Forest Assessment

Fixed-Area Plot Data Collection Protocol

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About this Protocol

This document provides standardized methods for conducting fixed-area, plot-based sampling in urban forested natural areas. While these methods can be applied in a variety of geographies to assess the condition, structure, and threats to these spaces, they were developed for upland, deciduous forest systems in the Northeastern U.S. As such, this approach may not fully capture characteristics of wetland or non-deciduous plant communities or plant communities not found within this region. We recommend you review this protocol to ensure it aligns with your objectives, forest types, and geographic context. Also, as with any vegetation assessment, data collection should be conducted during the growing season.

History

These methods were developed by Natural Areas Conservancy in 2012-2013 as part of the first forest assessment, with help from the NYC Parks' Natural Resources Group & USDA Forest Service to adapt existing methods (Cooke et al. 1996; Jennings et al. 1999; Woodall et al. 2008; USDA Forest Service 2011). These methods were refined in 2024 for the second NYC Forest Assessment in partnership with NYC Parks.

Getting Started

To get started with a forest assessment using this protocol you'll need to establish the following:

Goals

Before getting started decide what you will use this data for and what area/extent you want to describe, and use this information to inform any variables you might want to omit or add, and how many samples you'll need. Ask yourself: will this data be used to inform policy, management, something else?

Study Area

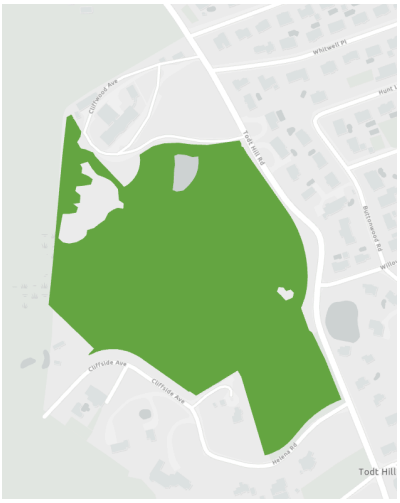
Obtain or create a shapefile of your study area. This should represent forested natural areas and include other covertypes insofar as they are embedded within the forest matrix. For example, if there is a grassy canopy gap, a small field house or similar that's fine -- avoid including large non-forested areas because the study area should be an area that you can extrapolate analyses to.

Sample Size & Plot Location

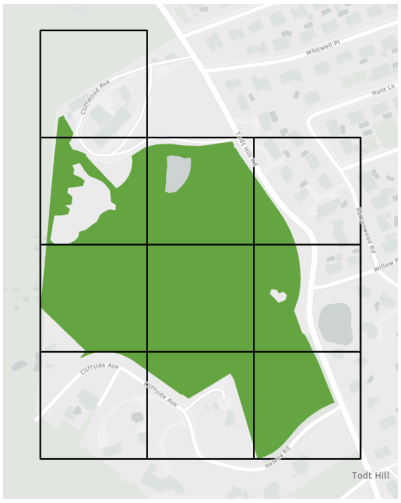
To ensure representative sampling across your study area, begin by generating random sample locations based on the desired spatial scale and the variables you intend to analyze. The required number of samples should be determined through a sample size calculation informed by pilot data or known variability in the target variables. Once your target sampling density is established, you can use a fishnet grid or some other tessellation based on that density (e.g., a 2-hectare grid if one plot per 2 hectares is needed), and randomly generate one point within each grid cell. This approach helps achieve an even spatial distribution of sample plots across the study area.

If your study area contains distinct forest types or land cover categories, consider stratified random sampling to ensure adequate representation within each type. You may need to apply different sampling densities to each stratum depending on its size, heterogeneity, or ecological importance.

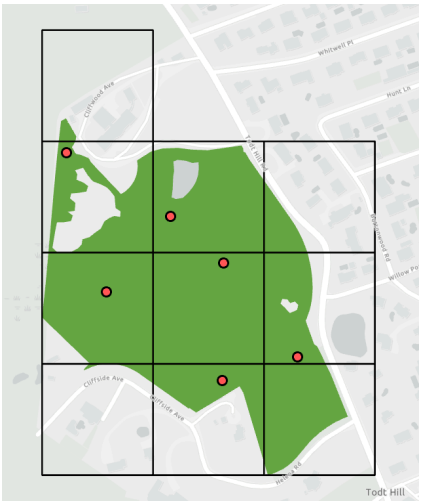
An example ArcGIS Pro workflow might look something like this:



Study Area
Begin with a shapefile representing your forested study area boundary. Ensure that the projection is appropriate for distance-based measurements (e.g., a local UTM zone).



Study Area With Grid
Use the *Generate Tessalation* tool specifying the study area as the extent and the size as determined by your required sampling density. Shape Type can be up to you, above is the output for Square.



Random Points
Use *Create Spatial Sampling Locations* tool with the sample grid as the study area, Sampling Method = Stratified by Individual Polygon, and Strata Sample Count = Equal count in each stratum.

⭐ **All plots must be assigned a unique plot ID that is not shared with another plot.**

Field Navigation Map

A navigable map on a mobile device that displays the plot locations so that you can navigate to them in the field. It is preferable if this map is searchable by the unique plot ID for ease locating the plots. ArcGIS Field Maps is a great option for this. If you don't have access to ArcGIS Online to create a field map you can also create a point layer navigable in Google Maps.

Data entry survey/form

After you collect your data on paper you will need a place to enter it so that it can be analyzed. Included along with this protocol is a Survey123 form design (Supplement 2) that you can modify with your own entries, but other options are out there if you prefer to use a different application. Whatever application you use for data entry it is highly recommended that quality assurance measures are built into the form such as: drop down menus for things like species and plot ID, date and number constraints, required fields, dependent fields, and duplicate-entry checks (where appropriate).

Information Collected

Information collecting using this protocol. See Plot Diagram on page 6 for clarity on the *Sample* column.

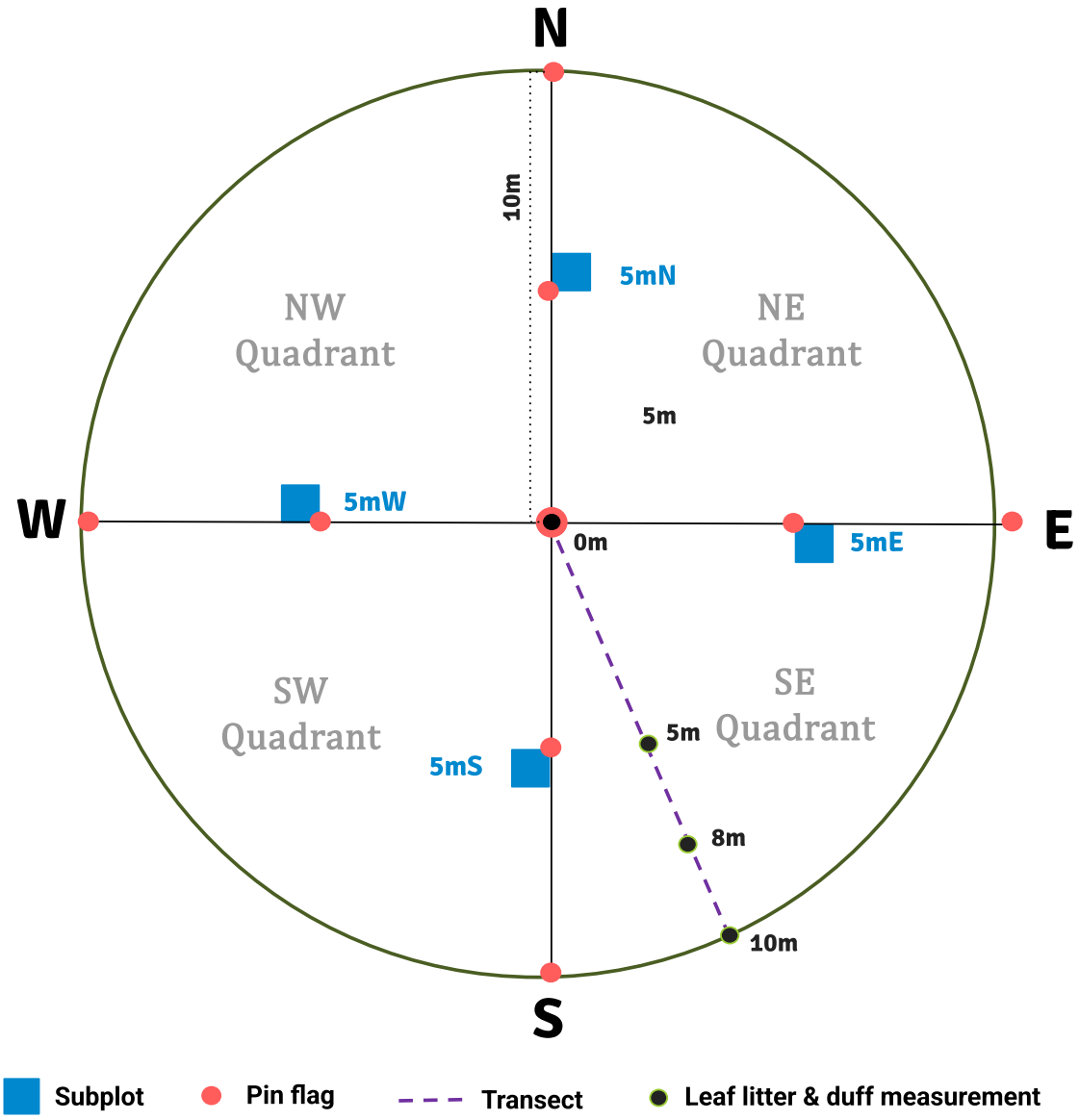
Sample	Layer	Attribute	Variable	Description
PLOT	Overstory	Species	Species	Species of stem ≥ 10 cm DBH, living or dead.
			DBH (cm)	Diameter at breast height (1.37m) of stem
		Vine Pressure	Vine Species	Vine species touching any part of the specimen
			Vine Class	The associated growth class (1-3) of the vine species
		Health	Vigor	A composite metric describing canopy condition.
	Midstory	Species	Species	Species of stem 2 - 9.9 cm DBH, living or dead.
		Vine Pressure	Vine Species	Vine species touching any part of the specimen
			Vine Class	The associated growth class (1-3) of the vine species.
	Any	Species	Species	Any species not captured in other layers
TRANSECT	Understory	Down Woody Material	CWM Diameter 1 (cm)	Diameter of larger end of a piece of CWM
			CWM Diameter 2 (cm)	Diameter of smaller end of a piece of CWM
			CWM Decay Class	Decay class of CWM piece.
			CWM Hollow Diameter (cm)	Diameter of a hollow if present on CWM piece
			CWM Length (cm)	Length of CWM piece.
			Duff thickness (cm)	Thickness of the duff layer.
			Leaf litter thickness (cm)	Thickness of the leaf litter layer.
		Worm presence	Worm Evidence	Presence/absence of worms and/or worm evidence
SUBPLOT		2D Cover	Vegetation %	% of the subplot covered by vegetation.
			Leaf Litter %	% of the subplot covered by leaf litter.
			Non-natural Impermeable Surface %	% of the subplot covered by non-natural impermeable surfaces such as pavement.
			Rock %	% of subplot covered by rock
			Dumping/Trash %	% of the subplot covered by trash.
			Bare Soil %	% of subplot covered by bare soil
			Dead Wood %	% of subplot covered by dead wood
			Live Wood %	% of subplot covered by live wood
		Species Cover	Species	Herbs, lianas, and seedlings.
			% cover	% of subplot covered by each species.
		Woody Regeneration	Species	Species of tree or shrub stems < 2 cm diameter.
			Tally < 30.5 cm	Tally of seedlings <30.5 cm height.
			Tally ≥30.5 cm	Tally of seedlings >= 30.5 cm height.
			Tally of Sprouts	Tally of sprouts growing off the base of the main stem
			% Cover	% of subplot covered by species.

Condition Indicators

The information collected using this protocol can be analyzed to quantify multiple measures of forest condition in an area of interest. Some condition indicators derivable from this protocol that you may consider as target variables for your assessment:

Layer or Attribute	Variable	Favorable State *(generally)*
Overstory	Native basal area	Higher
	Native proportion basal area	Higher
	Invasive basal area	Lower
	Invasive proportion basal area	Lower
	Mean Vigor	Lower
	% of stems with invasive vines	Lower
Midstory	Native stem density	Higher
	Native stem proportion	Higher
	Invasive stem density	Lower
	Invasive stem proportion	Lower
	% of stems with invasive vines	Lower
Herbaceous Layer & Ground Cover	Native % Cover	Higher
	Native proportion	Higher
	Invasive % cover	Lower
	Invasive proportion	Lower
Tree Regeneration	Native tree seedling density	Higher
	Native tree seedling proportion	Higher
	Invasive tree seedling density	Lower
	Invasive tree seedling proportion	Lower
Site Quality & Habitat Structure	Coarse woody debris volume	Ecosystem dependent
	Worm presence	Absent
	Leaf litter thickness	Higher
	Duff thickness	Higher
	Trash/dumping % cover	Lower
	Non-natural impervious surface %	Lower / Absent
Biodiversity & Integrity Indicators	Species count across all layers	Higher
	Floristic Quality Index	Higher
	Tree age class diversity	Ecosystem dependent
	Shannon Diversity Index (H')	Higher
	Simpson Diversity Index (D)	Higher

Plot Diagram



A diagram of a 10m radius/20m diameter data collection plot

Equipment List

Equipment

🔍 Navigation & Access

- Mobile device or GPS unit with map of plot locations loaded so you can navigate to plots
- *(optional) Loppers or hedge shears to aid in accessing overgrown plots*

📝 Data recording

- A clipboard to store datasheets and other documentation
- Datasheets A - F (1 set for each plot) to record data. If in a damp environment print on Rite in the Rain
- Copy of this protocol (printed or electronic)
- Pen or pencil to fill out the datasheet
- *(optional) Camera to take plot photos for reference*

📐 Plot construction

- Sighting compass to determine direction of random transect and plot set up
- Clinometer to determine plot slope
- 3 x transect tapes (reel tape measures) (30m) to measure and mark plot layout
- 7 Chaining pins to secure the transect tapes at the plot
- A 1m x 1m sampling square for use as the groundcover subplot, preferably w/ painted 10 cm marks
- 12 or more bright wire flags to flag plot landmarks for visibility (recommend having extra on hand)
- *(optional) Flagging tape which can be useful to tie around things so they're visible.*
- *(optional) Supplement 3 materials if you are undertaking permanent plot marking.*

📏 Measuring equipment

- Diameter tape (cm) for measuring the diameter of woody stems
- A 1.37m stick to make it easy to identify the point at which to measure tree diameter ⭐
- Folding ruler (cm) to measure seedling height and the distance from the ground for cover estimates ⭐
- Chalk to mark trees and shrubs after you count them
- 10 cm x 10 cm plastic square to use as a reference to aid with subplot percent cover estimates ⭐
- 2x 1 m sticks/dowels to subsect the subplot into quarters to aid in percent cover estimates ⭐
- A thin small ruler (cm) to measure leaf litter and duff thickness

🌿 Plant ID

- Hand lens to aid in visualizing small plant structures
- Binoculars to get a clear view of leaves that are too high to see unaided
- Plant field guides
- *(optional) Unknown Species Tracking Materials [See Supplement 1]*

⭐ *These items might seem like overkill, but through painstaking assessment we've learned that without these additional guides to aid in measurement, accuracy declines demonstrably.*

Helpful Extras

All optional but many highly recommended!

🛡️ Field Safety & Protection

- Tecnu so you can quickly treat poison ivy encounters
- Head nets & jackets to keep biting insects away
- Rain gear and/or muck boots in wet weather
- First Aid kit to handle scrapes and cuts
- Insect repellant to keep the biting critters away
- Garden gloves to protect your hands from thorns
- Duct tape or a lint roller for easily get ticks off you

💧 Hydration & Energy

- Water & high-energy snacks so you can stay functional and hydrated in the field
- Large water jug to keep in the car so you always have water on hand

🧠 Other Helpful Things

- Field notebook to record notes and observations
- External battery for mobile device to ensure you don't run out of battery in the field
- Chaining pin quiver or 18in length of PVC pipe to protect yourself from the sharp pin ends

🔧 Measurement Precision Quick Reference

Variable	Unit	Rounding Rule
DBH (Diameter at Breast Height)	cm	Nearest 0.1 cm
2D % Cover	%	Nearest whole number
Species % Cover	%	($\geq 0.5\% = 0.5\%$), else nearest whole number
Coarse Woody Material Diameters	cm	Nearest 0.1 cm
Coarse Woody Material Length	cm	Nearest 1 cm
Coarse Woody Material Hollow	cm	Nearest 1 cm
Leaf Litter Thickness	cm	Nearest 0.1 cm
Duff Thickness	cm	Nearest 0.1 cm

Data Collection Methods

What if a location is unsafe or not forested? If a plot is unsafe or >25% non-forested, move it 10 m in a random compass direction and update the location in your map/GPS system. Ensure plot remains in the same sample grid cell to maintain the sample distribution.

1. Establish the Plot

Datasheet A Section 1

- Navigate to the plot center using your map and mark it with a chaining pin AND a pin flag (for visibility).
- Record metadata on Datasheet A Section 1 (Plot ID, Park Name, Data Recorder(s), Data Collector(s), Start Date).
- If the plot is sloped, use the clinometer to measure the slope of the plot in degrees.
    - If the slope is $< 10\ \%$, move to the next step.
    - If the slope is $\geq 10\ \%$, correct the radius of the plot (using the radius in the table to the left) along the slope (See **Appendix A**). Mark the extended radius with pin flags. Record the correction in the Comments section of the datasheet. *If the slope is only for half of the plot, extend the radius for that half. If the whole plot is sloped, extend the radius in both directions from the center.*

Slope (%)	Radius
10-17	10.1
18-22	10.2
23-26	10.3
27-30	10.4
31-33	10.5
34-36	10.6
37-39	10.7
40-42	10.8
43-44	10.9
45-47	11.0
48-49	11.1
50-51	11.2
52-53	11.3
54-55	11.4
56-57	11.5
58-59	11.6
60-61	11.7

Slope corrected plot radii

- To mark the plot quadrants, use the transect tape and a compass to measure 20 m across the diameter of the plot along the *N*-S and E-W axes, leaving the tapes in place, centered on the plot center.
- Place a pin flag at 5m (subplot start) and plot boundary (10 m or corrected radius) in each cardinal direction. *You can also place wire flags at the boundary in the intercardinal directions (NE, SE, SW, NW) to make the boundaries clearer.*
- [OPTIONAL] *Take a plot photo from the S plot boundary facing N.*

2. Collect Data

Conduct data collection in the following order

1. Litter & Duff
2. Understory
3. Overstory
4. Midstory
5. Additional Species
6. Coarse Woody Material

For understory, overstory, and midstory, start in the NE quadrant of the plot and work clockwise

TIP: If you collect data in a predictable order it can help later. Forgot to record a subplot ID? If you always collect in the same order, you'll be able to deduce what you missed. **Being organized results in higher quality data.**

Leaf Litter & Duff

Datasheet A Section 2

- Set up a 10 m transect along an azimuth (see diagram on page 6)- which should be randomly determined by spinning the bezel of the sighting compass.
    - Stand at the centerpoint facing the azimuth holding the end of the transect tape, and have a second person pull the tape to the plot boundary (10m) in that direction. Secure the ends with chaining pins.

- Record thickness leaf litter and duff to the nearest 0.1 cm at the 10 m (center), 15 m, 18 m, and 20 m points along the transect (see Plot Diagram on page 6).
    - Gently insert your ruler into the ground and feel down to the mineral soil. Locate the boundaries between the litter, duff, and mineral soil layers, and vertically measure the thickness of the litter and duff layers.
    - See **Appendix C** for how to identify the leaf litter and duff layers.
    - If none present, record 0.

- Record worm evidence:
    - Note the presence or absence of worms, worm casts or activity in the duff or soil at the same locations on the transect where litter and duff thicknesses are measured.
    - See **Appendix C** for how to identify the presence of worms.

- Refill any holes left after measuring. Pick up transect tape.

Species nomenclature: While collecting data you will identify all vascular plant species within a plot. When recording this information in the United States, we recommend using the accepted scientific name and code as listed in the USDA Plants Database (plants.usda.gov) as this is the most comprehensive plant list available in the country. If you are using this protocol outside the United States, we recommend referencing a similar national level list that provides coded values.

Understory

Work through the four subplots in a clockwise direction starting with the 5mN subplot.

- Place your 1m x 1m sampling square (subplot) in the NE quadrant as shown in the diagram on page 6.
    - As you are standing at the centerpoint looking in a cardinal direction, the lower left corner of the subplot will be at the 5 m mark of the transect tape - where you placed a pin flag (page 6).

- Divide the subplot into quarters using 1m dowels.

2D Cover Data

Datasheet A Section 3

- Record percent cover for each cover category to the nearest 1%. *NOTE: To guide your cover estimations, break the plot into quarters, and use the 10cm x 10cm card that represents 1% cover of the subplot.*
    - See **Appendix B** for how to estimate percent cover and descriptions of each category.

- 2+ observers should each estimate percent cover. If they don't agree, discuss until agreement is reached

- Leave the subplot in place and move on to collect Subplot Species for the same subplot.

Field Check: Sum the percent cover of all groundcover types to make sure it does not exceed 100%.

Subplot Species

Datasheet B

*See **Appendix B** for tips on how to estimate percent cover.*

- Record Woody Seedling and Sprout Data for all live tree & shrub seedlings and sprout species < 2cm in diameter at any height rooted in the subplot:
  - Subplot ID
  - Scientific name. *Only cotyledon leaves? Record as UNKNOWN GERMINANT.*
  - Percent Cover: Estimate percent cover only for foliage growing at 1m or below.
  - Tally woody seedlings by species for two size classes: <30.5cm height, and ≥30.5cm height
  - Tally sprouts growing from a main stem, dead tree, or stump (any height)

- Record Groundcover Species Data for all species growing below 1 m height:
  - Subplot ID
  - Scientific name of all herbaceous plants rooted in the subplot, and vines *regardless of root origin*
  - Species Cover. Estimate percent cover for foliage growing at 1m or below.
    - If % cover is <0.5%, round to 0.5%; for all other values round to the nearest integer.
    - The sum of all species cover may exceed 100%.

Field Check: does any species' cover exceed the 2D vegetation cover in the same subplot? If so, revisit your estimate. Is any woody species missing a seedling count? If so, fill it in before lifting up the sampling square.

Repeat the 2D and subplot species steps, moving clockwise through the remaining subplots

Overstory

Datasheet C

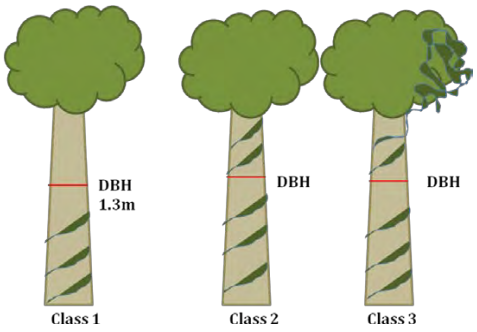
- Begin overstory measurements in the NE quadrant of the plot.

- Record the following for each overstory stem, <u>living or dead</u>. *If stems are rooted on the plot edge, alternate counting stems as "in" or "out". Dead trees leaning >45° from vertical are counted as coarse woody material.*
  - <u>Species</u>: The scientific name of the species, even for dead stems if possible
  - <u>Diameter at Breast Height (DBH)</u>: Using the breast height stick, measure diameter at breast height (1.37m) on the uphill side of the stem. Round to the nearest 0.1 cm. *See **Appendix D** for how to measure trees with special growth situations, such as multi-stemmed trees, trees in sloped areas, bulges, etc.*

- Crown Vigor: Two observers should assess Vigor independently and discuss until they agree on a single rating: 1- Healthy | 2- Slight decline | 3- Moderate decline | 4- Severe decline | 5- Dead
  *See **Appendix E** for rating parameters and more information about how to assess vigor*
- Vine species: All living vine species touching any part of the overstory stem. If there are more than four present, continue vine data collection onto the next row of the datasheet.
- Vine growth class: Growth class of each vine species present on the stem.

Vine growth classes:

Class 1: Present only below DBH
Class 2: Present above DBH, but not in the canopy
Class 3: Present in the canopy



- Notes: If anything is notable about a stem, include it here. You may also leave this section blank.

- Mark stem with chalk after data is collected to avoid double counting.

🔁 *Repeat the overstory steps for all stems in a quadrant, then move clockwise through the remaining quadrants.*

Midstory

Datasheet D

- Begin midstory data collection in the NE quadrant of the plot, recording each individual stem 2-9.9 cm DBH, *living or dead*. *If stems are rooted on the plot edge, alternate counting stems as "in" or "out".*

- For each midstory stem record the following:
  - Species: The scientific name of the species.
  - Vine species: *All* living vine species touching any part of the stem.
  - Vine growth class: The growth class of each vine species. *see Overstory section for classes.*

- Mark stems with chalk after data is collected to avoid double counting.

🔁 *Repeat the midstory steps moving clockwise through the remaining quadrants of the plot.*

Additional Species

Datasheet E

Set a timer for 5 minutes and systematically walk the plot. Note down the scientific name of any species found that

was not already recorded during the understory, midstory, and overstory data collection. This may include herbaceous species growing in the understory outside the subplots, vine species growing on shrubs too small to be counted as midstory, and woody seedlings not captured by the subplot.

Coarse Woody Material (CWM)

Datasheet F

For each piece of coarse woody material (down, dead woody stems ≥10 cm diameter along a minimum length of 50 cm, including rooted stems leaning >45° from vertical) (USDA 2011) within the plot, record the following:

- Decay class (1-5): The decay class of the piece (see parameters in **Appendix F**)
- Diameter at small end (cm): The diameter of the smaller end of the piece to the nearest 0.1cm *for classes 1-4 only*
- Diameter at large end (cm): The diameter at the larger end of the piece to the nearest 0.1cm *for classes 1-4 only*
- Length (cm): Length between small and large end of the piece to the nearest cm.
- Hollow diameter (cm): Only if hollow is >=50 cm, with a diameter at least ¼ of the diameter at that point.
- Species: Species scientific name, if identifiable. Otherwise record Unknown.

NOTE: If a CWM piece overlaps the plot boundary, only measure the part present within the plot boundary.

See **Appendix F** for detailed instructions on CWM data collection.

Complete Data Collection

Datasheet A Section 1

- Record the plant community type and CEGL if you have a way of assessing this information.

  If you are conducting this protocol in New York City you can derive this information from the Forest Identification and Restoration Selection Tool by standing at plot center and running through this key: https://naturalareasnyc.org/first-tool/#/chooser. *Only consider stems within the 10m radius plot*. This tool may be suitable for use in proximate locations, but note that some community types may be missing as the CEGL list is derived from the NYC Forest Assessment.

- If anything is notable about the plot that was not previously recorded, record it in the Comments section.

In-Field Quality Control

Before you break down the plot, with all the tapes and flags still in place, review the datasheets for completeness:

- *Does the sum of 2D cover exceed 100%?*
- *Does any individual species cover exceed the total 2D vegetation cover?*
- *Are any woody subplot species missing seedling counts?*

Because of the changing nature of forests throughout the season, and the inaccuracy of GPS on mobile devices, if any information is missed (particularly subplot and herbaceous species data) it cannot be re-collected piecemeal. Only once you are satisfied that all data collection is complete should you break down the plot and pack your gear.

Glossary

Bole: The portion of a tree trunk beneath the point where branching begins.

Canopy: A forest layer consisting of one or more overlapping tree crowns and the space between or below them (e.g., Bongers 2001).

Clinometer: An instrument used to measure angles of slope, elevation, or depression relative to gravity. Also known as an inclinometer.

Coarse Woody Material (CWM): Dead and downed woody material greater than 10 cm in diameter. This includes dead boles, large limbs, severed pieces on the ground, and leaning dead trees (leaning >45° from vertical), as well as unprocessed roundwood like fence posts or cabin logs.

Crown: The part of a tree that includes the branches, leaves, and reproductive structures (like cones or flowers) that grow out from the main stem. It's essentially the "top" of the tree, where the foliage is located. Dead or straggler branches that hang down are generally excluded.

Crown dieback: Dieback in the crown of a tree (see *Dieback*), often an early indication of stress.

Defoliation: The shedding of leaves, either naturally at maturity or due to stress from frost, disease, insects, drought, mineral deficiency, or chemical defoliants (Iboyi et al. 2021).

Diameter at Breast Height (DBH): a standard forestry measurement for the diameter of a tree trunk measured at 4.5 feet (1.37 meters) above the ground.

Dieback: a gradual decline in tree health, sometimes leading to death. It's defined as the progressive death of shoots, branches, or roots, usually starting at the tip. It's usually caused by a combination of factors, such as: Disease, pathogens, insect attack, stressful climate conditions, parasites, and acid rain (ACT 2024). This condition is also known as tree decline and tree damage.

Duff: The decomposing layer of organic material just below litter. It contains no identifiable plant parts and is typically dark. When moss is present, the duff begins just below the green portion. The bottom of the duff layer is where mineral soil begins.

Impervious surface: A solid surface that water cannot penetrate (e.g. large rocks, concrete, or asphalt). Piles of small rocks or construction debris do not count as impervious surfaces because the space between them makes them permeable.

Leaf Discoloration: an abnormal change in leaf tissue color (i.e. not from change in season).

Leaf litter: Freshly fallen plant material on the forest floor, including leaves, needles, twigs (<0.6 cm diameter), cones, bark chunks, moss, lichens, and herbaceous stems. Little to no decomposition has occurred. Material must be detached and not upright. Rotten wood pieces still embedded in logs are not considered litter.

Limb: A large or main branch of a tree.

Midstory: Shrubs and small trees 2 - 9.9 cm DBH. Trees in this size range are often referred to as *saplings*.

Overstory: the uppermost layer of foliage in a forest, forming the canopy. For the purpose of this protocol any woody stem with a diameter of 10 cm at breast height (1.37 m from the ground) is counted as overstory.

Path: Walkway not accessible or used by cars including dirt path, desire line, concrete, asphalt, wood chip or any other type of path.

Pith: The center of the tree. Pith is composed of soft, spongy parenchyma cells, which store and transport nutrients throughout the plant. In eudicots, pith is located in the center of the stem.

Root collar: Transition point between the roots and the trunk.

Seedling: Young woody plants with a diameter less than 2 cm at any height.

Shrubs: Woody, perennial, often multi-stemmed, sub-canopy plants. Shrubs do not have the potential of reaching the canopy (i.e. Viburnum, Lindera, Rubus) in a mature forest.

Sprout: stems that arise off of the base of the main stem, sometimes from a dead stump or tree.

Tree: a woody plant that typically has a single dominant central leader and large stature; though they may have multiple stems as a result of injury.

Twig: Any woody lateral growth, with secondary branching, < 2.5 cm in diameter at the base above the swelling at the point of attachment to a branch or crown stem.

Understory: Plant life growing beneath the forest canopy without penetrating it to any extent

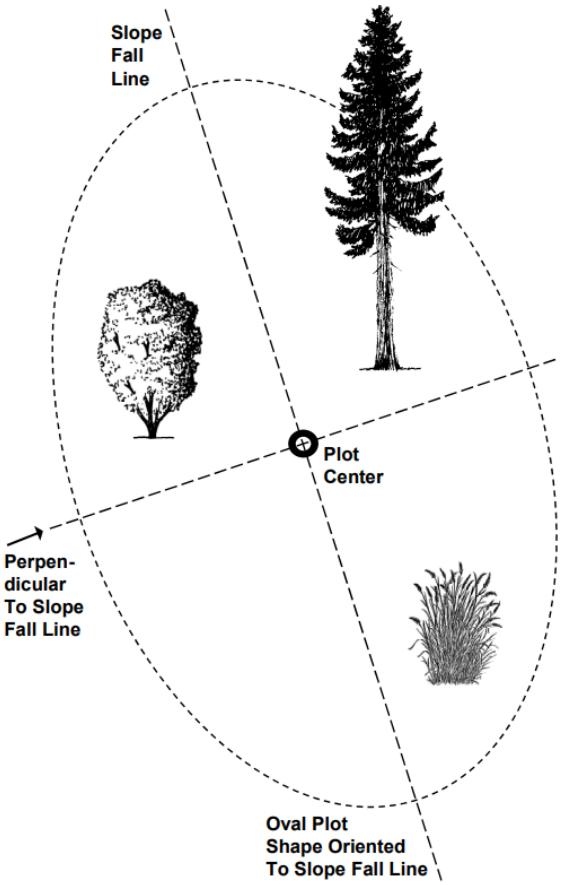
Vigor (Crown Vigor): In this project vigor takes into account twig and branch dieback, defoliation, and leaf discoloration to estimate a general condition of the examined tree.

Vines: Woody or herbaceous plants that trail along the ground or are supported on a living plant or structure.

Appendix A: Correcting Plot Radius

On sloped terrain, plot radii that follow the slope (i.e., the slope fall line) must be adjusted to ensure the correct horizontal distance is measured. This correction is necessary only when the slope is ≥ 10%.

When applied, this adjustment results in an oval-shaped plot, where the radii along the slope fall line are longer than those perpendicular to it. Only the radii aligned with the slope fall line are corrected; those perpendicular to the slope should remain unchanged.



How to Measure Slope and Apply Radius Corrections

- **Identify the slope fall line:** Stand at the lowest elevation point along the intended plot boundary. Have a second person stand directly upslope on the opposite boundary point—this line should align with the slope fall line.

- **Measure slope using a clinometer**: Aim your clinometer at the second person's eye level, keeping the measurement line horizontal. Record the slope in percent (%).

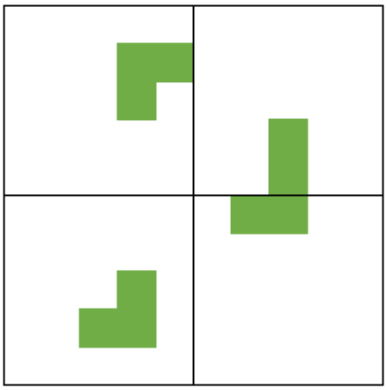
- **Determine if correction is needed:**
  - If the slope is < 10%, no correction is required—use standard radii.
  - If the slope is ≥ 10%, consult the table on page 9 of the Data Collection Methods section to determine the corrected radius length along the slope fall line.

- **Apply the corrected radius:**
  - When measuring radii along the slope fall line, pull the transect tape to the corrected radius length shown in the table on page 9.

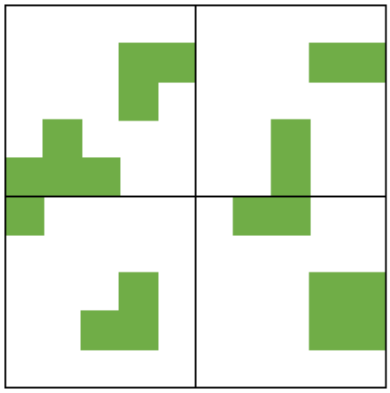
⚠️ **Do not apply this correction to the radii perpendicular to the slope. These remain at their standard horizontal length.**

Appendix B: Estimating Percent Cover

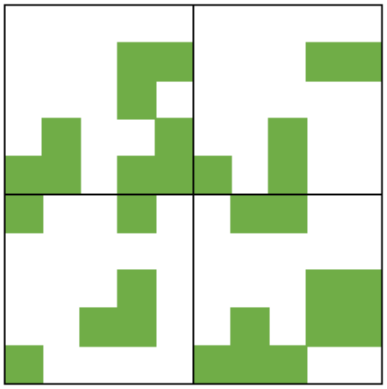
Visual guide for how different percent covers appear visually:



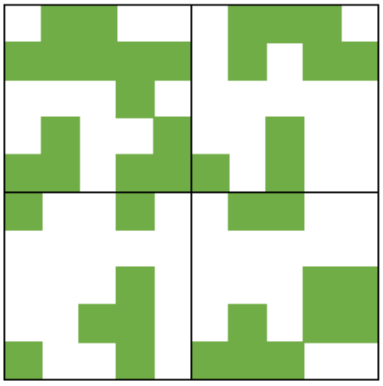
10%



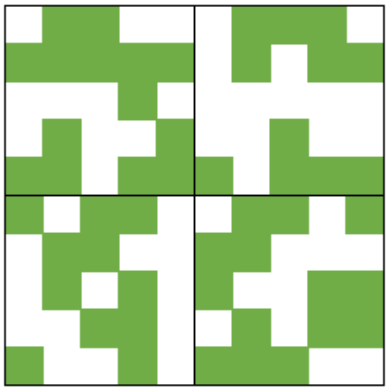
20%



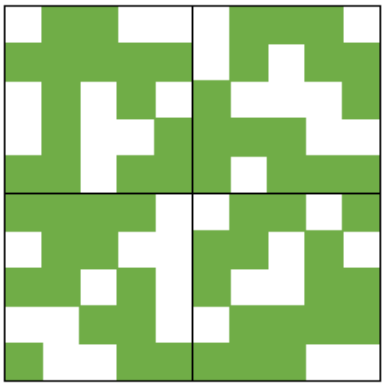
30%



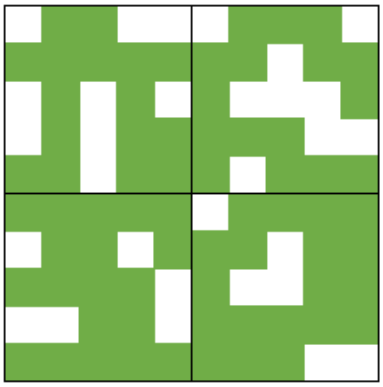
40%



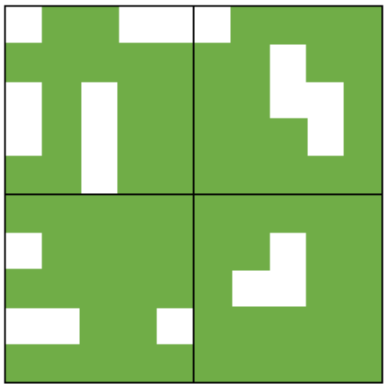
50%



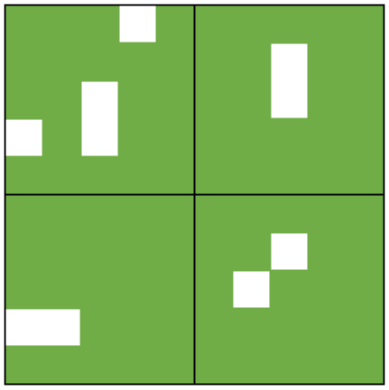
60%



70%



80%



90%

2D Cover

2D Cover refers to the percentage of the 1 m × 1 m subplot surface occupied by various ground cover types, based on a top-down view from 1 meter above the ground. Because only the uppermost visible layer is assessed (not overlapping or vertical layers), the sum of all 2D cover categories must not exceed 100%. If the total is less than 100%, the remaining portion is assumed to be occupied by unlisted or unclassified cover types.

2D Cover should be recorded to the nearest whole number for each of the following cover types:

1. Vegetation: All plants rooted within the subplot, as well as trailing vines even if not fully rooted. Includes moss, but excludes lichens and fungi.
2. Live Wood: Live woody stems and roots from midstory or overstory vegetation. Does not include seedlings.
3. Leaf Litter and Fine Woody Debris: Recently fallen deciduous leaves, evergreen needles, twigs, cones, detached bark, dead moss and lichens, small chunks of rotted wood, dead herbaceous stems, and flower parts (detached and not upright). Also includes downed woody material less than 10 cm in diameter.
4. Dead Wood: Downed woody debris greater than or equal to 10 cm in diameter, including logs, standing dead trees, and stumps.
5. Bare Soil: Exposed soil not covered by vegetation or other material.
6. Rock: Rocks ≥ 64 mm in diameter. Rocks < 64 mm are counted as bare soil.
7. Non-natural Impervious Surface: Manmade surfaces impermeable to water, such as asphalt or concrete.
8. Trash/Dumping: Human-related debris or waste, whether scattered or in piles. Includes household trash, bottles, cans, construction debris (e.g., bricks, asphalt), wood chips or piles, and discarded vehicles.

Species Cover

Species cover refers to the percent of the 1 m × 1 m subplot occupied by each individual herbaceous or liana species and woody species with foliage below 1 m. Cover is estimated independently for each species, meaning the total species cover within a subplot may exceed 100%. However, the cover for any single species cannot exceed 100%, nor can it exceed the vegetation 2D cover recorded for that subplot. When individuals of the same species overlap, their combined cover is estimated as the total area occupied by the species—not the sum of individual areas.

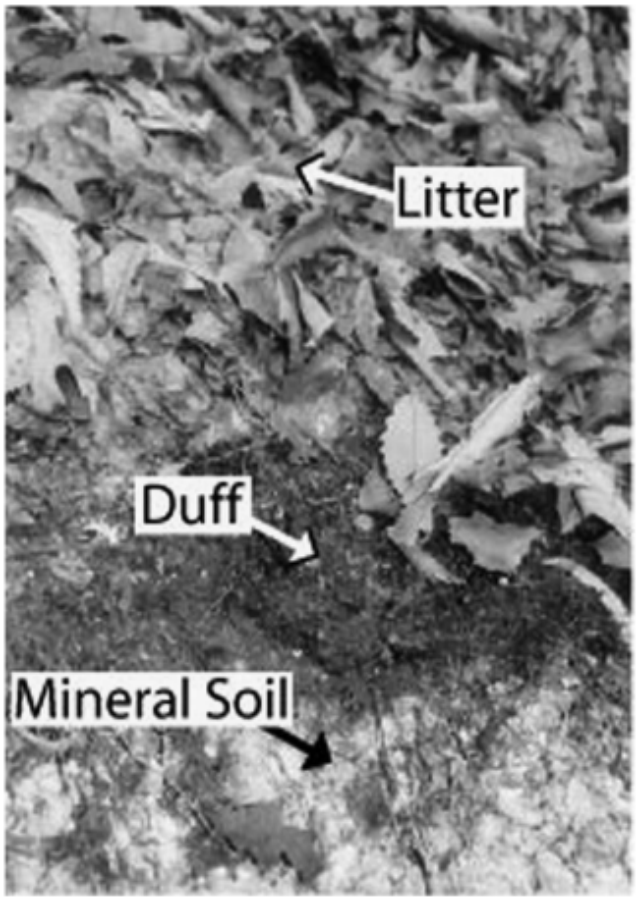
Species cover is recorded for the following:

- Woody seedlings and sprouts < 2 cm diameter rooted in the subplot
- Herbaceous plants rooted in the subplot
- Lianas regardless of root origin
- Moss, although not identified to species. Record as “MOSS”.

Only consider parts of the plant below 1m height, except for herbaceous plants which should be estimated at the height of the tallest individual.

Appendix C: Leaf Litter, Duff, & Earthworm Evidence

Leaf litter and duff are found in upland mesic forests and are most well-developed where soils are less disturbed. Microbial activity is high in the duff layer where soil organisms slowly decompose the organic matter and transform it into nutrients usable by plants. When earthworm presence is high, there is an absence of duff and a reduction in litter as they rapidly process organic material and mechanically churn the leaf and duff layers deep into the mineral soil.



Leaf litter is the uppermost organic layer of the forest floor, composed of easily recognizable and minimally decomposed plant parts. Typical components include fallen leaves, evergreen needles, twigs (< 0.25 cm in diameter), cones, bark fragments, dead moss and lichens, small rotted wood pieces, detached dead herbaceous stems, and flower parts that are not upright.

Duff lies just below the leaf litter and consists of partially to highly decomposed organic material, including leaf fragments that are no longer readily identifiable. This layer often contains visible fungal hyphae—white, threadlike structures—woven through the decomposing matter. The bottom of the duff layer marks the transition to mineral soil.

IS IT DUFF OR MINERAL SOIL? Rub the soil between your fingers to assess texture.
Does it crumble (duff)? Or does it feel more like modeling clay or sand (mineral soil)?

Earthworm Evidence

As you measure the leaf litter and duff layers you might encounter earthworms or evidence of earthworms. The soil that earthworms process is crumbly and aggregated into small "nuggets" that appear like a mass of coffee grounds. In large quantities this can be a deep layer of processed homogenized loose soil. In infested forests the duff layer is often missing

Appendix D: Special Growth Situations

This appendix provides guidance for measuring midstory and overstory stems growing in atypical situations.

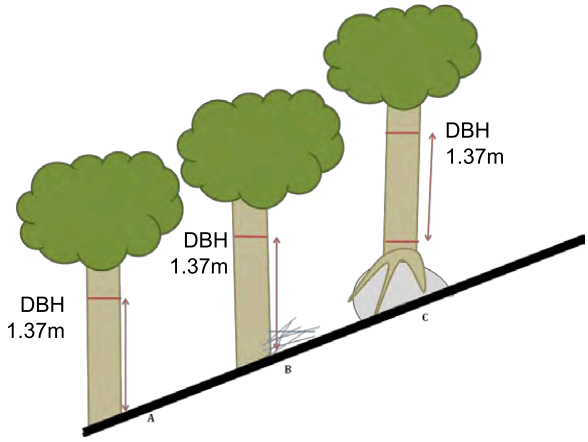
Ambiguous Location: If trees or shrubs are rooted on the plot edge, alternate between counting the stems as "in" and "out." For example, if there are 4 trees intercepting the plot boundary, collect data only for the first and third trees.

Independent trees that grow together: If two or more independent stems have grown together at or above breast height, continue to treat them as separate trees. Estimate the diameter of each.

Trees with irregularities at breast height: On trees with small bumps, depressions, and branches at breast height, measure the diameter immediately above the irregularity.

Missing wood or missing bark: If the tree has missing wood or bark at breast height, record the diameter as-is.

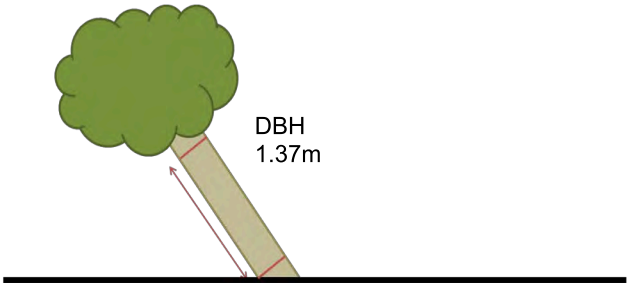
Curved bole: Measure along the bole on the uphill side of the tree.



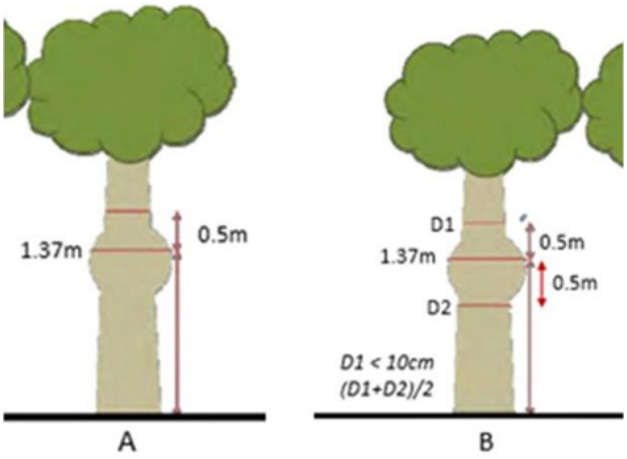
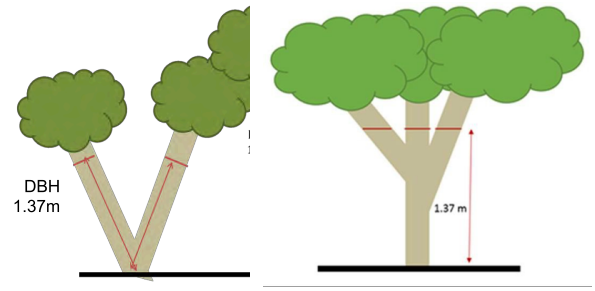
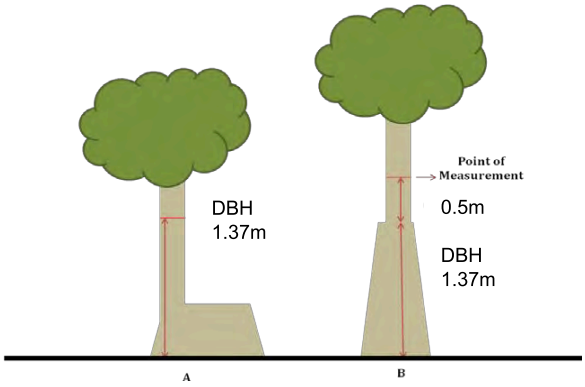
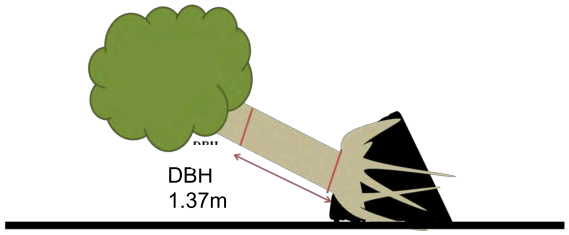
A. Slope: When a tree is growing on a slope, measure its diameter at 1.37m from the ground along the bole on the uphill side of the tree.

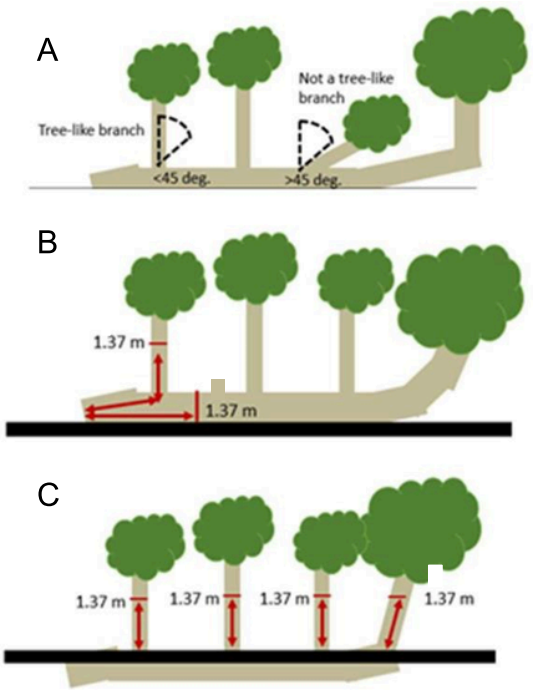
B. Obstruction: When materials (pile of woody material, etc.) are present beside the bole, measure 1.37m up from the base of the bole (not from the pile of materials).

C. Rooted on rock: when a tree is rooted on a rock, measure the diameter at 1.37m from the root collar.



Leaning tree: when a tree is leaning, measure the diameter at 1.37m along the underside face of the bole.

	**Trunk swell**: If a trunk swell is present at breast height, measure 0.5 m above the end of the swell (Fig A). If at this point of measurement the diameter is <10cm, average the diameters 0.5 m above and below 1.37m (Fig B).
	**Multi-stemmed Trees**: For trees that split below breast height (1.37 m), each stem should be treated as an individual and measured separately at 1.37 m, as long as the angle between the split stem and the main stem is ≤ 45 degrees. For trees that split above breast height, the tree is considered a single stem, and diameter is measured at the standard 1.37 m.
	**Stump sprouts**: Stump sprouts originate between ground level and breast height on the boles of trees that have died or been cut. They are measured at 1.37m. If the sprout originates at 1.37m, measure the diameter 0.5m above the origin of the sprout. If there are multi-stemmed stump sprouts, use the rules described for Multi-stemmed trees.
	**Live windthrown tree**: A live windthrown tree must be touching the ground. Measure from the top of the root collar along the bole to 1.37m.



Tree-like branches coming off a downed tree: Downed trees may have vertical, tree-like branches coming off the main bole. To be considered a "tree-like branch," branches must be less than 45 degrees from the vertical axis (Fig A).

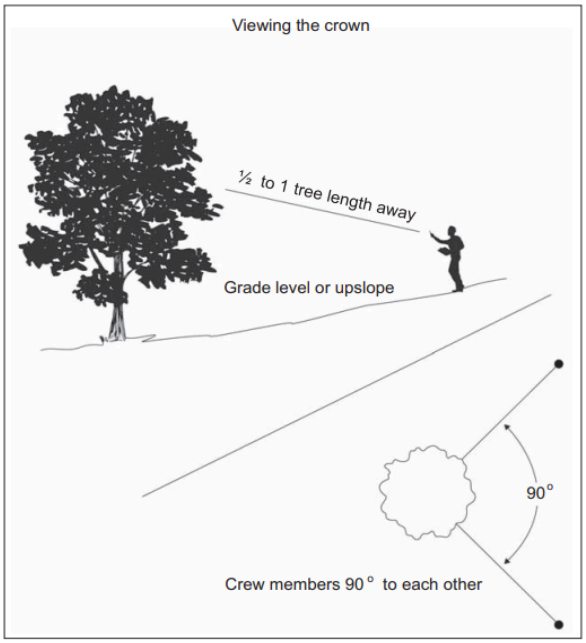
- If the main bole of the tree is touching the ground, the pith of the main bole is above the leaf litter layer, and the tree is alive, this tree is considered a live windthrown tree. Use multi-stemmed tree rules. For any tree-like branches at or below breast height, measure the diameter of each at 1.37m from the root collar of the main bole (Fig B).
- If the pith of the main bole is below the litter layer, treat each tree-like branch as a separate tree regardless of where along the main stem it originates. Measure at 1.37m from the ground, as opposed to from the root collar (Fig C).

Appendix E: Crown Vigor

Each overstory stem ≥ 10 cm DBH should receive a crown vigor rating from 1 to 5. This rating reflects overall tree condition and incorporates observations of crown dieback, twig and branch mortality, leaf discoloration, defoliation, and missing portions of the crown (see Glossary). Each of these factors should be evaluated independently and contribute to the final rating.

At least two trained observers should assess crown vigor for each stem. Observers should stand approximately one-half to one full tree length away, positioned 90 degrees apart from each other. Both should be at roughly the same elevation, avoiding the downhill side of the tree whenever possible. In dense or closed-canopy forests, additional effort may be needed to obtain a clear view of the crown.

If a stem meets criteria in multiple rating categories, assign the higher (worse) value. For example, if a stem is missing 20% of its crown (suggesting a rating of 2) and also has leaf discoloration in 60% of the crown (suggesting a rating of 3), assign a rating of 3.



Optimal viewpoints for rating tree crowns.

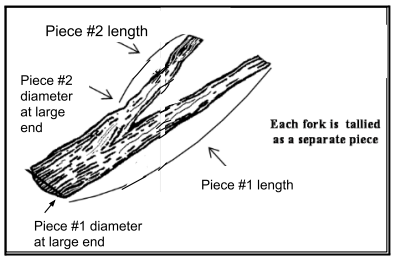
Rating	Attributes
1	**Healthy:** *All of the following* • Appears to be in reasonably good health with no major branch mortality • Crown size is appropriate for its canopy position (dominant, co-dominant, etc) • Less than 10% of the crown shows branch or twig mortality, defoliation, or leaf discoloration 
2	**Slight decline:** *One or more of the following* • 10-25% of crown has branch mortality, twig dieback, or leaf discoloration • Up to 25% of the crown has broken branches or crown area missing (based on presence of old snags).
3	**Moderate decline:** *One or more of the following* • 26-50% of crown has branch mortality, twig dieback, or leaf discoloration • 26-50% of crown has broken branches or crown area missing (based on presence of old snags)
4	**Severe decline:** *One or more of the following* • More than 50% of crown has branch mortality, twig dieback, or leaf discoloration, but foliage is still present to indicate the specimen is alive; • More than 50% of crown has broken branches or crown area missing (based on presence of old snags) 
5	**Dead:** Green leaves are absent during the growing season; fine twigs easily snap; peeling bark may be present; phloem under bark has brown streaks; epicormic shoots may be present; signs of decay..

Appendix F: Coarse Woody Material

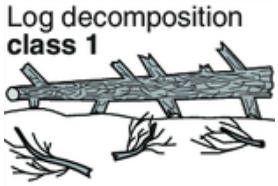
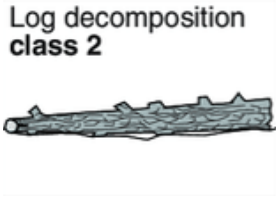
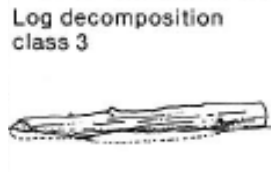
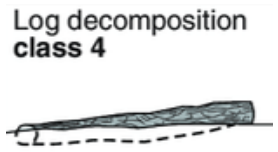
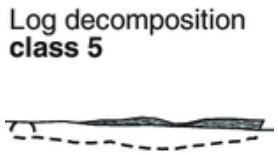
Coarse Woody Material (CWM) consists of downed dead boles or large branches in various stages of decay. CWM is an important component of forest ecosystems, providing wildlife habitats, structural diversity, carbon storage, and nutrient and water cycling within the system. Data for CWM is collected by the **piece**.

CWM includes…	CWM does NOT include…
• downed dead bole • large fallen limbs • woody pieces severed from their growth source • fence posts, cabin logs, and other anthropogenic woody debris **the piece must be one of the above AND at least 50 cm in length, and 10 cm in diameter at BOTH ends of that length within the plot and not suspended above 2 m.**	• pieces <10 cm diameter or <50 cm length • standing dead trees or shrubs • rooted stumps • dead foliage, bark, and other non-woody pieces not integral to the bole or limb ○ Bark attached to a piece is an integral part • roots or main bole below the root collar

Special situations

Situation	Rule
Fractured piece	If pulling at both ends would cause it to separate, treat it as two pieces.
Forked piece	Count each fork as a separate piece. 
Piece partially in plot	Must have ≥ 50 cm qualifying section **within** the plot to count.
Tapering diameter	Only record the portion of the piece where diameter ≥ 10 cm.
Tapers to <10 cm in the middle	Count as **two pieces** if both sides qualify by length and diameter
Suspended pieces	Only count the portion at or below 2 m from ground.
Leaning dead tree <45°	Record as overstory tree (dead/crown vigor = 5), **not** as CWM.
Leaning dead tree ≥45°	Record as CWM, **not** as overstory.

Decay Class Descriptions

Class	Illustration (Maser et al. 1979)	Description
1		Sound, freshly fallen, intact logs with no rot, no conks present, original color of wood, no invading roots, fine twigs attached with tight bark
2*		Sapwood partly soft but can't be pulled apart by hand, original color of wood, no invading roots, many fine twigs are gone, remaining have peeling bark
3		Heartwood is sound with piece supporting its own weight, sapwood can be pulled apart by hand or is missing, wood color is reddish-brown or original color, roots may be invading sapwood, only branch stubs are remaining which can't be pulled out of log
4		Heartwood is rotten with piece unable to support own weight, rotten portions of piece are soft and/or blocky in appearance, a metal pin can be pushed into heartwood, wood color is reddish or light brown, invading roots may be found throughout the log, branch stubs can be pulled out
5**		Fully decomposed, soft, powdery, losing shape. Must still resemble a log: ≥ 15 cm diameter, ≥ 15 cm off the ground, ≥ 50 cm long. There is no remaining structural integrity as rot spreads, wood color is red-brown to dark brown.

*If a log is case hardened (hard, intact outer sapwood shell) but the heartwood is rotten, code this as Class 2 and note the presence and measure the diameter (cm) of the hollow within.

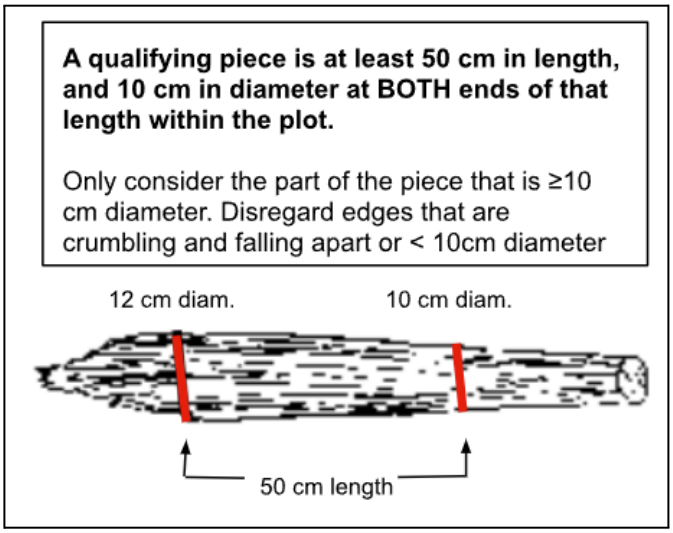
**CWM pieces with decay class 5 can be difficult to identify because they often blend into the duff and litter layers. Note the tally rule is that they must be ≥15 cm in diameter, ≥15 cm from the surface of the ground as opposed to the usual 10 cm. Decomposed logs that present as 'humps' on the ground are not tallied.

Diameters

- Only record diameters for Decay Classes 1–4.

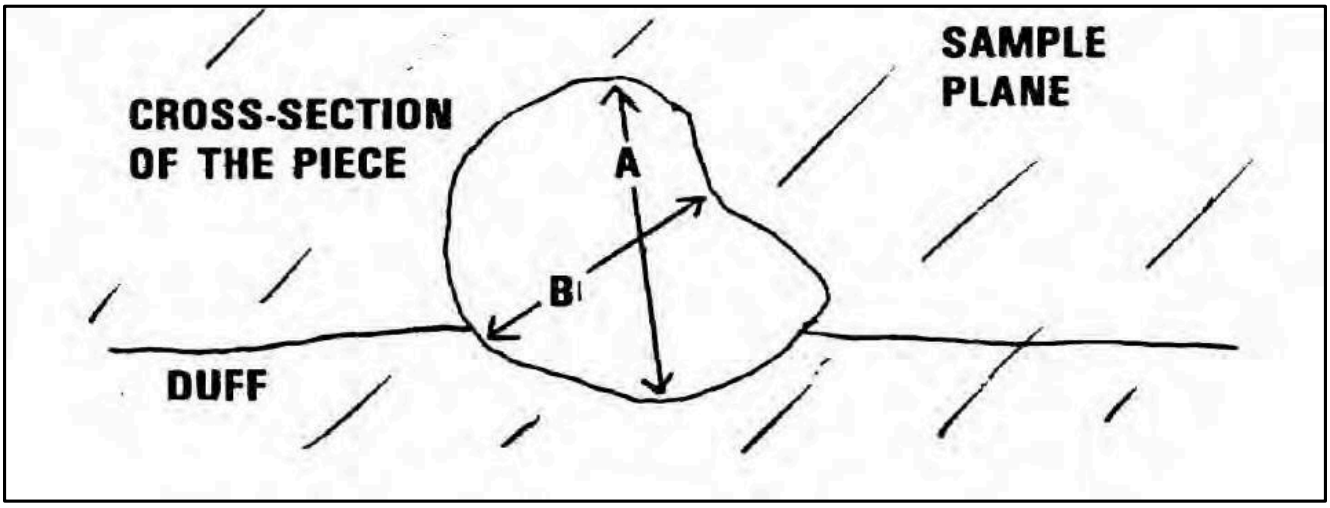
- Measure large and small end diameters (in cm), rounded to the nearest cm.
    - Large end = broken/sawn/fractured/root collar (whichever is most representative).
    - If ends are splintered or decomposed, measure at the point where intact wood begins.

- For irregular shapes:
    - Measure the longest and shortest (A & B) cross-sections.
    - Record the average diameter:
      Diameter = (A + B) ÷ 2



Length

For decay classes 1-4, record the total length of the CWM piece between where you took the two diameter measurements. For decay class 5, take the length of the full physical length of the piece. The goal is to get an



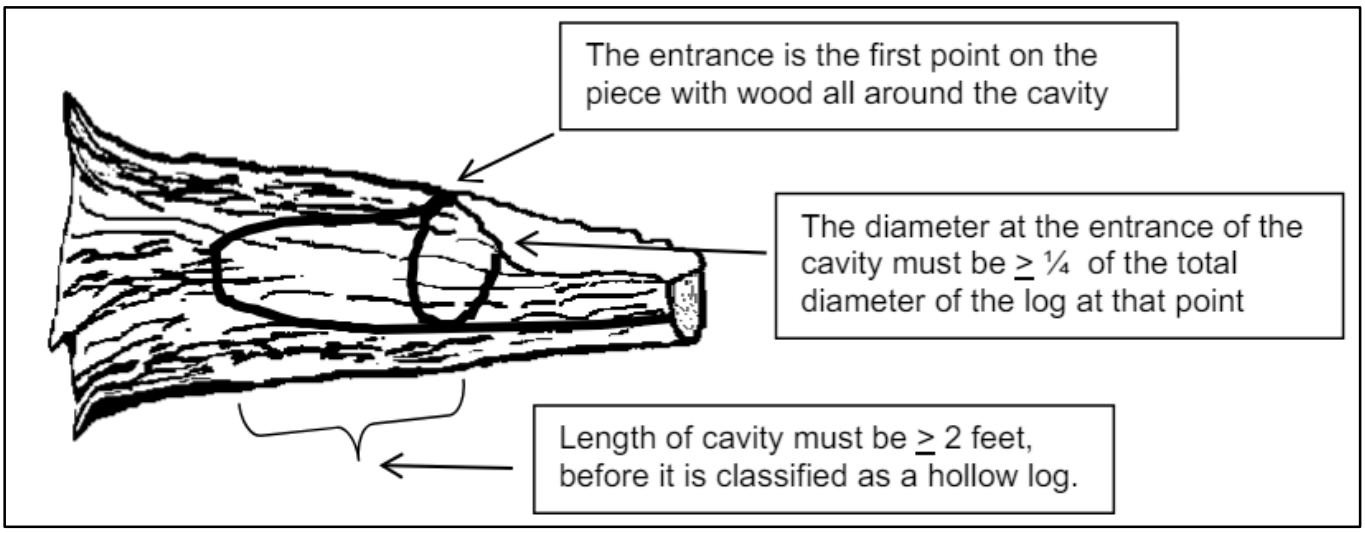
accurate measurement to calculate the volume.

Special situations:

- If part of a piece is buried in the litter, duff, or mineral soil, only the visible/above ground portion counts.
- If part of a piece is outside the plot, the piece ends at the point where it intersects the plot boundary.
- For curved logs, measure along the curve.

Hollow Presence & Size

If the piece is hollow, record the presence and the diameter of the hollow. A piece is considered hollow if a cavity extends at least 50 cm along the central longitudinal axis of the piece, and the diameter of the entrance to the cavity is at least 1/4 of the diameter of the piece where the entrance occurs. The entrance occurs at the point where the circumference of the cavity is whole -- the point where wood is present completely around the circumference of the cavity. The length of the cavity begins at this point.



Species

If you are able to identify the specimen to genus or species, record the scientific name, otherwise record 'Unknown.'

Citations

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USDA. 2011. Forest Inventory and Analysis (FIA) method Phase 3 Field Guide – Down Woody Materials. *FIA Library*, 1–34. https://www.fia.fs.usda.gov/library/field-guides-methods-proc/

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