Measuring Woodland Timber

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Forest products, like other agricultural commodities, must be measured before they are sold. Few woodland owners, however, understand the reasons for or the methods of measuring woodland timber. Timber volume information benefits both the seller and buyer. Being knowledgeable about timber volumes, the seller is more likely to receive full value for his/her trees and the buyer will know approximately what to bid or offer for the timber being sold.

It is also important to know the volume sold after a timber sale. Accurate sale information will help in the preparation of federal income tax returns, especially when taking advantage of the timber tax depletion.

Another advantage of measuring timber is for recordkeeping or inventory purposes. Knowing the volume of timber in a forest stand is important in settling possible casualty losses by fire or timber theft. Knowledge of timber volumes is also important to establish a forest management plan on woodland property.

This fact sheet is designed to familiarize woodland owners about the methods used to measure merchantable volumes of timber on their property. The information presented is useful for measuring a small number of trees. To account for stumpage volumes on a large woodland area a forest inventory would be conducted by a sampling technique. For more information about forest inventories see page 6 of this fact sheet.

Volume Measurement

The first steps involved in estimating tree volume include measuring the tree diameter and the tree height.

Diameter Measurement

The most frequent tree measurement made by foresters is diameter at breast height (DBH). DBH is defined as the stem diameter, outside bark, at a point taken 4.5 feet above the ground. Care should be exercised to measure trees exactly at DBH. Trees growing on slopes should be measured from the uphill side of the tree.

Direct measurements of DBH are usually made with a diameter tape, tree caliper, or Biltmore stick. These instruments, collectively, are referred to as dendrometers. Individuals lacking a dendrometer can easily calculate the diameter of a tree by dividing the circumference by 3.14. For example, a tree with a circumference of 40 inches at DBH would have diameter of approximately 13 inches (40 ÷ 3.14 = 12.74). Diameters should be rounded to the nearest inch. As an example, trees measuring 8.6 inches to 9.5 inches are considered to have a DBH of nine inches.

Measuring Height

The merchantable height of timber refers to the usable portion of the tree stem. This is the part of the tree for which volume is computed or the section expected to be utilized by a logging operation. It is measured from a stump height of one foot to a point on the stem where the diameter is too small to obtain a particular product. The product being cut and the tree species determine the merchantable height. Normally for sawlog products the minimum "top diameter" is where the tree tapers to 8 inches for pine and 10 inches for hardwood. Often, however, the merchantable height for sawlogs is determined by branches, crook, or defect rather than minimum top diameter.

Instruments used for measuring tree heights are collectively referred to as hypsometers. A Biltmore stick has a type of hypsometer used to estimate the number of merchantable logs in a tree. When measuring tree height with a Biltmore stick, the observer stands 66 feet away from the tree and holds it 25 inches away from his/her eye. The very bottom of the stick is aligned with a one foot stump of the tree. Once aligned with the stump, the observer sites through the stick to align the number of logs with the merchantable height of the tree. The number of logs is then read directly from the Biltmore stick. Figure 1 shows the correct way to use a Biltmore stick to measure the merchantable height of a tree.

A more sophisticated type of hypsometer, which many foresters use, is called a clinometer. The clinometer operates on the same principle as the Biltmore stick, but yields height readings directly in feet. For measuring small trees, a woodland owner could use an accurately measured pole graduated in one foot intervals to measure merchantable tree height. This pole, stood alongside the tree, will help a woodland owner estimate the height of merchantable timber in a tree.

Once diameter and height measurements are collected, they are used with a volume table to estimate the volume of the standing tree. Tables 2 through 5 are various volume tables used in Oklahoma to estimate the volume of a standing tree. The following information presents some examples on how to use a volume table.

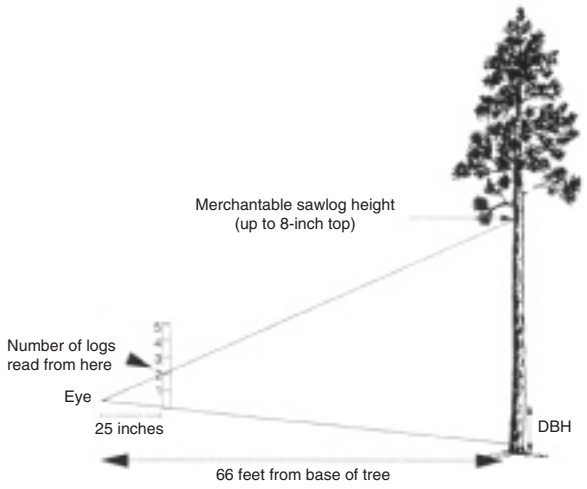


Figure 1. Using a Biltmore stick to measure merchantable height.

Unit Measurements

The unit of measurement used to determine merchantable timber usually depends on the product to be manufactured from the tree. Board foot, cubic foot, cord, and ton (weight) are common measurement units. Each unit can be estimated with a reasonable degree of accuracy with practice and by following the guidelines outlined below.

Board Foot

The board foot is equivalent to a plank one inch thick and 12 inches square (Figure 2). In the United States, the most common way to describe a volume of roundwood/timber is in units of 1,000 board feet (MBF). MBF defines the amount of roundwood which would produce, after all sawing operations, 1,000 board feet of lumber. As an example, 5,000 board feet of timber would be denoted as five MBF. However, the concept of measuring raw material (trees) in terms of a manufactured product (lumber) has led to problems because the board foot can be an ambiguous and inconsistent unit due to:

- variability of logs,
- efficiency of sawmills and their operators, and
- differences in dimensions of lumber which may be produced from a log.

Nevertheless, the board foot continues to be used to estimate standing tree volumes because people have used it in the past and they are resistant to change and because it is a logical unit of measurement for sawn lumber.

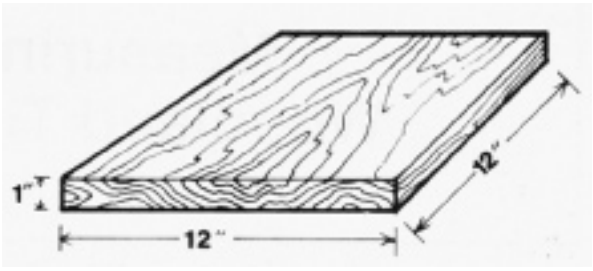


Figure 2. One board foot.

Estimating Board Feet. To predict volume from diameter and height measurements, the amount of taper a tree has must be taken into consideration. Mathematical formulas are used to assess tree taper. Due to the variability in tree form among tree species, in the United States standing trees and logs are bought and sold by approximately 100 different formulas used to determine volume. These formulas produce tree scales and log rules with varying degrees of accuracy. Three of the most common log rules used in the United States are the Doyle, Scribner, and International. Table 1 compares these log rules with respect to volume estimation of various log sizes. Some states, by law, specify which scales or rules are recognized as official mediums of exchange. However, this is not the case in Oklahoma.

Table 1. Comparison of board foot log rules for 16-foot logs.

Log Diameter	Log Rule		
	International	Scribner	Doyle
(inches)		(board feet)	
8	40	32	16
12	95	79	64
16	180	159	144
20	290	280	256
24	425	404	400
28	585	582	576
32	770	736	784
36	980	923	1,024

Source: T. Eugene Avery, Forest Measurements, 1967.

The Doyle log rule is the most commonly used rule in Oklahoma. However, it is well known that this rule underscales tree diameters below 28 inches and overscales diameters larger than 28 inches. The occasional seller of sawlogs, unaware of this fact, may place himself at a disadvantage when selling timber.

Two board foot volume tables using the Doyle rule for standing trees are included for use in Oklahoma. Table 2 should be used for stream bottom hardwoods found in central Oklahoma. Stream bottom hardwoods are defined as naturally mixed stands of hardwood trees growing in a river bottom. Table 3 should be used for both pines and hardwoods that are found in eastern Oklahoma. Merchantable sawtimber is expressed in 16-foot log increments. Measurements should be rounded to the nearest half log (8-foot increments).

Example: In Table 2, find the diameter of the tree in the left-hand column and move across to the column headed by number of 16-foot logs. A bottomland hardwood with an 18-inch DBH, in central Oklahoma, with 1 1/2 merchantable logs contains 161 board feet. As computed by Table 3, a pine tree with a DBH of 20 inches, in southeastern Oklahoma, with two merchantable logs contains 225 board feet.

Cubic Foot

Cubic volume is a more accurate and logical method of determining tree volumes. A cubic foot is an amount of wood equivalent to a solid cube where width, length, and height measurements all equal 12 inches (12-x 12 x 12 inches). There have been numerous attempts to promote the cubic foot as the national log scaling unit for sawtimber in the United States. The cubic foot is a clearly defined measurement that has the advantages of being independent of utilization stan-

Table 2. Standing tree board foot volumes for stream bottom hardwoods in central Oklahoma (Doyle Rule).

DBH*	Number of 16-foot Logs				
(inches)	1/2	1	1 1/2	2	2 1/2
12	18	51	72	97	127
13	26	60	86	112	143
14	34	70	100	128	159
15	42	80	114	145	178
16	51	91	129	163	197
17	59	102	145	181	219
18	67	114	161	201	242
19	76	126	178	222	266
20	85	139	195	243	292
21	94	152	213	266	320
22	103	166	231	289	349
23	112	180	250	314	379
24	121	194	270	339	411
25	130	209	290	366	445
26	140	225	311	393	480
27	149	241	332	421	517
28	159	258	354	451	555
29	169	275	377	487	595
30	179	292	400	512	636
31	189	310	424	544	679
32	199	328	448	577	724
33	209	347	473	612	769

Source: "A Volume Table for Central Oklahoma Stream Bottom Hardwoods" by D.W. Robinson and D.L. Weeks, Bulletin B-662, November, 1968.
* Diameter Breast High: 4 1/2 feet from ground.

Table 3. Standing tree board foot volumes for sawtimber in eastern Oklahoma (Doyle Rule).

DBH*	Number of 16-foot Logs						
(inches)	1	1 1/2	2	2 1/2	3	3 1/2	4
10	14	17	20	21	22		
11	22	27	32	35	38		
12	29	36	43	48	53	54	56
13	38	48	59	66	73	76	80
14	48	62	75	84	93	98	103
15	60	78	96	108	121	128	136
16	72	94	116	132	149	160	170
17	86	113	140	161	182	196	209
18	100	132	164	190	215	232	248
19	118	156	194	225	256	276	297
20	135	180	225	261	297	322	346
21	154	207	260	302	344	374	404
22	174	234	295	344	392	427	462
23	195	264	332	388	444	483	522
24	216	293	370	433	496	539	582
25	241	328	414	486	558	609	660
26	266	362	459	539	619	678	737
27	292	398	505	594	684	749	814
28	317	434	551	650	750	820	890
29	346	475	604	714	824	902	980
30	376	517	658	778	898	984	1,069

Form Class 78.
Source: U.S. Forest Service.
* Diameter Breast High: 4 1/2 feet from ground.

dards, manufacturing efficiencies, and final product utilization (unlike the board foot measurement).

Pine pulpwood stumpage volumes in Oklahoma are often measured in cubic foot units. Table 4 shows cubic foot volume for pine in Oklahoma. Merchantable tree heights for pulpwood should be estimated to a top diameter of four inches. Logs less than eight feet in length are called sticks or bolts. Merchantable pulpwood tree heights are recorded in four-foot sticks and measurements should be rounded to the nearest four-foot stick.

Example: In Table 4, find the diameter of the tree in the left-hand column and move across to the column headed buy tree height to a four-inch top. A 10-inch diameter tree with 28 merchantable feet (7 sticks) would contain 9.5 cubic feet.

Cord

A standard cord of wood measures four feet high, four feet wide, and eight feet long and occupies 128 cubic feet of space (Figure 3). Since this 128 cubic feet includes wood, bark, and air pockets, the cord is more an indication of space occupied than actual solid wood measure. Ninety cubic feet of solid wood and bark in a standard rough cord is an average figure for southern pine (80 cubic feet of solid wood). Cubic foot volumes in Table 4 can be converted to cords by dividing volume by 90.

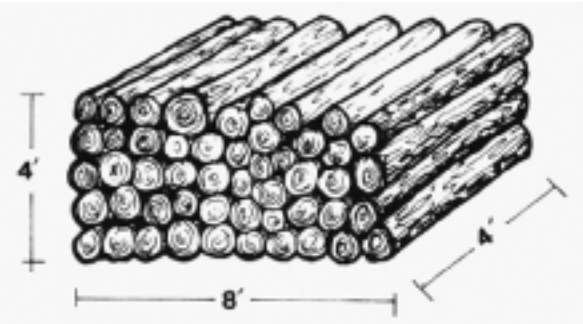


Figure 3. A cord is a standard measure 4' x 4' x 8'.

Example: The above example shows that a 10-inch diameter tree with a merchantable height of 28 feet would contain 9.5 cubic feet (Table 4). Dividing 9.5 cubic feet by 90 cubic feet per cord gives 0.105 cords of wood and bark in the tree.

In Oklahoma, as required by state regulation, firewood must be sold by the cubic foot or cord or fraction of a cord. Table 5 provides an estimate of the number of cords of firewood in hardwood trees. The table was designed to be used in measuring groups of trees. Accuracy decreases when only a few trees are measured. Height measurements for Table 5 should be made to a four-inch top diameter.

Example: In Table 5, find the diameter of the tree in the left-hand column and move across to the column headed by tree height to a four-inch top. A 16-inch diameter oak tree with height of 40 feet to a four-inch top would contain (approximately) 0.38 cords of firewood.

Weight Measurement

Measuring wood by weight has gained popularity in Oklahoma and throughout the U.S. Wood used to be measured in the forest; measurements are now being made at mill sites or wood concentration yards. This method of measurement is more convenient for the timber industry. Table 6 provides a method of converting standing timber to merchantable green weight for loblolly and shortleaf pine. A log is 16 feet in length and merchantable top diameter is six inches for Table 6.

Example: In Table 6, find the diameter of the tree in the left-hand column and move across to the column headed by 1 to 4 log tree(s). An 18-inch diameter shortleaf pine with two merchantable logs contains 1.05 tons of merchantable green weight, including bark.

It should be noted that different species of trees will have different weights per unit. Green weight is a measure of wood weight that includes moisture content. To make this more clear, the green weight of a log is its weight immediately after it has been removed from the stump. Moisture contents among trees vary considerably. Sapwood moisture contents range

Table 4. Cubic foot volume table (including bark) for southern pine.

DBH*	Tree Height (feet) to a 4-inch top													
(inches)	12	16	20	24	28	32	36	40	44	48	52	56	60	64
5	1.2	1.6	2.0	2.4	2.8	–	–	–	–	–	–	–	–	–
6	1.6	2.2	2.7	3.2	3.8	4.3	4.8	–	–	–	–	–	–	–
7	2.1	2.8	3.6	4.3	5.0	5.7	6.4	7.1	–	–	–	–	–	–
8	2.3	3.6	4.6	5.5	6.4	7.3	8.3	9.1	10.1	11.0	–	–	–	–
9	–	4.5	5.7	6.8	8.0	9.1	10.2	11.3	12.5	13.6	14.7	–	–	–
10	–	–	6.8	8.2	9.5	10.8	12.3	13.6	14.9	16.3	17.7	19.0	20.4	–
11	–	–	–	9.6	11.6	12.8	14.4	16.0	17.6	19.2	20.8	22.4	24.0	25.6
12	–	–	–	11.2	13.0	14.9	16.7	18.6	20.5	22.3	24.2	26.0	27.9	29.8

Source: U.S. Forest Service.
Odd diameters calculated.
* Diameter Breast High: 4 1/2 feet from ground.

Table 5. Firewood cord volumes in hardwood trees.

DBH*	Tree Height (feet) to a 4-inch top								
(inches)	10	20	30	40	50	60	70	80	90
6	.02	.03	.05	.06	.07	.09	–	–	–
8	.03	.05	.08	.10	.12	.14	.16	.19	–
10	–	.08	.12	.15	.18	.21	.25	.28	.31
12	–	–	.17	.22	.27	.32	.37	.42	.47
14	–	–	.22	.29	.36	.43	.50	.56	.63
16	–	–	–	.38	.46	.55	.64	.73	.81
18	–	–	–	.47	.58	.69	.80	.91	1.02
20	–	–	–	.58	.71	.84	.98	1.11	1.24
22	–	–	–	.69	.85	1.01	1.17	1.33	1.49
24	–	–	–	.81	1.00	1.20	1.38	1.57	1.76

Hardwood trees with deliquescent crown such as oaks, hickories, and elms.
Volume of wood in firewood 4 inches in diameter outside bark and larger in the main stem and braches (total tree).
Source: Clark, Curtis, and Darwin 1981.
* Diameter Breast High: 4 1/2 feet from ground.

Table 6. Merchantable green weight (including bark) of loblolly and shortleaf pine stems.

	Number of 16-foot Logs to a 6-inch Top Diameter			
	1	2	3	4
DHB* (inches)	Tons			
10	.16	.35	.48	–
12	.21	.48	.69	–
14	.28	.65	.93	1.15
16	–	.83	1.19	1.54
18	–	1.05	1.51	1.95
20	–	1.30	1.78	2.38

Trees were cut in north Louisiana and south Arkansas.
Form class 66, 77, 79, and 81, respectively for 1, 2. 3, and 4 log tree.
Source: Seigel and Row 1960.
* Diameter Breast High: 4 1/2 feet from ground.

Where Can I Get Forestry Equipment?

Forestry equipment may be borrowed from your local service forester or purchased from a forestry supply company. The phone numbers for the two major suppliers of forestry equipment are:

Forestry Suppliers	800-647-5368
Ben Meadows Company	800-241-6401
Logger's and Forestry Supplies	800-592-6940

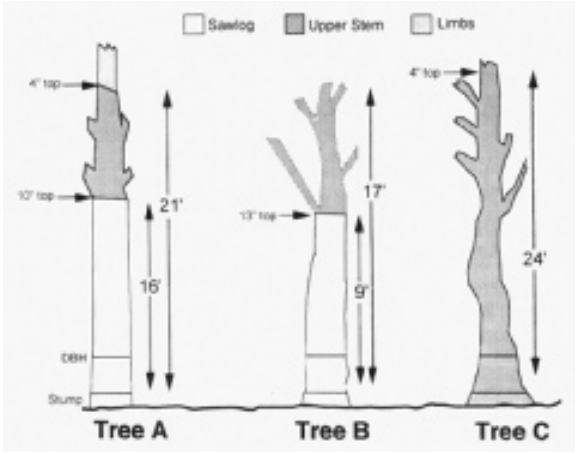
What is a Sawtimber Tree?

For hardwood sawtimber, the merchantable height diameter of the tree is often determined by tree form. Some examples of typical tree forms that may be encountered during height measurement are discussed below. Sections in the diagrams designated as upper stem refer to portions of the tree unsuitable for sawlogs, but usable for lower-grade products, such as fence posts or pulpwood.

A. Sawtimber tree. Sawlog determined by minimum top diameter of 10 inches. Sawlog material from this tree would consist of one 16-foot log.

B. Sawtimber tree. Sawlog portion of tree determined by lower branches and limbs at a diameter of 13 inches, rather than minimum top diameter of 10 inches. The sawlog portion of this tree would consist of one nine-foot log. (For using the table this would be 1/2 log.)

C. Rough tree. No sawlogs exist in this tree. This can be attributed to the trees poor form and numerous limbs.



from 44 to 137 percent and 110 to 249 percent for hardwoods and softwoods, respectively. Moisture content can be more than 100 percent because the weight of the water is divided by the oven-dried weight of the wood, rather than total wood weight. The formula is expressed as follows:

$$\% \text{ moisture content} = \frac{\text{weight of water}}{\text{oven-dried weight}} \times 100$$

Example: If a block of wood had a green weight of 45 pounds and an oven-dried weight of 20 pounds, the moisture content (m.c.) would be 125 percent and calculated as follows:

$$\% \text{ m.c.} = \frac{\text{green weight - oven-dried weight}}{\text{oven-dried weight}} \times 100 =$$

$$\frac{45\text{-}20}{20} \times 100 = 125\%$$

Table 7 displays the green weight of some tree species (based on 12-inch diameter green logs) in Oklahoma.

Table 7. Green tree weights per standard cord and per MBF Doyle log scale. Cordwood estimates are based on 80 cubic feet of solid wood per cord.

Species	Doyle (Pounds/MBF)	Cord (Pounds)
Ash	10,250	4,150
Elm	10,800	4,400
Oak, Red	13,550	5,500
Oak, White	14,350	5,850
Pine, Loblolly	10,600	4,300
Pine, Shortleaf	10,500	4,300
Sycamore	13,050	5,300
Walnut, Black	12,100	4,900

Table 8. Conversion factors among units of wood volume measurement.

Pine	Hardwood
2.8 cords/MBF	3 cords/MBF
7.5 tons/MBF	8.75 cords/MBF
162 FT^3/MBF	162 FT^3/MBF

Source: Timber-Mart South.

A Word About Forest Inventories

For large woodland areas, it may not to be economically feasible to measure all the merchantable trees on the property. Furthermore, the time involved to count and measure every tree would be enormous. These two factors alone dictate that some form of sampling is required to assess the stumpage volume of a large woodland.

A common forest inventory sampling procedure involves randomly placing measuring points (plots) throughout the area to be assessed. At these points, all the trees that meet specified criteria (such as diameter and species) and fall within plot boundaries are measured. The merchantable volume for the trees measured is then calculated. Volume estimates are expanded to account for the merchantable timber of the entire population of trees. If a timber sale is to be conducted, the volume estimates are provided to possible buyers so that they can make a bid to purchase the timber.

For woodland owners who are interested in managing their property, a forest inventory is a good first step. However, it is unlikely that most forest landowners are skilled enough to conduct an accurate forest inventory. In Oklahoma, several consulting foresters are available to assist landowners who want to conduct an inventory of woodland property. For a list of consulting foresters and other natural resource professionals, contact your local county extension office.

Additional References

For more information, read the following OSU Extension forestry fact sheets:

NREM-5015 Farm Woodland Improvement
NREM-5028 Even and Uneven - Aged Forest Management
NREM-5030 Tree Improvement in Oklahoma Woodlands
NREM-5033 Agroforestry Alternatives
NREM-5034 Riparian Forest Buffers

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