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Introduction

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. Conversely, a low amount of canopy closure can indicate changes in the canopy due to natural or human caused disturbance such as wind throw, forest pest damage, etc. The spherical densiometer is an economical and durable device for measuring canopy cover. The instructions for use of the spherical densiometer 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 is 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.

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), methods detailed in SOP FVM08 *Woody Debris—Version 1.0* (Prats 2019), to obtain a CWD volume as a percentage of live tree volume (Tierney et al. 2016). Stand height is calculated either by triangulation or by using a laser rangefinder. For triangulation, an optical reading clinometer and meter tape are used. The network also has an Impulse 200 laser rangefinder available for use. Instructions for both methods are described in this SOP. While use of either method is 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 data are collected correctly. The datasheet used for this SOP is *SFCN Veg Form 3—Plot Photo Points and Canopy Closure Measures*, which can be found in SOP 4: *Plot Photo Points-Version 1.0* (Shamblin 2019).

SOP Source and How It Was Modified

This SOP is an adaptation of SOP 5: *Canopy Closure and Stand Height Measurements—Version 1.2* of the *Vegetation Monitoring Protocol for the Cumberland Piedmont Network* (White et al. 2011). For a general explanation of how the South Florida/Caribbean Network (SFCN) modified the Cumberland Piedmont Network (CUPN) protocol and its SOPs, see the *South Florida/Caribbean Network Forest Vegetation Monitoring Protocol Implementation Plan* (Whelan et al. 2020). For this specific SOP, the South Florida/Caribbean Network made minor editorial modifications to CUPN SOP 5 *Canopy Closure and Stand Height Measurements* and added instrument information for the Impulse 200 laser rangefinder.

Step by Step Instructions for Canopy Closure Measurements

While this SOP title refers to ‘canopy’ cover, for this protocol crew members should record 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 10 × 10 meter (32.8 × 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-degree angle and your upper arm will be rigidly by your side so that the device is always held at approximately the same distance away from your eyes. In addition, we have found that reading the densiometer with one eye closed tends to yield measurements that are 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 should count up 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. Crew members repeat this measurement in each of the four cardinal directions (N, E, S, and W), and do this in each of the four modules. These raw counts obtained in the field are entered into the database, where 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. A spherical densiometer grid, illustrating how 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 is visually estimated. Although visual estimation is a much less repeatable method than the 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% (to the nearest 10%). Repeat this measure at the center of each module.

Table 1. Datasheet Field Descriptions for *Veg Form 3—Plot Photo Points and Canopy Closure Measures*, found in SOP 4.

Field Name	Field Description
Data taker initials	Initials of individual collecting the data. In some cases, one person will call out data, while another records data. 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	Height of three co-dominant canopy trees either on or just off-plot, averaged for plot stand height. Use clinometer and 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.

Step by Step Instructions for Stand Height Measurements

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 are not discussed here.

When a codominant canopy tree has been chosen, pin the end of the meter tape at the base of the tree with a pin flag. Walk away from the tree with the reel end of the meter tape 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 SFCN 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 (see Figure 2). 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 is used. Estimate where the top of the tree is and record the number on the percent scale where the crosshair meets the treetop, 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. Note that crews should only estimate height from below the base of the tree as a last resort. This is less accurate than being on the same level or slightly above the base of the tree. Add these two numbers together, divide by 100, and multiply by the distance to the tree to obtain the height of the tree.

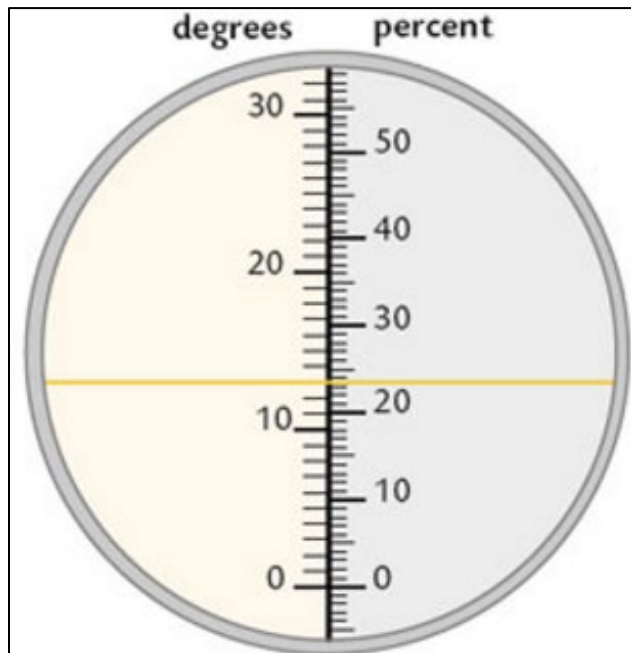


Figure 2. View through the eyepiece of a clinometer.

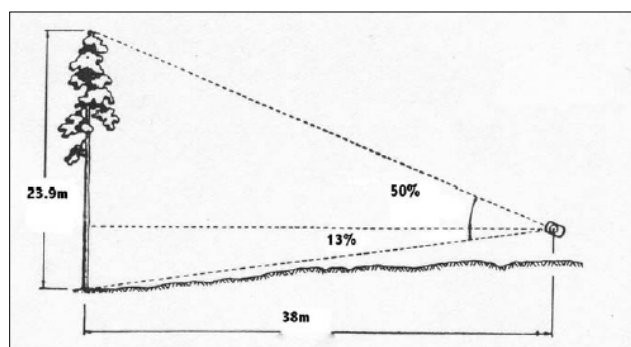


Figure 3. Using a clinometer to measure tree height on sloping ground when the base of the trunk is below eye level.

When the base of the trunk is below eye level, the percent values are added (see Figure 3). The height is then calculated as follows. For example, if the treetop reading is 50%, the ground reading is 13% and the distance to the tree is 38 meters (125 ft), the mathematical calculation is:

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

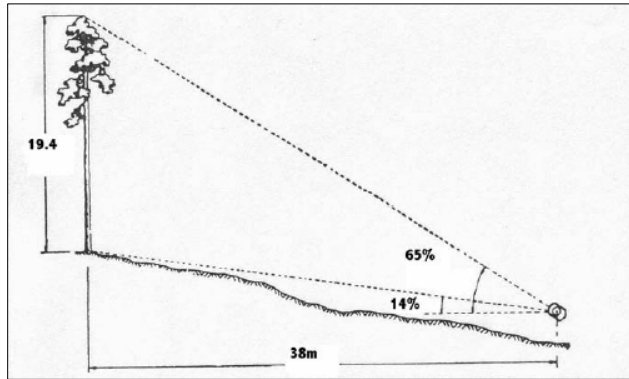


Figure 4. Using a clinometer to measure tree height on sloping ground when the base of the trunk is above eye level.

Where the base of the trunk is above eye level, the trunk base percent is subtracted from the tree-top percent (see Figure 4). 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 meters, the calculation is:

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

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

The Impulse 200 laser rangefinder provides distance (horizontal and slope) and vertical angle measurements to a target. The laser rangefinder is used to measure canopy height by selecting three co-dominant canopy trees and measuring the height by sighting the base of the tree to determine a horizontal distance, then sighting the base of the tree and then the top of the tree to calculate the height of the tree.

The instrument is highly sensitive and expensive, and must be treated with care, including protecting it from getting wet. When not in use the instrument is stored in its Pelican carrying case. The laser rangefinder has two lenses at the front. Do not touch these lenses and avoid obstructing them while in use. If they need to be cleaned, use a soft clean lens tissue.

The hand strap can be mounted on either the left side or the right side of the laser rangefinder depending on the preference of the user. Control buttons are located on either side of the instrument.

Specifications

Max Range: 575 meters (1,880 ft) to a cooperative target (meaning using a reflector)

Target Ranges: 100 meters (328 ft) to overhead cable/stake; 500 meters (1,640 ft) to rock face/building

Range Resolution: 0.01 meters (0.05 ft)

Inclination Limits: $\pm 180^\circ$

Inclination Accuracy: $\pm 0.1^\circ$

Power Supply: Two AA batteries providing up to 20 hours of use. Do not use “voltage check” cells.

Getting Started

Inserting the Batteries

Load the two AA batteries by inserting them positive-end first into the battery compartment on the instrument’s back panel (Figure 5). When batteries are inserted, twist the battery compartment cap clockwise, finger tight, to secure it. **DO NOT** use AA batteries with the “voltage check” feature built into the cell. The “voltage check” cells are slightly larger in diameter and will cause problems when inserting into and extracting from the battery compartment.

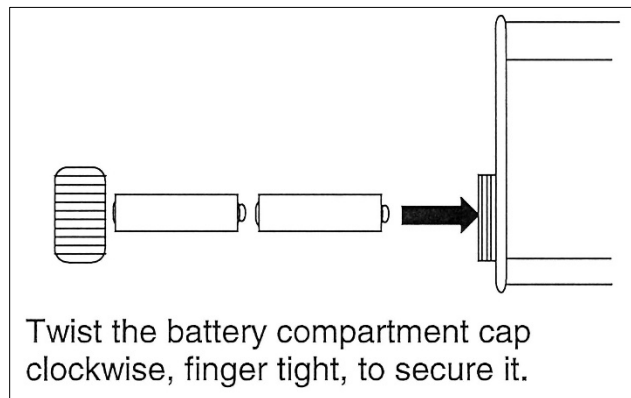


Figure 5. The laser rangefinder uses two AA batteries inserted into the battery compartment at the back of the instrument.

Powering on and off

The laser rangefinder has a row of three buttons on either side of the instrument (Figure 6). Power on by pressing the rear-most button (the button closest to you) on either button panel. Power off by simultaneously pressing the two forward-most buttons on the left panel. The instrument will also power itself off after a period of inactivity.

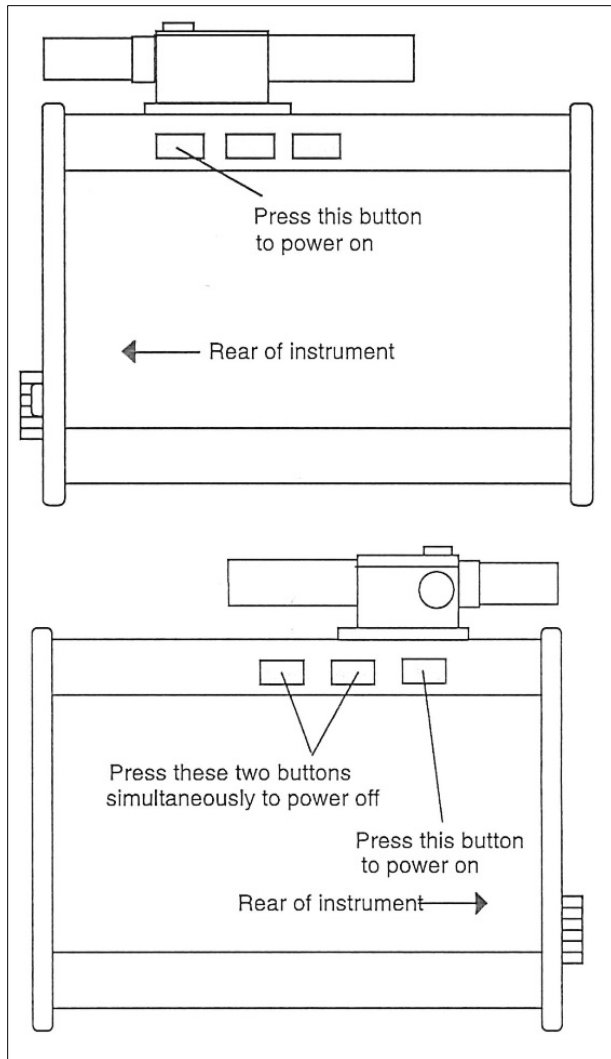


Figure 6. The power buttons are located on either side of the instrument. The power on button is on the right side of the instrument and the power off buttons are located on the left side of the instrument.

Taking a Distance Measurement

When powering the instrument on for the first time, the LCD screen on the rear panel will show the display in Figure 7. The indicator “RIGHT” in the upper left of the screen means the right-handed button panel is activated as the primary control panel. The “HD” means the instrument is prepared to take a horizontal distance measurement. The slope distance “SD” can also be activated on slopes. The “M” means the measurement will be taken in meters, while an “F” in this location means the measurement will be taken in feet. When taking distance measurements for the forest monitoring protocol, record measurements in meters.

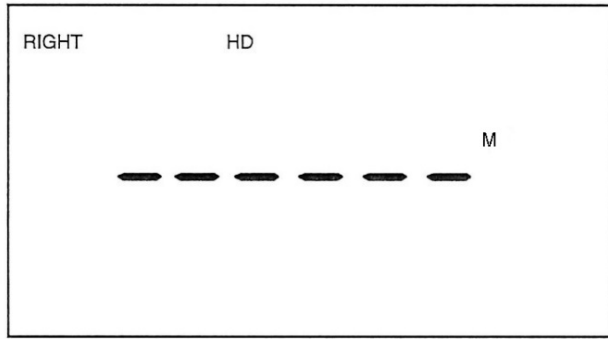


Figure 7. The LCD screen will look like this when powering on the instrument.

To take a horizontal distance measurement:

1. Aim to a target, press the rear-most button on the right panel (the same button used to power on the instrument), and hold it down until the instrument acquires a target.
2. The first press of the button will turn on a red dot in the sighting scope.
3. A second press of the button will take the measurement. After a brief delay, the instrument emits a high-pitched beep and the LCD screen will display the measurement (Figure 8). The number in the screen displays the distance to the target. The “DNLD” in the lower right of the screen means the number is available at the serial port if the instrument is connected to a data logger or notebook computer (Figure 8).

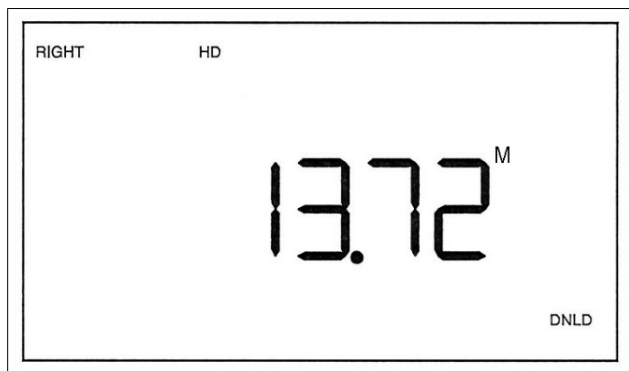


Figure 8. The LCD screen will display the measurement after emitting a high-pitched beep.

Taking a Height Measurement

The laser rangefinder implements height measurements with the “HT” option. The option works by requiring that the measurements be taken in a specific order. A flashing indicator shows the measurement that needs to be taken next; the indicator for the number being displayed also shows on the screen, but does not blink.

Follow this procedure to take a height measurement (also displayed in Figures 9 and 10):

1. Begin by pressing the on (fire or rearmost button on the right side) button to turn the instrument on.
2. Press the back button (forward-most button on the right side) to display the height indicator (HT).
3. Press the fire button again to advance to the height subprocedure. The “HD” indicator will be flashing.
4. Sight the target through the scope and press the fire button twice to take the horizontal distance measurement of the target.
5. Aim to the base of the target and press the fire button to take the base inclination reading.
6. Aim to the top of the target and press the fire button to take the top inclination reading.
7. Press the fire button again to display the height of the target.

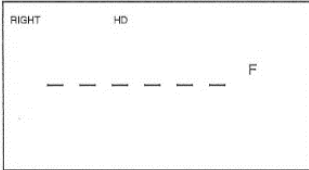
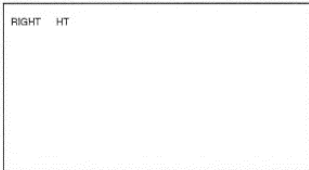
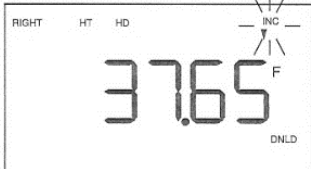
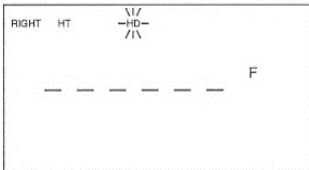
Button/Action	Result (example)	Button/Action	Result (example)
Press Fire to turn on the instrument		Sight the target through the scope	
Press Back to reach the Height indicator		Press Fire to take the horizontal distance measurement	
Press Fire to advance into the height subprocedure		Aim to the base of the object (even if you can't sight it), and press Fire to take the base inclination reading	

Figure 9. Graphic displaying the procedures for taking a height measurement (1 of 2). Note: This figure was taken from the user’s manual and shows distances in feet. Network staff will record the distance measurements in meters.

Button/Action	Result (example)
Aim to the top of the object (even if you can't sight it), and press Fire to take the top inclination reading	
Press Fire to display the height of the object	

Figure 10. Graphic displaying the procedures for taking a height measurement (2 of 2).

Suggested Reading

Impulse 200 User Manual (Adams and Mannik 1998)

Equipment List

Spherical densiometer

Clinometer

30m meter tape

Chaining pin

Impulse 200 Laser Rangefinder

Canopy closure datasheets (1 for each plot)

Literature Cited

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