W 1117

A SIMPLE GUIDE TO COMMON FOREST MEASUREMENTS

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Purpose

Trees and the forests in which they grow are measured to obtain information for making natural resources decisions. Decisions include a number of reasons, such as financial, wildlife management or forest health. This publication introduces several common concepts in forest measurements. Readers will benefit by gaining a general understanding of how and why forest measurements are taken. Some common tree and stand variables include:

- Diameter at breast height
- Basal area (tree basal area and basal area per acre)
- Trees per acre
- Tree age
- Tree height (total, crown and merchantable)
- Crown class
- Site index
- Board-foot volume

Diameter at Breast Height (DBH)

Diameter at breast height (DBH) is an important tree measurement in forestry. DBH is the diameter of a tree measured outside of the bark at breast height (4.5 feet above the ground, on the uphill side of the tree). DBH is useful to characterize stand structure and estimate wood volume. DBH is also closely correlated with tree value. DBH is usually measured with a fabric or metal diameter tape that is wrapped around the circumference or with a Biltmore stick held 25 inches (in.) from the observer's eye at breast height on the edge of the trunk and recorded in inches (Fig. 1).

Fig. 1. Measuring DBH using a Biltmore Stick. **Source:** *D. Mercker*

Basal Area (BA)

Basal area (BA) is commonly quantified at the tree and stand levels. At the tree level, BA is the cross-sectional area of a tree stem at breast height in square feet (sq. ft.), (Fig. 2). To calculate BA of a standing tree, use the following equation:

$$BA \text{ (sq. ft.)} = .005454 \times [DBH \text{ (in.)}]^2$$

Fig. 2. An example of calculating BA for a 14-inch tree. **Source:** *D. Mercker*

For example, the basal area of a 10-inch DBH tree is $0.005454 \times 10^2 = 0.5454$ (sq. ft.), whereas a tree measuring 20 in DBH would have over two square feet of BA, derived as ($0.005454 \times 20^2 = 2.181$ sq. ft.). Table 1 includes additional examples of tree BA calculated from different tree DBH. Notice that a 14-inch DBH tree is equal to about 1 sq. ft. of BA. At the *stand level*, BA is the sum of tree BA from all trees on a per-acre basis, commonly referred to as BA per acre (per ac.). For simplicity's sake, think of an acre of forest where all the trees have been cut at DBH so only 4.5-foot high stumps remain. Let's look at two examples:

- Stand 1: Given there are two hundred 4 in DBH trees in a 1-acre stand, the BA per ac is equal to 17.4 sq. ft/ac, derived as ($200 \times [.005454 \times 4^2]$ sq. ft/1 ac = $200 \times .087$ sq. ft /1 ac = 17.4 sq. ft/ac).
- Stand 2: Given there are fifty 8 in DBH trees in a 1-acre stand, the BA per acre is equal to 17.5 sq. ft/ac, derived as ($50 \times [.005454 \times 8^2]$ sq. ft/1 ac = $50 \times .349$ sq. ft/1 ac = 17.5 sq. ft/ac).

From the above examples, similar amount of BA per ac was found in both stands; stand 2 has a fewer number of trees per acre but the trees are larger than stand 1. Therefore, younger stands and more mature stands may measure the same BA per ac, but the more mature stands achieve this with a fewer number of trees per ac. In forest management, BA per ac measures the crowding of trees, which aids in quantifying forest stocking and determining when thinning is needed. For instance, as a very general guide, southern hardwood stands that approach 100 to 120 sq. ft. of BA per ac should be evaluated for the need of thinning. This varies according to the average stand DBH, species of trees and the forest site quality. Site quality includes the collective factors that determine the potential productivity of a forest area and includes attributes such as soil fertility, soil depth and water availability.

Table 1. Basal Area for Select DBH

DBH (in.)	Basal Area (sq. ft.)
4	0.087
6	0.196
8	0.349
10	0.545
12	0.785
14	1.069
16	1.396
18	1.767
20	2.182
22	2.640
24	3.142

Trees per Acre (TPA)

In addition to BA per ac, trees per ac (TPA) is another important stand parameter that is often needed to make decisions. TPA is the total count of all standing trees on a per-acre basis. For example, if there are 200 trees on a 2-acre stand, TPA of the stand is 100, which was derived as (200 trees/2 ac = 100 TPA).

Because it is not practical to measure all the trees in a forest, estimates of BA per acre and TPA are made via plot samples. To ensure the sample represents the target population, multiple plots are often taken and evenly spaced across the forest. There are two common methods of plot samples in forest measurements: fixed radius plot and variable radius plot.

Fixed Radius Plot

Of the two methods, fixed radius plots are the easiest to explain and understand. With this method, a plot center is first established. Then, all trees within the radius of the plot circle are tallied, trees are measured and each is multiplied by that "portion" of an acre sampled to provide per-ac values (e.g., BA per ac and TPA).

For instance, a 1/10-acre plot has a plot radius of 37.2 feet. All trees within the 37.2-foot radius circle are tallied. Each tallied tree within the circle represents 10 trees per ac. If a 1/20-ac plot is used, then use a 26.4-foot radius plot and multiply each tree tallied by 20, and so on. The accuracy in estimating stand variables generally increases as plot size increases, but so too do the number of trees to be tallied. A list of common plot sizes and their radius is shown in Table 2.

Table 2. Basal Area for Select DBH

Plot Size (ac.)	Radius of the Plot (ft.)
1/100	11.8′
1/20	26.4′
1/10	37.2′
1/5	52.7′
1/2	83.3

Variable Radius Plot

The variable radius plot method avoids the use of a fixed plot radius and instead relies on the DBH of the trees and the distance between those trees and the plot center. In variable radius plot sampling, we need to first determine the BA factor (BAF). In the southern hardwood region, a BAF of 10 (sq. ft/ac) is commonly used, meaning that each tree tallied in a plot represents 10 sq. ft of BA/ac. Using either an angle gauge or a prism (specialty tools that are common with professionals), an observer determines which trees are "in" the plot, then measures and records the "in" trees and records them by DBH class. For instance, using an angle gauge, an "in" tree will appear wider than the gauge when sighted at DBH height with the observer's eye over plot center. When using a prism for "in" trees, the offset image of the tree seen in the prism will overlap with the view of the tree sighted with the prism held over plot center (Fig. 3).

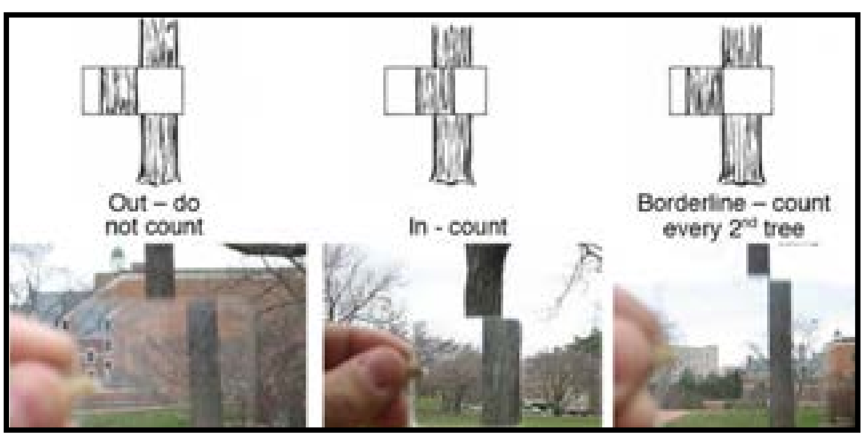

Fig. 3. Determining an "in" tree using a prism (Ref. www.uhcl.edu). **Source:** *D. Mercker*

The number of trees tallied by DBH class is then expanded using a tree factor. The tree factor formula estimates the number of trees per ac by diameter class. The formula for calculating tree factor (TF) using a BAF of 10 is:

$TF = 1833.46/D^2$, where:

TF = the number of trees per acre for each "in" tree tallied

D = DBH (in.)

Using the TF formula, the TF for trees in 2-inch DBH classes is summarized in Table 3.

To interpret this, if one 8-inch DBH tree is tallied in a plot using a 10 BAF prism, that tree represents 28.6 trees per ac. If two 4-inch DBH trees are tallied, those trees represent 2 x 114.6 = 229.2 trees per ac, and so on. If accuracy is of utmost importance, then DBH can be in 1″ diameter classes. The odd numbers can be added to Table 3 by using the formula given. Again, to improve accuracy, often several plots are taken.

Table 3. Tree Factor by 2-in. DBH Class[1]

DBH	Tree Factor[2]
2	458.4
4	114.6
6	50.9
8	28.6
10	18.3
12	12.7
14	9.4
16	7.2
18	5.7
20	4.6
22	3.8
24	3.2
26	2.7
28	2.3
30	2.0

[1]Using a 10-factor angle guage or prism

[2]Tree Factor = the number of tress per acre per tree tallied

Tree Age

Tree age, particularly when combined with DBH, provides a measure that reflects stand productivity and is useful in making forest management recommendations. Tree age can be known based on history and previous land uses, or it can be determined by counting tree rings using an increment borer. A borer has a hollow center that is penetrated (screwed) into a tree (normally at DBH height) to the center (or pith) of the stem from which a core of wood is extracted, and then the growth rings are counted to estimate tree age. The outermost rings reflect the most recent growth.

Tree Height (Total, Crown and Merchantable)

There are several measurements of tree height that can be taken. Three are considered here, and each provides useful information.

Total height – a measure from the groundline to the highest point of the tree crown. Tree height, when combined with tree age, provides an estimate of site index (explained later in this publication).

Crown length – a measure of that portion of the total tree height having living branches. Sometimes called live crown ratio (defined as the ratio of crown length to the total tree height), it is useful in determining when forest stands are ready to be thinned. Small crown length can imply slow growth and poor health.

Merchantable height – is the height above the ground level to which the tree bole can be cut and sold for commercial products. For hardwood sawtimber, merchantable height is normally reached when the diameter inside the bark at the small end of the log reaches 10 inches.

Clinometers and laser hypsometers are instruments widely used by professionals to measure tree height. Merchantable height is commonly measured in 16-foot lengths. For most trees to be counted as sawtimber, there must be at least one 16-foot log.

Crown Class

Tree crowns make up the canopy (or uppermost layer) of a forest. Crown classes cannot be measured precisely; their measurement is relative. Crown classes are broken into distinct layers. Four crown classes are generally recognized (Fig. 4).

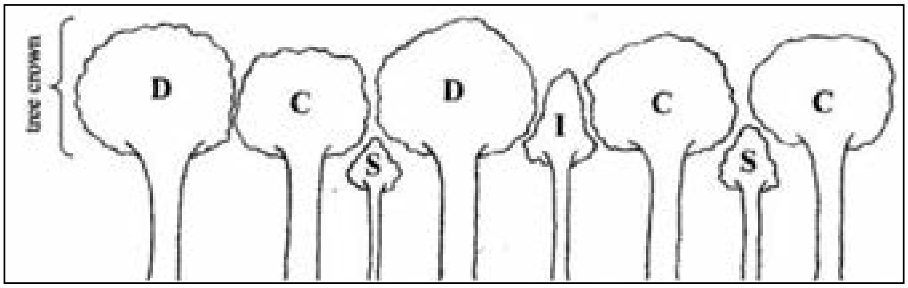

Fig. 4. Example of four crown classes. **Source:** *K. P. Bennett, Managing for High-Value Trees*

Dominant – trees much taller than the general level of the canopy, receiving direct sunlight on all sides of their crown.

Codominant – trees that form the general level of the canopy, but below the dominants, receiving sunlight from above their crown and some from the side.

Intermediate – trees with crowns that fall below the general level of the canopy, receiving sunlight only from above at midday.

Suppressed – trees much shorter than the general level of the canopy, receiving only filtered sunlight.

Site Index

The site index (SI) of a forest is a quantitative expression of the forest site quality based on the average height of the dominant and codominant trees of a specific species at a specified base age, usually 50 years for deciduous hardwood trees and 25 years for planted pine.

Two variables are needed to estimate the SI: average height of the dominant or codominant trees and their age. Site index curves are used to estimate the SI for each species. For instance, when white oak trees (Quercus alba) are 85 feet tall at 50 years of age, the SI for that group of trees is 85 (ft.). If the white oak trees are only 65 feet tall at 50 years of age, the SI is 65 (ft.). Normally, the higher the SI for a species, the better it will grow and produce wood volume. Professionals often focus management activities first on sites with better SI.

Board-Foot Volume

A board foot (BF) is a measure of wood volume totaling 144 cubic inches that is commonly used for estimating wood volume in trees, sawlogs or individual pieces of lumber. For instance, a piece of wood measuring 1-foot long x 1-foot wide x 1-inch thick, or a piece of wood measuring 1-foot x 2-inches x 6-inches, each contains 1 BF of wood (Fig. 5).

Fig. 5. Example of a board foot. **Source:** *D. Mercker*

Tables have been developed for both felled logs and standing trees, called log rules, whereby estimates of BF can be made quickly. The log diameter and length are needed to use these rules (Fig. 6).

Fig. 6. A standing tree measuring 22″ DBH with three 16′ logs has 392 board feet using Doyle Scale and FC 78. **Source:** *D. Mercker*

The tables for standing trees are modified to account for taper. This is known as form class. Form class (FC) is a measure of the taper of a tree bole derived by dividing the diameter inside the bark (DIB) at a given height (usually 16 feet above the ground) by DBH, times 100. For example, a common FC used with hardwood timber is FC 78, inferring that the DIB of a tree bole at 16 feet is 78% that of the DBH (Fig. 7). Source: D. Mercker. Trees with a FC of 82 would have less taper and more wood volume than trees with a FC of 78. The most commonly used FC for southern hardwoods is FC 78.

Increasingly, board foot volume measurement is being replaced by log weight as a measurement. Although not as accurate (weight varies by species, size of trees and location), many mills prefer this method of wood measurement due to the ease in business transactions.

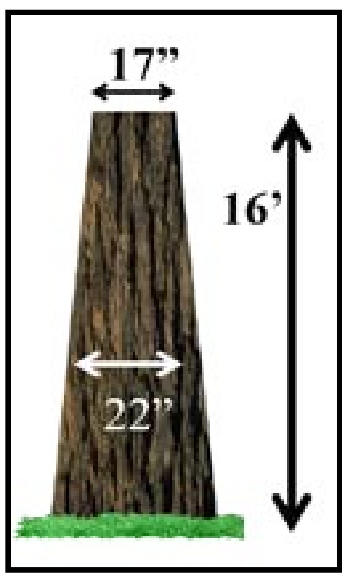

Fig. 7. The Form Class of this tree is 77 calculated (17/22) = 77%. **Source:** *D. Mercker*

Conclusion

Measuring trees and forests is important for assessing the present condition and for developing strategies to achieve future goals. Foresters and natural resource professionals utilize multiple techniques to measure trees and forests. This publication explains some of those techniques to better prepare private landowners when engaging the services of professionals.

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