



## Environmental Analysis Program

Pomona College  
Biogeochemistry Laboratory

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SOP-F604

# Tree DBH and Forest Inventory

Standard Operating Procedure

|                     |                            |
|---------------------|----------------------------|
| <b>SOP Number</b>   | SOP-F604                   |
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## Table of contents

|                                                                |          |
|----------------------------------------------------------------|----------|
| <b>1 Purpose</b>                                               | <b>2</b> |
| <b>2 Scope</b>                                                 | <b>2</b> |
| <b>3 Definitions</b>                                           | <b>2</b> |
| <b>4 Responsibilities</b>                                      | <b>3</b> |
| <b>5 Safety and Hazards</b>                                    | <b>3</b> |
| 5.1 Required PPE . . . . .                                     | 3        |
| 5.2 Emergency Procedures . . . . .                             | 3        |
| <b>6 Equipment and Materials</b>                               | <b>3</b> |
| <b>7 Procedure</b>                                             | <b>4</b> |
| 7.1 Measuring DBH . . . . .                                    | 4        |
| 7.2 Fixed-Area Plot Inventory . . . . .                        | 5        |
| 7.3 Variable-Radius Plot Sampling (Basal Area Prism) . . . . . | 5        |
| 7.4 Tree Height Measurement (Optional) . . . . .               | 6        |
| <b>8 Derived Calculations</b>                                  | <b>6</b> |
| 8.1 Basal Area per Tree . . . . .                              | 6        |
| 8.2 Stand Density and Basal Area per Hectare . . . . .         | 6        |
| 8.3 Biomass Estimation . . . . .                               | 7        |
| 8.4 Interpreting Size Distributions . . . . .                  | 7        |
| <b>9 Quality Control</b>                                       | <b>7</b> |
| <b>10 References</b>                                           | <b>7</b> |
| <b>11 Related SOPs</b>                                         | <b>8</b> |
| <b>12 Training Record</b>                                      | <b>8</b> |
| <b>13 Appendix A: Forest Inventory Data Sheet</b>              | <b>8</b> |

## 1. Purpose

This SOP describes standardized procedures for measuring tree diameter at breast height (DBH), conducting fixed-area plot-based forest inventories, and estimating basal area using prism or angle-gauge sampling. These measurements are fundamental to characterizing forest structure, estimating stand density and biomass, monitoring tree growth, and providing inputs to allometric equations for carbon accounting (Avery & Burkhardt, 2002; Westfall & Westfall, 2020). The measurement conventions follow the USDA Forest Service Forest Inventory and Analysis (FIA) national standards (USDA Forest Service, 2023).

Accurate DBH measurement is the single most important field variable in forest ecology because nearly all derived quantities (basal area, volume, biomass, and carbon) depend on it through nonlinear allometric relationships. Small systematic errors in DBH propagate disproportionately into biomass estimates, especially for large-diameter trees, which store a disproportionate fraction of stand-level carbon (Lutz et al., 2018; **west2009?**).

## 2. Scope

- **Applies to:** All EA Program field sites with tree cover, including riparian forests, oak woodlands, mixed conifer stands, and planted trees at restoration and campus sites
- **Does not apply to:** Shrubs with DBH below 2.5 cm (use [SOP-F603](#) for shrub cover); timber cruising for commercial harvest; urban tree risk assessment
- **Location:** All EA Program terrestrial field sites with woody vegetation

## 3. Definitions

- **Diameter at breast height (DBH):** The diameter of a tree trunk measured at 1.37 m (4.5 ft) above ground level on the uphill side of the tree. DBH is the standard dimension for characterizing tree size (Avery & Burkhardt, 2002; USDA Forest Service, 2023).
- **Basal area (BA):** The cross-sectional area of a tree trunk at breast height, calculated as  $BA = \frac{\pi}{4} \times DBH^2$ . Often expressed per hectare ( $m^2/ha$ ) as a measure of stand density.
- **Basal area factor (BAF):** The conversion factor for a wedge prism or angle gauge that translates the number of “in” trees to stand basal area ( $m^2/ha$ ).
- **Variable-radius plot (point sampling):** A sampling method where the probability of a tree being included is proportional to its basal area, achieved using a BAF prism. Originally described by
  - 1.
- **Fixed-area plot:** A plot of known area (e.g., 0.04 ha circular plot, radius 11.28 m) within which all trees above a minimum DBH threshold are measured (Laar & Ak cca, 2007).
- **Allometric equation:** A mathematical model relating an easily measured tree dimension (usually DBH) to a harder-to-measure quantity (usually biomass or volume) through a power function (Chojnacky et al., 2014; Jenkins et al., 2003).
- **Crown class:** A classification of a tree’s position in the canopy: dominant, co-dominant, intermediate, or suppressed. Crown class reflects competitive status and light availability.

- **Snag:** A standing dead tree. Snags provide habitat for cavity nesters and are recorded separately from live trees in inventories.
- **Stand density index (SDI):** A relative measure of stand density that accounts for tree size, allowing comparison across species and sites (**pretzsch2009?**).
- **Size distribution:** The frequency distribution of tree diameters in a stand. Reverse-J distributions characterize uneven-aged stands with continuous recruitment; normal or bimodal distributions suggest even-aged cohorts or past disturbance (**muller-landau2006?**).

## 4. Responsibilities

| Role              | Responsibility                                   |
|-------------------|--------------------------------------------------|
| PI / Field Lead   | Approve plot design and minimum DBH threshold    |
| Trained Personnel | Measure trees and record data per this SOP       |
| New Students      | Complete training before independent measurement |

## 5. Safety and Hazards

### Hazards

- **Physical:** Dead or leaning trees (snags, widow-makers) may shed branches. Look up before working under any tree. Do not measure trees during high winds.
- **Biological:** Poison oak, ticks, stinging insects, and snakes in wooded habitats. Wasp nests may be present in tree cavities.
- **Terrain:** Steep slopes in forested areas increase fall risk. Use caution when navigating uneven terrain with equipment.

### 5.1. Required PPE

- ☐ Closed-toed shoes or field boots
- ☐ Long pants
- ☐ Hard hat (in areas with overhead hazard trees)
- ☐ Sun protection (hat, sunscreen)
- ☐ Tick repellent

### 5.2. Emergency Procedures

Refer to [SOP-F001 Field Safety](#). Work in pairs in remote forested areas.

## 6. Equipment and Materials

| Item                                         | Notes                                                       |
|----------------------------------------------|-------------------------------------------------------------|
| Diameter tape (DBH tape, metric)             | Graduated in diameter units (pi tape); reads directly in cm |
| Standard measuring tape (50 m)               | For establishing plot boundaries                            |
| Clinometer (Suunto or equivalent)            | For measuring tree height (optional)                        |
| Basal area factor (BAF) prism or angle gauge | For variable-radius plot sampling                           |
| GPS unit or smartphone                       | Per <a href="#">SOP-F006</a>                                |
| Field notebook or data sheet                 | Pre-printed inventory form (Appendix A)                     |
| Compass                                      | For plot layout and stem mapping                            |
| Flagging tape                                | For marking plot center and measured trees                  |
| Tree tags and nails (aluminum)               | For permanent plot re-measurement                           |
| Paint marker or timber crayon                | For marking the DBH measurement point                       |
| Laser rangefinder (optional)                 | For measuring tree height and distances                     |
| Calculator                                   | For basal area and density calculations                     |

## 7. Procedure

### 7.1. Measuring DBH

DBH is measured at 1.37 m (4.5 ft) above ground level on the uphill side of the tree (Avery & Burkhardt, 2002; USDA Forest Service, 2023).

1. Identify the measurement height: 1.37 m above the ground surface on the uphill side of the tree. If the ground is level, measure from any side.
2. Wrap the diameter tape around the trunk at 1.37 m, perpendicular to the axis of the trunk (not perpendicular to the slope).
3. Ensure the tape is snug against the bark, not twisted, and level. Read the diameter directly from the DBH tape to the nearest 0.1 cm.
4. Record the measurement in the field notebook or data sheet.

#### Special cases:

| Situation                         | Measurement Rule                                               |
|-----------------------------------|----------------------------------------------------------------|
| Tree on a slope                   | Measure at 1.37 m from the uphill side of the base             |
| Forked below 1.37 m               | Measure each fork as a separate tree                           |
| Forked at or above 1.37 m         | Measure as one tree below the fork                             |
| Swelling or abnormality at 1.37 m | Measure above and below the abnormality and average            |
| Leaning tree                      | Measure 1.37 m along the underside of the trunk                |
| Buttressed tree                   | Measure above the buttress where the trunk becomes cylindrical |

 Tip

For permanent monitoring plots, mark the DBH measurement point on the bark with a paint marker or timber crayon so that subsequent measurements are taken at the exact same height. For long-term studies, tag each tree with a numbered aluminum tag nailed above breast height.

## 7.2. Fixed-Area Plot Inventory

Fixed-area plots are the standard method for forest inventory (Laar & Ak cca, 2007; **west2009?**). Plot size depends on tree density.

| Tree Density    | Recommended Plot Size          | Radius (circular) |
|-----------------|--------------------------------|-------------------|
| Dense forest    | 0.01 ha (100 m <sup>2</sup> )  | 5.64 m            |
| Moderate forest | 0.04 ha (400 m <sup>2</sup> )  | 11.28 m           |
| Open woodland   | 0.10 ha (1000 m <sup>2</sup> ) | 17.84 m           |

### Procedure:

1. Navigate to the plot center and record GPS coordinates per [SOP-F006](#).
2. Mark the plot center with a stake or flagging tape.
3. For circular plots, use the measuring tape as a radius to determine which trees are inside the plot boundary. A tree is “in” if more than half of its trunk at DBH lies within the plot radius.
4. Measure and record the following for every tree with DBH at or above the minimum threshold (typically 2.5 cm or 10 cm, as specified by the project):
  - Species (common name and/or scientific name)
  - DBH (cm)
  - Condition class: live, standing dead (snag), leaning
  - Crown class (optional): dominant, co-dominant, intermediate, suppressed
  - Height (optional; measured with a clinometer or rangefinder)
5. Record the total number of stems and species per plot.

## 7.3. Variable-Radius Plot Sampling (Basal Area Prism)

The BAF prism provides a rapid estimate of stand basal area without establishing fixed plot boundaries (Avery & Burkhart, 2002; Grosenbaugh, 1952).

1. Stand at the sample point and hold the BAF prism at arm’s length, looking through it at each surrounding tree at breast height.
2. For each tree, the prism refracts the image of the trunk. Compare the offset image to the original:
  - **Tree is “in”:** The offset image overlaps the unrefracted trunk. Count the tree.
  - **Tree is “out”:** The offset image is completely separated from the unrefracted trunk. Do not count.

- **Borderline:** The offset image just touches the trunk edge. Count every other borderline tree.
3. Rotate 360 degrees, counting all “in” trees.
  4. Calculate basal area:

$$\text{Basal area (m}^2/\text{ha)} = n \times \text{BAF}$$

where  $n$  is the number of “in” trees and BAF is the basal area factor of the prism (typically 1, 2, 4, or 5 m<sup>2</sup>/ha per tree counted; check the prism label).

#### 7.4. Tree Height Measurement (Optional)

Use a clinometer or laser rangefinder to measure total tree height (Laar & Ak cca, 2007; west2009?):

1. Stand at a known horizontal distance from the tree base (e.g., 15–30 m; measure with a tape or rangefinder).
2. Sight the tree top through the clinometer and record the angle to the top ( $\alpha$ ).
3. Sight the tree base and record the angle to the base ( $\beta$ ). If the base is below eye level,  $\beta$  is negative.
4. Calculate height:

$$H = D \times (\tan \alpha - \tan \beta)$$

where  $D$  is the horizontal distance (m) and  $H$  is the total height (m). This formula assumes the observer’s line of sight to the top of the tree is unobstructed and that the tree is vertical; for leaning trees, measure height along the leaning axis and record the lean angle.

## 8. Derived Calculations

### 8.1. Basal Area per Tree

$$\text{BA (m}^2) = \frac{\pi}{4} \times \left( \frac{\text{DBH}}{100} \right)^2$$

where DBH is in cm.

### 8.2. Stand Density and Basal Area per Hectare

$$\text{Trees/ha} = \frac{n}{\text{plot area (ha)}}$$

$$\text{BA/ha (m}^2/\text{ha)} = \frac{\sum \text{BA}_i}{\text{plot area (ha)}}$$

### 8.3. Biomass Estimation

Above-ground biomass can be estimated using published allometric equations of the form:

$$\text{Biomass (kg)} = a \times \text{DBH}^b$$

where  $a$  and  $b$  are species-specific coefficients from published sources (Chojnacky et al., 2014; Jenkins et al., 2003). Document the allometric equation, source, and species used in the project README. Because the exponent  $b$  typically ranges from 2 to 3, measurement errors in DBH are amplified in biomass estimates: a 1 cm error at DBH = 50 cm produces a roughly 4–6% error in biomass (west2009?). Large-diameter trees store a disproportionately large fraction of aboveground carbon in most forest types; accurate measurement of the largest individuals in a stand is therefore critical for unbiased biomass and carbon stock estimates (Lutz et al., 2018).

### 8.4. Interpreting Size Distributions

Plotting the diameter distribution (number of trees per DBH class) provides insight into stand history and dynamics. A reverse-J (negative exponential) distribution suggests continuous recruitment across size classes, typical of uneven-aged or mixed-species stands. A bell-shaped or bimodal distribution suggests one or more distinct cohorts established after disturbance events (muller-landau2006?; pretzsch2009?).

## 9. Quality Control

- Measure DBH twice (wrap the tape, read, remove, re-wrap, re-read). The two readings should agree within 0.5 cm. Record the mean.
- On 10% of plots, have a second observer independently measure all trees. DBH measurements should agree within 1 cm; tree counts should match exactly.
- Verify the diameter tape calibration at the start of each field season by measuring a cylinder of known diameter.
- For permanent plots, verify that tags are intact and measurement points are correctly located at each re-measurement.
- When comparing DBH across re-measurement intervals, confirm that the measurement point has not shifted due to bark ingrowth over tags or paint marks (Westfall & Westfall, 2020).

## 10. References

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## 11. Related SOPs

| SOP                  | Title                   | Relationship                  |
|----------------------|-------------------------|-------------------------------|
| <a href="#">F001</a> | Field Safety            | Required prerequisite         |
| <a href="#">F006</a> | GPS and Site Navigation | Plot center coordinates       |
| <a href="#">F603</a> | Vegetation Transects    | Understory and shrub cover    |
| <a href="#">F605</a> | Leaf Area Index         | Canopy measurement companion  |
| <a href="#">F606</a> | Canopy Cover            | Densiometer and photo methods |

## 12. Training Record

Before conducting tree measurements independently, personnel must:

1. Read this SOP in full
2. Demonstrate correct DBH measurement technique, including special cases (forks, slopes, buttresses)
3. Participate in a supervised plot inventory
4. Demonstrate BAF prism technique with results within 10% of the trainer's count
5. Be signed off by the PI or field lead

## 13. Appendix A: Forest Inventory Data Sheet

Site: \_\_\_\_\_ Plot ID: \_\_\_\_\_ Date: \_\_\_\_\_

Observer: \_\_\_\_\_ Plot size: \_\_\_\_\_ m<sup>2</sup> Min DBH: \_\_\_\_\_ cm

GPS: \_\_\_\_\_ Elevation: \_\_\_\_\_ m Slope: \_\_\_\_\_ %

| Tree # | Species | DBH (cm) | Height (m) | Condition | Crown Class | Notes |
|--------|---------|----------|------------|-----------|-------------|-------|
|--------|---------|----------|------------|-----------|-------------|-------|

Basal area prism count (BAF = \_\_\_\_\_): \_\_\_\_\_ trees in = \_\_\_\_\_ m<sup>2</sup>/ha