# Southeast Coast Network

**National Park Service**
**Inventory and Monitoring Division**

# Standard Operating Procedure 1.4.11

*Tree Measurements—Version 1.1*

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## Summary

This standard operating procedure (SOP) provides instruction for how to collect and record data on canopy closure, average stand height, species presence, stem diameter, and condition of all live and standing dead woody stems greater than or equal to 10 centimeters (3.9 inches [in]) diameter-at-breast height (DBH), within each of the four modules of the 20 × 20-meter (65.6 × 65.6 feet [ft]) vegetation plot. These data are used to track tree growth, mortality, condition and stand composition over time. The datasheets used for this SOP include SECN *Veg Form 3—Plot Photo Points and Canopy Closure Measures* and *Form 4—Tree Measurements* and are in Appendix A of this SOP.

## Revision Log

| Revision Date | Author | Changes Made | Reason for Change | New Version # |
|---|---|---|---|---|
| August 2020 | M.F. Boyle | Revised the "Stand Height and Canopy Closure Estimates" section from including language on how to estimate height in non-forested habitats to removing this requirement. Stand height is only calculated in plots that have woody stems present. | Stand height is not a useful metric in grassland habitat, because of the large variance in observations, and is mostly used to estimate biomass—a metric not used for vegetation condition in the SECN. | 1.1 |
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# SOP Source and How It Was Modified

This SOP is an adaptation of SOP 5 *Canopy Closure and Stand Height Measurements—Version 1.3* and SOP 6 *Tree Measurements—Version 1.4* of the *Cumberland Piedmont Network Vegetation Monitoring Protocol* (White et al. 2011). For a general explanation of how the Southeast Coast Network (SECN) modified the Cumberland Piedmont Network (CUPN) protocol and its SOPs, see the *Terrestrial Vegetation Monitoring in Southeast Coast Network Parks: Protocol Implementation Plan* (Boyle et al. 2019a). With regards to this SOP, the Southeast Coast Network made four specific modifications to the CUPN SOPs, including (1) combining the two CUPN SOPs into a single SOP; (2) combining trees, shrubs, and lianas into a single woody stem category; (3) damage codes for woody stems are only included for forest pests and disease; and (4) the triangulation method is the only method for stand height described in this SOP. The detailed list of modifications to CUPN SOP 5 and CUPN SOP 6 is in Appendix B of this SOP.

# Definitions

**Plot size** will be 400 square meters (4,306 square feet [$ft^2$]) with dimensions of 20 × 20 meters (65.6 feet × 65.6 ft) for all vegetation monitoring plots within SECN parks.

**Diameter-at-breast-height (DBH)** is measured at 1.37 meters (4.5 ft) above the ground line on the uphill side of a tree. In this protocol, only woody stems with DBH greater than or equal to 10 centimeters (3.9 inches [in]) are measured. The DBH is measured and rounded to the nearest centimeter. The one exception to rounding is that the Southeast Coast Network and Cumberland Piedmont Network do not round up from 9.5 centimeters (3.7 in). In other words, a trunk or bole must be greater than or equal to 10 centimeters (3.9 in) to count as a tree.

**Woody stems** that reach 1.37 meters (4.5 ft) above the ground and are at least 10 centimeters (3.9 in) DBH at that height are measured. Woody stems are plant species that produce wood as a structural tissue and include trees, shrubs, and lianas (vines).

**Live woody stems** are individuals with any living parts (leaves, buds, cambium) present at or above 1.37 meters (4.5 ft) from the ground. These include trees that have been temporarily defoliated.

**Standing dead trees (snags)** are dead stems that are standing and lean less than 45 degrees from vertical. They need not be self-supported. Dead snags are measured until they have fallen or are leaning greater than 45 degrees from vertical.

# Data Collection Procedures

### Plot Establishment Years: Species, Diameter, Health, and Maps

Beginning in module 1, visually determine the best strategy for measuring woody stems in a coherent pattern so that each stem greater than or equal to 10 centimeters (3.9 in) DBH is recorded on the datasheet (SECN Veg Form 4 *Tree Measurements*). This can be done by measuring the woody stems starting in one corner of each module and working through the whole module in either a circular or

linear pattern, depending on the arrangement of woody stems. Tree chalk can be used to mark stems that have been recorded. **Do not skip around from one side of the module to the other when recording woody stems**. In particularly dense foliage, flagging may be helpful to mark the starting measured stems and the boundary between stems that have been recorded and those that have not.

Once a strategy has been determined, one field crew member (the 'measurer') measures the location of 1.37 meters (4.5 ft) from the ground on their body, using plot meter sticks. This will allow for rapid estimation of this height when measuring a stem's diameter. Once DBH has been established on the measurer's body, that individual can begin recording, or calling information out to another crew member (the 'recorder'), woody stem information. These data are recorded on SECN Veg Form 4 *Tree Measurements* and include:

#### *Module #*

Record the module where the stem is located (e.g., 1, 2, 3, 4). If a stem falls along the boundary between two modules, it is recorded for the module that its base center occurs in. If a stem falls along the boundary of the plot, then the horizontal distance from the plot centerline tape to the front of a crew member standing adjacent to the tree base center is measured. If the distance from the plot centerline to the center of the stem base is greater than 10 meters (32.8 ft), then the stem falls outside the plot and is not tallied.

#### *Species Code*

Record the species code of a tallied tree using the taxonomic standard identified in SOP 1.4.14 *Species Diversity and Seedling/Sapling Measurements—Version 1.0* (Boyle 2019). Unique codes generally consist of the first four letters of the genus and the first three letters of the species of that tree with an extra eighth digit where there would be duplicate seven letter codes. For example, shagbark hickory (*Carya ovata*) and red hickory (*Carya ovalis*) would have the same seven-letter code, so the former's eight-letter code is CARYOVAT and the latter's correct code is CARYOVAL.

#### *DBH*

Using a DBH tape, measure the stem diameter at a position on the stem of 1.37 meters (4.5 ft) above the ground, on the uphill side of tree (Figure 1). Do not measure from a pit or atop a mound or emergent rock. The diameter value is reported to the nearest 1 centimeter (0.4 in). In other words, if measured DBH is 10.4 centimeters (4.09 in), then it would be rounded to 10 centimeters (3.93 in). If measured DBH is 10.5 centimeters (4.13 in), it would be rounded up to 11 centimeters (4.33 in). The one exception to rounding is that a stem must be at least 10 centimeters (3.93 in) DBH to be recorded. So, if it measures 9.9 centimeters (3.90 in) or less, it is not rounded up to 10. In any case where a stem branches above 1.37 meters (4.5 ft; breast height) from its base or more, you will only record the main stem. In contrast, if the stem branches below 1.37 meters (4.5 ft) from the base, you will measure all stems greater than or equal to 10 centimeters (3.93 in) DBH.

Make certain you are reading the correct side of the DBH tape; often one side has standard centimeters and the other side has units calibrated to give the diameter in centimeters when wrapped around the circumference of the tree. Press the hook at the end of the tape into the bark and then run the tape around the trunk, ensuring the tape is straight, pulled tight (no kinks) and perpendicular to

the axis of the trunk. Tapes that are not run straight will overestimate the trunk diameter. Read the number where the tape crosses the zero mark at the hook end of the tape. For unusual situations when it is difficult to determine where DBH should be located on the stem, use the guidelines in Figure 1 and "DBH Notes" below. Record the location of unusual DBH measurements in the Tree Notes section of the datasheet.

DBH Notes:

*Trunk abnormality*: If a trunk abnormality occurs at breast height (1.37 meters [4.5 ft]), take the diameter measurement just below the abnormality, if possible. If the abnormality extends far below breast height (1.37 meters [4.5 ft]), then take the measurement just above breast height (1.37 meters [4.5 ft]). Record the height where measured in Tree Notes.

*Missing wood or bark:* Do not reconstruct (i.e., hypothetically guess) the DBH of a tree that is missing wood or bark. Record diameter of the stem in its current condition, and note that wood or bark was missing in Tree Notes.

*Leaning tree*: Diameter is always measured perpendicular to the bole axis. Find the point equivalent to breast height (1.37 meters [4.5 ft]) by measuring along the uphill side of the tree. Measure diameter perpendicular to the tree trunk (bole) as shown in Figure 1. If a living tree is leaning more than 45 degrees, find the point equivalent to breast height (1.37 meters [4.5 ft]) by measuring along the uphill side of the tree starting with the root collar and measure diameter perpendicular to the bole (Note that a dead tree leaning more than 45 degrees is not measured).

*Curved bole:* Find the point equivalent to breast height (1.37 meters [4.5 ft]) by measuring along the curvature of the bole on the uphill side of the bole as shown in Figure 1 and measure diameter perpendicular to the bole.

*Live windthrown tree*: Find the point equivalent to breast height (1.37 meters [4.5 ft]) by measuring along the uphill side of the tree starting with the root collar and measure diameter perpendicular to the bole (see Figure 1).

*Swollen base*: Trees with swollen bases rising higher than 0.91 meters (3.0 ft) are measured 0.46 meters (1.5 ft) above the top of the swelling. Trees with swelling below 0.91 meters (3.0 ft) are measured at standard DBH. Make a note in Tree Notes about the swelling and diameter location.

*Independent trees that grow together*: If two or more independent stems have grown together at or above the point of DBH, continue to treat them as separate trees. Estimate the diameter of each and explain the situation in Tree Notes.

*Forked tree*: Trees which fork at or above breast height (1.37 meters [4.5 ft]) are tallied and measured as one tree. Diameter should be measured below the point at which forking affects DBH (see Figure 1). For trees that fork below breast height (1.37 meters [4.5 ft]), each trunk greater than or equal to 10 centimeters (3.93 in) is tallied as a separate tree. Measure the diameter of each trunk at breast height unless the fork affects the diameter of the stem, in which case measure above breast height where the fork does not affect the diameter of the stem and make a note in Tree Notes of

measurement location. For consistency, multiple stems should be recorded from left to right when facing the trees from plot center. Note the spatial relationship of forked trees to each other in Tree Notes and mark forked trees on the tree diagram. Record any unusual tree features or the relative position of each of the stems of a clumped tree/copse if applicable.

*Trees with vines*: It is imperative that trees with vines climbing the bole at breast height have the DBH measured underneath the vines. The easiest way to remove the vine is by prying it away from the tree with the hammer to get underneath it. Be especially careful when handling poison ivy vines (use gloves) because the hairs on the vine can cause a reaction similar to the leaves.

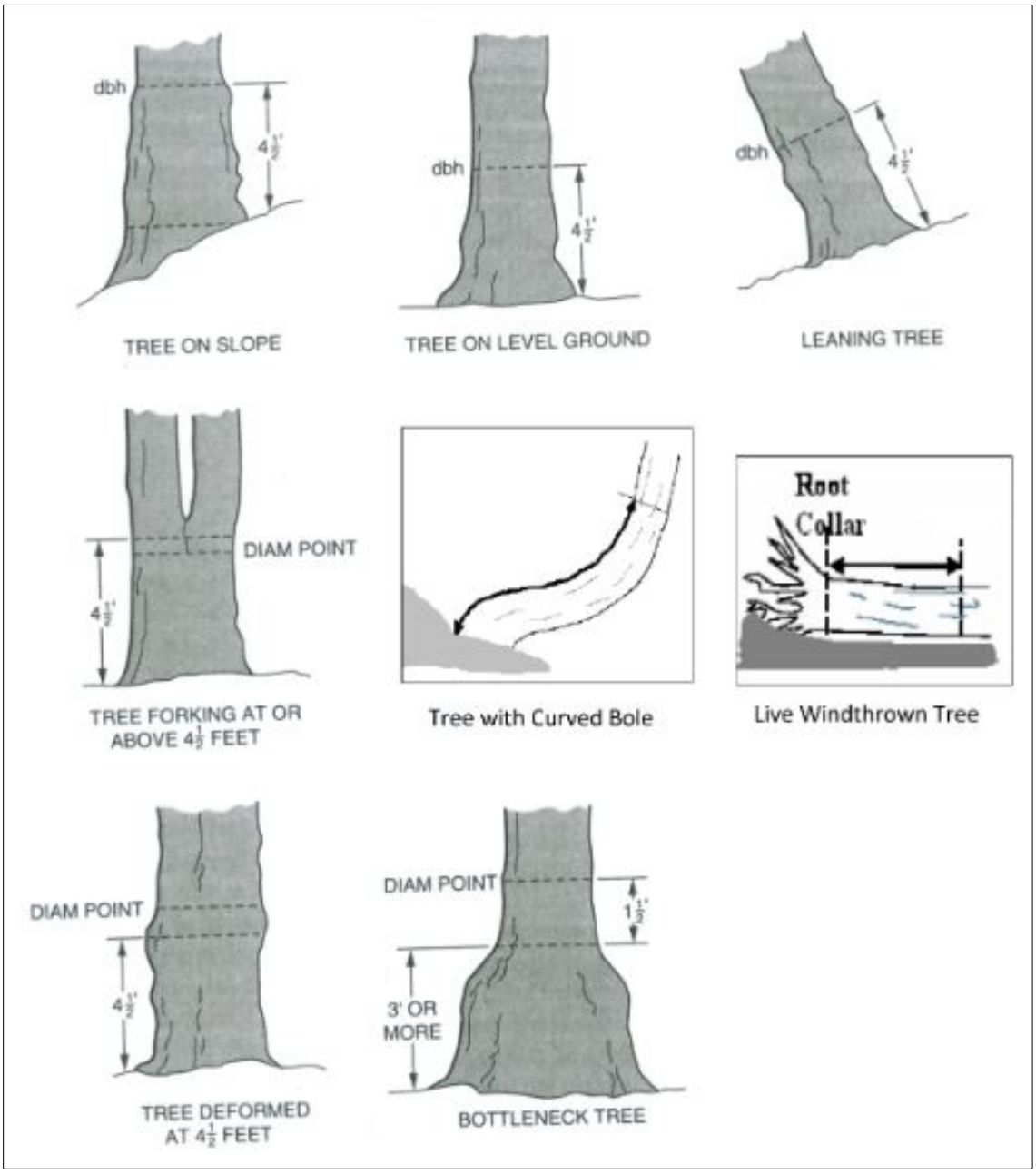


**Figure 1.** Standard and irregular locations for reporting a woody stem diameter measurement.

### *Tree Status*

Determine the tree status of each recorded tree (see below). In differentiating whether a tree should be alive or dead, refer to the definitions at the beginning of this SOP. If the tree in question is determined to be dead, move on to the Decay Class measurement.

1. Live tree (1): The stem has living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft])

2. Standing dead tree (2): Tree lacks any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft]), and leans less than or equal to 45 degrees away from vertical, or straight up and down.

### *Crown Class, Tree Vigor, Tree Dieback, Tree Condition/Damage Codes*

Each live tree's crown, vigor, degree of dieback, and condition will be assessed using a consensus of each metric from two observers observing the tree from different locations. Metrics are described below.

Crown Class

Every live tree will receive a Crown Class Code. Assign codes by describing the tree crown position in the canopy and amount of sunlight received (see Figure 2). If there is any uncertainty in assigning this code to a stem, make a note in Tree Notes about why.

1. Open grown: Crown has received full sunlight from above and all sides through much of its life, particularly during early development, as seen by well-developed lower branches. Open-grown trees may be present at different positions within the general canopy, but are identified by their form. They are much older and larger than all the other trees in the plot with unusually spreading branches indicative of a past that included growing in a full-sun, low competition environment resulting in a much more rounded, as opposed to linear crown.

2. Dominant: Crown extends above canopy, receiving full light from above and some light from sides. Taller than the average tree in stand and has well-developed crown.

3. Co-dominant: Crown at the general level of the canopy, receiving full light from above but little direct light from sides. Typically, co-dominant trees have medium-sized crowns and are crowded on the sides; in dense stands, co-dominant trees have small crowns.

4. Intermediate: Stem is shorter than co-dominant trees but with a crown that extends into the general canopy. Tree has small crown and is very crowded from the sides.

5. Overtopped: Crown is entirely below the general level of the canopy.

Tree Vigor

Every live tree will receive a Tree Vigor Code. Vigor is a measure of overall tree health and vitality. This measure compares the subject stem to an ideal healthy specimen of that species. Record the general overall health of the tree using the codes below. Estimate vigor before estimating Tree Dieback or Tree Condition/Damage Codes.

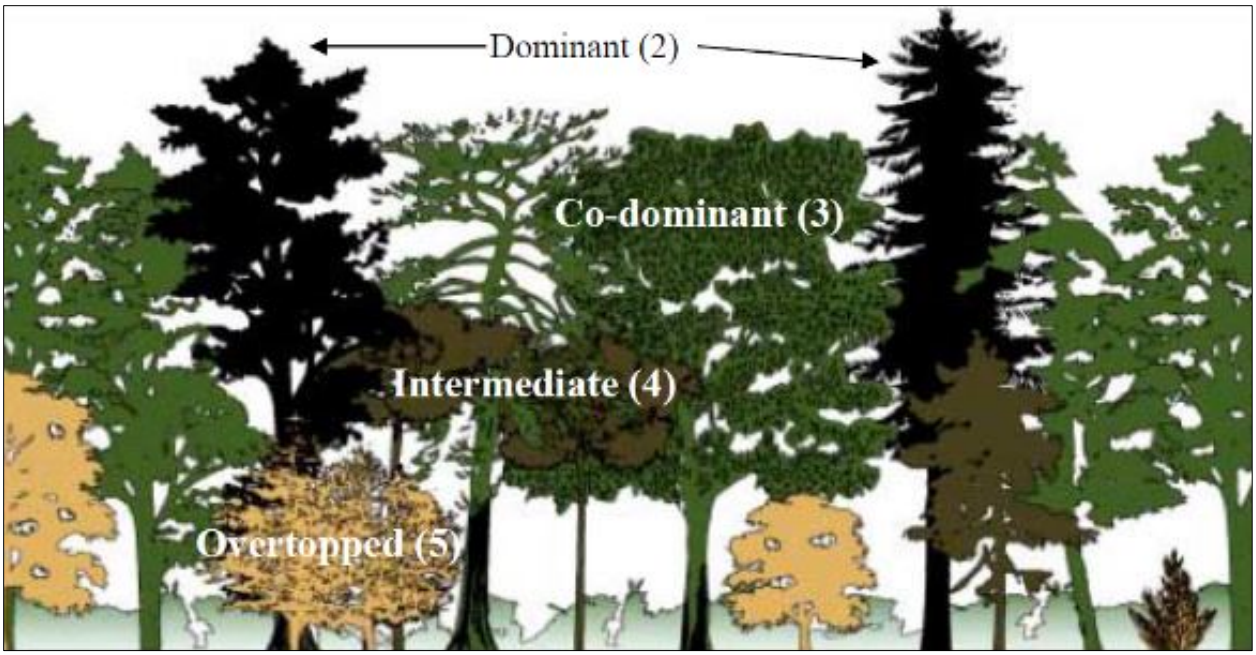


**Figure 2**. Crown Class examples and codes used by the Southeast Coast Network Terrestrial Vegetation Monitoring protocol (Boyle et al. 2019a).

1. Healthy: Tree appears to be in reasonably good health with < 10% missing/damaged crown, branch or twig mortality, discoloration, or dwarfed leaves present.

2. Light decline: Less than 25% of the crown is missing or damaged. Branch mortality, twig dieback, foliage discoloration, or dwarfed leaves are present on 10–25% of the crown.

3. Moderate decline: Branch mortality, twig dieback, foliage discoloration or dwarfed leaves on 26–50% of the crown. Between 26 and 50% of the crown is missing or damaged.

4. Severe decline: More than half of the crown is missing, damaged, or contains branch mortality, dieback, discoloration or leaf dwarfing, but foliage still present to indicate that the tree is alive.

5. Functionally dead: There may be a few epicormic shoots on the bole, but a majority of crown branches are missing or dead and leaf-less. Phloem under bark has brown streaks.

Several factors should be considered when assessing vigor:

- How much of the crown is missing or damaged from recent or long past disturbances? Old injuries should be considered in the vigor assessment until the tree builds a new crown that makes the old injury largely invisible.

- How much of the crown is composed of dead snag branches? Snag branches are large branches without small twigs less than 2.5 centimeters (1 in) in diameter, usually with the bark absent or with dead bark peeling away.

- How much of the crown contains foliar discoloration or dwarfed or misshapen leaves?
- Current defoliation should **not** be considered in the vigor assessment. A defoliated tree does not necessarily have low vigor. Vigor is difficult to assess for trees currently undergoing partial or severe defoliation. For those trees, make the best assessment possible by considering crown structure, snag branches, and any intact foliage that may remain.

Tree Dieback

Only live trees displaying dieback will receive a Dieback Code. Branch and fine twig dieback is defined as branch mortality that begins at the terminal portion of a limb and progresses downward (Figure 3). This measurement is an estimate of the proportion of the crown silhouette involved in dieback. Assume the perimeter of the crown is a two-dimensional outline from branch-tip to branch-tip. Then estimate the amount of the outline that includes dieback. Record the proportion of the crown with crown dieback using the following categories:

1. 1–10%
2. 10–25%
3. 25–50%
4. 50–75%
5. 75–100%

Exclude the following from the dieback percentage:

- Snag branches (large branches without small twigs less than 2.5 centimeters (1 in) in diameter, usually with the bark absent or with dead bark peeling away). Snag branches are assumed to have died much earlier and should not be included in the dieback percentage.
- Large holes or gaps in the crown where branches never developed.
- Branch mortality at the base of the crown, assumed to be the result of shading.

Dieback should ideally be estimated when leaves are mature, but before the appearance of fall color. One crew member is required to make the estimate of dieback from two different sides of each tree, standing at a minimum of a 90° angle apart around the tree. Figure 3 illustrates what to include and exclude when assessing dieback.

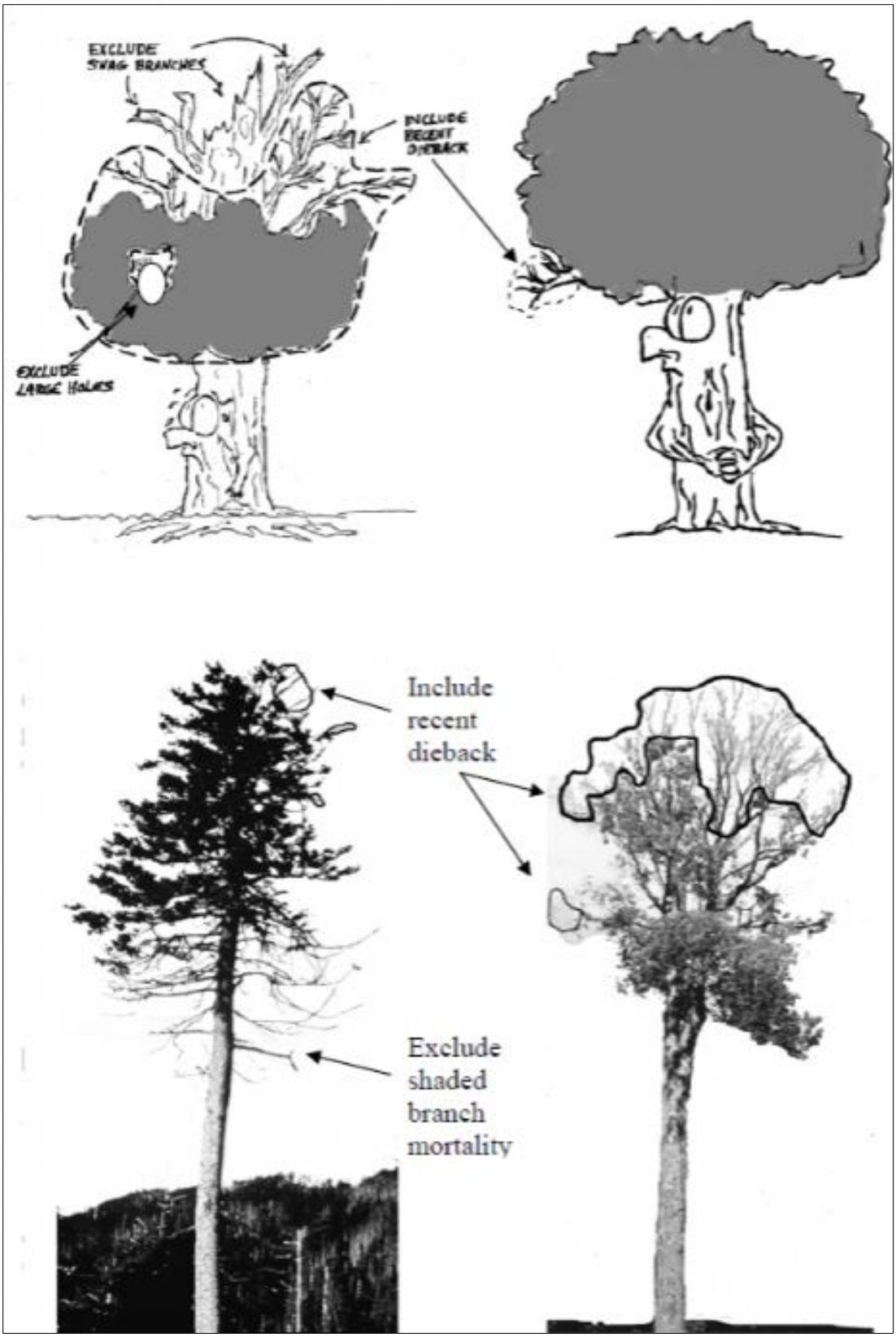


**Figure 3**. Examples of tree dieback.

Tree Condition/Damage Codes

Only live trees exhibiting conditions/damages listed below will receive a code. Field teams need to have some familiarity with the identification of these codes before assessing. Specific tree damage types will be indicated by placing the appropriate three- or four-letter code in the Tree Condition/Damage Code column. You can add up to three codes in this column (if you need to write more than three codes, add the additional codes in the "Tree Notes" section). The following codes are used to cover Pests and Pathogens in this protocol:

- **BBD** Beech Bark Disease
- **DWA** Dogwood Anthracnose
- **EAB** Emerald Ash Borer
- **ETC** Eastern Tent Caterpillar
- **PBB** Pine Bark Beetle
- **RAB** Redbay Ambrosia Beetle
- **SPB** Southern Pine Beetle

### *Decay Class and Snag Height*

If the woody stem is a dead standing tree (see definitions at beginning of this SOP), then collect information on Decay Class and Snag Height (visual estimate in meters, to the nearest 5 meters). If tree is dead, you are not required to name the species, though if you can determine it based on bark and twigs, then please do so. Recording genus only on snags is also helpful but it is important to be right--do not simply guess.

For each standing dead tree, record the code indicating the tree's stage of decay (Table 2).

**Table 1.** Decay class codes used in the Southeast Coast Network Terrestrial Vegetation Monitoring protocol.

| Snag decay class | Bark | Log shape and integrity | Color of exposed wood | Texture of rotten portions | Primary surface substrate | Branches and twigs |
|---|---|---|---|---|---|---|
| 1 | Firmly attached | Round and solid. Freshly fallen, intact logs | Fresh color, not stained by weathering | Intact, no rot or conks. Stem decay absent. | Sound, tight bark | Branches retain many small twigs |
| 2 | If present, decayed, faded and not firmly attached | Round and solid | May be bleached and relatively smooth (like driftwood) | Mostly intact, sapwood partly soft and starting to decay, but can't be pulled apart by hand | Decayed bark and hard wood - impenetrable with fingernail or pen point | Branches retain some small twigs, often with peeling bark |
| 3 | Generally absent, except in Betula and Prunus | Round and firm, piece supports its own weight | Reddish-brown, or original color | Hard, large pieces of sapwood can be pulled apart by hand. | Soft wood - will spring back if compressed, easily penetrated with fingernail or pen point | No small twigs, but branch stubs will not pull out |
| 4 | Absent | Oval or flattened, no longer a solid piece, though some hard chunks remain. Piece does not support its own weight, but maintains its shape | Reddish or light brown | Soft, small blocky pieces, a metal pin can be pushed into heartwood | Very spongy wood - responds to finger pressure and may exude moisture. Powder wood flows through fingers like coarse sawdust | No small twigs, branch stubs pull out |
| 5 | Absent | Quite flat or flat with some rounding. Piece no longer maintains its shape, but spreads out on the ground | Red-brown to dark brown | Soft, powdery when dry | Loosely aggregated powder wood | No small twigs. Branch stubs and pitch pockets have usually rotted down |

***Tree Map***

All recorded woody stems (live or dead) are mapped on the tree diagram (Figure 4). The tree diagram is gridded in one meter increments. It is important that trees are mapped correctly, as this will give future monitoring teams an easy way of determining whether the stem they are measuring is the same as the one the previous team measured or a different one. To most accurately plot the stems, use the meter marks on the tape measures surrounding the module. Also, make sure you know which direction is north and that you have the tree diagram oriented correctly before marking trees on the map. It is also helpful to map stems that lie just outside plot, particularly if they are touching or very near the plot boundary, as this can aid in future plot layout during revisits.

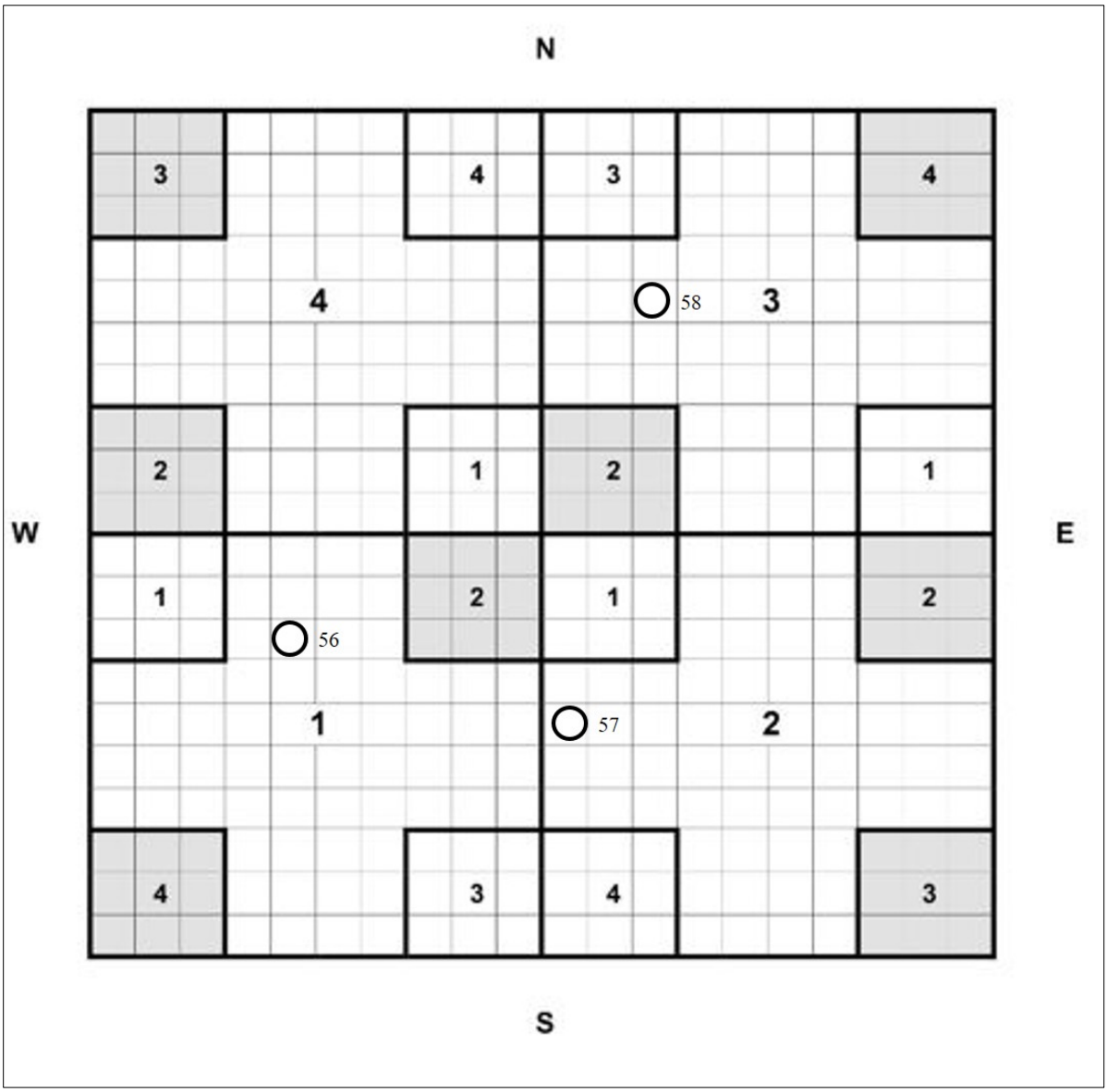


**Figure 4.** An example of a tree diagram from the *Southeast Coast Network Veg Form 4—Tree Measurements* illustrating all live or standing dead woody stems over 10 centimeters DBH mapped (circled numbers).

Repeat the above procedures in modules 2, 3, and 4. It is a good practice to periodically have someone else on the field crew re-measure a stem or two within the plot to check for consistency.

### Plot Revisit Years: Species, Diameter, Health, and Maps

For plot revisits, the SECN Veg Form 4—*Tree Measurements* datasheet and gridded map is prepopulated with recorded species, diameters, status assessments, and stem locations from the previous sampling event. Crews should work in a pattern that ensures all trees are measured efficiently, that minimizes missed trees, and detects trees that reached 10 centimeters (3.9 in) since the last sample event.

Note the added classes to the Tree Status category during Plot Revisit Years:

1. No status (0): Previously tallied tree is no longer in sample because the tree: (a) shrunk below 10 centimeters (3.9 in) DBH (i.e. tree damage); (b) after a thorough search the tree cannot be found due to natural causes-don't forget to look on the ground; (c) was incorrectly tallied last time; or (d) a change in procedure now excludes this tree. Record the reason in Tree Notes.

2. Live tree (1): New live trees in revisit plots are assumed to be in-growth. If a tallied new tree was obviously missed during a previous inventory, note this in Tree Notes. New trees will be given the next tree number available (if there are 25 trees documented in the plot, then a new tree would be assigned tree number 26). Live trees have living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft]).

3. Standing dead tree (2): Tree lacks any living parts (i.e., leaves, buds, or cambium) at or above breast height (1.37 meters [4.5 ft]), and leans less than or equal to 45° away from vertical, or straight up and down.

4. Removed (3): Previously tallied tree has been cut and removed by humans during harvest, forestry treatment, hazard tree removal, or land clearing-signs of cut/destroyed tree such as stump or chips can be found.

5. Fallen dead tree (4): Previously tallied tree has fallen and will no longer be tracked as a live tree. This includes dead trees leaning and greater than 45° from vertical.

Other items to keep in mind during plot revisit years include:

1. There will likely be trees that have died since the previous survey and are no longer standing, in which case the tree may be standing and dead, fallen, or gone. Update tree status according to tree status definitions.

2. If a tree was obviously missed during the previous survey (e.g., in the middle of the module), note this in Tree Notes. New trees will be given the next tree number available. In other words, if there were 20 trees measured during the last sampling event then the first new tree will receive number 21.

3. There will also likely be trees that have grown to 10 centimeters (3.9 in) DBH since the previous survey that will need to be added to the datasheet. These new trees will be given the next tree number available.

4. Make sure to note in tree notes which trees are tagged trees and tag number if not already done during plot establishment.

5. If species ID was incorrect or missing during the previous survey, cross out the incorrect species code and write the correct code. If needed, make note in tree notes about why it was corrected. Utilize information such as previous DBH, location on tree map, and any other available data from the previous survey to make certain that you are confident in your decision. Before making any species ID changes consult the botanist for confirmation as the botanist on the plot is the final authority.

6. Similarly, if tree DBH appears grossly different from the previous survey (such as increasing by 10 centimeters [3.9 in]), consult the previous survey's field forms to ensure you are measuring the correct tree. It is also possible the correct diameter was written on the field form during the previous survey and the erroneous DBH was a data entry error in the database.

7. If a tree note written on the datasheet during a previous survey is no longer relevant, cross it off to prevent confusion during the next revisit, because tree notes get carried over to subsequent visits.

### Stand Height and Canopy Closure Estimates

Stand height is an important metric used to calculate 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. The live tree volume can be compared to dead tree volume as measured by the coarse woody debris estimate, see SOP 1.4.12 *Fuel Load Measurements* (Boyle et al. 2019b) to obtain a coarse woody debris (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 meter tape are used. Instructions for the triangulation method are provided below. On sites that are devoid of trees, stand height data are not collected.

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 and forest pest damage. A 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 important that the instructions be understood and followed, to ensure the data are collected correctly. Periodically calibrate your measurements with those of others on your field team so 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.

### *Measuring Stand Height*

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 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 SECN 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 5). 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 foliage is and record the number on the percent scale 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. 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.

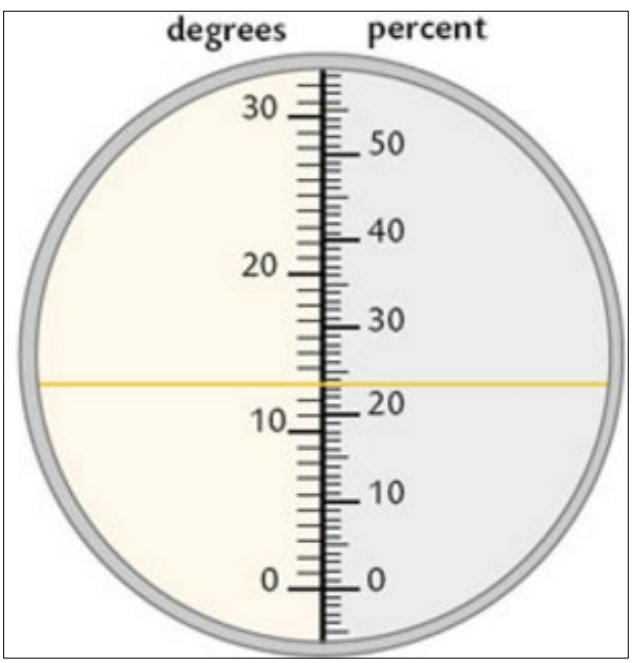


**Figure 5.** View through the eyepiece of a clinometer.

When the base of the trunk is below eye level, the percent values are added (see Figure 6). 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 meters (125 ft), the mathematical calculation is:

Tree height = (50 + 13)/100 × 38 = 23.9 meters (78.4 ft)

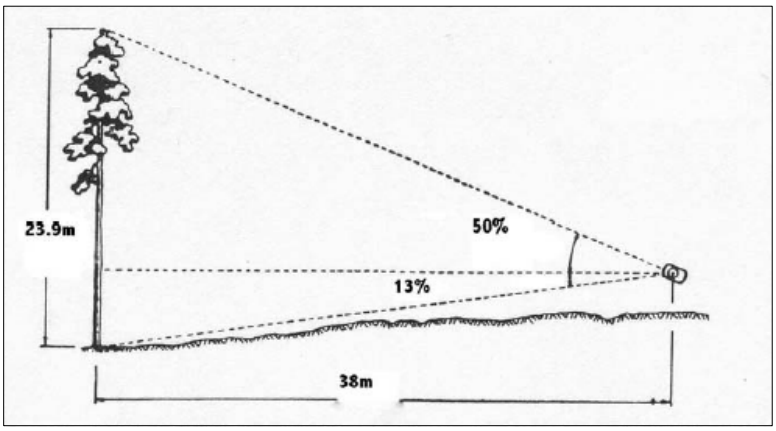


**Figure 6**. Using a clinometer to measure tree height on sloping ground when the base of the trunk is below eye level.

Where the base of the trunk is above eye level, the trunk base percent is subtracted from the tree-top percent (see Figure 7). 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 (125 ft), the calculation is:

Tree height = (65 – 14) /100 × 38 = 19.4 meters (63.6 ft)

Repeat these measurements for two more co-dominant trees in or around the plot, if trees are available. These data are recorded on the *SECN Veg Form 3 Plot Photo Points and Canopy Closure Measures* datasheet.

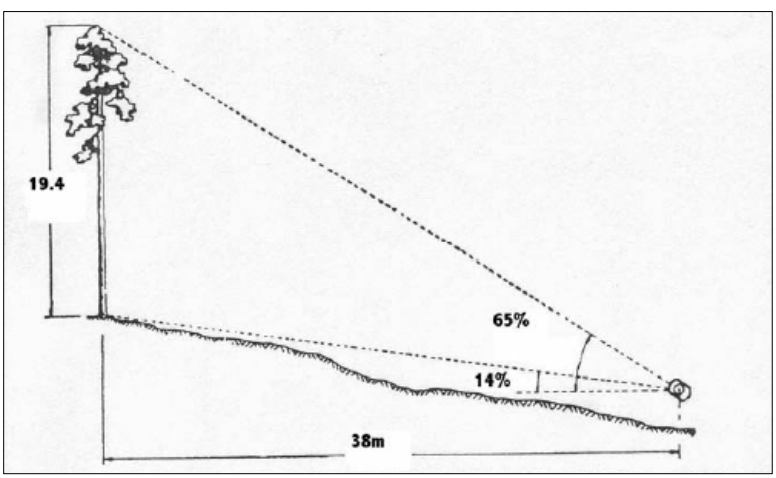


**Figure 7**. Using a clinometer to measure tree height on sloping ground when the base of the trunk is above eye level.

### *Measuring Canopy Closure*

While this SOP title refers to canopy cover, for this protocol crew members 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 meters (32.8 × 32.8 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 8). A crew member holds the spherical densiometer out in front of them, at elbow height (approximately 1 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 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 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. In each grid cell, one must imagine four dots, as described in the instructions. In forested environments, crew members should add 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 the center of the four modules. These raw counts obtained in the field will be 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 8**. A spherical densiometer grid, illustrating how users visualize a dot in each corner of a grid (n=96 dots) and count the number of dots covered by canopy. Note the directions printed on the lid in the inset photo.

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% (to the nearest 10%). Repeat this measure at the center of each module.

## Equipment List

- DBH Tape (w/ centimeter units)
- Meter stick
- Small binoculars, for identifying trees based on hard-to-see canopy leaves
- Fiberglass measuring tapes
- Spherical densiometer
- Clinometer
- Field datasheets (SECN Veg Form 3 *Plot Photo Points and Canopy Closure Measures* and Veg Form 4 *Tree Measurements*)
- Pencil

**Table 2.** Datasheet Field Descriptions for *Veg Form 3—Plot Photo Points and Canopy Closure Measures.*

| 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. |

**Table 3**. Datasheet Field Descriptions Veg Form 4—Tree Measurements.

| 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 the one with greatest knowledge and experience in tree identification, condition codes, etc. |
| Reviewed by | Initials of individual who reviewed completed data sheet for SOP VEG04 elements. Ideally this should be someone other than individual who recorded data on this portion of datasheet. |
| Module | Module (1, 2, 3, or 4) where woody stem occurs. For revisit plots, a pre-populated stem list will be provided. Update/correct as necessary. |
| Tree # | Recorded sequentially beginning with 1 until completed. For revisit plots, a pre-populated stem list will be provided. Update/correct as necessary. |
| Species | Seven or in some cases eight letter species code, typically comprised of first four letters of genus and first three letters of species. Refer to park species list to determine which species require the eight letter tie breaker codes. In instances where a species does not occur on the species list (i.e., no known species code), write out the entire scientific name. Ask field crew leader for assistance with spelling. For revisit plots, a pre-populated stem list will be provided. Update/correct as necessary. |
| DBH | Record DBH of measured stem, rounding to nearest centimeter. Stem must measure 10.0 cm before it is recorded (i.e., don't round up to 10). For revisit plots, previous DBH will be provided as well. |
| Tree Status | Record stem status where 0=No status, previously tallied tree no longer in sample, 1=Live stem, 2=Standing stem, 3=Removed, 4=Fallen dead stem. For revisit plots, previous tree status will be provided as well. |
| Crown Class | ***For all live stems only*** – record crown class where 1=Open-grown, 2=Dominant, 3=Co-dominant, 4=Intermediate, and 5=Overtopped. |
| Tree Vigor | ***For all live stem only*** – record tree vigor where 1=Healthy, 2=Light decline, 3=Moderate decline, 4=Severe decline, and 5=Functionally dead. |
| Tree Dieback | ***For applicable live stems only*** – record tree dieback where 1=1-10%, 2=10-25%, 3=25-50%, 4=50-75%, and 5=75-100%. |

| Field Name | Field Description |
|---|---|
| Tree Condition/ Damage Codes | ***For live stems only*** – record one or more of the 4-letter tree condition codes, as appropriate, from the provided list. |
| Decay Class | ***For dead stems only*** – record snag decay class (1-5) based on provided table and associated descriptions. |
| Snag Height | ***For dead stems only*** – record estimated snag height to nearest 5 meters. |
| Tree Notes | Record any noteworthy information, as well as use this area as overflow to record additional damage codes, etc. Tree notes from previous survey will be carried over for revisit plots-update/correct/cross out as needed. |
| Tree Diagram | Plot out all recorded woody stems with a status of 1 or 2 on the diagram, as well as smaller trees on edge of plot lines to aid in future plot layout. Update/correct if necessary on revisit plots and check “updated” box. |

# Literature Cited


Boyle, M. F. 2019. Species diversity and seedling/sapling measurements—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.4.14. Southeast Coast Network, Athens, Georgia. Available at: https://irma.nps.gov/DataStore/Reference/profile/2260353 (last accessed May 2019).

Boyle, M. F., M. B. Gregory, M. W. Byrne, P. I. Capece, and S. Corbett. 2019a. Terrestrial vegetation monitoring in Southeast Coast Network parks: Protocol implementation plan. Natural Resource Report NPS/SECN/NRR—2019/1930. National Park Service, Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/Reference/Profile/2263392 (last accessed May 2019).

Boyle, M. F., S. L. Corbett, B. D. Smrekar, and C. S. Harris. 2019b. Fuel load measurements—Version 1.0. Southeast Coast Network Standard Operating Procedure NPS/SECN/SOP—1.4.12. Southeast Coast Network, Athens, Georgia. Available at: https://irma.nps.gov/DataStore/Reference/profile/2260352 (last accessed May 2019).

Ganey, J. L., and W. M. Block. 1994. A comparison of two techniques for measuring canopy closure. West. J. Appl. For. 9:21–23.

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. Available at: https://irma.nps.gov/DataStore/DownloadFile/595886 (last accessed March 2019).

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation Monitoring Protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/515620 (last accessed March 2019).

# Appendix A. Field Data Forms

**SECN Vegetation Monitoring Protocol** **Plot ID** _____ **Start Date**_____
**Veg Form 3– Plot Photopoints and Canopy Closure** **(plot acronym + GRTS Order #)** **(mm/dd/yy)**

**SOP VEG03 – 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 datasheet 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): text** _____

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

**SOP VEG04 – Canopy Closure** **Data taker initials** ____ **Reviewed by:** _____

**#1 Stem ID**___ **Height (m)**_____ **#2 Stem ID**___ **Height (m)**_____ **#3 Stem ID**___ **Height (m)**_____

| Module | Direction | Spherical Densiometer 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 | |

| Module | Alternative Quick Estimate of % Canopy Cover* |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| **Average % Canopy Cover:** | |

* "Quick method should only be used in rare circumstances with explanation noted below

**Cover Notes (if any):** _____

_____

_____

_____

_____

**Note: It is only necessary in the field to collect the tally of "shaded" dots in canopy; the remaining calculations can be done at the time of data entry (the table is provided for convenience). 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.**

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**Figure A-1**. Example of *Veg Form 3—Plot Photo Points and Canopy Closure*.

SECN Vegetation Monitoring Protocol
Veg Form 4– Tree Measurements

Plot ID _____ Start Date_____
(plot acronym + GRTS Order #) (mm/dd/yy)

SOP VEG04 – Tree Measurements (> 10cm dbh) Data taker initials _____ Reviewed by: _____

(Tree measurement and health assessment code symbols occur on a separate laminated doc)

| Data on all trees dead and alive | | | | | Data on living trees only | | | | Dead Standing Trees | |
|---|---|---|---|---|---|---|---|---|---|---|
| Module # | Tree # | Species Code | DBH >10 cm | Tree Status | Crown Class | Tree Vigor | Tree Dieback | Tree Condition/Damage Codes | Decay Class | Snag Height m (estimated) |
| | 1 | | | | | | | | | |
| | 2 | | | | | | | | | |
| | 3 | | | | | | | | | |
| | 4 | | | | | | | | | |
| | 5 | | | | | | | | | |
| | 6 | | | | | | | | | |
| | 7 | | | | | | | | | |
| | 8 | | | | | | | | | |
| | 9 | | | | | | | | | |
| | 10 | | | | | | | | | |
| | 11 | | | | | | | | | |
| | 12 | | | | | | | | | |
| | 13 | | | | | | | | | |
| | 14 | | | | | | | | | |
| | 15 | | | | | | | | | |
| | 16 | | | | | | | | | |
| | 17 | | | | | | | | | |
| | 18 | | | | | | | | | |
| | 19 | | | | | | | | | |
| | 20 | | | | | | | | | |

Tree Notes -I f ID confidence is not "certain" record this as well, (i.e., Probable or Uncertain)

| Tree # | ID confidence | |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

SECN_Vegetation_Monitoring_Protocol
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**Figure A-2**. Example of *Veg Form 4—Tree Measurements* page 1 of 3.

**SECN Vegetation Monitoring Protocol** **Plot ID _____** **Start Date_____**
**Veg Form 4– Tree Measurements** **(plot acronym + GRTS Order #)** **(mm/dd/yy)**

**SOP VEG04 – Tree Measurements** (> 10cm dbh) (cont, pg 2)

**(Tree measurement and health assessment code symbols occur on a separate laminated resuable doc)**

| Data on all trees dead and alive | | | | | Data on living trees only | | | | Dead Standing Trees | |
|---|---|---|---|---|---|---|---|---|---|---|
| Module # | Tree # | Species Code | DBH >10 cm | Tree Status | Crown Class | Tree Vigor | Tree Dieback | Tree Condition/Damage Codes | Decay Class | Snag Height m (estimated) |
| | 21 | | | | | | | | | |
| | 22 | | | | | | | | | |
| | 23 | | | | | | | | | |
| | 24 | | | | | | | | | |
| | 25 | | | | | | | | | |
| | 26 | | | | | | | | | |
| | 27 | | | | | | | | | |
| | 28 | | | | | | | | | |
| | 29 | | | | | | | | | |
| | 30 | | | | | | | | | |
| | 31 | | | | | | | | | |
| | 32 | | | | | | | | | |
| | 33 | | | | | | | | | |
| | 34 | | | | | | | | | |
| | 35 | | | | | | | | | |
| | 36 | | | | | | | | | |
| | 37 | | | | | | | | | |
| | 38 | | | | | | | | | |
| | 39 | | | | | | | | | |
| | 40 | | | | | | | | | |

**Tree Notes - If ID confidence is not "certain" record this as well, (i.e., Probable or Uncertain)**

| Tree # | ID confidence | |
|---|---|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

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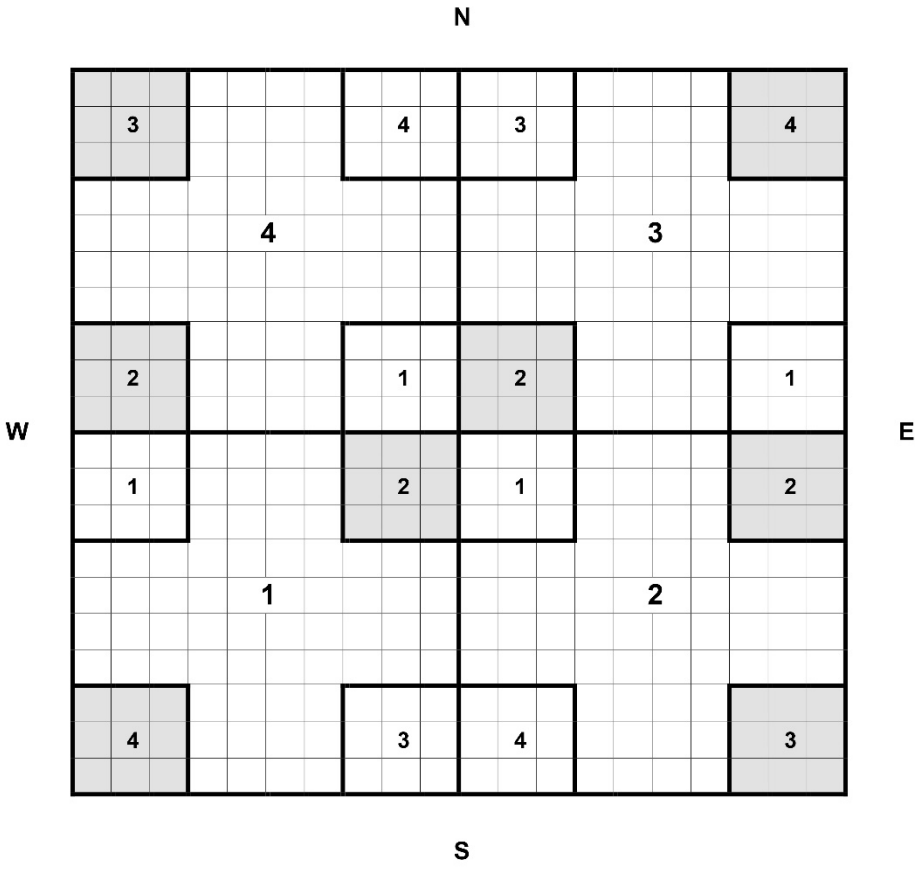
**Figure A-3**. Example of *Veg Form 4—Tree Measurements* page 2 of 3.

SECN Vegetation Monitoring Protocol
Veg Form 4– Tree Measurements

Plot ID _____ Start Date_____
(plot acronym + GRTS Order #) (mm/dd/yy)

**SOP VEG04 – Tree Measurements / Tree Map** (cont, pg 3)

**Grid lines = 1 m on a typical 20 by 20 m plot**




SECN_Vegetation_Monitoring_Protocol
Data_Form_20190306

**Figure A-4**. Example of *Veg Form 4—Tree Measurements* page 3 of 3.

# Appendix B. Modifications to CUPN SOP 5 and CUPN SOP 6 for SECN SOP 1.4.11

The CUPN SOP 5 *Canopy Closure and Stand Height Measurements—Version 1.3* and CUPN SOP 6 *Tree Measurements—Version 1.4* of the *Cumberland Piedmont Network Vegetation Monitoring Protocol* (White et al. 2011) were modified to create SECN SOP 1.4.11 *Tree Measurements—Version 1.0*. The major modifications to these SOPs are listed and explained.

### Combination of SOP 5 and 6

The Cumberland Piedmont Network wrote separate SOPs describing the methods to capture tree diameter and overall health and canopy height and canopy coverage. Because of the linkage between these elements, the Southeast Coast Network decided to combine these two SOPs into a single SOP.

### Measurement of Both Tree and Non-tree Growth Forms (all Woody Stems)

The Cumberland Piedmont Network approach to vegetation monitoring focuses on park-wide inference for forest and woodland habitats, whereas that of the Southeast Coast Network focuses on inference across these and other non-forested habitats. It is quite possible that tree or any woody plant will be absent from some percentage of SECN parks, particularly those along the maritime fringe. Woody growth forms such as shrubs and lianas are an important component of SECN habitats, and are treated similarly to trees with respect to tracking diameter and health conditions over time. It should be noted, however, that we do not expect to measure many shrubs and vines, as the Southeast Coast Network uses the 10-centimeter (3.93 inches) diameter cut-off employed by the Cumberland Piedmont Network and other inventory and monitoring networks (e.g., Gulf Coast Network).

### Tree Condition or Damage Codes and Foliage Condition

The Southeast Coast Network focuses on detecting only forest pests and pathogens on woody stems, and does not record damages such as fire scars, burls, and conks like the Cumberland Piedmont Network. This is due to the high proportion of woody stems in the Southeast Coastal Plain that exhibit these conditions, and these perceived ‘damages’ are often part of the ecosystem’s natural processes. The Southeast Coast Network focus on well-documented exotic (and the occasional native) pests and pathogens. Furthermore, Foliage Condition is not measured by the Southeast Coast Network.

### Triangulation Method for Stand Height Determination

The CUPN SOP describes two methods for calculating stand height; (1) the triangulation method using a handheld clinometer, and (2) laser rangefinder. The Southeast Coast Network will only use the first method when conducting this overall protocol, so the laser rangefinder method was left out.

### Appendix B Literature Cited

White, R., C. Nordman, L. Smart, T. Leibfreid, B. Moore, R. Smyth, and T. Govus. 2011. Vegetation Monitoring Protocol for the Cumberland Piedmont Network, Version 1. Natural Resource Report NPS/CUPN/NRR—2011/XXX. National Park Service. Fort Collins, Colorado. Available at: https://irma.nps.gov/DataStore/DownloadFile/515620 (last accessed March 2019).