Pennsylvania Envirothon Forest Measurements and Management

2020

MEASUREMENTS

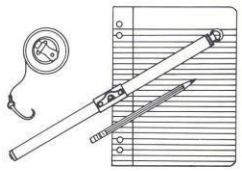
Introduction:

Like many other disciplines, forestry is a science based on measurements. While participating in the Envirothon program, you will learn to use the same instruments and collect the same data that professional foresters use to learn about and manage our forest resources. Many students enjoy the forestry section of Envirothon because it is very "hands on". Becoming proficient with basic forest measurements is very important, because many of the more complex measurements require accurate forest data collection.

Learning Objectives:

At the end of this section, you should:

- Understand why measurements are important in forestry and understand which tools are used to obtain specific measurements.
- Demonstrate proficiency in "pacing" to measure distances and determine how many paces you have in a chain (66 feet).
- Demonstrate proficiency in the use of the following forestry tools:
    - Diameter Tape
    - Biltmore Stick/Merritt Hypsometer
    - Clinometer
    - Wedge Prism
    - Angle Gauge (Not required for 2020 Envirothon)
- Conduct a sample plot as part of a forest inventory using forestry instruments
- Apply data to specific charts and tables to determine forest growth conditions.



Let's Get Started:

Pacing: The most basic forest measurement is **pacing** or counting your number of steps to determine how far you've traveled in the woods. A compass will help you determine which direction you are walking, but pacing allows you to determine distance.

In forestry, distance measurements are based on a **chain**, which equals 66 feet. Many years ago surveyors literally dragged a 66-foot-long chain around with them to measure properties, which were measured in chains and links.

Today, foresters measure chains by knowing how many steps they take in 66 feet. To determine your pace, measure out 66 feet using a 100-foot measuring tape, and count every other step (for example, every time your right foot hits the ground). Most people have between 12 and 15 paces per chain.

CHAIN FACTS:

- *80 chains = 1 mile*
- *10 square chains = 1 acre (very helpful in determining the size of wildfires!)*
- *Several forestry tools are calibrated to be accurate at one chain.*

Tree Diameter:

Tree diameter is an important measure of tree growth, especially when combined with additional measurements such as the height and age of a tree (such as determining the volume or site index of a tree). Diameter is always measured in inches, on the uphill side of a tree, at 4.5 feet above the ground and is called DBH (Diameter at Breast Height).

A **diameter tape** (or d-tape for short) is used for this measurement.

A d-tape has feet, tenths of feet and hundredths of feet on one side. On the other side of the d-tape, the inches look a lot longer than expected, (3.14 inches to be exact). This is because the d- tape is calibrated in "diameter equivalents of circumference by inches and tenths of inches" saving you the trouble of converting circumference into diameter.

Remember that diameter measurements should be expressed to the nearest tenth of an inch (for example 29.2" in photo below).

Diameter Tape

Measure Tree at DBH

Measure to nearest tenth of an inch (29.2 inches in this example)

Measuring Tree Diameter With a Biltmore Stick

1. Hold the stick at breast height (4.5 feet from the ground), 25" from your eye, with the back of the stick against the tree you are measuring.
2. Hold the stick at a right angle to the axis of the tree and keep your eyes level with the stick.
3. Adjust the stick so that the left or zero is in line of sight with the left side of the tree.
4. Without moving your head, shift the line of sight to the right-hand side of the trunk.
5. Read the diameter on the stick nearest the point at which the line of sight crosses it.

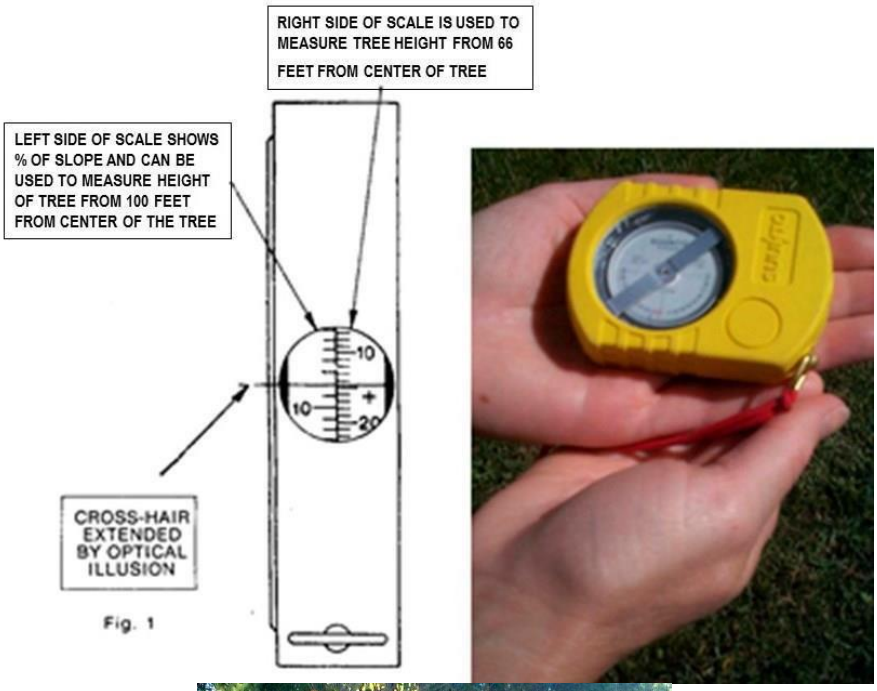
Using the Biltmore stick to measure diameter at breast height

Measuring Tree Height

Measuring tree height with a clinometer

Tree height is measured using the principle of triangulation with a **clinometer.** Of all the forestry tools you will use, the clinometer requires the most practice and skill. Assuming that the tree grows at a right angle to the ground (even on a slope), we use the clinometer at 1 chain (66 feet) away from the center of the tree using the following steps:

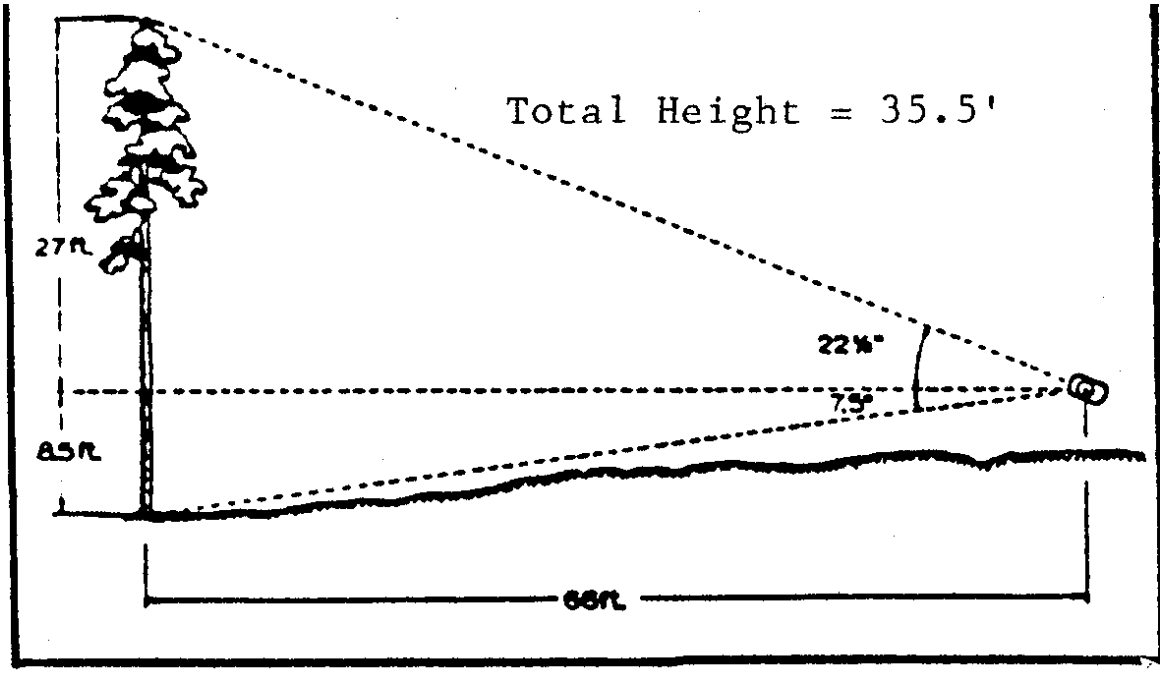
- Standing 66' from the center of the tree, with both eyes open, aim the black crosshair of the clinometer level with the base of the tree at the soil line. Using the right-hand scale (the left scale is for measuring percentage of slope and can be used for measuring the height of trees at 100' from the center of the tree). You will read a "negative" number if the tree is on level ground or down slope. You will read a "positive" number if the tree is up slope.
- With both eyes open, aim the black crosshair of the clinometer to the top of the tree. This is a tricky measurement because your view may be obscured by leaves or nearby tree branches. If the top of the tree were an open umbrella, you'd want to be aiming at the point on the top of the umbrella.



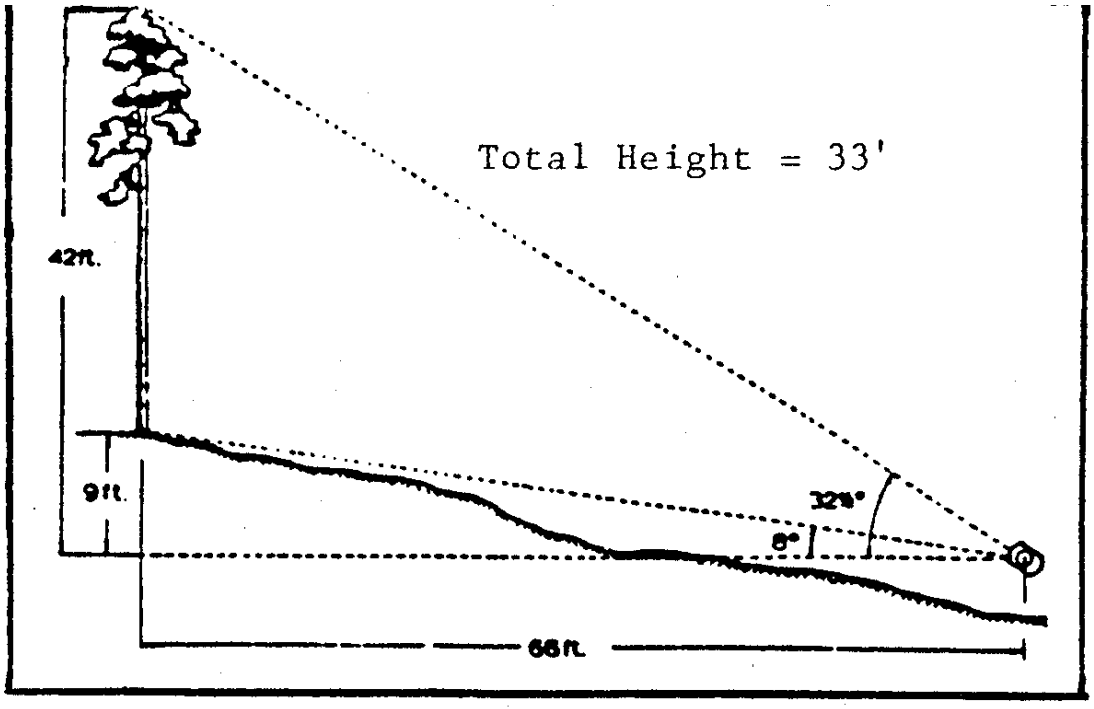
Above clinometer reading is 15' above level

Adding these positive and negative numbers for a final height:

1. If your eye level is above the base of the tree, the two numbers are added together to determine total height.
2. If your eye level is below the base of the tree (the tree is upslope), the base reading must be subtracted from the top reading to determine total height:



EYE LEVEL IS ABOVE BASE OF TREE (BASE + TOP = HEIGHT)



EYE LEVEL IS BELOW BASE OF TREE (TOP – BASE = HEIGHT)

The Biltmore Stick

by Justin Black, USU Forestry Extension

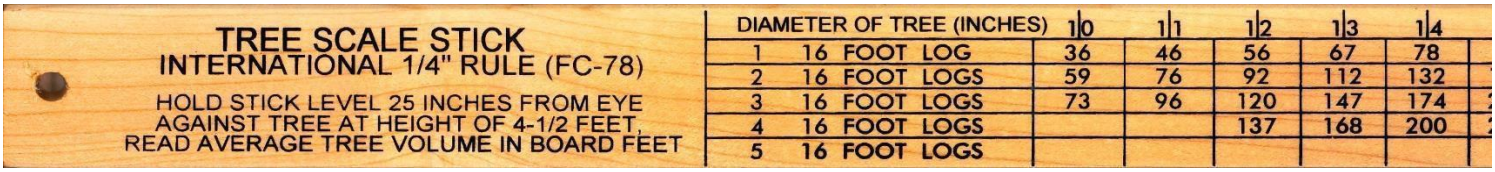
Measuring Tree Height with a Biltmore stick

1. Total tree height is measured from the ground to the top of the tree. Merchantable tree height is measured from the stump height to the point at which the tree is no longer useable.
2. Stand 66 feet or 100 feet from the tree you are going to measure. Your Merritt Hypsometer is calibrated to one of these distances and the appropriate distance will be clearly marked on the Merritt Hypsometer face. If the ground is not level, stand on a spot which has about the same elevation as the base of the tree.
3. Hold the stick vertical, 25" from your eye, with the Merritt Hypsometer side facing toward you.
4. Align the base of the stick at the ground (or at your estimated stump height for merchantable height).
5. Without moving your head, shift your line of sight so you can read the height at the point where your line of sight and the top of the tree intersect (or merchantable height).
6. This can also be done opposite: Zero the stick at the top of the tree and check height at the ground.

Using your Biltmore stick to measure tree height:

Measuring Tree Volume with a Biltmore Stick

A Biltmore stick, dated to the early 19th century, is one method used for measuring tree diameter and height (total or merchantable). From that information, the total board feet of the tree can be established, along with tonnage and cubic feet.



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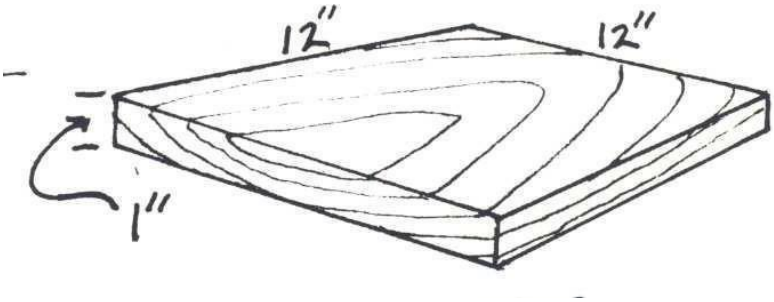
3. Adjust the stick so that the left or zero is in line of sight with the left side of the tree.
4. Without moving your head, shift the line of sight to the right-hand side of the trunk.
5. Read the diameter on the stick nearest the point at which the line of sight crosses it.

Using the Biltmore stick to measure diameter at breast height

Determining tree volume:

1. Once we know the diameter, height, and the number of logs a tree contains, we can determine the **volume** of the tree.
2. In forestry, volume is expressed in **board feet,** which is an imaginary chunk of wood 12" (30.4 cm) X 12" X 1" (2.5 cm) thick.



3. In forestry volume may also expressed in cubic feet, which is an imaginary chunk of wood 12" X 12" X 12"

Estimating Board Feet with a Biltmore Stick

Board Feet: After determining tree diameter and height (in 16 foot lengths), use the chart on the back of the Biltmore stick to determine board feet. Using the "inches" scale along the top, find your tree diameter. Look on the table corresponding to the number of 16-foot log sections you have.

TREE SCALE STICK
INTERNATIONAL 1/4" RULE (FC-78)
HOLD STICK LEVEL 25 INCHES FROM EYE AGAINST TREE AT HEIGHT OF 4-1/2 FEET. READ AVERAGE TREE VOLUME IN BOARD FEET

DIAMETER OF TREE (INCHES)		10	11	12	13	14	15	16	17
1	16 FOOT LOG	36	46	56	67	78	92	106	121
2	16 FOOT LOGS	59	76	92	112	132	156	180	206
3	16 FOOT LOGS	73	96	120	147	174	208	241	278
4	16 FOOT LOGS			137	168	200	242	285	330
5	16 FOOT LOGS								

To make measurements easier, foresters often use volume tables to quickly compute volume. For eastern forests, we use the International ¼ inch rule volume table, because it provides the most accurate volume measurements for the size classes of trees we have.

Some Biltmore Sticks have volume tables on them; because you are measuring a standing tree, make sure to use the tree scale side of the stick, not the log scale side. Volume tables are also used to calculate volume. Form class tables (like the one below) were built to match the taper of logs that are typical of various species and locales.

FORM CLASS 78

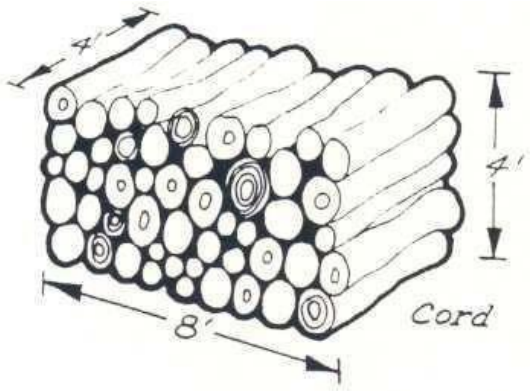
Gross volume of tree, International ¼-inch rule

Tree diameter (inches)	VOLUME (board feet) BY NUMBER OF USABLE 16-FOOT LOGS										
	1	1½	2	2½	3	3½	4	4½	5	5½	6
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	603	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	1,280	1,358
29	375	521	667	794	920	1,016	1,112	1,210	1,308	1,398	1,488
30	403	560	718	854	991	1,094	1,198	1,306	1,415	1,517	1,619
31	432	602	772	921	1,070	1,184	1,299	1,412	1,526	1,640	1,754
32	462	644	826	988	1,149	1,274	1,400	1,518	1,637	1,762	1,888
33	492	686	880	1,053	1,226	1,360	1,495	1,622	1,750	1,888	2,026
34	521	728	934	1,119	1,304	1,447	1,590	1,727	1,864	2,014	2,163
35	555	776	998	1,196	1,394	1,548	1,702	1,851	2,000	2,156	2,312
36	589	826	1,063	1,274	1,485	1,650	1,814	1,974	2,135	2,298	2,461
37	622	873	1,124	1,351	1,578	1,752	1,926	2,099	2,272	2,444	2,616
38	656	921	1,186	1,428	1,670	1,854	2,038	2,224	2,410	2,590	2,771
39	694	976	1,258	1,514	1,769	1,968	2,166	2,359	2,552	2,744	2,937
40	731	1,030	1,329	1,598	1,868	2,081	2,294	2,494	2,693	2,898	3,103

INTERNATIONAL ¼" RULE VOLUME TABLE USED FOR MOST EASTERN FORESTS

Determining the firewood volume of standing trees:

Many of us heat our homes with firewood because it is an inexpensive and renewable resource. Because we want to wisely use our forest resources, poorly formed trees that may not be usable as lumber and large branches left after harvesting may be used as firewood. The volume of firewood is expressed in a **cord**, a stack of firewood measuring 4 feet wide X 4 feet high X 8 feet long. Firewood in Pennsylvania is typically sold by the cord or the half cord, may also be sold by the bundle, or by the ton.



To determine the firewood volume of standing trees, foresters use a **cord volume table**

dbh Inches	HEIGHT IN FEET TO A 4 INCH DIAMETER TOP								
	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

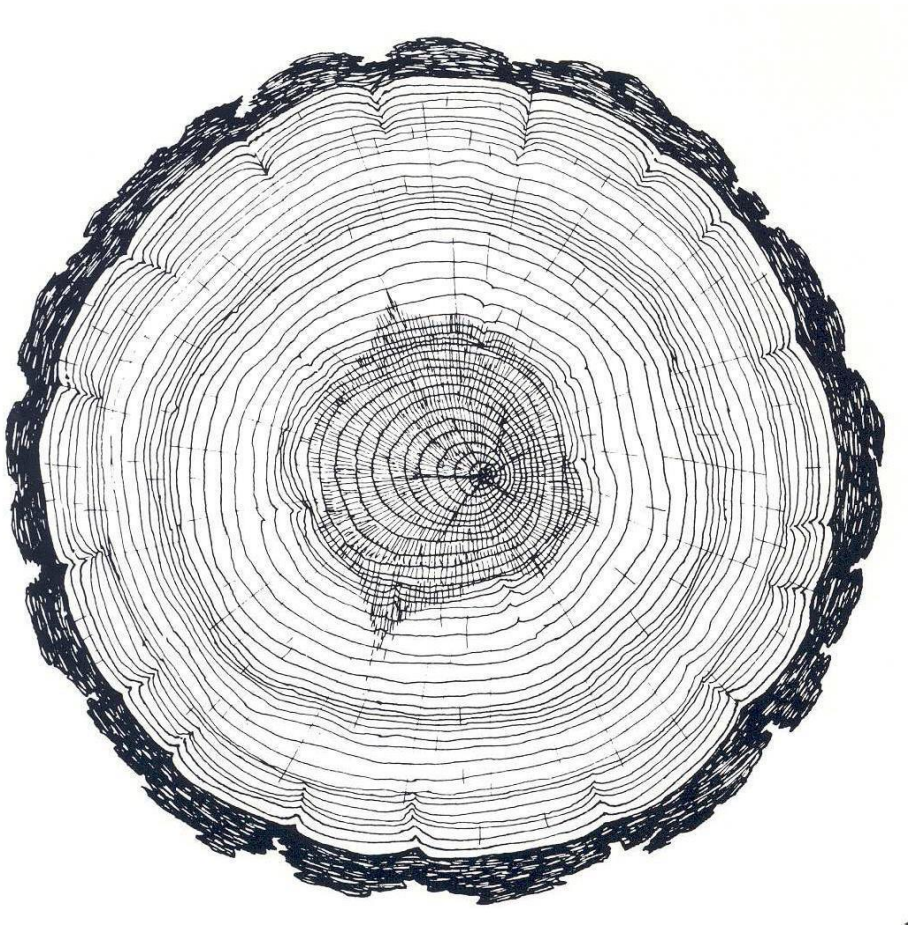
Determining tree age:

Another important measurement is tree age. Not only is counting the number of growth rings important to determine the tree's age, but interpreting the spacing of growth rings can tell us much about its life. Examining the growth of a tree can tell us many things about the growing conditions about the site, or environment the tree is growing in.

A tree's age, when compared to its diameter or height, can be an excellent indicator of how productive a specific site is for growing a particular species of tree, or may also be an indicator of stocking (or how crowded the trees are).

Because trees are many times older than we are, growth rings serve as a "history book" of the tree and its surrounding community. Droughts, wet seasons, competition with neighboring trees, injuries, and even forest fires can be reflected in tree growth rings.

GROWTH RINGS ON PINE TREE CROSSCUT



For standing trees, age is determined by using an **increment borer,** which is a threaded hollow drill that is turned by hand into a tree's trunk at until the borer reaches the center of the tree. The increment core, a pencil-thin sample of wood, is extracted from the trunk, showing the tree's growth rings and ring spacing. Although this boring does not usually harm forest trees, it is not recommended for urban or other "specimen" trees.

During the Envirothon competition, a sample increment core or the tree's known age will usually be provided.

Always bore on uphill side of tree

Pull extractor to remove increment core

Determining basal area:

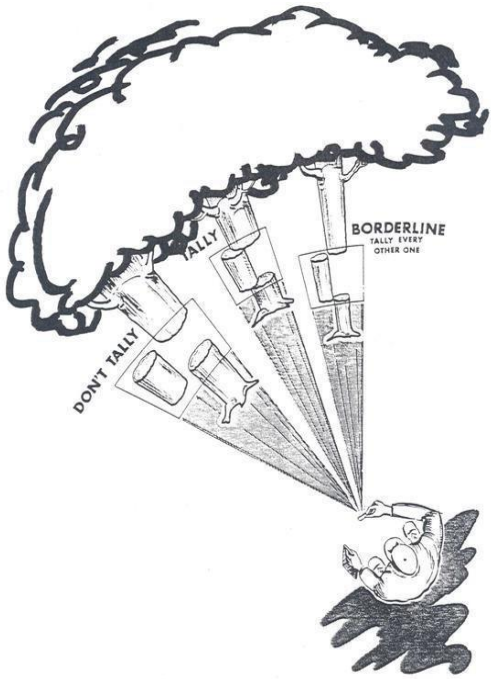
Once we've learned how to take measurements on individual trees, we will now look at the characteristics of the forest community. One important measurement is determining the **basal area,** or level of tree stocking on a particular site. Basal area is a measurement of the cross-sectional area of a given tree stem (or trunk) expressed in square feet at DBH (4.5 feet). The basal area of a forest stand is the sum of the basal areas the individual trees, and is expressed in square feet of basal area per acre.

Determining the basal area of an individual tree requires a d-tape and a calculator. The formula is:

$$BA = .005454 \times DBH^2$$

Foresters use a surprisingly simple, yet innovative instrument to determine the basal area on a specific site or sample point. The **wedge prism** is a small piece of glass that has been ground to refract light rays at a specific offset angle, which creates an "optical illusion". Technically speaking, in most eastern forests, we use a 10 basal area factor prism. This means that each tree that is measured or tallied represents 10 square feet of basal area.

When using the wedge prism, it is very important to remember that the instrument must always be held directly above the "plot center" stick for accuracy.



The "optical illusion" the wedge prism creates (as a result of the angle it is ground) appears to "offset" a portion of the tree's stem or trunk when viewed, preferably at DBH.

If the offset portion viewed through the prism appears to connect with the main stem of the tree, you will "tally" that tree as "in" or "countable". If the offset portion appears completely removed from the main stem of the tree, do not "tally" that tree as it is "out" or "not countable".

For trees that appear to be "borderline" or on the edge, use the following equation for use with a 10 factor prism - 2.75 feet per inch of DBH or (DBH X 2.75) = distance from plot center in feet, to the center of the tree being considered. If the calculated distance from plot center to the center of the tree is less than the calculated distance, the tree is tallied as "in".

After determining the number of "in" or countable trees, simply multiply that number of countable trees by 10 to determine your basal area (because you are using a 10 BAF prism). For example, if you have 8 "in" trees, your basal area is 80, or you have "80 square feet of basal area per acre". If you think about it, an acre contains 43, 560 square feet, while in this example, only 80 square feet is actually occupied by tree stems, or trunks. The branches and crowns of the trees, as well as other smaller vegetation occupy the remainder of a forested acre.

Lets' assume that you measured a 10 acre stand of trees with your 10 BAF prism. You measured 10 plots and in the 10 plots you counted 86 trees. 86 trees divided by the number of plots, 93/10 = 9.3 trees per plot. This average of 9.3 trees per plot represents 93 square feet of basal area per acre.

Determining the stocking level with a fixed diameter plot:

In addition to basal area, another important piece of data is the stocking level, often expressed in "trees per acre". Nobody has time to measure off an entire acre and count every tree, so we again depend on a sample point to give us representative number of the stand or property we are collecting forest data on.

To complete this measurement, we begin at our "plot center" and measure out 26 feet in each of the cardinal directions (north, south, east, and west) and flag the circle boundaries. This circle is equal to 1/20th acre. We then count all of the trees within this circle that are greater than 2". We then calculate the trees per acre by multiplying that number of trees by 20. In the example below, 13 trees within the circle multiplied by 20 indicates there are 260 trees per acre.

Determining stocking level using a table:

After we determine the trees per acre by conducting a 1/20th acre sample plot, we can combine this data with the basal area of the site to determine whether the forest is understocked, fully stocked, or overstocked. A chart like the one shown below is used to determine stocking level.

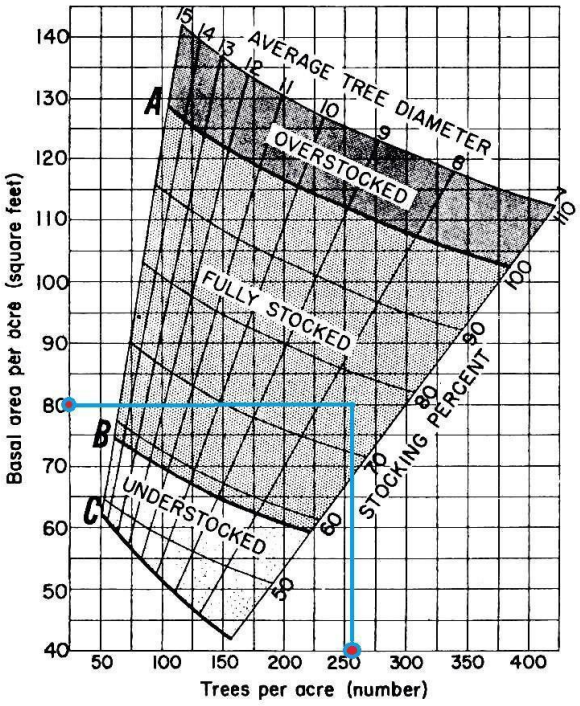
This information is very important to the forester when making forest management recommendations and deciding which silvicultural practices to implement based upon the landowner's objectives. Pennsylvania's forests cover 16.8 million acres. Of this forested acreage, Private landowners own 11.9 million acres of forests across 738,000 private ownerships. This represents 71 percent of forest land in Pennsylvania.

We have determined that the stand has 80 square feet of basal area per acre which we locate on the vertical axis of the chart to the right.

We have determined that there are 260 trees per acre which we locate on the horizontal axis of the chart.

When we extend these points we see that our Stocking Percent (diagonal axis) is at approximately 77 percent. This indicates that the stand is fully stocked with room for the trees to grow.

When stocking is approaching or exceeds 100%, the trees are crowding one another and a thinning or harvest of some sort may be in order.



About sample points:

Foresters often conduct a stocking level measurement on the same sample point where they collect basal area information, site index, volume measurements, tree age, height, and species composition data. This information, when combined with numerous other sample points (one sample point may be conducted for every five acres) gives a clear, statistically accurate picture of the forest community being studied. Sample points are designated based on a grid pattern (for example: 7 chains x 7 chains if you wanted to complete a sample plot every 5 acres) while the property is being mapped in the office. This ensures statistical accuracy and eliminates bias (and sometimes causes you to have to collect data in wetlands, on steep slopes, and thick brush!). Conducting sample points involves bringing all of your forestry skills (compass reading, pacing, tree identification, and proficiency in using instruments) together!

1/20th ACRE CIRCULAR PLOT

An important tip: Although each measurement is sometimes conducted on the same sample lot, don't confuse basal area with the 1/20th acre tree count. When using the wedge prism above "plot center," measure all of the trees as far as you can see (there may be a huge tree in the distance that is "in"). When you are counting trees in your 1/20th acre plot, count only those within the radius of your circle. During the Envirothon competition, each of these measurements would be conducted on a separate plot to avoid confusion.

Summary…

Many students enjoy the forestry resource area of the Envirothon program because it is very "hands-on". As you can see, it is important to become competent in using forestry tools to obtain accurate measurements, especially when you combine two measurements together to determine site index or stocking level. Becoming proficient with forestry tools takes practice, and your local forestry professionals can assist you.

Much of this document is taken from the NCF-Envirothon Forestry Resource Guide, Maryland 2017