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How Much Timber Do I Have: A Landowner's Guide to Evaluating Basal Area and Volume

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Introduction

This guide is not a substitute for the advice of a registered state or consulting forester. It is intended for landowners seeking a general understanding of their forest's timber quantity and density. The purpose is to help landowners communicate more effectively with forestry professionals by introducing key terms and simple, low-cost methods for estimating:

- **Basal Area (BA):** The area of land occupied by the cross-sectional area of tree stems
- **Diameter at Breast Height (DBH):** The diameter of a tree measured 4.5 feet above the ground
- **Trees Per Acre (TPA):** The number of tree stems in one acre of forest

Understanding Basal Area

Basal area is often misunderstood because it varies significantly with forest type, structure, and age. For example, a mature hardwood forest and a young, regenerated stand can have the same basal area, but very different tree counts and structures (see Figure 1).

By itself, basal area is not especially informative. However, when paired with DBH and TPA data, it becomes a powerful metric for evaluating stand conditions and making management decisions.

This guide outlines two common approaches to measuring basal area:

1. **Fixed Plot Basal Area Measurements**
2. **Variable Plot Basal Area Measurements**

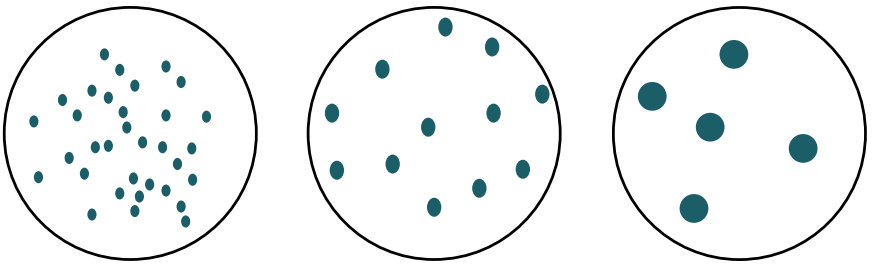

Figure 1: The above figure demonstrates that on a 1/10 acre that 100ft^2 of basal area can indicate that there are many smaller trees or a few large trees. Note that there are substantially more trees per acre when stems are 4 inches vs. stems that are 10 inches in diameter, but the same total basal area.

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Fixed Plot Basal Area Measurements

Fixed plot sampling involves selecting specific, measured areas within a stand and recording data on all qualifying trees within those plots.

This method is ideal for:

- Controlled experiments
- Long-term monitoring
- Reproducible results

However, this method can be **time-consuming** and often requires **GPS coordinates** for plot corners. For general timber cruising, this method may be more detailed than necessary (see Figure 2).

Steps to Calculate Fixed Plot Basal Area

Step 1: Determine the expansion factor or the number of trees per area. The expansion factor is the denominator of the plot size divided by the number of plots in that acre. Figure 2 below shows a plot size of 1/10 of an acre and 4 plots. Ten divided by 4 results in an expansion factor of 2.5.

Step 2: Determine how many trees are in the plot. Multiply the number of trees in the plot by the number of fixed plots. Example: If a plot has 20 trees and there are 4 fixed plots, the number of trees is 80 trees total.

Step 3: Begin measuring the DBH of each tree in the plots.

Step 4: For each tree, perform the following calculation for basal area. Since there are 80 trees in the first fixed plot, the following calculations will be performed 80 times for each tree's DBH)

1. **Tree BA (ft^2) =** .005454 x DBH2
2. **Basal Area per Acre(ft^2) =** Tree BA x expansion factor
   (2.5 in this case from step 1)

Step 5: Add all 80 trees

Basal Area Per Acre (ft^2) = Total stand basal area (ft^2)

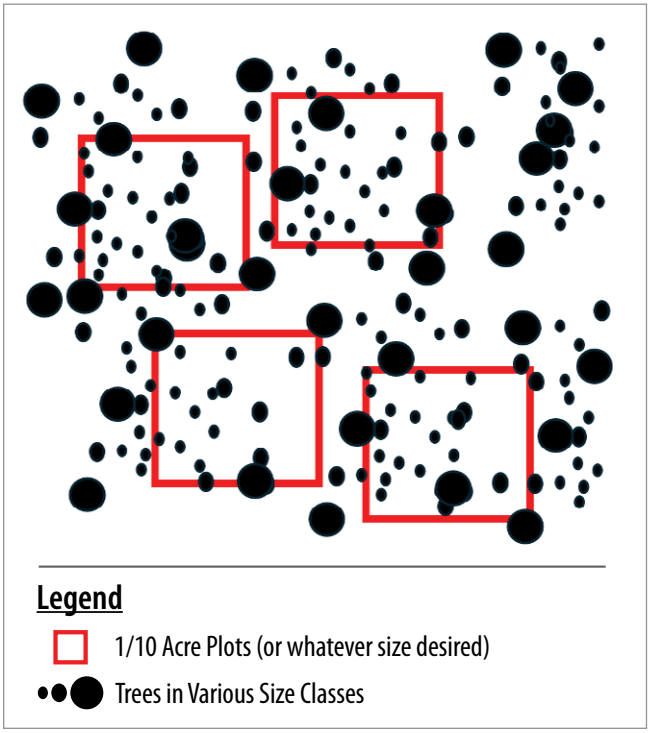

Figure 2: Collecting basal area from fixed sample plots using exact measurements, plot corners, and measuring all trees within the fixed sample plots. Red squares represent exact one-tenth acre measurement plots collected randomly within the stand of timber. Black dots indicate different stem size classes of trees. Only stems within the red squares are counted and measured in these plots.

Variable Plot Basal Area Measurements

This method uses **tools with built-in basal area factors (BAF)** to determine basal area without fixed boundaries. Common tools include:

- Wedge prisms
- Angle gauges

Variable plots are often quicker to use and well-suited to **reconnaissance cruises.**

Wedge Prisms

A wedge prism is a glass tool that deflects light at a specific angle, allowing you to count trees based on overlap (Figure 3a, 3b). A **10-factor prism** is commonly used in Arkansas forests.

- Trees that align with the displaced image are counted as "**in**".
- Trees that do not align are "**out**".
- **Borderline trees** may be included or excluded at the user's discretion but must be treated consistently.

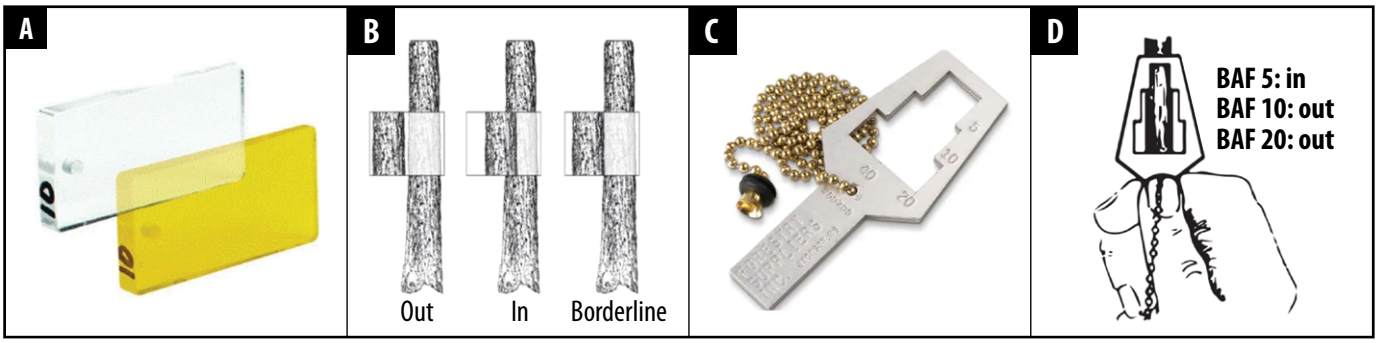

Figure 3: (A) Representation of wedge prism in two colors, clear and amber, for variable light conditions. (B) When holding the wedge prism up to the eye, if the stem overlaps with the rest of the tree, that tree is considered "In" and should be tallied and measured. If it does not overlap with the stem, it is considered "Out" and should not be measured. Borderline trees should be used at the discretion of the forester or landowner. Whether to exclude or include these trees should be consistent with additional locations. (C) The angle gauge has a standard length of chain that is meant to be held in the user's teeth, while simultaneously holding the gauge fully extended from the eye. The angle gauge has four basal area factors that should be consistent with each plot collected in a stand. (D) The tree on basal area factor 5 is overlapping the space on the sides of the angle gauge; this tree is counted as "in". There is a space for the BAF 10 and 20; therefore, that tree would be considered "Out".

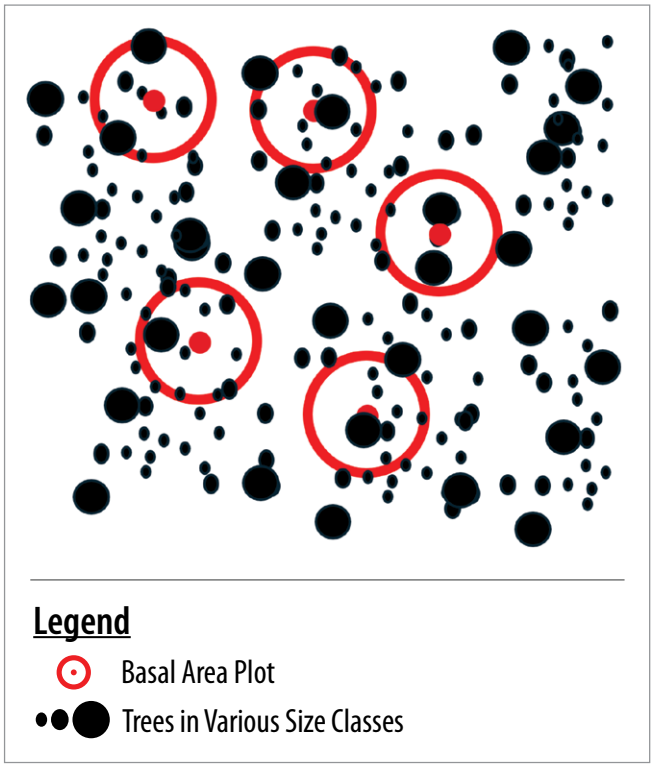

Figure 4: Collecting multiple basal area plots using a 10 basal area factor wedge prism with 5 plots. Collect multiple basal area plots to average together when cruising timber for the best overall representation of the timber.

Angle Gauges

Angle gauges work by holding a fixed-length chain (usually in the teeth) and extending the gauge at arm's length (Figure 3c, 3d). Trees overlapping the gauge edges are counted as **"in"**; trees with visible space are **"out."**

This method is versatile because angle gauges often allow users to switch between **multiple BAF settings.**

Steps to Use Variable Plot Sampling:

1. Choose a plot center and mark it (e.g., with flagging or a stake).
2. Hold your prism or angle gauge at the correct distance.
3. Slowly rotate 360 degrees, counting all **"in" trees** from that center point.
4. Repeat this process at **multiple points** across the stand (see Figure 4).

Calculating Basal Area Using Variable Plots

To calculate basal area from variable plots:

1. Add up the total trees counted across all plots (e.g., 80 trees).
2. Multiply Tree Total by the Basal Area Factor (BAF): Example: 80 trees × 10 BAF = 800
3. Divide by the number of plots to get the average:

Total BA/acre = (Trees x BAF) / Plots = 800/5 = 160 ft^2 basal area

See Table 1 for a reference of estimated trees per acre based on BA and DBH.

Using Mobile Technology

Several mobile applications now support forestry field measurements, including:

- DBH estimation
- Tree height measurement (using LiDAR or trigonometric methods)

Table 1 : Estimated trees per acre based off basal area and DBH measurements collected in the field. Note how as DBH increases and basal area decreases, there are fewer trees per acre in the stand (Coder 2023).

	BA	BA	BA	BA	BA	BA	BA	BA	BA	BA	BA	BA	BA
DBH	**20ft^2**	**30ft^2**	**40ft^2**	**50ft^2**	**60ft^2**	**70ft^2**	**80ft^2**	**90ft^2**	**100ft^2**	**110ft^2**	**120ft^2**	**130ft^2**	**140ft^2**
3in	407	611	815	1019	1222	1426	1630	1834	2037	2241	2445	2649	2852
4in	229	344	458	573	688	802	917	1031	1146	1261	1375	1490	1604
5in	147	220	293	367	440	513	587	660	733	807	880	953	1027
6in	102	153	204	255	306	357	407	458	509	560	611	662	713
7in	75	112	150	187	225	262	299	337	374	412	449	486	524
8in	57	86	115	143	172	201	229	258	287	315	344	372	401
9in	45	68	91	113	136	158	181	204	226	249	272	294	317
10in	37	55	73	92	110	128	147	165	183	202	220	238	257
11in	30	46	61	76	91	106	121	136	152	167	182	197	212
12in	25	38	51	64	76	89	102	115	127	140	153	166	178
13in	22	33	43	54	65	76	87	98	109	119	130	141	152
14in	19	28	37	47	56	65	75	84	94	103	112	122	131
15in	16	24	33	41	49	57	65	73	81	90	98	106	114
16in	14	21	29	36	43	50	57	64	72	79	86	93	100
17in	13	19	25	32	38	44	51	57	63	70	76	82	89
18in	11	17	23	28	34	40	45	51	57	62	68	74	79
19in	10	15	20	25	30	36	41	46	51	56	61	66	71
20in	9	14	18	23	28	32	37	41	46	50	55	60	64
21in	8	12	17	21	25	29	33	37	42	46	50	54	58
22in	8	11	15	19	23	27	30	34	38	42	45	49	53
23in	7	10	14	17	21	24	28	31	35	38	42	45	49
24in	6	10	13	16	19	22	25	29	32	35	38	41	45
25in	6	9	12	15	18	21	23	26	29	32	35	38	41
26in	5	8	11	14	16	19	22	24	27	30	33	35	38
27in	5	8	10	13	15	18	20	23	25	28	30	33	35
28in	5	7	9	12	14	16	19	21	23	26	28	30	33
29in	4	7	9	11	13	15	17	20	22	24	26	28	31
30in	4	6	8	10	12	14	16	18	20	22	24	26	29

iPhones (models 14 and newer) include LiDAR, offering centimeter-level accuracy. Android phones currently do not have integrated LiDAR, so results may vary.

Landowners are encouraged to explore available tools on their app stores.

Volume Determination

To estimate **volume**, you must know:

- DBH
- Tree height

With this data, refer to the **species-specific volume tables** for estimates of board feet.

Measuring Tree Height

Tools include:

- Height poles (for small trees)
- Clinometers
- Laser range finders
- Biltmore sticks
- Mobile apps (with clinometer features)

Although detailed volume calculations are beyond the scope of this guide, the following **conversion factors and formulas** are commonly used in forestry.

Timber Specifications and Conversion Factors

DBH Classifications

- Pulpwood: 6”+
- Chip-N-Saw: 8–12”
- Sawtimber: 12”+

Standard Volume Conversions

Type	Volume (ft^3)	Notes
1 Standard Cord	128 ft^3 (Bark included)	~90 ft^3 solid wood
1 Cord of Pine	75 ft^3 solid wood	~2.124 m^3
1 Cord Mixed Hardwood	80 ft^3 solid wood	~2.265 m^3

Weight-Based Conversions

- 1 short ton = 2,000 lbs
- 1 metric tonne = 1.102 short tons = 2,204 lbs

Green wood weight examples

- Pine: ~0.822 m^3 of solid wood/ton
- Mixed Hardwood: ~0.787 m^3 of solid wood/ton

Cubic Meter to Cubic Feet

- 1 m^3 = 35.315 ft^3

Board Foot Conversions

Pine

- **Sawtimber/Large Logs:**
  - 7.0 Tons/MBF (Scribner)
  - 8.0 Tons/MBF (Doyle)
  - 5.5 Tons/MBF (International)
- **Chip-N-Saw:**
  - 8.0 Tons/MBF (Scribner)
  - 9.975 Tons/MBF (Doyle)
  - 6.225 Tons/MBF (International)
- **Pulpwood:**
  - 5,350 lbs/cord (avg)
  - 2.68 tons/cord

Hardwood

- **Sawtimber:**
  - 9.0 Tons/MBF (Doyle)
  - 8.0 Tons/MBF (Scribner)
  - 6.5 Tons/MBF (International)
- **Pulpwood:**
  - 5,800 lbs/cord
  - ~2.90 tons

Board Foot Estimation Formulas

MBF: *Thousand board feet*

MBF Doyle

The formula is: **$(D-4)^2 \times (L/16)$**

For the Doyle formula, D is the diameter inside the bark and L is the length in feet. The Doyle measurement formula works well for larger trees but loses accuracy the smaller the trees. MBF is expressed in 1,000 board feet.

MBF Scribner

The formula is: **$(D-4)^2 \times L / 16$**

For the Scribner formula, D is the diameter inside the bark at the small end of the log, and L is the length. Generally, MBF Scribner is a more conservative estimate and good for measuring small/medium size timber. Scribner does not account for taper of trees, underestimating volume of longer logs. It is expressed in 1,000 board feet.

MBF International

The formula is:
Board Feet (BF) = ((Log Constant * D^2) - (Log Constant * D)

For the international measurement formula, the Log Constant values change depending on log length (see below). The International estimation is considered the most accurate of the three but also the most time-consuming.

- 4-foot lengths: BF = (0.199 * D^2) - (0.642 * D)
- 8-foot lengths: BF = (0.398 * D^2) - (1.086 * D) - 0.271
- 12-foot lengths: BF = (0.597 * D^2) - (1.330 * D) - 0.715
- 16-foot lengths: BF = (0.796 * D^2) - (1.375 * D) - 1.230
- 20-foot lengths: BF = (0.995 * D^2) - (1.221 * D) - 1.71

References

Coder, Kim D. 2023. Trees per acre: By diameter & basal area. University of Georgia, Warnell School of Forestry & Natural Resources Outreach Factsheet WSFNR23-03C. Pp.3.

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