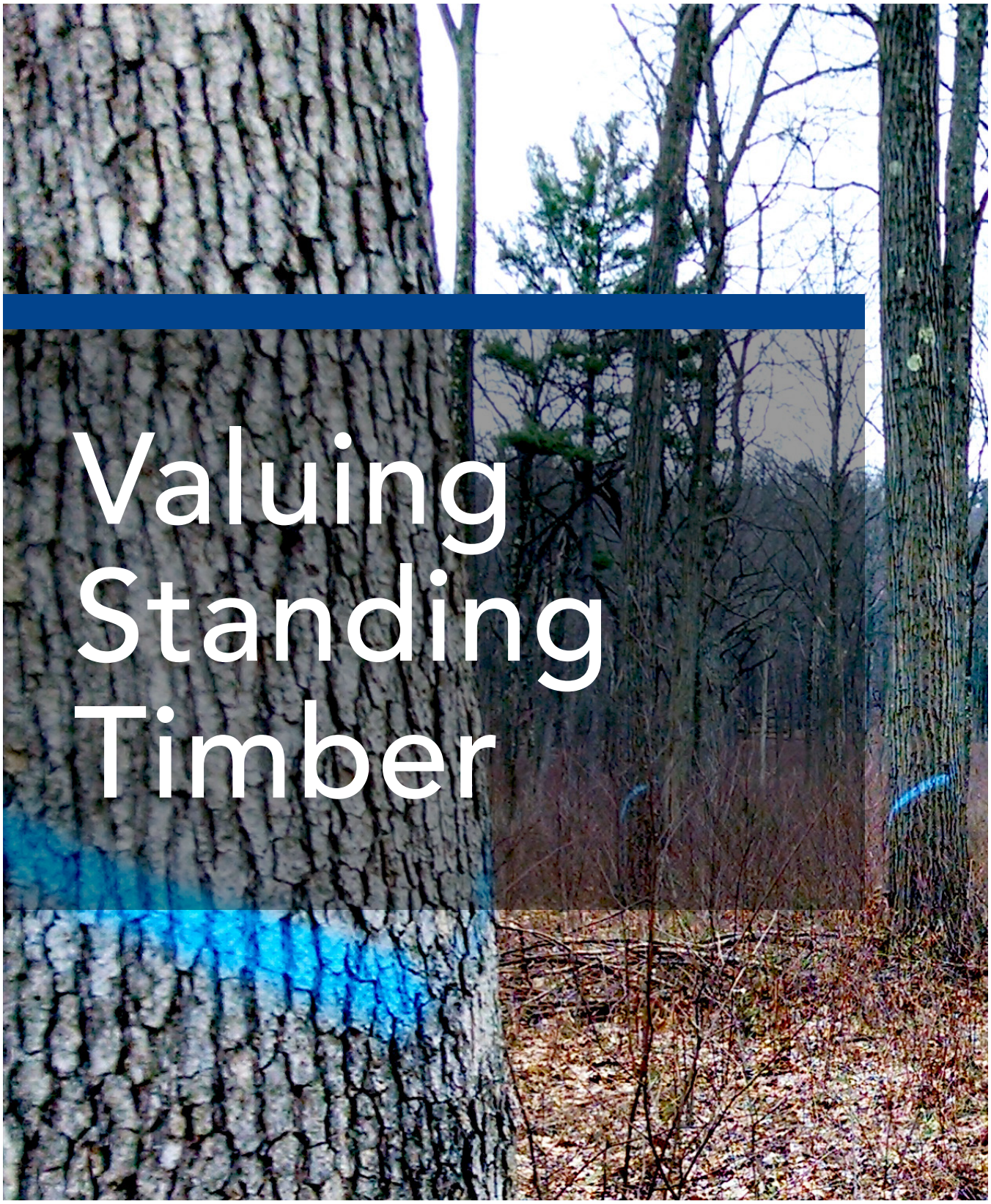


Valuing Standing Timber

PennState Extension

Introduction

This publication is designed to:

- Make landowners and loggers aware of the economic value of timber and how that value is determined
- Increase opportunities for obtaining fair market price when selling timber
- Describe simplified methods by which reasonable estimates of timber volumes and values can be obtained

Pennsylvania has a large timber resource. Nearly 60 percent of the state is forested, accounting for almost 17 million acres, much of it over 100 years old and in large diameter size classes. Pennsylvania's forests are dominated by world-class, high-quality hardwood tree species such as oak, cherry, and maple. Most of this forestland is privately owned nonindustrial, nearly 70 percent or 11.5 million acres.

Before standing timber is sold, it is generally necessary to complete an inventory of the species, size, and volume of trees so an accurate assessment of its value can be determined. Foresters, who are primarily responsible for assessing standing timber value, utilize an assessment called a cruise to establish this value. To complete a cruise, it is necessary to be familiar with a number of measuring tools and the units of measure involved.

Timber buyers commonly, after looking over a forest, offer its owner a lump sum for all the merchantable trees. Landowners generally do not know how to measure and evaluate the timber they own and often take the word of the first potential buyer as to its value. It is the responsibility of the owner to ascertain if this represents a fair price. Timber should never be sold unless its owner has an independent estimate of its worth. That estimate should not be made by the buyer; it should be done by a professional forester or by the landowner, if they have the expertise.

One solution is to hire a consulting forester to evaluate the timber in your forest. Forestry consultants are available in most parts of the country who will provide independent volume and value estimates for timber on private lands. Consulting foresters charge for their services, but don't let that stop you. Study after study has shown that they more than pay for their service by the increased price you will get when you know what you are selling and what its value is.

Among the services consultants provide are:

- Locating of property lines
- Estimating of timber volumes and values
- Solicitating of bids for your timber
- Developing a sales contract
- Supervising of the logging operation

Should you decide to utilize the services of a consultant, study this publication before making that contact. This will give you background that will make it easier for you to "talk the language" and be certain of getting the services you need.

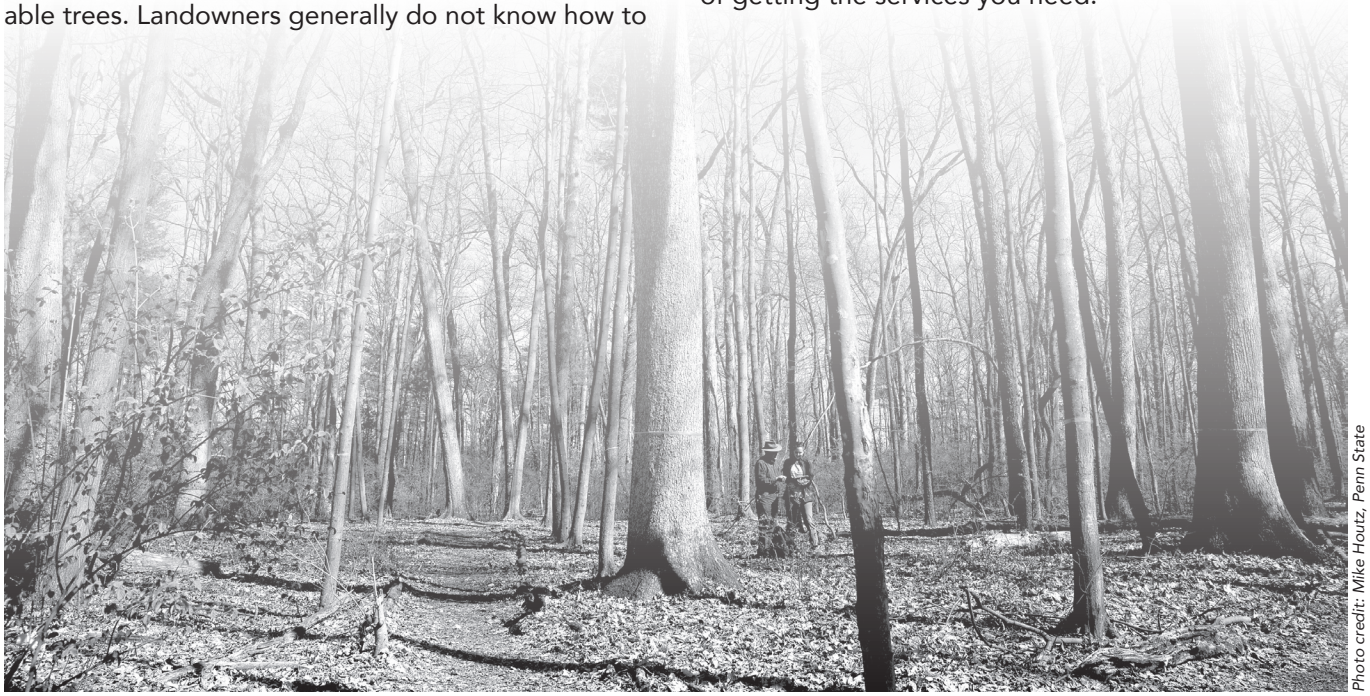


Photo credit: Mike Houtz, Penn State

Locating Your Forest

Before timber can be sold, it is important to first know where your property corners and boundary lines are located. Begin by visiting all known and suspected corners. Be sure to note fence lines, marked property lines, and other features that might indicate property lines. Unless you and your neighbors know and agree on common boundaries, it may be advisable to hire a registered surveyor. It is important to note, simply agreeing on a boundary location is not a legal process and does not replace the role of a surveyor. Be sure all survey work is recorded at the county courthouse.

Establishing Corners

Property corners whose location you know for certain should be well marked and established by licensed surveyors. A solid iron bar driven into the soil serves well to mark a corner. Witness trees near the corner should be triple blazed and/or painted facing the corner to indicate it is near and what direction from the blazed trees it is (Figure 1). Corner witness trees should never be harvested; they may serve as witness trees in the deed.

Establishing Property Lines

Property lines can be established adequately using a good hand compass (Figure 2). The hand compass should have an adjustment mechanism by which it can be set to account for magnetic declination, the deviation of the compass needle from true north. Magnetic declination varies with location and time. The current declination for your location can be obtained from this NOAA website: **https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#declination**.

Figure 2. Sighting direction with a compass.

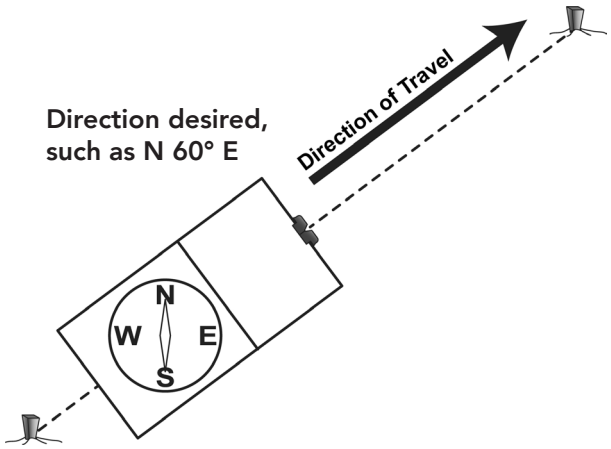
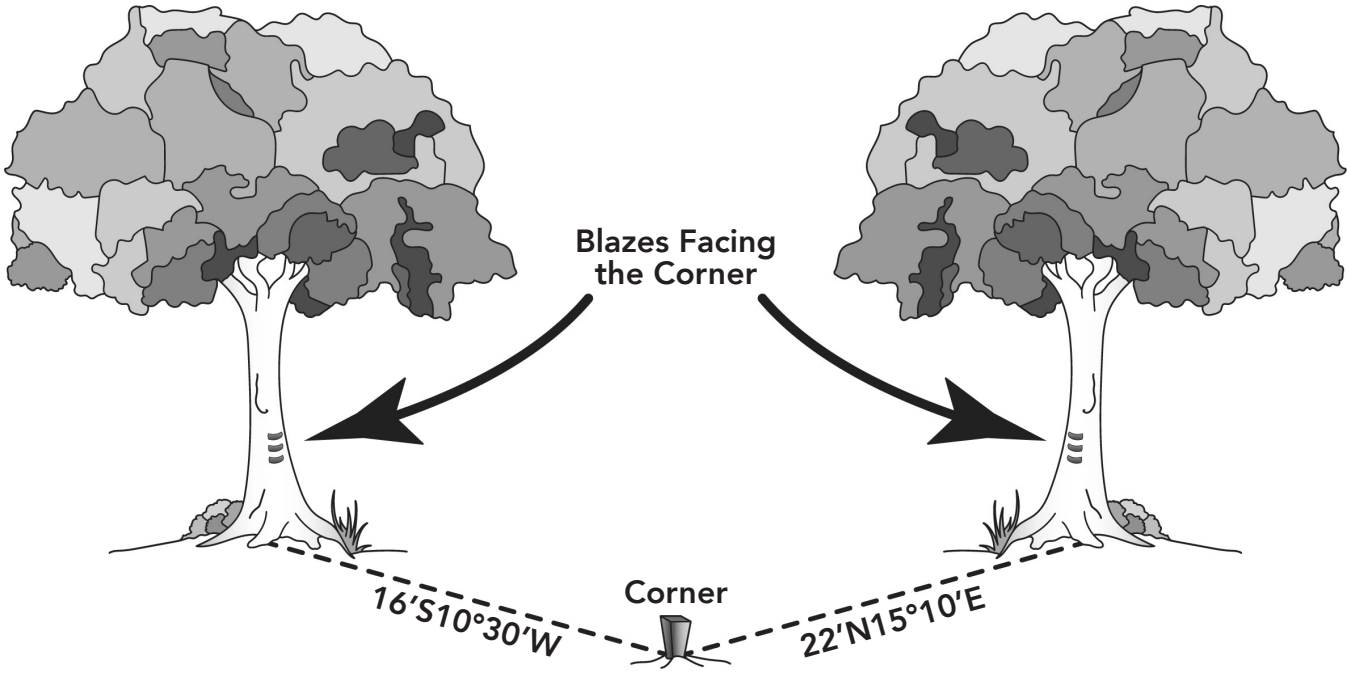


Figure 1. Making a corner with witness trees.



Starting from a known corner, travel the distance and direction given in your deed to the next corner. Attach surveyor ribbon/flagging to trees at or very near the line. Bear in mind that property lines located in this crude fashion are only approximate and have no legal standing. A professional surveyor should be employed to permanently mark the boundary by blazing and painting selected trees along the line (Figure 3).

Trees on the line, referred to as line trees, are blazed/painted on two sides, indicating the line passes through the center of the tree. They are the property of both owners. Trees to the left or right of the actual line are blazed/painted on the side facing the line. It is a good practice to keep all blazed/painted trees in place as boundary markers.

Boundary Maintenance

Maintaining established boundaries with paint and flagging on at least a five-year cycle is an important management activity. Check all permanent corner monuments and repaint the blazes on all corner witness trees and line trees. Once set by a surveyor, these can be easily maintained by landowners.

Identifying Tree Species

Resource valuation of a woodland begins with tree identification. In Pennsylvania there are more than 100 species of trees, but only about 15–20 species have significant commercial value. Start by learning the common trees in your area. Learn to recognize their leaves, bark, buds, and fruit. Note how they look at different times of the year. Learn to recognize their general form, branch arrangement, and the types of sites you find them growing on.

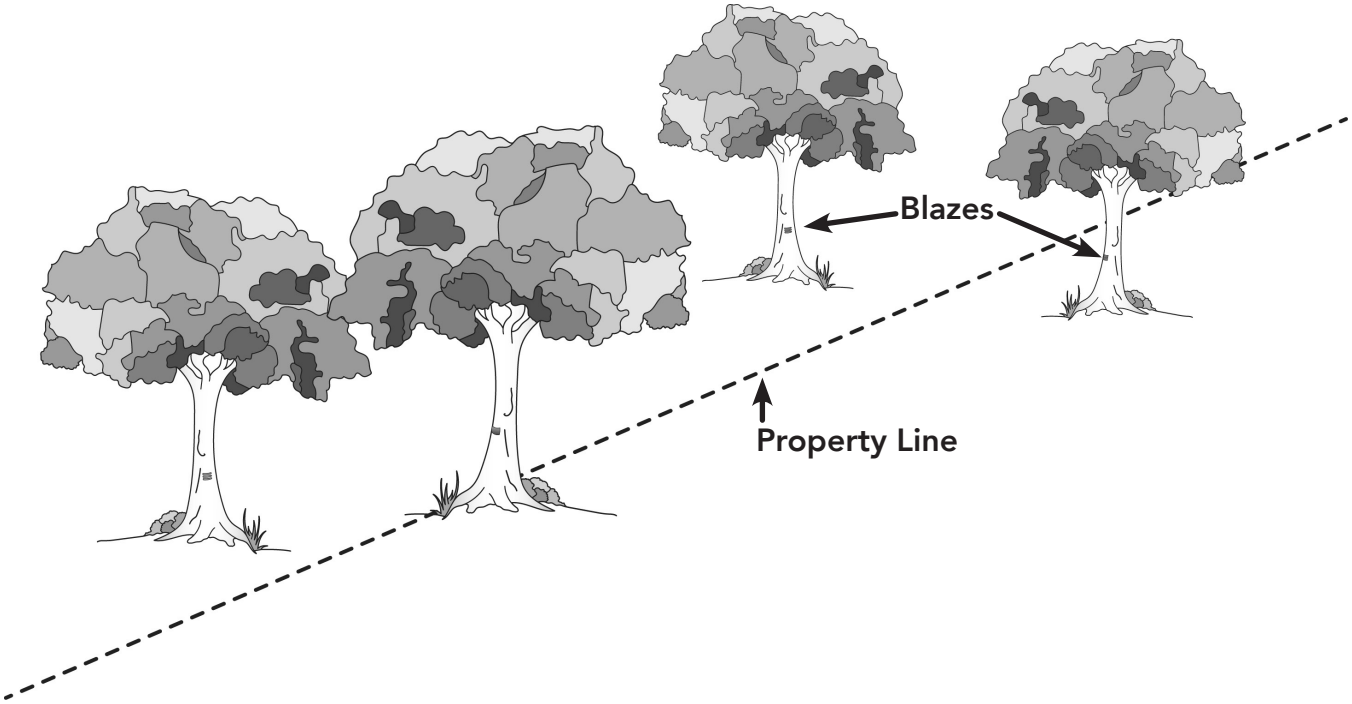
A good reference book with color images and general descriptions of identification characteristics will be useful. Visit your local bookstore to see what is available. In addition, there are a number of useful websites and apps you can use on your phone. A knowledgeable friend or resource professional are other possible sources of assistance.

Tree Measurements

Diameter

Diameter at breast height (DBH) is one of the most important tree measurements taken when determining volume. DBH is the diameter outside the bark of the tree's stem measured at a point 4½ feet above the ground, on the uphill side, if the tree is on a slope (Figure 4).

Figure 3. Blazing trees along a property line.



Instruments

Direct diameter measurements are usually made with a diameter tape, a Biltmore stick, or a tree caliper. Collectively, these instruments are referred to as dendrometers. When using a diameter tape, circumference of the stem is actually measured. However, the tape graduations are based on the relationship between diameter and circumference, and tree diameter is read directly from the tape. Most diameter tapes measure diameter to the tenth of an inch. When using a diameter tape, be sure not to let the tape sag; it must be horizonal around the tree (Figure 5).

The graduations on the tapes are determined using the relationship *circumference* = $\pi \times$ *diameter*. A regular cloth or steel carpenter tape can also be used to measure the circumference of the tree, and then divide this measurement by 3.14 to calculate tree diameter. Commercial diameter tapes are available from forestry supply catalogues. The diameter tape is a very satisfactory tool, but it can slow down field work if many trees need to be measured.

The diameter tape is easy to use, fairly inexpensive, and reasonably precise. However, the less the tree's cross-section resembles a perfect circle, the less accurate the measure will be. So, use caution when reading to the nearest 1/10 inch with irregular-shaped trees; however, this is the most accurate tool foresters use to measure diameter.

A rather ingenious instrument, the Biltmore stick, speeds up the process of DBH measurements (Figure 6A). It is not as accurate as the diameter tape, but if used with reasonable care it is adequate for most timber inventory work. The Biltmore stick is a straight wooden stick, similar to a yardstick, specially graduated for direct reading of DBH.

Based on the principle of similar triangles, the stick must be held horizontally against the tree at 4.5 feet above the ground, at a predetermined distance from the observer's eye (Figure 6B). This distance is generally 25 inches. However, a stick can be constructed for any reach. The stick is moved horizontally right or left until the line of sight over the left end grazes the left edge on the tree trunk. Then, moving only your eye, read the graduations on the stick over which your line of sight passes to the right edge of the tree trunk (Figures 6A and 6B). This graduation is the diameter of the tree. Since the DBH graduations on the stick get progressively shorter as the tree di-

Figure 4. Measuring tree diameter with a diameter tape. Be sure to measure diameter from the uphill side of the tree.

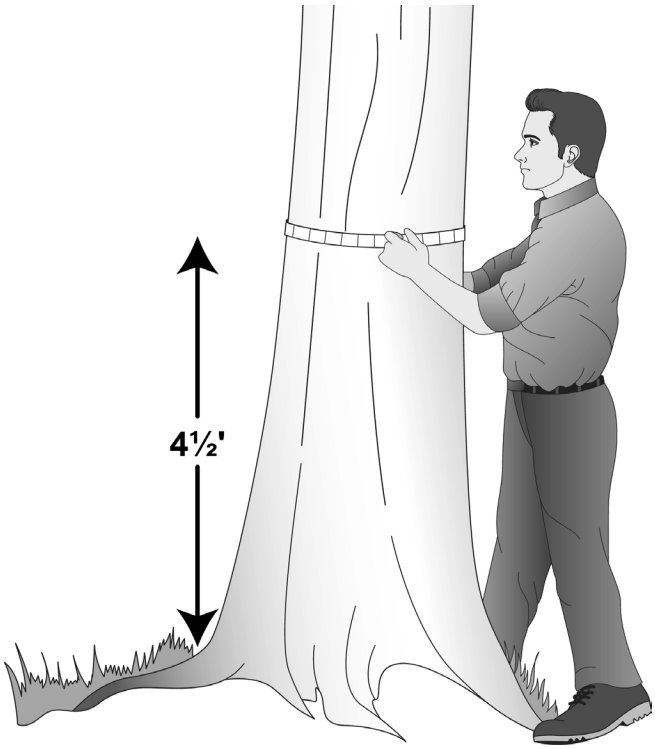


Figure 5. Correct and incorrect use of a diameter tape.

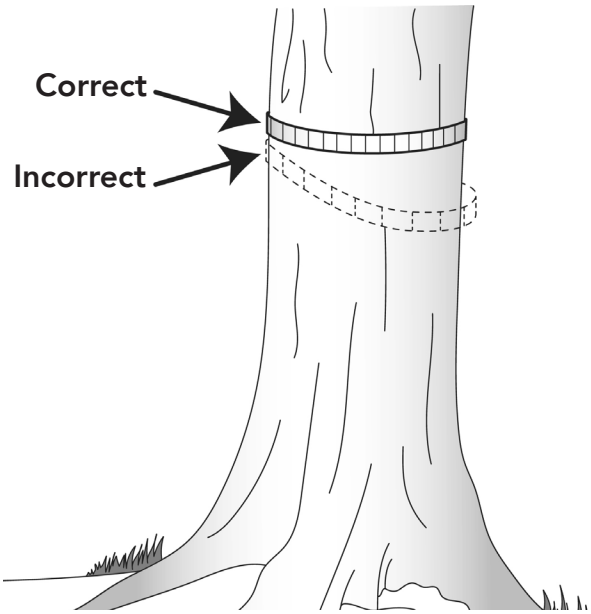


Figure 6A. Measuring tree diameter with a Biltmore stick.

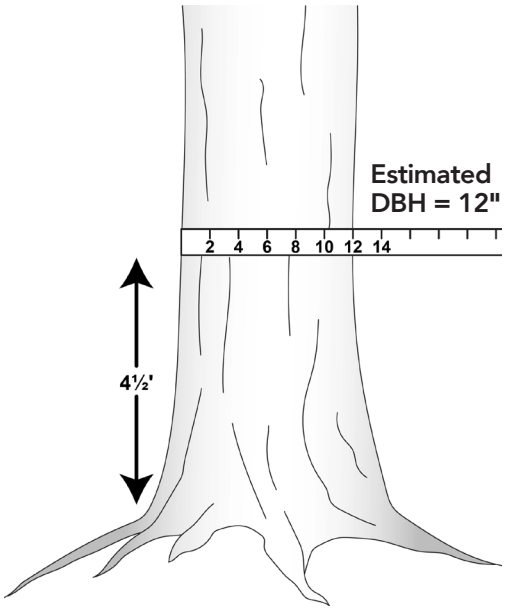
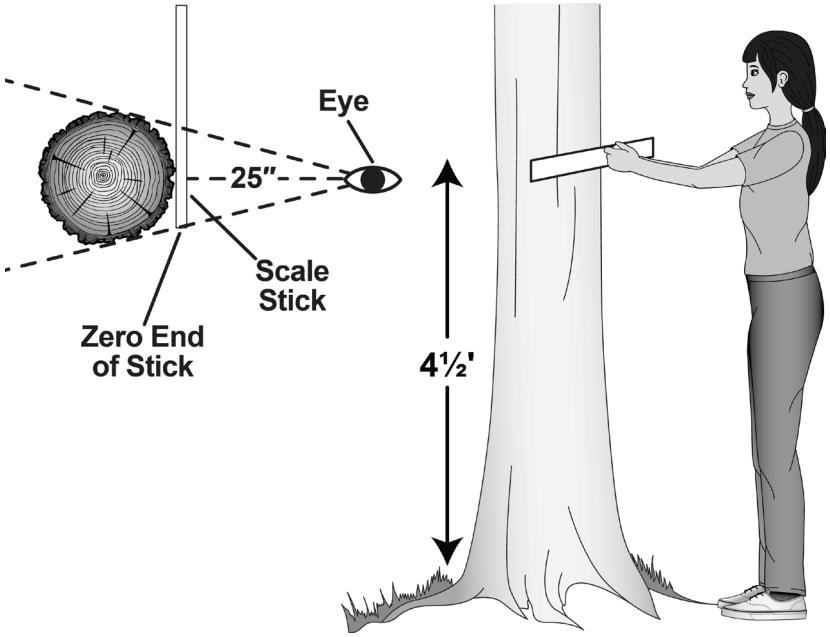


Figure 6B. A Biltmore stick must be held horizontally against the tree, 25 inches from the user's eye.



ameters increase, it is possible to measure a tree with a 50-inch DBH with a stick that is only 30 inches long.

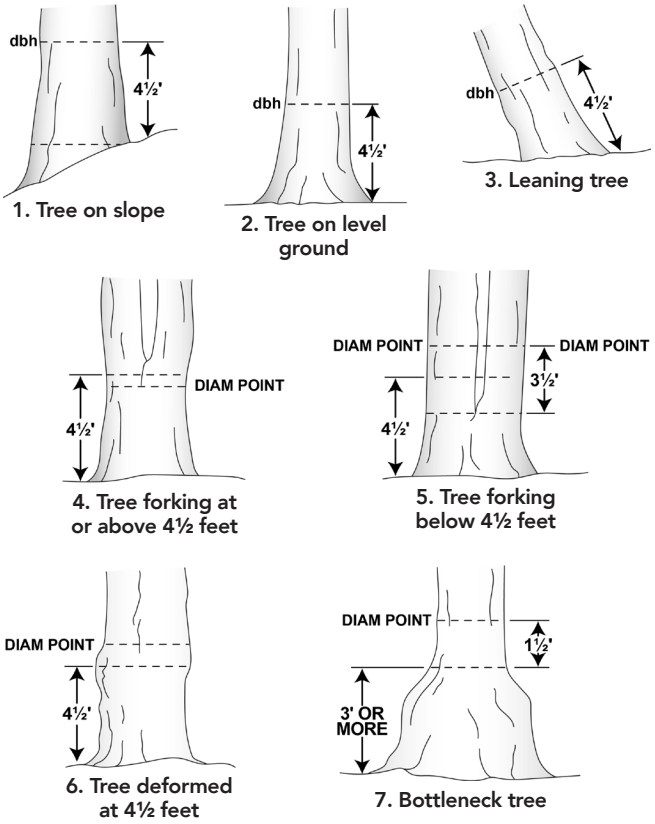
The Biltmore stick is also easy to use and fairly inexpensive. It typically contains other useful scales for estimating height and volume. When the level of accuracy requires the diameter to the nearest 1- or 2-inch tree-diameter class, it is an acceptable instrument. For greater accuracy, take a second reading at 90 degrees from the first and then average the two for your DBH estimate, especially on irregularly shaped trees.

Measuring DBH to the nearest even inch (14, 16, 18, etc.) is adequate for the forest evaluation work described in this publication, particularly if using a Biltmore stick. For example, a 12-inch tree has a DBH between 11.1 and 13 inches, a 14-inch tree between 13.1 and 15 inches, and so forth. If using a diameter tape, trees can be recorded to one-inch diameter classes. For example, 12.6–13.5 = 13-inch class, 13.6–14.5 = 14-inch class, and so forth.

Measuring DBH

Whatever type of instrument is used, care must be exercised to measure trees exactly at DBH or at a rational deviation from this point when irregular stems are encountered (Figure 7). Trees that are growing on a steep slope should be measured at 4½ feet on the uphill side of the tree. When a swelling, depression, or branch exists on the stem at breast height, the diameter should be measured above the irregulari-

Figure 7. Points of DBH measurement for sloping ground or irregular tree stems. (Source: Avery and Burkhart, *Forest Measurements*, 4th ed.)



ty, at a point where it no longer affects normal stem growth. Trees that fork below 4½ feet should be treated as two trees and the diameter is measured at 3½ feet above the fork. In deep snow, use a 4½-foot stick and probe to the ground before measuring.

Merchantable Height

When measuring tree heights for volume determination, it is important to only measure the usable or merchantable portion of the tree as opposed to total tree height. Merchantable tree height is defined as the linear distance between the top of the stump and the last useable portion of the stem. That point may depend on merchantability limits of local markets and is rather subjective.

The height of stumps left after trees are cut is generally one foot or less. Stumps higher than one foot indicate careless cutting practices and wasted wood. When estimating stump height, it is best to measure from just above the root flare.

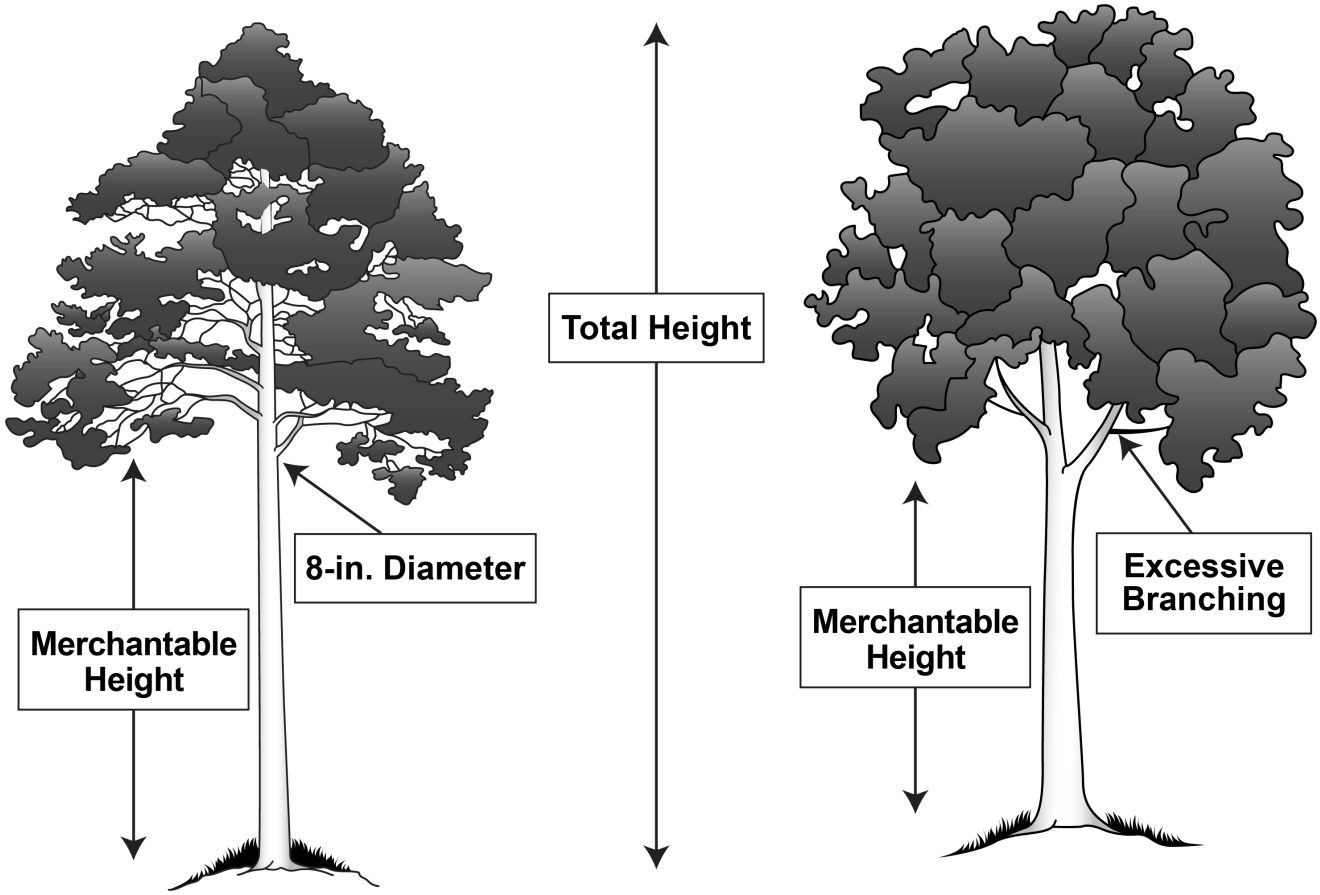
Several criteria can define the upper limit. It is most often determined by a minimum upper stem diameter (e.g., 8 inches). However, excessive branching, irregular form, and other defects may also determine the upper usable limit of the stem. The minimum top diameter is dependent on local utilization standards. In the Northeast, it is usually 8 inches for sawlogs (Figure 8).

Instruments

The height of large standing timber may be measured indirectly using a variety of instruments. Instruments used for measuring tree heights are collectively referred to as hypsometers. Common instruments used for this purpose include the Merritt hypsometer and the clinometer. When using these instruments, the observer locates themselves at a fixed horizontal distance from the tree, usually 50, 66, or 100 feet.

The Merritt hypsometer consists of a linear scale generally inscribed on one side of the Biltmore stick. When using this instrument, one can determine the height of the tree in terms of 16-foot and 8-foot intervals, called logs and half logs. Similar to the Biltmore stick, the Merritt hypsometer must be held

Figure 8. Distinguishing total tree height and merchantable height.



vertically at a fixed distance from the eye and the user must stand at a set distance away from the tree being measured. Most commercial instruments are calibrated for a 25-inch reach from the eye and must be read at a distance of 66 feet from the tree.

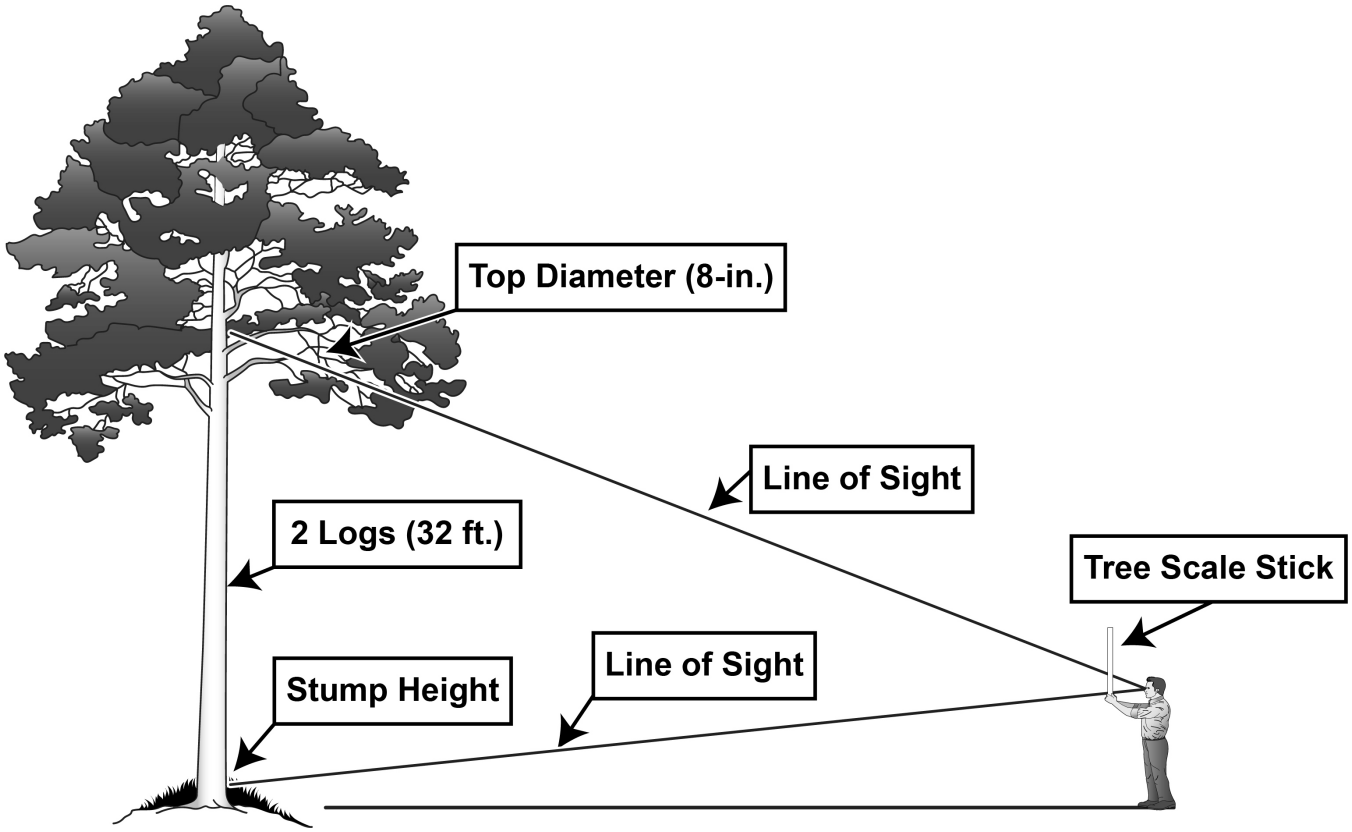
To use the Merritt hypsometer, measure or pace off a distance of 66 feet from the center of the tree. Hold the stick vertically 25 inches from your eye with the zero end of scale downward. Raise or lower the stick until it intercepts the line of sight with your eye and the base of the tree (stump height). Without moving your head, sight to the point on the tree where merchantable height is to be measured and note where the line of sight intercepts the stick. Read the graduation on the stick at this point. This is the number of 16-foot sections in the tree (Figure 9).

For more precise estimates use a clinometer or other specialized height-measuring instruments. The clinometer is an optical instrument that provides readings within 2 to 5 percent of true height. Whether the expense of using higher priced equipment is justified will depend on how accurately merchantable height needs to be measured. The clinometer is also useful to measure slope and for laying out roads and trails. These additional uses may warrant the added expense.

Most clinometers have two scales, percent (%) and topographic (1/66). When using the percent scale, the user can stand any distance from the tree. Point the instrument at stump height and take a reading, then take another reading at merchantable height. If both readings are on the same side of zero, subtract the smaller reading from the larger, divide by 100, and then multiply the result by the horizontal distance from the tree.

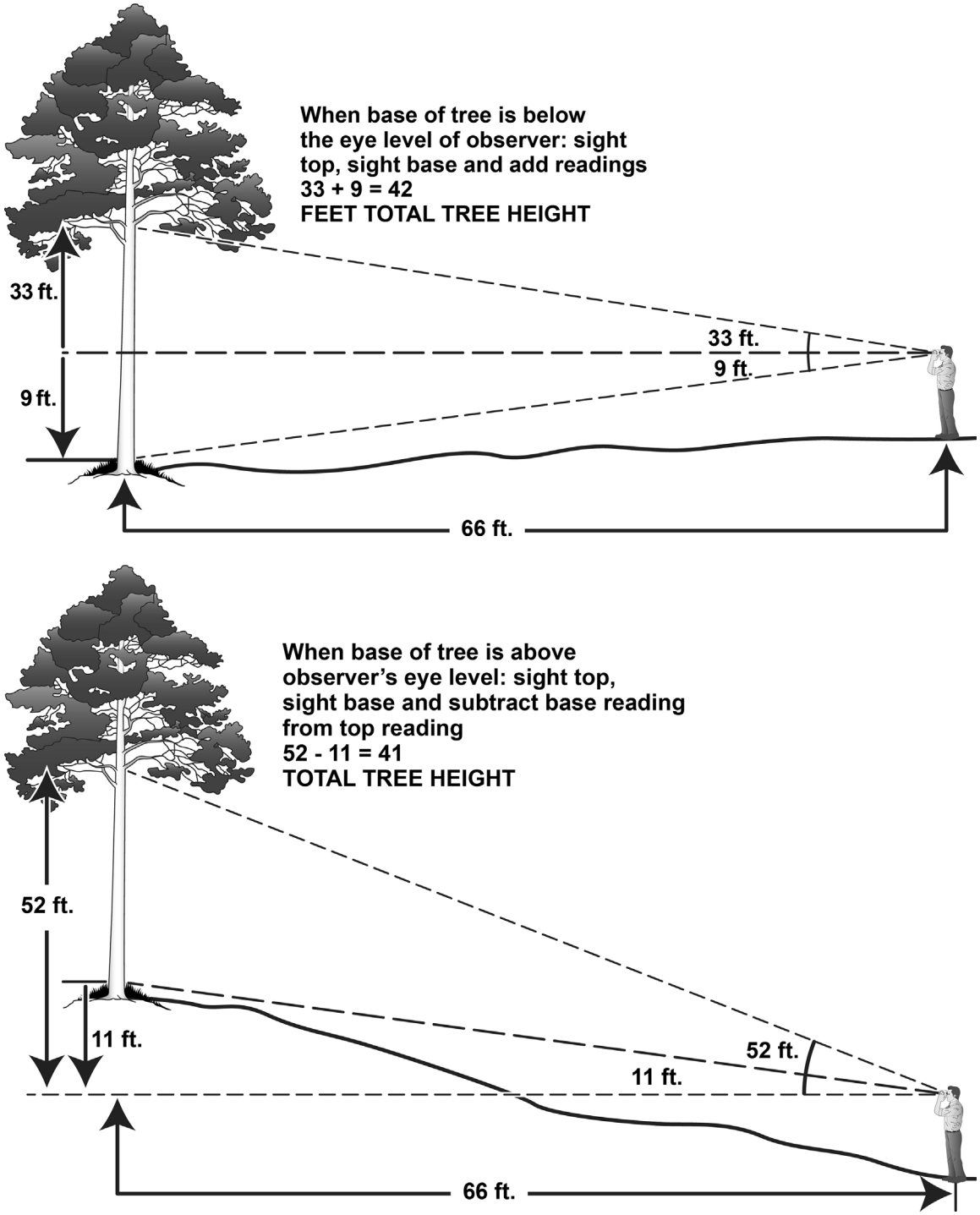
When one reading is below zero (a negative number) and the other above zero (a positive number), subtract the negative number from the positive, essentially adding the distance below zero to the distance above zero [e.g., the upper reading is 36 and the lower reading is -4; 36 – (-4) =36 + 4 = 40]. Divide the sum by 100 and then multiply the result by the horizontal distance from the tree (Figure 10). Or, direct height readings can be made using the percent scale by standing 100 feet from the tree or by standing 50 feet away and dividing the result by two.

Figure 9. Measuring merchantable tree height with a tree scale stick called a Merritt hypsometer.



When using the topo, 1/66, scale the user stands 66 feet from the tree. Readings are taken at stump height and merchantable height. If readings are on the same side of zero, the height estimate is the difference between the two readings. When one reading is below zero and the other above zero, add the two for the height measurement (Figures 10A and 10B).

Figures 10A and 10B. Using a clinometer to estimate total tree height. (Source: Martin, Lake States Woodlands: Measuring Trees and Estimating Volume, 2017.)



Measuring Merchantable Height

The instruments mentioned above yield height readings directly in number of logs or feet at a fixed horizontal distance from the tree. For our use, merchantable tree heights need only be measured in terms of the number of logs they will yield. As a unit of measure, a standard log is 16 feet long. Merchantable height is generally measured by rounding down to the nearest half-log. To convert clinometer readings measured in feet to number of logs, divide merchantable tree height by 16, the number of feet in one log (Figure 11).

Measuring Distance

The distances measured for all procedures described in this publication will be horizontal distances. When measuring on slopes, the tape must be held high on one end, so it is level (Figure 12). Steel logger tapes are very durable and accurate for measuring distances from trees when estimating merchantable heights.

When measuring distance within the woods requires a high degree of accuracy, a surveyor's tape or chain is used. The fundamental unit for horizontal distance employed by foresters is the surveyors or

Figure 11. Determining the number of sawlogs in the main stem of a standing tree.

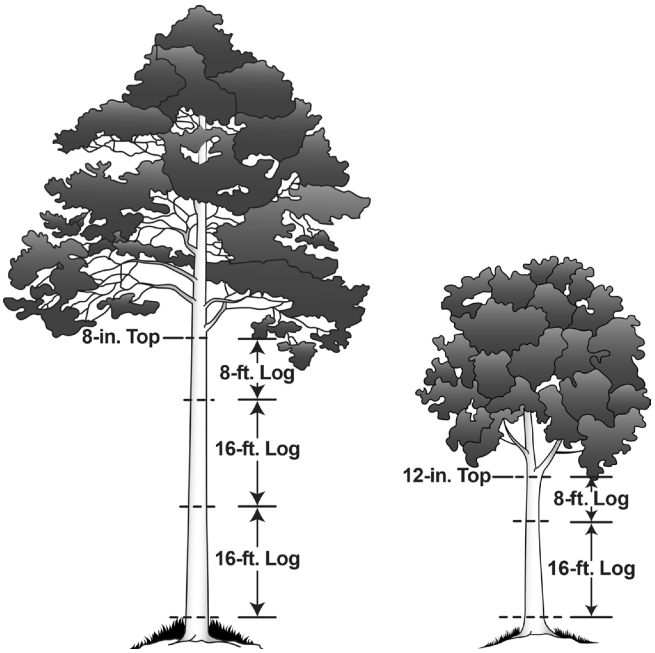
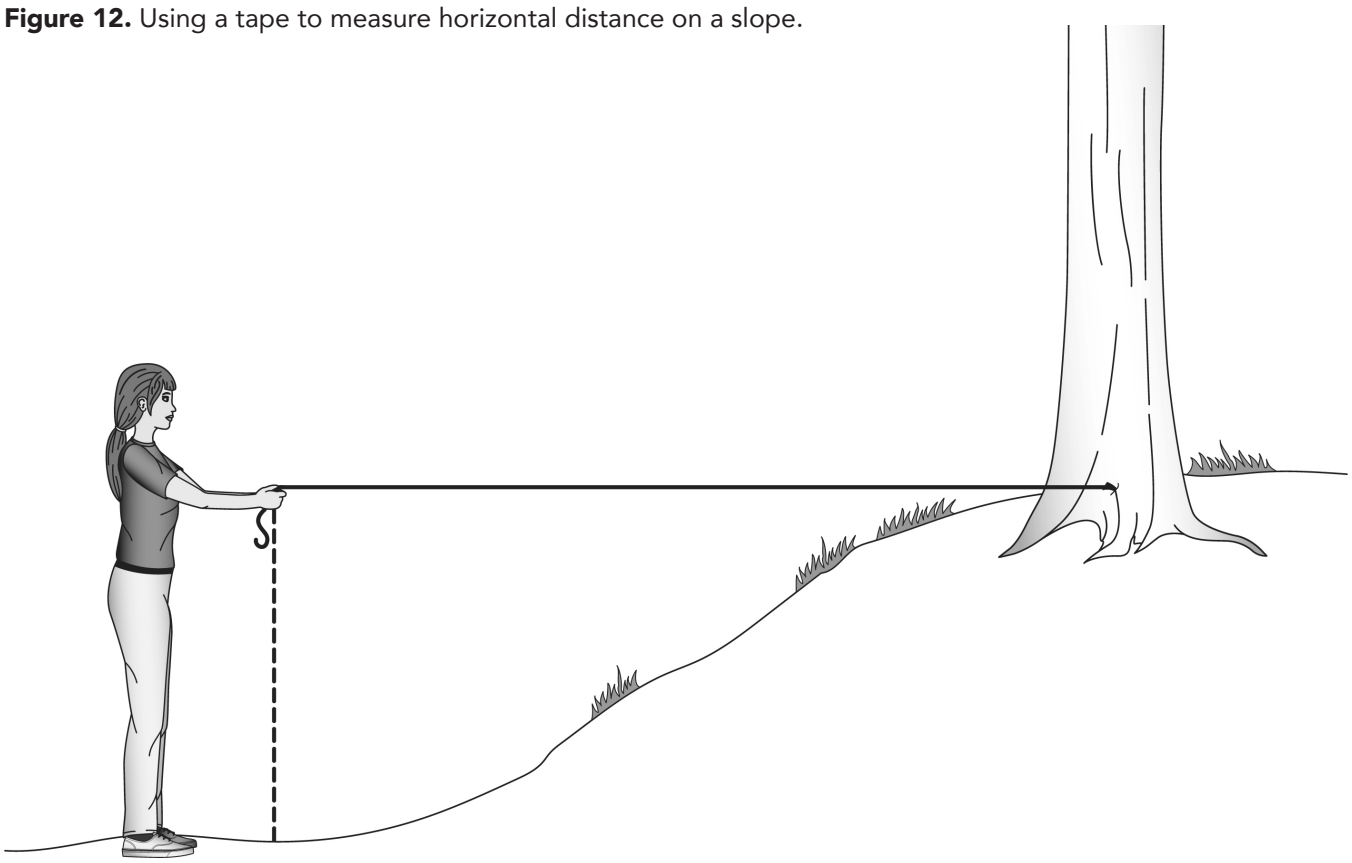


Figure 12. Using a tape to measure horizontal distance on a slope.



Gunters chain. As a unit, a chain is 66 feet in length. A simple conversion from chained dimensions to acres is one reason for its popularity: one acre is equal to 10 square chains. For example, an area that is two chains by five chains is one acre in size. Areas expressed in square chains can be immediately converted to acres by dividing by 10.

Pacing

For many procedures, the accuracy of using a steel tape or chain is not necessary and the measuring of distance by pacing is a very useful procedure. A pace is the average length of two natural steps. A count is made each time the same foot hits the ground. To determine how many feet you have per pace, measure with a tape a distance of three to five chains on level ground. Pace the distance several times using your natural steps until a consistent gait has been established. The average number of paces divided by the number of chains within your course will determine the number of paces per chain. For example, if you count 39 paces over a three-chain course, then your pace for one chain is 13.

You may have to adjust your pace if walking is difficult. As a rule of thumb, if you are walking up or down a moderate slope, count each tenth pace twice to get an approximately correct horizontal distance. On steep slopes, count each fifth pace twice. With a little practice, you will become confident in your pacing ability and will find it a useful skill.

Volume

Wood is commonly bought and sold in units of volume. Large trees (greater than 11 inches DBH) of fair to good quality are generally sawed into lumber at a mill. It has been traditional in North America to determine their volume in board feet. Small trees, deciduous trees of inferior quality, and certain conifer species that are used primarily for pulp are not sawed into boards at a mill. They are customarily sold in the round, and their volume is measured in cords.

Cords

Pulpwood or firewood is often sold by the standard cord. A standard cord is a stack of wood measuring 4 feet tall, 4 feet wide, and 8 feet long, occupying 128 cubic feet of space (Figure 13). Recognize that this cubic foot volume is not all wood; portions of it are air space and bark. Any stack of wood can be converted to standard cords by using the formula *cords = height (feet) × width (feet) × stick length (feet) / 128*.

Purchasers of cord wood are generally more interested in the quantity of solid wood contained in a cord rather than the area occupied. Depending on the size, straightness, and degree of branching of the individual pieces and the method of stacking, a cord may contain from 65 to 90 cubic feet of solid wood. On average, a standard cord of hardwoods has about 80 cubic feet of solid wood.

Pulpwood cord volume may be found by referring to Table 1. Tree diameter and the number of 8-foot sticks or bolts are used to determine the amount of cordwood volume in a tree. For example, a tree 9 inches in diameter with three 8-foot sticks contains 0.07 cord of wood. It would take approximately 14 trees of this size to make one cord.

Due to the disadvantages of the cord measure, pulpwood is often measured by weight at the point of delivery. That is, trucks containing a load of pulpwood are weighed at the mill. This is a more rapid and objective method than estimating the number of cords. A standard cord of freshly cut red oak will weigh around 5,500 pounds.

Figure 13. A standard cord of wood is 8 feet long, 4 feet high, and 4 feet wide, or 128 cubic feet.

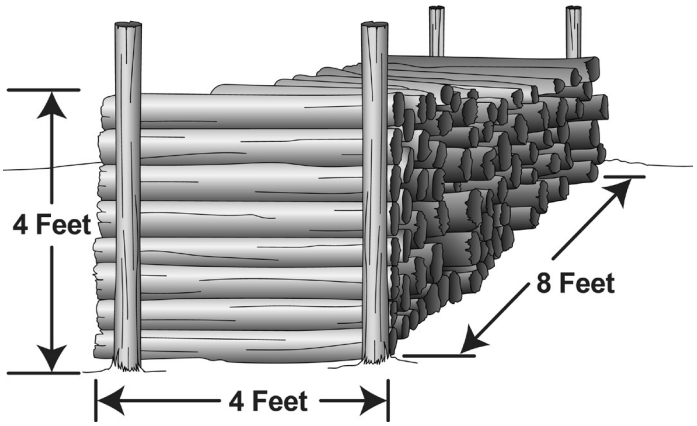


Table 1. Cord volume of standing trees.

DBH (inches)	Number of 8-foot sticks						
	1	2	3	4	5	6	7
	Cords						
5	0.010	0.018					
6	0.018	0.030	0.043				
7	0.025	0.039	0.056	0.074			
8	0.032	0.050	0.070	0.092	0.116		
9	0.040	0.061	0.085	0.112	0.140	0.168	
10	0.049	0.074	0.101	0.132	0.167	0.200	0.239
11	0.059	0.087	0.119	0.155	0.195	0.233	0.280
12	0.070	0.100	0.138	0.180	0.225	0.271	0.324
14	0.095	0.134	0.179	0.233	0.291	0.351	0.419
16	0.120	0.168	0.222	0.290	0.361	0.437	0.521
18	0.146	0.208	0.270	0.350	0.439	0.531	0.634
20	0.186	0.246	0.320	0.416	0.522	0.632	0.755
22	0.220	0.294	0.374	0.494	0.612	0.739	0.883

Board Feet

For this publication, we are most interested in determining the board foot volume in a tree. A board foot, by definition, is a piece of wood 1 inch thick, 12 inches wide, and 12 inches long. That means the amount of wood in a board foot equals *(1 inch) × (12 inches) × (12 inches) = 144 cubic inches* (Figure 14).

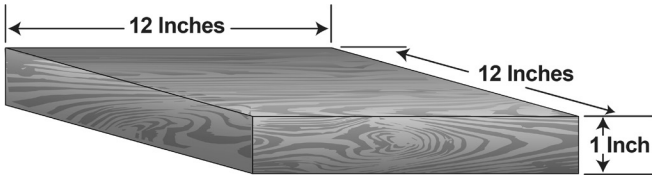
The number of board feet contained in sawed lumber is calculated using this formula:

$$\text{Board feet} = \frac{\text{thickness (inches)} \times \text{width (inches)} \times \text{length (feet)}}{12}$$

For example, a 12-foot-long piece of 2-inch by 6-inch construction lumber contains 12 board feet:

$$12 = \frac{2 \times 6 \times 12}{12}$$

Figure 14. One board foot of wood.



The board foot is used for volume estimates involving merchantable tree sections that will go to a sawmill and be sawn into lumber, railroad ties, pallet stock, etc. These sections are referred to as sawlogs.

Because lumbermen and foresters often deal with large quantities of product, the term thousand board feet (abbreviated MBF) is the customary unit for buying and selling timber.

The use of board foot measure may seem logical when dealing with square-sawed wood; however, it has many short comings when applied to logs that are round in cross-section, encased in unusable bark, and smaller at one end than the other. Furthermore, when sawed, some amount of the wood contained in a log is converted to sawdust.

Log Rules

To estimate the number of board feet of lumber, which can be obtained from a log of a given diameter and length, foresters have developed log rules. Log rules are essentially formulas that attempt to estimate before processing the amount of lumber contained in a log of given dimensions. During the last two centuries, over 100 different log rules have been devised, with each region developing its own rules based on local utilization standards. The most

common log rules in use today are Doyle, Scribner, and International ¼-inch; see Tables 2 and 3 below for International and Doyle log rules. Estimating the volume of a log using one of the log rules is referred to as log scaling. The diameter of the log is measured inside the bark at the small end of the log.

The Doyle log rule is one of the oldest and most widely used log rules, despite its inconsistencies. This rule greatly underestimates the actual board foot yield of small diameter logs, the sizes of trees most commonly found in eastern forests today. The Scribner log rule is also very old, but it is much more reliable than the Doyle log rule. The International ¼-inch log rule is the most accurate predictor of actual yield of the commonly used rules.

Timber sellers and buyers are advised to know which log rule was used to estimate timber volume. If selling based on the Doyle rule, one needs to understand that the actual board foot volume may be 40 percent greater than the Doyle estimate. Buyers need to take this into account and offer a higher price per thousand board feet than if the International rule was used. By being aware of this, buyers and sellers are less likely to lose in the log rule game.

Weight

Trucks loaded with large logs from which lumber will be produced are sometimes evaluated on a weight basis as well. However, other factors, such as quality

Table 2. International ¼-inch log rule scale.

Diameter (inches)	**Length of Log** (feet)					
	6	**8**	**10**	**12**	**14**	**16**
	Contents in Board Feet					
8	10	15	20	25	35	40
9	15	20	30	35	45	50
10	20	30	35	45	55	65
11	25	35	45	55	70	80
12	30	45	55	70	85	95
13	40	55	70	85	100	115
14	45	65	80	100	115	135
15	55	75	95	115	135	160
16	60	85	110	130	155	180
17	70	95	125	150	180	205
18	80	110	140	170	200	230
19	90	125	155	190	225	260
20	100	135	175	210	250	290
21	115	155	195	235	280	320
22	125	170	215	260	305	355
23	140	185	235	285	335	390
24	150	205	255	310	370	425
25	165	220	280	340	400	460
26	180	240	305	370	435	500
27	195	260	330	400	470	540
28	210	280	355	430	510	585
29	225	305	385	465	545	630
30	245	325	410	495	585	675

Table 3. Doyle log rule scale.

Diameter (inches)	**Length of Log** (feet)					
	6	**8**	**10**	**12**	**14**	**16**
	Contents in Board Feet					
8	6	8	10	12	14	16
9	9	13	16	19	22	25
10	14	18	23	27	32	36
11	18	25	31	37	43	49
12	24	32	40	48	56	64
13	30	41	51	61	71	81
14	38	50	63	75	88	100
15	45	61	76	91	106	121
16	54	72	90	108	126	144
17	63	85	106	127	148	169
18	74	98	123	147	172	196
19	84	113	141	169	197	225
20	96	128	160	192	224	256
21	108	145	181	217	253	289
22	122	162	203	143	284	324
23	135	181	226	271	316	361
24	150	200	250	300	350	400
25	165	221	276	331	386	441
26	182	242	303	363	424	484
27	198	265	331	397	463	529
28	216	288	360	432	504	576
29	234	313	391	469	547	625
30	254	338	423	507	592	676

and species, influence log value so much that weight alone is typically not a satisfactory method of sawlog evaluation.

Estimating Volume of Standing Trees

When considering timber to sell, the landowner must know the board foot content, or volume, of the trees they intend to have harvested. The merchantable volume of wood contained in a standing tree is the sum of the volumes of the logs that would be obtained if the tree were felled, bucked, and scaled. Volume estimates for standing trees are normally limited to the central stem, or bole; branchwood volume is usually ignored.

To determine the volume of standing trees, foresters use a volume table. Note that they require measurements of DBH and estimates of the number of 16-foot logs. As mentioned previously, logs should be estimated to an 8-inch top or where the utilizable length stops due to excessive crook and/or branching.

Board foot volume tables are based on existing log rules. Therefore, they can be no more reliable than the log rule selected as a basis for their construction. Use the log rule that is acceptable to potential buyers in your area (International, Scribner, or Doyle). Tables 4 through 6 that follow may be used to estimate the board foot volume of standing trees with each log rule.

For example, if you measure a tree and find the DBH is 18 inches and the merchantable height is 2½ logs, using the International volume table the estimated volume is 274 board feet. When measuring trees, DBH is typically measured to one or two-inch diameter classes and heights are rounded down to the nearest half-log.

Defect and Cull

The methods described here facilitate estimation of gross volume. Rot, splits, crooks, etc., reduces the amount of lumber that can be sawn from a given tree. In addition to volume loss or cull, the value of lumber sawn from a given tree depends on a number of factors called defects, such as the presence or absence of knots. Both defect and cull influence the volume and value of standing timber. Most timber measurements only report gross volume; it is left to the buyer to estimate grade and volume loss or cull.

The evaluation of defect and cull in standing trees is complicated by the fact that it is difficult to see defect and grade indicators (knots, etc.) on standing trees since the ends of the logs are not visible and close inspection of the outside of potential logs is more difficult the higher they occur on the tree. Common sense tells us that if trees are large in diameter, with few knots and other defects showing on the lower logs, and they appear to be sound, the timber will tend to be of high value.

Estimates of losses in tree volume are largely dependent on visible external defects and require some experience with the species under consideration. When dealing with high-quality timber, use of Table 7 will facilitate a log-by-log estimate of volume loss on account of cull. For example, in a tree containing only one log (16 feet), 31 percent of the volume is contained in the bottom 4 feet, 27 percent is contained in the next 4 feet, and so on. If this tree had a significant defect in the first 4 feet, then you would need to account for a 31 percent reduction in the volume for this tree.

Form Class

The logs in some species of trees taper (decrease in diameter from butt to top) more than others—for example, there is significantly more taper in a hemlock versus a yellow-poplar butt log. The amount of taper in a log directly influences the amount of wood sawn from the log. Taper is measured by what is referred to as form class or the ratio between stem diameter, inside bark at the top of the first 16-foot log (including a one-foot stump), and the diameter outside bark at DBH.

Form class = diameter inside bark at 17-foot height / DBH outside bark × 100

For example, a tree with a 16-inch diameter inside bark at 17 feet and a DBH of 20 inches has a form class of 80 percent. A form class 80 says that the diameter inside the bark at the end of the first log is 80 percent of the DBH.

Volume tables have been adjusted to account for variations in taper by different species. In much of the Northeast, hardwood trees have an average form class of 78 on most sites. Note that the tables included in this publication are for trees with a form class of 78. It is important to learn the average form class for merchantable logs in your area. By assigning the correct form class to specific species, volumes will be adjusted accordingly.

A good reference was developed by Mesavage and Girard of the U.S. Forest Service Southern Forest Experiment Station to adjust volume tables for form class; see **http://www.uky.edu/~jmlhot2/bdft_tables/bf_tables.htm**.

Table 4. International ¼-inch log rule, form class 78: gross tree volume (board feet) by DBH and number of usable 16-foot logs.

DBH (inches)	1	1½	2	2½	3	3½	4	4½	5
10	36	48	59	66	73	–	–	–	–
11	46	61	76	86	96	–	–	–	–
12	56	74	92	106	120	128	137	–	–
13	67	90	112	130	147	158	168	–	–
14	78	105	132	153	174	187	200	–	–
15	92	124	156	182	208	225	242	–	–
16	106	143	180	210	241	263	285	–	–
17	121	164	206	242	278	304	330	–	–
18	136	184	233	274	314	344	374	–	–
19	154	209	264	311	358	392	427	–	–
20	171	234	296	348	401	440	480	511	542
21	191	262	332	391	450	496	542	579	616
22	211	290	368	434	500	552	608	647	691
23	231	318	404	478	552	608	663	714	766
24	251	346	441	523	605	664	723	782	840
25	275	380	484	574	665	732	800	865	930
26	299	414	528	626	725	801	877	949	1,021
27	323	448	572	680	788	870	952	1,032	1,111
28	347	482	616	733	850	938	1,027	1,114	1,201
29	375	521	667	794	920	1,016	1,112	1,210	1,308
30	403	560	718	854	991	1,094	1,198	1,306	1,415
31	432	602	772	921	1,070	1,184	1,299	1,412	1,526
32	462	644	826	988	1,149	1,274	1,400	1,518	1,637
33	492	686	880	1,053	1,226	1,360	1,495	1,622	1,750
34	521	728	934	1,119	1,304	1,447	1,590	1,727	1,864
35	555	776	998	1,196	1,394	1,548	1,702	1,851	2,000
36	589	826	1,063	1,274	1,485	1,650	1,814	1,974	2,134
37	622	873	1,124	1,351	1,578	1,752	1,926	2,099	2,272
38	656	921	1,186	1,428	1,670	1,654	2,038	2,224	2,410
39	694	976	1,258	1,514	1,769	1,968	2,166	2,359	2,552
40	731	1,030	1,329	1,598	1,868	2,081	2,294	2,494	2,693

Source: U.S. Forest Service, *Service Foresters Handbook*, Tree Volume Tables

Table 5. Scribner log rule, form class 78: gross tree volume (board feet) by DBH and number of usable 16-foot logs.

DBH (inches)	1	1½	2	2½	3	3½	4	4½	5
10	28	36	44	48	52	–	–	–	–
11	38	49	60	67	74	–	–	–	–
12	47	61	75	85	95	100	106	–	–
13	58	76	94	107	120	128	136	–	–
14	69	92	114	130	146	156	166	–	–
15	82	109	136	157	178	192	206	–	–
16	95	127	159	185	211	229	247	–	–
17	109	146	184	215	246	268	289	–	–
18	123	166	209	244	280	306	331	–	–
19	140	190	240	281	322	352	382	–	–
20	157	214	270	317	364	398	432	459	486
21	176	240	304	358	411	450	490	523	556
22	194	266	338	398	458	504	549	588	626
23	214	294	374	441	508	558	607	652	698
24	234	322	409	484	558	611	665	718	770
25	258	355	452	534	617	678	740	799	858
26	281	388	494	585	676	745	814	880	945
27	304	420	536	636	736	811	886	959	1,032
28	327	452	578	686	795	877	939	1,040	1,120
29	354	491	628	746	864	953	1,042	1,132	1,222
30	382	530	678	806	933	1,028	1,124	1,224	1,325
31	411	571	731	871	1,011	1,117	1,223	1,328	1,434
32	440	612	784	938	1,089	1,206	1,322	1,432	1,543
33	469	654	838	1,001	1,164	1,289	1,414	1,534	1,654
34	498	695	892	1,066	1,239	1,373	1,507	1,636	1,766
35	530	742	954	1,141	1,328	1,473	1,618	1,757	1,896
36	563	789	1,015	1,216	1,416	1,572	1,728	1,877	2,026
37	598	836	1,075	1,209	1,506	1,670	1,835	1,998	2,160
38	629	882	1,135	1,366	1,596	1,769	1,952	2,118	2,295
39	666	935	1,204	1,449	1,694	1,881	2,088	2,251	2,434
40	703	988	1,274	1,532	1,791	1,993	2,195	2,384	2,574

Source: U.S. Forest Service, *Service Foresters Handbook*, Tree Volume Tables

Table 6. Doyle log rule, form class 78: gross tree volume (board feet) by DBH and number of usable 16-foot logs.

DBH (inches)	1	1½	2	2½	3	3½	4	4½	5
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	364	383
21	154	207	260	302	344	374	404	428	452
22	174	234	295	344	392	427	462	492	521
23	195	264	332	388	444	483	522	558	594
24	216	293	370	433	496	539	582	625	668
25	241	328	414	486	558	609	660	709	758
26	266	362	459	539	619	678	737	793	849
27	292	398	505	594	684	749	814	877	940
28	317	434	551	650	750	820	890	961	1,032
29	346	475	604	714	824	902	980	1,061	1,142
30	376	517	658	778	898	984	1,069	1,160	1,251
31	408	562	717	850	983	1,080	1,176	1,273	1,370
32	441	608	776	922	1,068	1,176	1,283	1,386	1,488
33	474	654	835	994	1,152	1,268	1,385	1,497	1,609
34	506	700	894	1,064	1,235	1,361	1,487	1,608	1,730
35	544	754	964	1,149	1,334	1,472	1,610	1,743	1,876
36	581	808	1,035	1,234	1,434	1,583	1,732	1,787	2,023
37	618	860	1,102	1,318	1,534	1,694	1,854	2,013	2,172
38	655	912	1,170	1,402	1,635	1,805	1,975	2,148	2,322
39	698	974	1,250	1,498	1,746	1,932	2,118	2,298	2,479
40	740	1,035	1,330	1,594	1,858	2,059	2,260	2,448	2,636

Source: U.S. Forest Service, *Service Foresters Handbook*, Tree Volume Tables

Table 7. Percent board foot volume of logs by 4-foot sections.

Logs	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80
½	54	46																		
1	31	27	23	19																
1½	23	20	17	15	13	12														
2	19	17	14	12	11	10	9	8												
2½	16	14	12	10	10	9	8	8	7	6										
3	14	13	11	9	9	8	7	7	6	6	5	5								
3½	13	11	10	8	8	7	7	7	6	6	5	5	4	3						
4	12	10	9	8	7	7	7	6	6	5	5	5	4	4	3	2				
4½	10	9	8	7	7	6	6	6	6	5	5	5	4	4	4	3	3	2		
5	10	9	8	6	6	6	6	5	5	5	5	5	4	4	4	3	3	2	2	2

Table 8. Penn State Timber Market Report fourth quarter 2018 stumpage prices for northwestern Pennsylvania. A range of stumpage prices one standard deviation on either side of the average usually includes two-thirds of all the reported prices for that species. This does not represent the complete range of prices for the species but shows where the majority (two-thirds) of the reported prices fell.

Species	Minus 1 Standard Deviation	Average $ per MBF International	Plus 1 Standard Deviation	Number of Prices Reported
Northern Red Oak	$330	$471	$612	11
White Oak	$268	$363	$458	9
Mixed Oak	$189	$252	$314	9
Black Cherry	$334	$1,003	$1,671	18
White Ash	$130	$216	$303	12
Hard Maple	$253	$452	$650	15
Soft Maple	$122	$232	$342	19
Yellow-Poplar	$65	$139	$213	7
Misc. Hardwoods	$43	$110	$178	16
White Pine	$26	$28	$30	2
Hemlock	$3	$20	$38	4

Assigning Tree Value

Stumpage Value versus Delivered

Stumpage refers to the value of standing trees in a woodlot or "on the stump." Trees are valued by buyers "on the stump" after deducting costs associated with cutting, transporting the felled tree to the log landing, hauling the logs to the mill, and other costs. These costs vary with equipment, maintenance, fuel prices, insurance, labor, markets for forest products (supply and demand), logging conditions, volume of timber per acre, road conditions, distance to mills, and other factors.

Don't get stumpage prices confused with "mill-delivered prices." Sawmills pay different prices according to the products they manufacture from the logs delivered. When a logger delivers a load of logs to the mill, they have a tremendous amount of money invested

in the process involved in the delivery. They are paid "mill-delivered prices" to compensate them for all their costs, plus a profit for their labor. All the costs of stumpage prices: *cutting + skidding + loading + hauling + other fixed costs + variable costs = mill-delivered prices.*

Timber Market Report

The Penn State Timber Market Report, found on the Extension website, provides the most current stumpage prices for Pennsylvania. The report is prepared quarterly and provides prices for common trees species by region of the state, northeast, northwest, southeast, and southwest. Prices are provided based on the value of one thousand board feet, abbreviated MBF; see Table 8. Along with the average price, the report includes columns representing the average price plus and minus one standard deviation. The standard deviation is a measure of the variability or dispersion of all the prices reported for a given species.

Timber Cruising

Timber cruising is the term foresters use to describe the process of determining the board foot volume and value of standing trees in a given forested tract, also referred to as an inventory. Many types of inventories can be performed to determine volume. This publication will describe one simple method, referred to as a 100 percent tally, where all trees designated for harvest are measured and tallied.

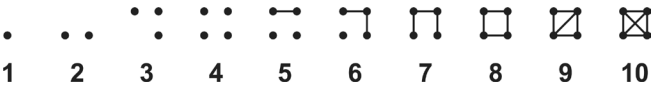
To tally trees, we will use a specially designed tally sheet and what is referred to as a dot tally (Figure 15). Dot tallies allow us to record a lot of information in a small space. When making dot tallies, a dot or line represents one tree.

Tally Sheet

Well-designed tally sheets are extremely important to facilitate recording information in the field. Figure 16 illustrates such a sheet and can be adapted for use in many different forest types. The sheet is for tallying saw timber of a given DBH, number of 16-foot logs, and species using codes such as WO for white oak, RO for red oak, RM for red maple, etc. Each forest type will have a set of specific species codes. Several tally sheets may be required to complete an inventory depending on the number of trees and tree species tallied.

Trees sold for pulpwood do not need to be separated by species but should be tallied by diameter as conifer or hardwood, as the market price may vary. Since pulpwood has such a low value, it is often ignored when completing a 100 percent tree tally. This tally sheet does not have a section for tallying pulpwood.

Figure 15. A dot tally.



100 Percent Tree Tally

For 100 percent tallies, each tree being sold will need to be visited and evaluated. The trees may have already been marked by the seller prior to your evaluation and should have paint at eye level and also near the ground. The eye-level mark is intended to indicate trees to be cut by the logger. The lower mark on the stump is intended for the owner to check that only designated trees were actually harvested.

When tallying trees already marked for sale, a chalk tree marker is a helpful tool to use. It allows potential buyers to mark trees as measured and tallied. The marks readily wash off after a couple of rains. For marked trees of sawtimber size, record them under the proper species and size with a dot tally. Trees that are small in size or very poor form that will be used as pulpwood, can be ignored or recorded on a separate tally sheet.

Stand and Stock Tables

Although total volume of timber being sold is a major objective of a 100 percent tree tally, the information is more useful when summarized by tree species and size classes. A stand table is the total number of stems tabulated by DBH class and species in a stand or forested tract. A stock table lists the total volume of stems in a stand by DBH class and species. Since stock tables are derived from stand table, they are often combined into one table (Table 9).

To illustrate how to create a stand and stock table from your tally sheet, see Figure 17. Using the International ¼-inch volume table, we find that a 12-inch, 1-log tree has 56 board feet. Record that value in the square (cell) on the tally sheet for one red oak (RO). Next, we have four 12-inch, 1½-log ROs, record (4)(74) = 296; and two 12-inch, 2-log ROs, record (2)(92) = 184. In the 16-inch, 2-log RO cell, record 180; in the 17-inch, 1½-log RO cell, record 164; and in the 18-inch, 2-log RO cell, record (2)(233) = 466. Continue in this fashion until all calculations for each species on the tally sheet are completed.

Figure 16. Example tally sheet for timber cruising.

DBH (inches)	# of 16-ft logs	Species 1	Species 2	Species 3	Species 4	Species 5	Species 6
11	1						
	1 1/2						
	2						
	2 1/2						
12	1						
	1 1/2						
	2						
	2 1/2						
13	1						
	1 1/2						
	2						
	2 1/2						
14	1						
	1 1/2						
	2						
	2 1/2						
15	1						
	1 1/2						
	2						
	2 1/2						
	3						
16	1						
	1 1/2						
	2						
	2 1/2						
	3						
17	1						
	1 1/2						
	2						
	2 1/2						
	3						
18	1						
	1 1/2						
	2						
	2 1/2						
	3						
19	1						
	1 1/2						
	2						
	2 1/2						
	3						

Figure 17. Completed tally sheet marked after examining timber being sold.

DBH (inches)	# of 16-ft logs	Species 1 RO	Species 2 WO	Species 3 RM	Species 4 YP	Species 5 BB	Species 6
11	1			• 46		• • 92	
	1 1/2			• • 122		: • 183	
	2						
	2 1/2						
12	1	• 56	• 56			: : 224	
	1 1/2	: : 296		: • 222		• • 148	
	2	• • 184					
	2 1/2						
13	1						
	1 1/2		• 90				
	2						
	2 1/2						
14	1						
	1 1/2					• • 210	
	2			• 132	• 132	• 132	
	2 1/2						
15	1						
	1 1/2						
	2		• • 312				
	2 1/2						
	3						
16	1						
	1 1/2		• 143				
	2	• 180					
	2 1/2						
	3						
17	1						
	1 1/2	• 164					
	2						
	2 1/2						
	3						
18	1						
	1 1/2						
	2	• • 466					
	2 1/2				• 548		
	3						
19	1						
	1 1/2						
	2				• 264		
	2 1/2						
	3	• 358					
	Totals:	12/1,704	5/601	7/522	4/944	14/989	42/4,760

Table 9. Sample stand and stock from Figure 17: number of trees and board foot volume (International ¼-inch) by size and species.

DBH	RO		WO		RM		YP		BB		Totals	
	No.	Volume	No.	Volume	No.	Volume	No.	Volume	No.	Volume	No.	Volume
11					3	168			5	275	8	443
12	7	536	1	56	3	222			6	372	17	1,186
13			1	90							1	90
14					1	132	1	132	3	342	5	606
15			2	312							2	312
16	1	180	1	143							2	323
17	1	164									1	164
18	2	466					2	548			4	1,014
19	1	358					1	264			2	622
Totals:	**12**	**1,704**	**5**	**601**	**7**	**522**	**4**	**944**	**14**	**989**	**42**	**4,760**

Table 10. Estimated stumpage value based on Penn State Timber Market Report 2018 fourth quarter report.

Species	Board Foot Volume	Timber Market Price ($ per Board Foot)	Stumpage Value
Red Oak	1,704	$0.471	$803
White Oak	601	$0.363	$218
Red Maple	522	$0.232	$121
Yellow-Poplar	944	$0.139	$131
Black Birch	989	$0.110	$109
			Total: $1,381

When this process is completed, we are able to build a stand and stock table. Stand and stock tables provide useful information to potential buyers and allow you to make accurate estimates of the stumpage value of this timber. Landowners typically sell based on a stumpage basis, where the buyer pays so much for the right to cut the specified trees as marked.

Estimating Stumpage Value

The Penn State Timber Market Report provides current average stumpage prices for your area. Using the 2018 fourth quarter report for northwestern Pennsylvania provided in this publication (Table 8 on page 17) we see that red oak is selling for $471 per thousand board feet (MBF), white oak for $363 per thousand, red maple for $232 per thousand, and yellow-poplar for $139 per thousand, and we use the miscellaneous hardwood price for black birch, $110 per thousand. To estimate the stumpage value, multiply the total volume for each species by the appropriate stumpage value for each species divided by 1,000. Dividing the stumpage value by 1,000 reduces the stumpage value to a price per board foot instead of 1,000 board feet (Table 10).

When to Sell Timber

Timber owners can lose thousands of dollars by cutting timber too early. Fortunes have been made by timber buyers who recognize the great increase in value timber makes when it moves from pulpwood to sawtimber size.

To illustrate this, consider a pulpwood-size tree 10 inches in diameter and 70 feet tall. Its estimated volume is only 0.21 cord. In most areas, stumpage for a cord of pulpwood is $4.00 per cord. Therefore, this tree would only be worth $0.84 for pulpwood (0.21 × 4.00 = 0.84).

Trees often grow from the 10-inch diameter class into the12-inch class in about 10 years. A 12-inch tree is the minimum size accepted for sawtimber. The number of board feet in a 12-inch tree depends on the number of 16-foot logs it contains. But, on average, 12-inch trees contain about 70 board feet. If stumpage sells for $400 per MBF (for oak), a 12-inch tree is worth $28. This indicates a significant increase in value. The lesson is clear: if trees are approaching sawtimber size, don't cut them for a low-value product, unless the stand is overstocked and in need of thinning.

There are other increases in value as trees grow from sawtimber to veneer quality. But these increases in value are not as dramatic as the pulpwood to sawtimber change. As a general rule, there is little real economic gain to the owner by letting trees grow much beyond 18–20 inches DBH. This is because the increase in value due to growth is low compared to the present value these large sawtimber trees represent. Said another way, the investment is earning a very low rate of return. However, the landowner may have other reasons to hold trees after they reach economic maturity, and decisions to harvest should be guided by a written forest management plan that provides recommendations for each particular timber stand based on landowner objectives.

In Summary

This publication is intended to help with an understanding of how trees and forests are evaluated prior to a timber sale. But many questions still need to be answered before proceeding with any type of harvest. For example, which trees do I sell to meet my objectives? How do I harvest in a sustainable way? Who are the potential buyers? How do I advertise the sale? What about a sale contract? Contacting a state service forester, extension forester, or private consultant can provide answers to these questions and many more. By studying the information provided in this publication, you can be better informed and more likely to receive a fair price when timber is offered for sale.

Prepared by Dave Jackson and Allyson Muth, Penn State Extension; and the Penn State Center for Private Forests. Illustrations by Lori Settlemyer. Revised from Harry V. Wiant, Jr., "How to Estimate the Value of Timber in Your Woodlot" (West Virginia University Agricultural and Forestry Experiment Station, 1989), and James R. Grace, "Basic Forest Measurements" (Penn State).

extension.psu.edu

Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

Where trade names appear, no discrimination is intended, and no endorsement by Penn State Extension is implied.

This publication is available in alternative media on request.

The University is committed to equal access to programs, facilities, admission and employment for all persons. It is the policy of the University to maintain an environment free of harassment and free of discrimination against any person because of age, race, color, ancestry, national origin, religion, creed, service in the uniformed services (as defined in state and federal law), veteran status, sex, sexual orientation, marital or family status, pregnancy, pregnancy-related conditions, physical or mental disability, gender, perceived gender, gender identity, genetic information or political ideas. Discriminatory conduct and harassment, as well as sexual misconduct and relationship violence, violates the dignity of individuals, impedes the realization of the University's educational mission, and will not be tolerated. Direct all inquiries regarding the nondiscrimination policy to the Affirmative Action Office, The Pennsylvania State University, 328 Boucke Building, University Park, PA 16802-5901, Email: aao@psu.edu, Tel (814) 863-0471.

Produced by Ag Communications and Marketing

© The Pennsylvania State University 2020

Code EE0386 2C06/20MPC