0 inches but variable depending on branches, defect, or other deformity that limited merchantable height.

Finally, our 12.1-inch saw log portion of the stand contains 8,417 board feet (gross Scribner), which is obtained by multiplying the 3.5 (conversion factor from table 5) by 2,405 cubic feet.

APPLICABILITY

These tables give better estimates in our study area than the composite volume tables of Gevorkiantz and Olsen (1955). Their tables have wide applicability but are commonly misused because corrections for differences in form class, bark thickness, and taper are often not applied when needed. Our tables do not have to be adjusted for these factors. Our tables and formulas are useful for estimating standing volumes and volumes to be removed in 60- to 70-year-old second-growth stands that have heavy proportions of sugar maple on similar sites (65 at 50 years for sugar maple) in northeastern Wisconsin. However, Gevorkiantz and Olsen (1955) have a better data base for applying their tables to large areas of the Lake States. Hahn (1973) also has developed a separate set of local tree volume equations for different species groups in Wisconsin.

Our formulas are very useful for quick estimates of cordwood volumes to be removed in sugar maple firewood sales. All that is required from the field is a stand table summary listing by full-inch diameter classes the number (N) of trees to be removed. Merchantable or total heights do not need to be measured because they were taken into account in developing the equations.

LITERATURE CITED

Gevorkiantz, S. R.; Olsen, L. P. Composite volume tables for timber and their application in the Lake States. Tech. Bull. 1104. Washington, D.C.: U.S. Department of Agriculture; 1955. 51 p.

Hahn, Jerold T. Local net timber volume equations for Wisconsin. Res. Note NC-149. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1973. 4 p.

Spurr, S. H. Simplified computation of volume growth. J. For. 52: 914-922; 1954.

Erdmann, Gayne G.; Crow, Thomas R.; Oberg, Robert R.
Volume tables for second-growth northern hardwood forests in northeastern Wisconsin.Research Paper NC-222. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1982. 5 p.

Cubic-foot volume equations are presented for sugar maple, basswood, yellow birch, and white ash. Conversion factors for board-foot and cordwood volumes are also provided. The equations are useful for even-aged, second-growth hardwoods in northeastern Wisconsin.

KEY WORDS: sugar maple, yellow birch, American basswood, white ash, cubic volume, board-foot, cordwood.

U.S. GOVENRMENT PRINTING OFFICE:1982-665-447/158