

# Cumberland Piedmont Network

National Park Service  
Inventory and Monitoring Division



## Standard Operating Procedure 5

### *Canopy Closure and Stand Height Measurements—Version 1.36*

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## Overview

Canopy closure provides a measure of the density of the leafy photosynthetic forest cover, at the time of year it is measured. Generally, a high amount of canopy closure indicates a low light environment on the forest floor, or field stratum. Conversely, a low amount of canopy closure can indicate changes in the canopy due to natural or human-caused disturbance such as wind throw, or forest pest damage. The spherical densiometer is an economical and durable device for measuring canopy cover. The instructions for use are found on the inside cover of the device. It is very important that the instructions be understood and followed, to ensure that the data are collected correctly. It's also important to periodically calibrate your measurements with those of others on your field team so that there is some consistency in measurement throughout the field season. If the instructions for the densiometer are not followed consistently, the reliability of the data collected is compromised.

Beginning in the 2015 field season, stand height measurements were added to plot data. Stand height is an important metric that is used to estimate live tree volume for a plot. Average stand height for a plot is calculated by measuring the heights of three co-dominant trees either inside or just outside the plot. This live tree volume is then compared to dead tree volume as measured by the coarse woody debris (CWD; SOP 8 *Coarse Woody Debris Measurements—Version 1.35* [CUPN 2023a]) to obtain a CWD volume as a percentage of live tree volume (Tierney et al. 2016). Stand height can be calculated either by triangulation or by using a laser rangefinder. For triangulation, an optical reading clinometer and tape measure are used, and the CUPN also has a TruPulse 200 and 360°R laser rangefinder available for use. Instructions for measuring stand height utilizing the various tools can be found in this standard operating procedure (SOP). While use of a particular method is somewhat a matter of personal preference, it is very important that the instructions for both triangulation and the use of the laser rangefinder be understood and followed to ensure that the data are collected correctly.

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## Step by Step Instructions for Canopy Closure Measurements

While this SOP title refers to “canopy” cover, for this protocol, crew members are recording total cover including subcanopy and shrub cover when collecting data. Crew members use the spherical densiometer to measure cover at the center of each of the four intensive  $10 \times 10$ -meter ( $32.8 \times 32.8$  feet [ft]) modules (1, 2, 3, and 4). Crew members must be familiar with the instructions for using the spherical densiometer, found on the inside cover of the device (Figure 1, inset photo). A crew member holds the spherical densiometer out in front of them, at elbow height (approximately 1.0 meter [3.3 ft]), to obtain a reading. Ideally your elbow will be bent at exactly a  $90^\circ$  angle and your upper arm will be rigidly by your side so the device is always held at approximately the same distance away from your eyes. In addition, reading the densiometer with one eye closed tends to yield measurements more consistent between users. Each reading will be a number from 1–96 and is based on the number of closed canopy grid cells on the device (Figure 1). In each grid cell, one must imagine four dots, as described in the instructions. In forested environments, crew members count and record all the shaded dots representing the canopy cover. There will be one to four shaded dots per grid cell. The total number of shaded dots will be a number 1–96. A single crew member collects densiometer data for the plot. Data are recorded in each of the four cardinal directions (N, E, S, and W) in each of the four modules. This results in 16 measurements for the plot. These raw counts obtained in the field are entered into the database, and then the four values collected from each module are multiplied by 1.04 to get a percent canopy cover (1–100%) and then averaged for the plot (Ganey and Block 1994).



**Figure 1.** Spherical densiometer grid, users visualize a dot in each corner of the grid ( $n=96$  dots) and count the number of dots covered by canopy. Note the directions printed on the lid in inset photo.

## Optional Canopy Closure Data Collection Method

We discourage teams from using the optional data collection method. However, if the spherical densiometer has been lost or broken, then canopy closure should be visually estimated. Although visual estimation is a much less repeatable method than spherical densiometer, a measure of canopy

closure is important to understand large scale changes over time. Ideally, team members will have calibrated their visual canopy closure measuring ability with each other during training and should come up with consistent numbers. Look up at the canopy and estimate the relative space of occupied canopy (all leaves and stems included) from 0–100%. Repeat this measure at each module.

## Stand Height Measurements

Within (or very near) each plot, three co-dominant trees should be chosen for height measurements. An average of these three should be taken and recorded on the field datasheet.

Each of the approaches listed below assumes the top of the tree, the point on the trunk and the base of the tree are on the same vertical line, which when violated can result in height estimation errors as illustrated in Figure 2. Measurements should be taken from a direction that provides the best view of tree top and bottom in the same vertical plane.

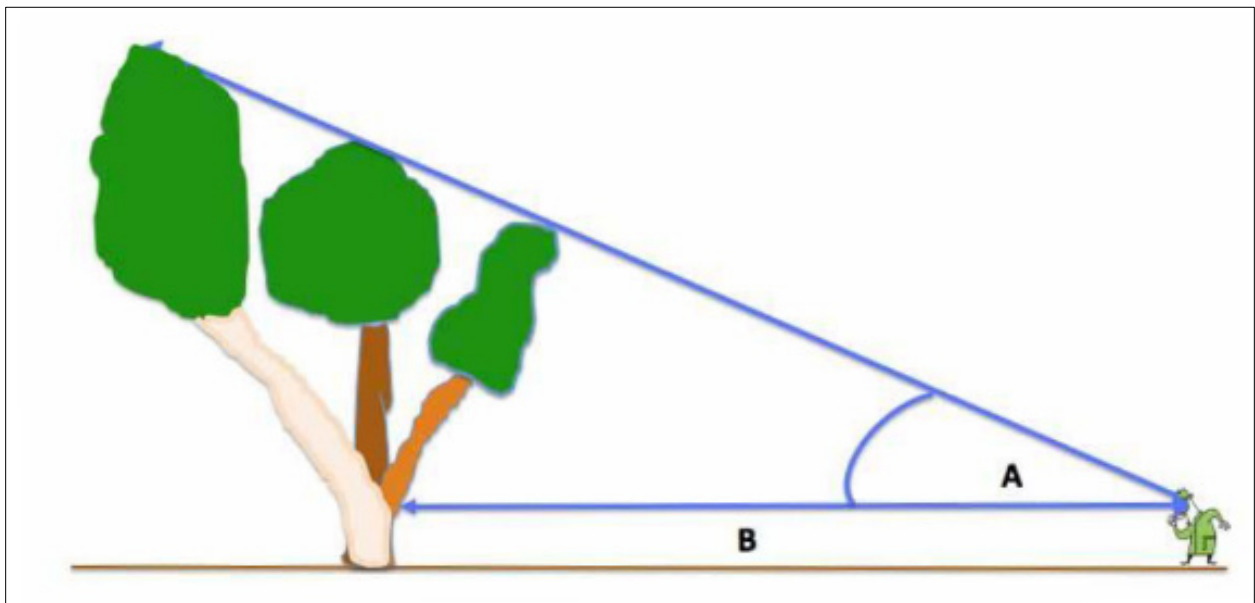


**Figure 2.** Tree height measurements should be taken from angle where top, bottom and bole are in same vertical plane to avoid error (from Leverett and Bertolette 2014).

## Triangulation

For this protocol, the easiest and most efficient method of calculating tree height via triangulation is using an optical reading clinometer (with a percent scale) and a tape measure. Other methods include the use of the degree scale of a clinometer and a tape measure, and the use of a hypsometer and tape measure. The latter two methods will not be discussed here.

When a codominant canopy tree has been chosen, pin the end of the tape measure at the base of the tree with a pin flag and walk away from the tree with the reel end of the tape measure until you are

far enough away from the tree to obtain a good view of both the top and bottom of the tree through the lens of the clinometer (usually 20–30 meters [65.6–98.4 ft] for trees at CUPN parks).

To view the tree through the clinometer, the clinometer is held in one hand and viewed through an optical lens fitted with a crosshair, a plus and minus degree scale and a plus and minus percent scale (Figure 3). Both eyes need to be open with one eye reading the scale on the instrument while the other looks at the target. Both scales measure the angle or slope to the target, expressed in either degrees or percent, from the horizontal at eye level. In this case, the percent scale will be used. Estimate where the top of the tree is and record the nearest percent where the crosshair meets the tree top, and then look to the base of the tree and record the number on the percent scale where the crosshair meets the base of the tree. These two numbers and the distance (nearest tenth of a meter) to the tree are used to calculate the height of the tree. Note, distance between tree and observer should be measured as horizontal distance as depicted in Figures 4 and 5.

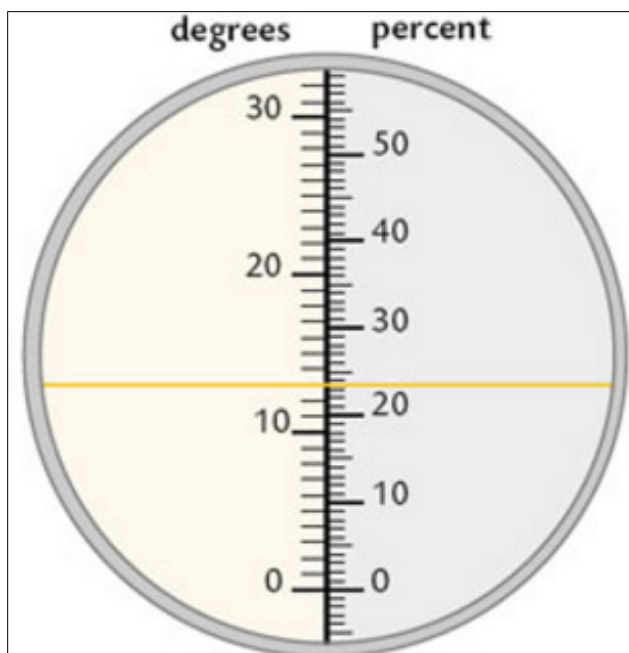


**Figure 3.** View through the eyepiece of a clinometer.

When the base of the trunk is below eye level, the percent values are added (Figure 4). The height is then calculated as follows. For example, if the tree-top reading is 50%, the ground reading is 13% and the distance to the tree is 38.0 meters (124.7 ft), the mathematical calculation is:

$$\text{Tree height} = (50 + 13)/100 \times 38 = 23.9 \text{ meters}$$

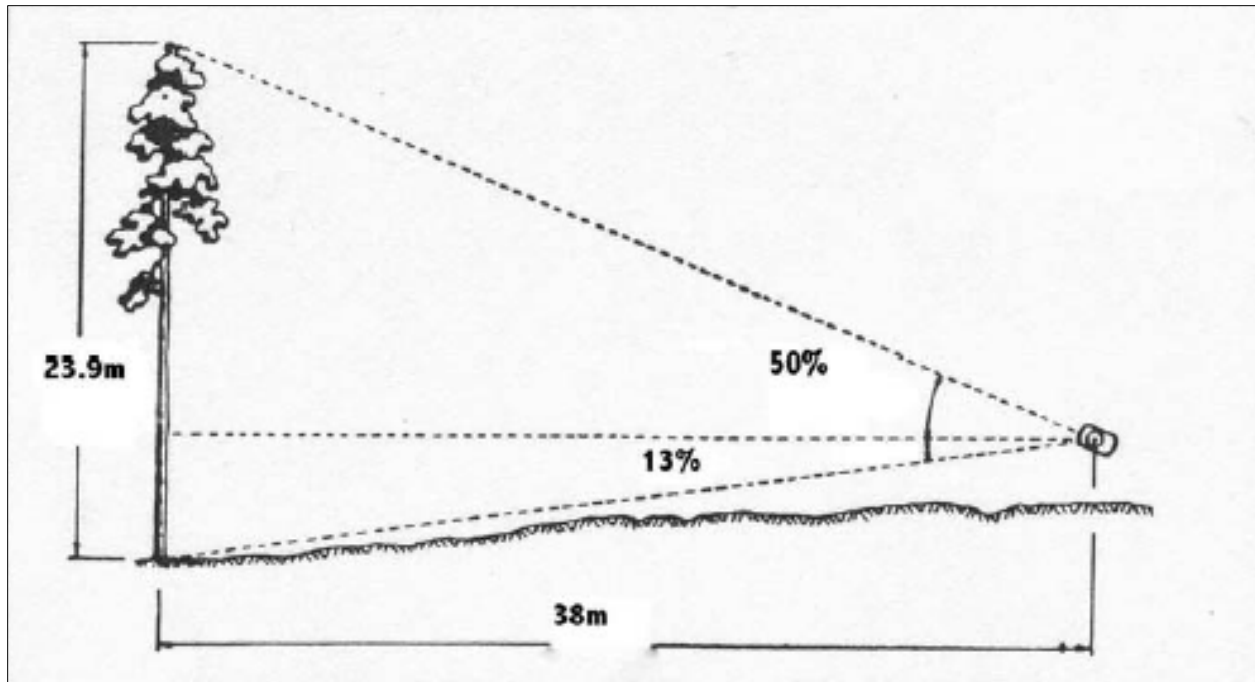


**Figure 4.** Using a clinometer to measure tree height on sloping ground when the base of the trunk is below eye level.

Measurements will be more accurate when the observer is at or slightly above the elevation of the tree base. However, this is not always possible. When the base of the trunk is above eye level, the trunk base percent is subtracted from the tree-top percent (Figure 5). The height is then calculated as follows. For example, if the tree-top reading is 65%, the base reading is 14% and the distance to the tree is 38.0 meters, the calculation is:

$$\text{Tree height} = (65 - 14) / 100 \times 38 = 19.4 \text{ meters}$$

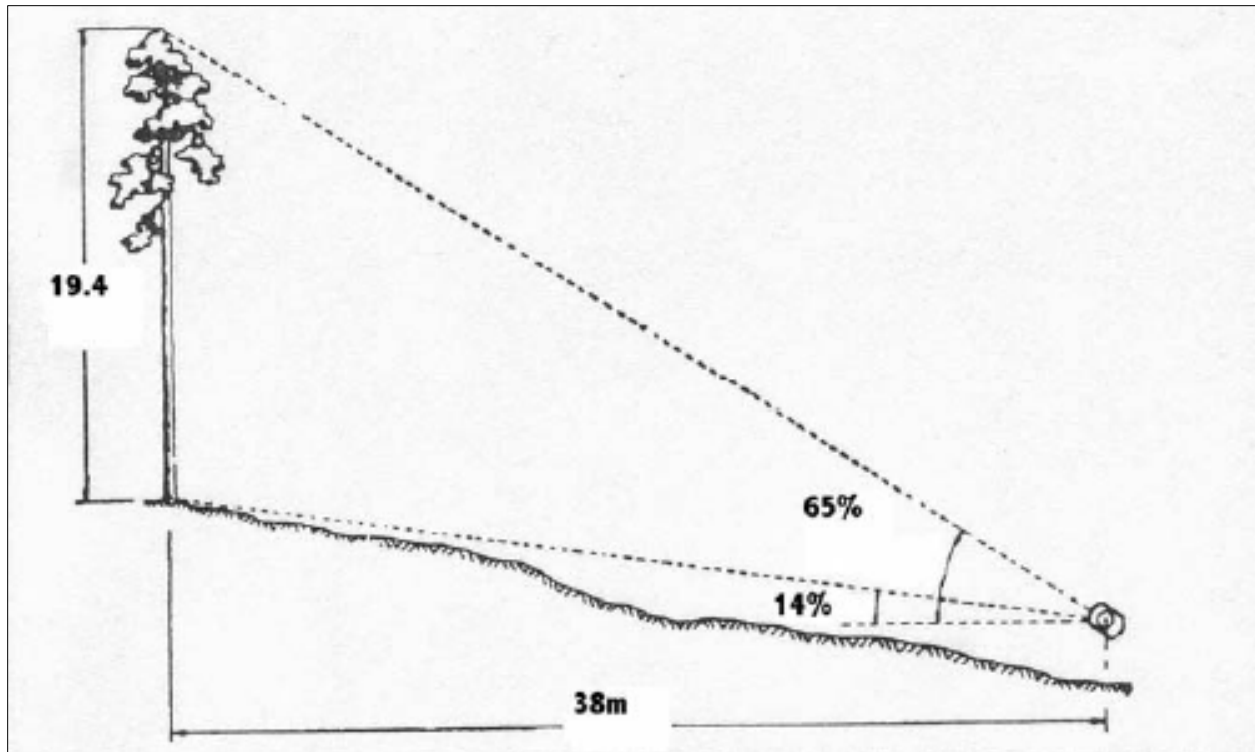


**Figure 5.** Using a clinometer to measure tree height on sloping ground when the base of the trunk is above eye level.

Repeat these measurements for two more co-dominant trees in or around the plot and average the three outcomes to obtain the stand height for the plot.

### **Laser Rangefinder**

When available, the TruPulse 200 or TruPulse 360°R laser rangefinders can be used to obtain tree height measurements. The TruPulse models do not require the use of a tape measure, but do require that the top, bottom, and eye-level height of the measured tree are not obscured by any other vegetation, which can be difficult in a forest setting. When a co-dominant canopy tree has been chosen, walk far enough away from the tree to obtain a clear view of the top, bottom and trunk of tree through the eyepiece of the rangefinder and initiate the “Three-point” tree height measuring routine (Figure 6). The advantage of the three-point method is that it is easier to shoot angles to points in the crown than distances. However, as noted earlier, the approach also assumes the top of the tree, the point on the trunk and the base of the tree are on the same vertical line.

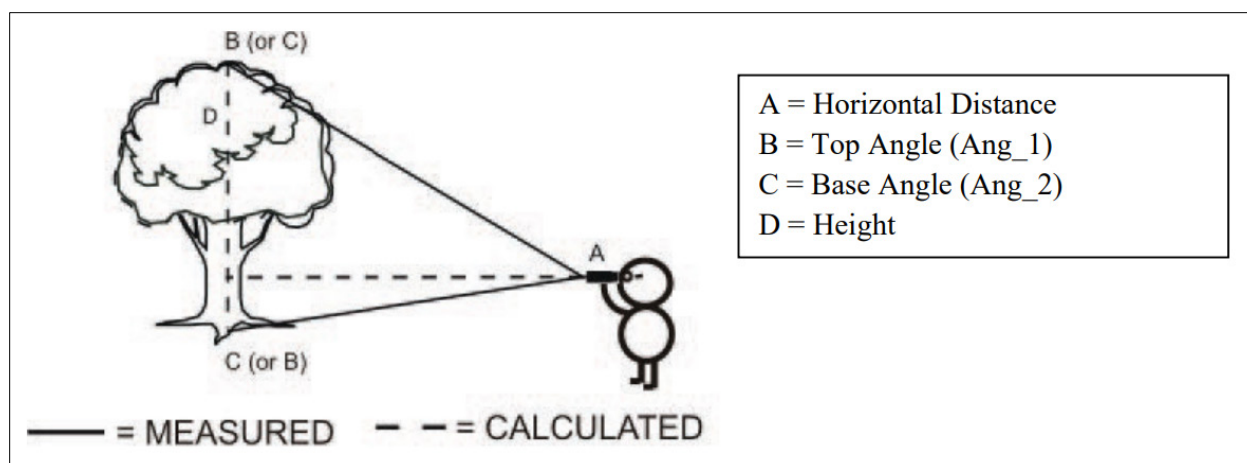


**Figure 6.** Three-point tree height measuring routine (from TruPulse user manual, Laser Technology, Inc.).

1. Press “Fire” to power on TruPulse
2. Press menu keys (up or down triangle) to select HT and HD (flashing)
3. Aim crosshair at reflector (TruPulse 360°R) or directly at trunk of tree (TruPulse 200), press-and-hold “Fire” until a value appears with HD. The measured horizontal distance appears briefly in the main display then Ang\_1 will appear.
4. With “Ang\_1” visible at top of display, aim crosshair at top of tree while depressing and holding down “Fire.” The measured INC continues to update if you continue to hold down “Fire.” When released the display will show a positive angle, which will flash once before displaying Ang\_2.
5. With “Ang\_2” visible at top of display, aim crosshair at base of tree while depressing and holding “Fire.” When released the display will show an angle to base of tree followed by the calculated tree height. The measurement will flash one time and continue to remain steady until you press a button or the unit powers off (approximately 10 seconds).

**General Notes about using the TruPulse laser rangefinders**

- The TruPulse 360°R should be used with filter mode and a reflective target.
- When you power on the TruPulse, the last used measurement mode will be active. If the device has been bumped, use the up or down arrows to select the correct measurement mode. When you scroll to the Height Mode (HT), HD will be flashing. The HD refers to Horizontal Distance, which is the first measurement needed in the three-point tree height measuring routine.
- Inclination or angle to tree top and base can be taken in either order, top or bottom recorded first.

- It is good practice to take measurements on the same tree multiple times, as it only takes a few seconds and aids in precision of measurements. If a second crew member is available, have them measure trees as well. This is good practice for crew members and aids in the reliability of measurements.
- These devices are supposed to be protected from dust and rain, but care and common sense should be utilized in their operation. They will not withstand submersion. If water leakage is suspected, power unit off, remove batteries and allow to air dry at room temperature.

## **Completing Field Data Forms**

A detailed list of field descriptions for each field on the field data form associated with this SOP and SOP 4 *Plot Photopoints—Version 1.34* (CUPN 2023b, Figure 7) can be found below in Table 1.

# SOP 4-5

COWP001

Start Date: / /21  
(mm/dd/yy)

## SOP 4 - Plot Photopoints

Photographer initials Reviewed by

Camera: text name of camera or make/model of camera

**Photopoint 1** Mark photopoint location and direction on plot diagram (pg 2) Yes or No

Photo of sign taken before taking plot photo (with Plot ID, Date, Photo Pt #, and Direction)? Yes or No

Photo notes (record photo file name from camera):

**Photopoint 2** Mark photopoint location and direction on plot diagram (pg 2) Yes or No

Photo of sign taken before taking plot photo (with Plot ID, Date, Photo Pt #, and Direction)? Yes or No

Photo notes (record photo file name from camera):

Add other photo notes in case there are other photos taken in plot:

## SOP 5 - Canopy Closure Measurements

Data taker initials Reviewed by

**Stand Height:** m Spherical Densiometer Measurements:

| Module | Direction | Tally of Shaded Dots (0-96): |
|--------|-----------|------------------------------|
| 1      | N         |                              |
| 1      | E         |                              |
| 1      | S         |                              |
| 1      | W         |                              |
| 2      | N         |                              |
| 2      | E         |                              |
| 2      | S         |                              |
| 2      | W         |                              |
| 3      | N         |                              |
| 3      | E         |                              |
| 3      | S         |                              |
| 3      | W         |                              |
| 4      | N         |                              |
| 4      | E         |                              |
| 4      | S         |                              |
| 4      | W         |                              |

Canopy Closure Notes (if any):

module 3 center near tree fall gap

←For forests, it is easiest to count the number of dots that are not shaded (sky is showing through canopy opening) and then subtract that number from 96 to obtain the number of "shaded" dots.

(fill in new page numbers if additional pages are added)  
p. 4 of 12 ( )

**Figure 7.** Example CUPN Forest Vegetation pre-printed data form (revisit form) for recording of canopy closure (densiometer) and stand height measurements.

**Table 1.** Field data form field name and field descriptions for SOP 4 (CUPN 2023b) and this SOP.

| Field Name                                | Field Description                                                                                                                                                                                                                       |
|-------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Photographer Initials                     | Record initials of photographer.                                                                                                                                                                                                        |
| Reviewed by                               | Initials of individual who reviewed completed data sheet for SOP 4 elements. Ideally this should be someone other than individual who completed this portion of datasheet.                                                              |
| Camera                                    | Text name of camera and/or make/model of camera (e.g., Nikon coolpix S6100).                                                                                                                                                            |
| Mark Photo Point                          | Is the photo point location, number and direction clearly marked on plot diagram (page 2 of datasheet), Yes or No.                                                                                                                      |
| Photo Sign                                | Was a photo of sign (designating photographer, date, plot id, photo point number and direction) taken with camera before taking plot photo?                                                                                             |
| Photo Notes                               | Include photo name (file name) from camera. Will likely be a generic number such as sd001, etc. Also, include other notes about photo point such as whether moved from standard position, etc.                                          |
| Other Photo Notes                         | To be used if other photos documenting something related to plot were taken. This may include additional reference photos to aid future teams in realigning plot or photos of potential forest pest evidence.                           |
| Data Taker Initials                       | Initials of individual collecting the data. In some cases will have one person calling out data, while another records. Data taker initials should be individual who is primarily making decisions on what is written on the datasheet. |
| Reviewed by                               | Initials of individual who reviewed completed data sheet for SOP 5 elements. Ideally this should be someone other than individual who recorded data on this portion of datasheet.                                                       |
| Stand Height (meters)                     | Avg. height of three co-dominant canopy trees either on or just off-plot, averaged for plot stand height. Use laser rangefinder or clinometer/meter tape.                                                                               |
| Spherical Densiometer Tally               | From module center, record the number of shaded dots (0–96) covered by canopy in each of the four cardinal directions (i.e., N, S, E, and W) for each of the four modules for a total of 16 counts.                                     |
| Canopy Cover – alternative quick estimate | Should only be used in the absence of a spherical densiometer. Standing in the middle of each module, the most experienced crew member should estimate % cover (note this includes cover from shrub layer).                             |
| Cover Notes                               | Record any notes related to collection of cover values.                                                                                                                                                                                 |

## Suggested Reading

- TruPulse 200 User Manual. Available at: [Laser Technology TruPulse 200 User's Manual](https://lasertech.com/wp-content/uploads/LTI-TruPulse-200.6.pdf) (https://lasertech.com/wp-content/uploads/LTI-TruPulse-200.6.pdf)
- TruPulse 360°R User Manual. Available at: [Laser Tech TruPulse 360 R Rangefinder](https://lasertech.com/product/trupulse-360-r-laser-rangefinder/) (https://lasertech.com/product/trupulse-360-r-laser-rangefinder/)

## Equipment List

- Spherical densiometer

- Clinometer, chaining pin and 30-meter (98.4 ft) tape measure **or** TruPulse 200 Laser Rangefinder **or** TruPulse 360°R Laser Rangefinder
- Brush Filter and Reflective Target (TruPulse 360°R only)
- Canopy closure datasheets (one for each plot)

## Literature Cited

- Cumberland Piedmont Network (CUPN). 2023a. Coarse woody debris measurements—Version 1.35. Cumberland Piedmont Network Standard Operating Procedure. NPS/CUPN/SOP—8. Cumberland Piedmont Network, Mammoth Cave, Kentucky. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2299609> (last accessed October 2023).
- Cumberland Piedmont Network (CUPN). 2023b. Plot photopoints—Version 1.34. Cumberland Piedmont Network Standard Operating Procedure NPS/CUPN/SOP—4. Cumberland Piedmont Network, Mammoth Cave, Kentucky. Available at: <https://irma.nps.gov/DataStore/Reference/Profile/2299605> (last accessed October 2023).
- Ganey, J. L., and W. M. Block. 1994. A comparison of two techniques for measuring canopy closure. *West. J. Appl. For.* 9:21–23.
- Leverett, B. and D. Bertolette. 2014. American Forests champion trees: Measuring guidelines handbook, American Forests. Available at: [https://www.americanforests.org/wp-content/uploads/2014/12/AF-Tree-Measuring-Guidelines\\_LR.pdf](https://www.americanforests.org/wp-content/uploads/2014/12/AF-Tree-Measuring-Guidelines_LR.pdf) (last accessed September 2023).
- Tierney, G., B. Mitchell, K. Miller, J. Comiskey, A. Kozlowski, and D. Faber-Langendoen. 2016. Northeast Temperate Network long-term forest monitoring protocol: 2016 revision. Natural Resource Report NPS/NETN/NRR—2016/1184. National Park Service, Fort Collins, Colorado.

# Revision Log

## Revision History Log.

| Version # | Date      | Revised by              | Changes                                                                                                                                                                                                                                                                                                                                                                                              |
|-----------|-----------|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1.1       | 01/15/12  | B. Moore and R. White   | Miscellaneous and minor formatting and other editorial changes in attempt to add clarity to document, following first field season. Noted that raw counts of dots (0-96) are what is entered in database (i.e., no field conversions to % are needed). Clarified that while title of SOP is Canopy Cover, field crews are in actuality recording total (overhead) cover, not just limited to canopy. |
| 1.2       | 9/27/12   | B. Moore and R. White   | Added note that team members should calibrate counts with one another. Added more detailed instruction on proper technique for holding the densiometer. Added note that it sometimes helps to close one eye when counting densiometer.                                                                                                                                                               |
| 1.3       | 3/29/17   | C. Bledsoe              | Changed Time allotted 15 minutes to Time estimated 20 minutes. Add short justification for incorporation of stand height as a plot measure (first implemented in 2015). Added detailed step by step directions for obtaining stand height via triangulation or using the Trupulse 200. Updated equipment list. Updated references incorporating stand height.                                        |
| 1.31      | 3/23/20   | C. Bledsoe and B. Moore | Added note that stand height measurements were incorporated in 2015. Moved Revision History to end of SOP and added more detailed list of changes made to date, where applicable.                                                                                                                                                                                                                    |
| 1.32      | 8/9/2020  | B. Moore                | Address grammatical changes and clarifying comments made by IMD regional program manager.                                                                                                                                                                                                                                                                                                            |
| 1.34      | 2/26/2021 | B. Moore                | Added directions for utilizing new rangefinder model (TruPulse 360°R) and attempted to simplify directions for utilizing laser rangefinders, generally. Added image of Field Data Form and table of field data form descriptions (moved from SOP 14).                                                                                                                                                |
| 1.36      | 8/3/2023  | –                       | Formatted by editor to regional I&M publication standards.                                                                                                                                                                                                                                                                                                                                           |