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Forestry Inventory Methods

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FORESTRY INVENTORY METHODS

General Information

Title 180, National Planning Procedures Handbook (NPPH), Part 600, Subpart C, Section 600.23, "Inventory Resources," describes the resource inventory process used to collect information about a planning area's resources and related offsite information. Inventory information is used to determine the condition and trends of the resources, identify resource concerns and opportunities, and formulate and evaluate the effects of alternatives. The level of detail needed for an inventory depends on the level of planning—a forest management plan may utilize generalized information while a practice implementation plan will often require greater detail and statistical reliability.

This technical note provides a description of the common inventory methods and tools used in forestry and agroforestry applications and describes the methods used to conduct resource inventories that support planning processes for forestland.

Forest land is defined in Title 440, Conservation Programs Manual, Part 502, Subpart A, Section 502.0, "Definitions," as—

> "a land cover/use category that is at least 10 percent stocked by single-stemmed woody species of any size that will be at least 4 meters (13 feet) tall at maturity. Also included is land bearing evidence of natural regeneration of tree cover (cut over forest or abandoned farmland) that is not currently developed for nonforest use. Ten-percent stocked, when viewed from a vertical direction, equates to an aerial canopy cover of leaves and branches of 25 percent or greater. The minimum area for classification as forest land is 1 acre, and the area must be at least 100 feet wide."

Forest Stand Inventory

Stand Mapping

Prior to conducting an inventory, forested areas are mapped into relatively homogenous units (i.e., stands). Stands are relatively uniform with respect to aspect, dominant crown class, stocking density, species composition, landforms, etc. Information used for stand mapping includes using orthophotos, topographic images, soil maps, and ecological site descriptions. Information on geology, wetlands, and vegetation may also be useful. Refer to Web Soil Survey at website https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm for detailed soils information. Stand boundaries can be refined in the field with spatial data.

Choice of Inventory Methods

Generally applied methods for inventorying forest stands include point sampling (also known as variable-radius plot sampling) and fixed plot sampling. Methods applicable to specific situations, depending on stand conditions and objectives of the inventory, include strip sampling, line transect sampling, crop-tree inventory, and the zig-zag transect. The method chosen must be appropriate for the geographic location and condition of the stand and efficient with regard to information collected in a given amount of time.

Point and fixed plot sampling methods are used to collect information for developing management plans and silvicultural prescriptions. The inventory typically includes plot-level measurements that are summarized to provide stand-level information including site index, basal area ((BA), sq.ft./acre), trees per acre (TPA), species present in each canopy class from dominants to ground vegetation, size class, wood or nontimber production potential, and other metrics needed to plan and schedule future management activities, or implement near-term activities.

There are a number of considerations in choosing between point and fixed plot methods. Fixed plots may be better suited to large stands with low variability; generally, in these situations, fewer plots are needed for an adequate sample size than if point sampling is used. In many stands, especially those with open understories, point sampling usually requires less time per plot which allows more plots to be sampled. A relatively larger number of plots is needed to provide statistically reliable estimates in stands with variable density and a diversity of tree species (Oderwald 1981).

Plot sampling and strip sampling methods are based on measuring a percentage of the stand. A proportion of the area is measured based on the assumption that the samples are representative of the entire stand. The percentage of the area sampled depends on how the information will be used as well as the uniformity of the stand and its size. For most planning purposes, a low intensity inventory is sufficient. Sampling percentages can range from as low as 0.2 percent using fixed-radius regeneration plots in homogeneous stands, up to 20 percent for variable-radius plots in diverse forests of a small acreage. As acreage increases, inventory intensity typically decreases. A complete discussion on statistical sampling intensity can be found in forest mensuration textbooks, such as Avery and Burkhart (1994).

Strip sampling is a form of fixed plot sampling using long, narrow plots. This method may be suitable for sites with variation due to environmental gradients.

Transect sampling is often used for seedling survival inventories. It is an efficient method when the number of entities is the main attribute of interest.

Crop tree inventory identifies desired trees to retain for objectives that may include wildlife habitat, visual quality, water quality, timber and nontimber products, and others. A crop-tree inventory is supplemented with a demonstration plot to illustrate forest management concepts and allow landowners to determine the desired intensity of management.

The zig-zag transect method was developed by NRCS, then known as the Soil Conservation Service (SCS), in the 1960s. It allowed SCS foresters to use a simplified process to quantify forest tree and stand characteristics and was useful in communicating information to landowners. Although the zig-zag transect method is no longer a common inventory technique, under certain stand conditions it is an efficient method to use and provides good estimates for stands that are dominated by one tree species, are even-aged, and have a narrow diameter range.

Purpose of Inventory

Forest inventories are conducted for different purposes, but in NRCS they usually support the development of a forest management plan (FMP) or a conservation plan.

Inventory methods are chosen to—

- Collect information that addresses client objectives.
- Suit site conditions.
- Provide efficiency and cost-effectiveness.

The inventory—

- Is the basis for identifying, assessing, and addressing resource concerns.
- Collects ancillary information needed for the forest management plan such as maps.

Some inventories meet multiple needs, such as qualifying landowners for State programs, and may require specific types of information.

The components of an FMP are listed in the Cooperative Forestry Assistance Act of 1978 (16 U.S.C. Sec. 2103a), Section 5(f)(1)(B), as referenced in the Food, Conservation, and Energy Act of 2008 (16 U.S.C. Sec. 3839aa), Section 2506(a)(4). An FMP "identifies and describes actions to be taken by the landowner to protect soil, water, range, aesthetic quality, recreation, timber, water, and fish and wildlife resources on such land in a manner that is compatible with the objectives of the landowner."

- Criteria for the NRCS FMP are included in Title 190, National Forestry Manual (NFM), Part 536, Subpart B, Section 536.10, "Forest Management Plan Criteria."
- As a general rule, FMPs should be reviewed and updated as necessary every 10 years, as recommended in the document "Understanding Your Plan: A Guide for Landowners using Managing Your Woodlands: A Template for Your Plans for the Future" (USDA NRCS, and USDA-Forest Service. 2015c (revised)).
- The NRCS State conservationist may publish supplemental guidance or information on how to complete an FMP.

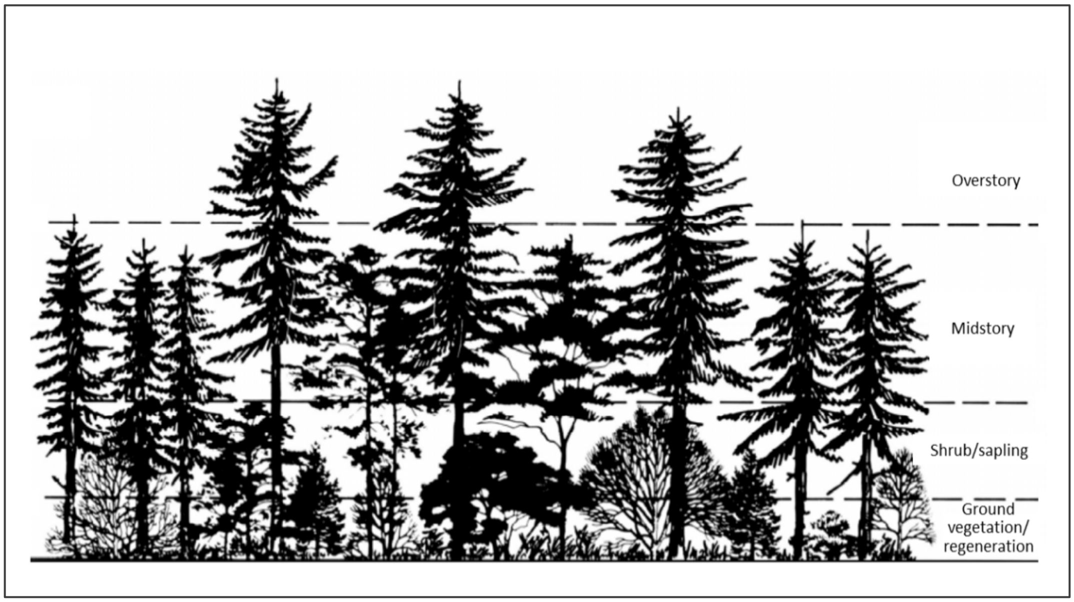
Stand Summary Information

Stand-level summaries provide information that allows foresters to describe current and potential future conditions to landowners, as an aid in setting goals for their property. Desired summaries may include stand-level information on structure by crown class and canopy stratification, average tree crown ratio, average tree growth rate, site index, diameter distribution, etc. Stand summaries are developed using various methods. Refer to State's "Resource Concern and Planning Criteria" document in the Field Office Technical Guide (FOTG), Section III, for guidance in selecting additional measurement and assessment tools.

- Stand Structure.—May be described by age classes or by canopy layers, from overstory to ground vegetation. Figure 1 shows the vegetation strata often found in a forest. Crown classes include dominants, codominants, intermediate, and overtopped.
- Crown Ratio.—Along with describing a stand by the different crown classes, crown ratio is a descriptive characteristic that conveys how well a tree is currently able to make use of available light for photosynthesis and how well it can be expected to respond to release. Crown ratio is simply what percentage of the total height of the tree includes live crown. An open grown tree may have nearly 100 percent crown ratio, while a suppressed tree has less than 25 percent.
- Tree Growth and Site Index

- Representative trees in the dominant crown class of each species in the stand are cored using an increment borer to determine tree age and growth. Choose a tree that is not growing close to a road or open area, as those trees express a growth advantage over trees deeper in the stand. Recording the radial growth for the past 10 years is a common practice. Noting the best 10 years growth is useful to understand potential growth and possible expectation of response to management activities.
- Site index trees, usually the same trees sampled for growth, are measured for age and height to determine stand growth potential. Site index curves are available from your forester. A cautionary note is that if the stand you are working in has been selectively harvested with numerous entries where the best lumber-producing trees were removed, the representative trees available may not offer an accurate site index.
- Site index information for a limited selection of tree species is often available by soil series from the Web Soil Survey at website https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm

Figure 1: Vertical Stratification in a Forest Stand



Graphic Adapted From Brown (1985)

Method

Point Sampling (or Variable-Radius Plot Sampling)

Point sampling, also known as variable-radius plot sampling, is a widely used forest inventory technique in which trees are selected and tallied based on their size relative to a preselected reference, either the BA prism or angle gauge. Results of point sampling can yield BA, TPA, and species composition depicted in a diameter distribution table if desired. Stand volume can also be estimated using point data.

- Determining the Number of Plots

- A low-intensity inventory is usually adequate for developing a forest management plan. The specific number of plots needed will vary, even for a low-intensity inventory. A stand that is relatively homogeneous in species composition and tree age can be represented with fewer plots, but as variability increases, so does the number of plots needed to provide adequate estimates of stand parameters.
- Table 1 offers minimum recommendations based on published sources and typical usage, but the optimal number of plots varies by forest type and other stand characteristics.

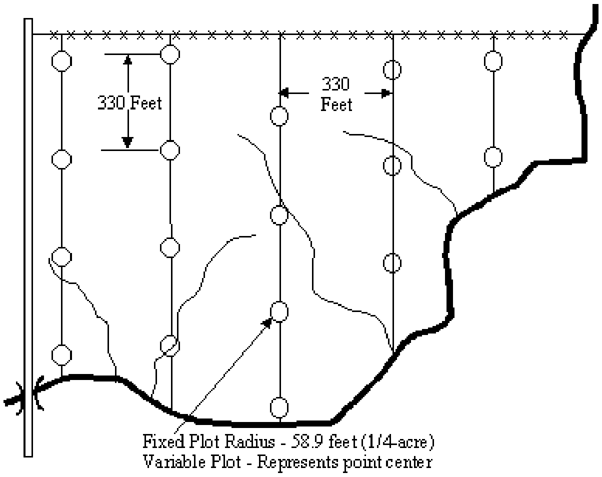
Table 1: Recommended Minimum Number of Plots for Low-Intensity Forest Inventory in Stands of Various Sizes

Acres	Minimum # of plots
10 or less	3
11–20	6
21–40	10
41–150	15
>150	1 plot/10 acres

- The minimum guideline of three plots for stands of 10 acres or less follows USDA-Forest Service (2015), which notes this recommendation is for homogenous stands. Other sources recommend a larger number of plots (e.g., Wenger 1984). Stand variability will determine the number of plots needed. Consult an area or State forester for recommendations on optimal numbers of plots to use in your location.
- For situations where a known level of statistical reliability is desired, refer to methods for determining the number of plots needed to provide an acceptable sampling error. See, for example, the “Number of Plots” discussion in chapter 2 of the FSVeg Common Stand Exam User Guide, Version: 2.12.6. (USDA-Forest Service 2015).

* Selecting Plot Locations
  - Plot locations are chosen without bias, so that all forested acres are equally represented in the sample. One way to locate plots is by using systematic sampling, which involves developing a parallel line pattern on a map with the plots evenly spaced along lines (fig. 2). Orienting the lines north-south or east-west makes it easier to establish on the ground, but other orientations may be used, such as aligning with a slope gradient. Make sure the sampling design places plots far enough away from property lines so that all the “in” trees are in the stand of interest. Plot locations can be preloaded into a device that uses spatial data (e.g., a data recorder, GPS navigation system, etc.). Alternatively, the distance between plots can be paced; in this case, bias will be reduced by stopping at the correctly paced distance even if the location is inconvenient.

Figure 2: Example of a Systematic Line-Plot Sampling Layout



  - o Another sampling protocol that limits bias involves using random distances and azimuths to locate plots. Note that it is possible, even when plots are located correctly using random or systematic protocols, that the resulting sampling design may not represent all parts of a stand equally. Sample enough plots that these random effects will not significantly affect stand-level summary data.

- Using the Prism
  - o A wedge prism is an angle-cut glass at a given basal area factor (BAF). Trees are sighted through the prism at 4.5 feet above ground, or diameter at breast height (DBH). Trees are counted as either "in" or "out." If the bole displacement as viewed through the prism overlaps, the tree is in (fig. 3). Include every other borderline tree. At each sample point, keep the prism over the plot center and rotate around the prism in one direction only.
  - o Note that a relatively small tree will need to be close to the plot center to be counted in, while a large tree can be quite far away.
- Using an Angle Gauge
  - o An angle gauge works on the same principle as a prism. Unlike a prism, the eye is kept at plot center and the gauge is moved in a circle. An angle gauge such as the cruz-all has several BAFs in one tool. A tree is considered out if the bole is narrower than the sides of the chosen BAF (fig. 4).
  - o A desirable number of trees per plot is between 5 and 12. If the number of trees in the plot tends to be fewer than 5, choose a prism or angle guage with a smaller BAF; if the plots routinely have more than 12 in trees, a larger BAF is appropriate. A stand of large trees requires a higher BAF and a stand of small trees a lower BAF. Keep the same BAF throughout the stand to simplify calculations later. As a recommendation, prior to conducting a forest cruise take a quick walk through the stand, using a prism or angle gauge occasionally to determine the appropriate BAF.

Figure 3: View of Tree Through Wedge Prism

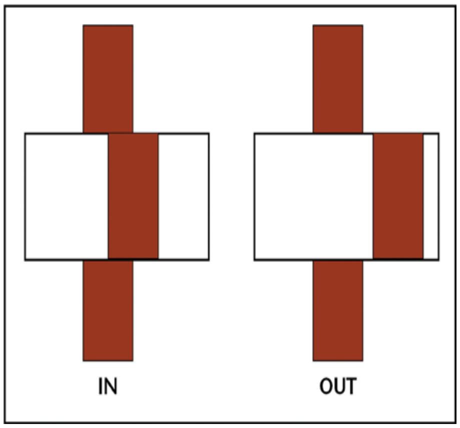
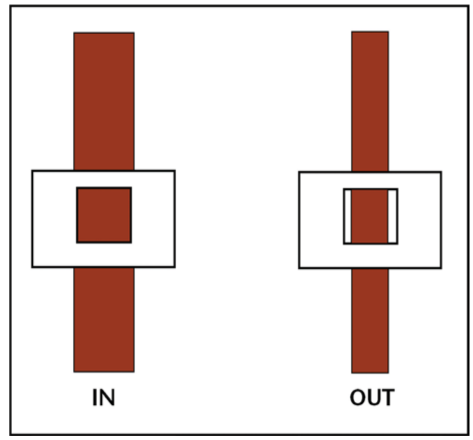
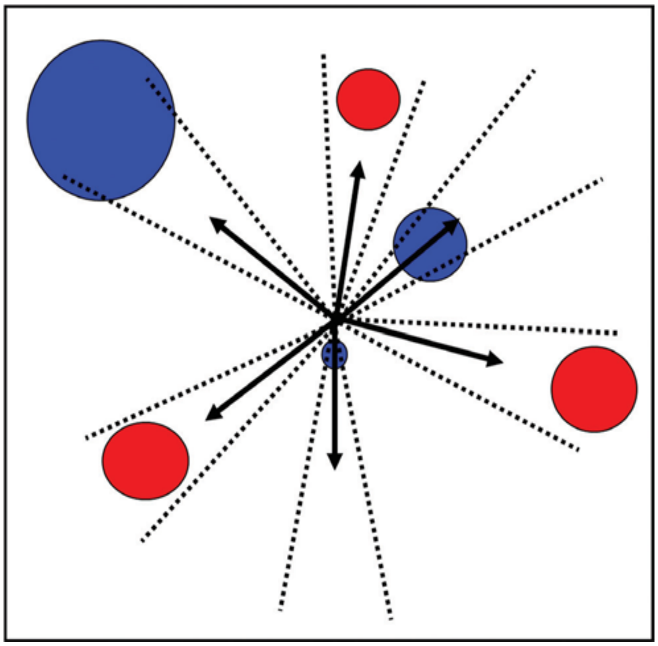


Figure 4: View of Tree Through Angle Gauge



- Establishing the Plot
  - At plot center, pivot in one direction, making a complete circle. Where to start the pivot is optional; some choose a cardinal direction, others simply the nearest tree. Use the wedge prism or angle gauge to identify trees that are in the plot. Inventory data will only be collected on the trees that are in the plot.
  - Note that each region will have a size threshold where trees below a certain diameter will not be included in a point sample; these trees will be sampled in regeneration plots. Consult with a forester on the lower size limit for point sampling.
  - If a tree is growing at an angle, tilt the prism or gauge to match. If the tree is obscured from view at DBH, either step away from plot center, maintaining the same distance to the tree in question, or target the tree above the obstruction. All trees counted in should be tallied by species and DBH within a 2-inch diameter class, at a minimum. Mark the plot center for reference if you need to physically measure the tree diameters; the eye quickly becomes calibrated and accurate ocular estimates of tree diameter can be achieved, but check your eye with actual measurements periodically.
  - Borderline trees are on the edge of the plot where it is difficult to determine whether they are in (fig. 5). The simplest approach is to count every other borderline tree as in; this approach provides an estimate of stand characteristics that is sufficient for most planning applications. If greater accuracy is desired, measure the distance from plot center to the borderline tree as per methods in appendix J of the FSVeg Common Stand Exam User Guide, Version: 2.12.6. (USDA-Forest Service 2015).

Figure 5: Trees indicated by blue circles are within the variable-radius plot; trees in red are outside the plot. Images used by permission of Pacific Northwest extension.



- Collecting Plot Data
  - Utilize a "tally sheet" (also known as a "cruise sheet"), similar to the one shown in figure 6, for recording plot data. Field data recorders with programmed tally sheets may be used.
  - For each tree in the plot—
    - Determine and record tree species using standard codes. Codes used by the Forest Inventory and Assessment (FIA) program are recommended for consistency; see appendix F in O'Connell et al. (2016).
    - Measure the diameter at DBH (4.5 feet) using a diameter tape, and record the measurement to the nearest inch.
    - Rate the tree's condition as vigorous, fair, or declining. A vigorous tree does not show signs of stress; it has a full healthy crown, no evidence of scars, wounds, or disease, and little or no epicormic branching. A declining tree may have a broken top, multiple forks, canker, wounds, scars, and disease; however, such trees may have high value for wildlife. Assign "fair" as an intermediate rating. Do not include species desirability in the condition rating; rate each tree on its merits, without regard to species. Record the condition rating in the field notes.
    - In the "notes" section, describe the reason for the tree's rating. Note features of the tree that are important as wildlife habitat, aesthetics, economic value, etc.

Figure 6: Example Tally Sheet With Three Plots

Notes on filling out cruise sheet
Keep the same basal area factor **(BAF)** and fixed plot size for all plots in a stand.
In species column, record "in" trees as they occur while pivoting in one circular direction.
Use the dot grid tally to save space: DF alone is one tree, DF* is two trees, ect. The dot tally can include up to 10 trees.
Basal area "in" trees are 10" and greater Diameter Breast Height **(DBH)** collected in 2" diameter classes.
Trees 8" and smaller are recorded in nested fixed plot as regeneration **(R)**; a 1/100th ac plot measures 11.8' and a 1/300th ac plot measures 6.8'
Regeneration can be recorded by actual diameter or in classes: 0-1, 2-3, 4-5, 6-7 and 8-9.
A growth tree **(GT)** is often a plot tree, however when it isn't, record it on its own line. Measure and record growth of the last 10 yrs.
Age is total age; need to add how many years it took for tree to reach DBH. When in doubt, use 10 yrs.
Crown ratio **(CR)** is % of tree with live crown.
Record a snag **(S)** as it occurs in the plot as if they were a separate species and you can determine snags per acre.
You can make additional notes recording insect or disease, understory, aspect, or slope in unused space on right side of cruise sheet.

	Property:	Producer/Stand 1			BAF:	10	
	Date:		Fixed Plot Size:		1/100th ac		
	Cruiser:	NRCS Planner		Field Office:			
WyPt	**Plot**	**SPECIES**	**DBH**	**AGE**	**GRTH/ 20ths**	**HT**	**CR %**
256	1	DF	10		WEST ASPECT		
		DF*	12		30% SLOPE		
		DF*	16				
		DF**	14		OREGON GRAPE,		
	R	LP**	8		KINNICKINICK,		
		WL	6		PINE GRASS		
		LP*	6				
257	2	DF	16		SOME SPRUCE BUDWORM		
		DF	14		NOT TOO BAD		
		WL*	12.4	75	10	62	40
		WL*	10				
		SNAG	18				
	R	DF**	0-1				
	GT	DF	16.2	96	12	75	50
258	3	DF	14				
		LP	10				
		LP	12				
		DF	10				
		DF	12				
	R	DF*	0-1				

Note that this is only an example; consult a forester for a tally sheet adjusted to local forest types.

- Basal Inventory Calculations
  - A programmed spreadsheet is useful in making these calculations efficiently and consistently. Check with a local or State forester to see if a spreadsheet is available.
  - Determining BA
    - BA.—A measure of how much of an acre is occupied by trees. Each forest type has a BA range that is optimal for individual tree growth. Determining BA is fairly simple:

      BA = (total trees tallied ÷ total # of plots) × BAF
    - In the example, only BAs for trees 10 inches DBH and greater are determined. There are 19 trees 10 inches DBH and greater, so: 19÷3×10 BAF = 63 square feet of BA per acre.
  - Determining TPA

- TPA is a measure of stand density. Each tree size class has a recommended stocking level that can be expressed as TPA. Determining TPA in point sampling is more complicated than when using fixed plots. The tree tally must be expanded to a per acre basis and diameter classes summed for a total TPA. Again, a programmed worksheet simplifies this process.

  TPA = # of trees tallied × BAF ÷ BA per tree ÷ total number of plots

  Where BA per tree = $0.005454 \times DBH^2$

  The BA for a 10-inch DBH tree = $0.005454 \times 10^2 = 0.5454$

  The BAF in the cruise example is 10.

  Five trees are tallied in the 10-inch DBH class.

  TPA for 10-inch DBH class = 5 tallied trees × 10 BAF ÷ 0.5454÷3 plots = 31 trees per acre

  If this calculation is carried out for the remaining diameter classes found in the cruise:

  TPA for 12-inch DBH class = 6×10÷0.7853÷3=25 TPA

  TPA for 14-inch DBH class = 5×10÷1.068÷3=16 TPA

  TPA for 16-inch DBH class = 3×10÷1.396÷3=7 TPA

  Total = 79 TPA 10-inch DBH and greater

- Diameter Distribution Table
  A diameter distribution table is a useful visual to help with the decision-making process for possible management options. Using a programmed worksheet or applications such as the Forest Vegetation Simulator (FVS), a diameter distribution table can be developed for each stand, broken down by species (see table 2).
- Volume of merchantable and nonmerchantable timber and biomass
  It is possible to develop timber volume estimates using information collected during point sampling; however, the accuracy of a volume estimate depends on attributes such as tree form and defect. Collecting this type of information requires specialized training. In instances where volume estimates are desired, consult an area or State forester.

Table 2: Example Stand-Level Diameter Distribution Table Using 2-Inch Size Classes Between 10 and 18 Inches DBH

	Douglas-Fir		**Lodgepole Pine**		**Western Larch**	
DBH	TPA	BA	TPA	BA	TPA	BA
10	12	7	6	3	12	7
12	13	10	4	3	8	7
14	16	16	0	0	0	0
16	7	10	0	0	0	0
18	0	0	0	0	0	0
Totals	**48**	**43**	**10**	**6**	**20**	**14**

- Tree Regeneration Sampling in Conjunction With Point Sampling
  - To obtain a complete stand description, consider collecting nested fixed-radius plots for trees in the seedling, sapling, or pole size at the same time as conducting point sampling of the stand overstory. A fixed-radius plot with the same plot center as the point sample can yield useful information for either a forest management plan or a conservation practice job sheet. Plot size is dependent on tree density.
  - Choose a plot size that will capture stocking without having to count more trees than necessary; a cursory walk through the stand will help determine an appropriate plot size. If tree density appears low enough that a 1/300th acre plot will often be empty, where a 1/100th acre plot will capture regeneration, then utilize the larger plot. Conversely, when surveying an extremely dense stand, the smaller plot is better to avoid missing stems. As with the BA factor, keep the same plot size for the entire stand to make expansion calculations easier.
  - Calculating Regeneration TPA

    Using the example tally sheet in figure 6, the fixed area plots are 1/100th acre in size (11.8 feet).

    There were 11 trees tallied in the 8-inch diameter class and smaller. So,

    TPA = 11 counted trees × 100 / 3 = 366 trees per acre
  - Again, a diameter distribution table is very useful to help target treatment options (table 3).

Table 3: Example Stand-Level Conifer Regeneration Table Showing Number of Trees in Seedling, Sapling, and Pole Size Classes

DBH	**Douglas-Fir**	**Lodgepole Pine**	**Western Larch**	**Totals**
0–1	167	0	0	167
2–3	0	0	0	0
4–5	0	0	0	0
6–7	0	66	33	99
8–9	0	100	0	100
Totals	**167**	**166**	**33**	**366 TPA**

Note that in different geographic areas and forest types, size classes are defined differently, so that some of the DBH classes shown in this table would be part of overstory tallies.

Fixed Plot Sampling

In fixed plot sampling, a set of plots, generally all the same size, are located throughout the area. Plots can be any shape; circular plots are commonly used because it is convenient to set up a plot of this shape from a single center point, but rectangular plots are equally acceptable. The number and size of plots is determined by the desired inventory intensity, stand variability, and stand size.

An adequate total sampled area is needed for accurate estimates of stand-level characteristics. A standard size for fixed plots may have been established regionally; in this case the number of plots sampled may be varied to reach the desired total sampled area.

A smaller number of plots is often acceptable in locations where there is relatively low variability in stand density and composition; more plots are needed in stands with high variability. The number of plots along with plot sizes determines the total area sampled, generally expressed as a percentage of the stand area. Consult a local forestry expert for optimal sampling percentages.

Sample plots may be located throughout the area in a number of ways.

- One method is to locate the plots systematically, at predetermined intervals on lines that are a set distance apart (fig. 7).
- Other methods utilize randomly generated distances and azimuths to select random plots, sometimes using rejection criteria for unnatural disturbances or nonforested locations.
- Ecological site descriptions often use deliberate placement of plots to capture a reference state, however a forest inventory requires an unbiased sample.

Nested subplots, all sharing the same center, are often used to capture sequentially smaller size classes (e.g., 1/5th acre plot for sawtimber, 1/10th acre for pole class, and 1/300th for seedling/saplings).

Refer to table 4 for the radii commonly used to construct plots of various sizes. See also the discussion in the section “Point Sampling” on page 4 of this TN. To calculate sampling percentage, the formula is—

(total plot size in acres/acres represented) × 100 = % inventory

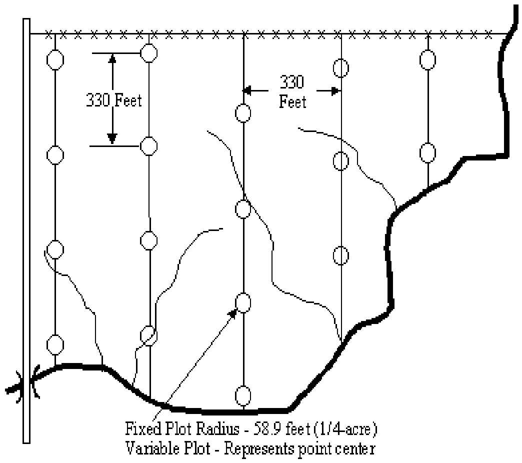
Using the systematic 1/4 acre plot sampling scenario shown in figure 7 as an example:

Total the number of plots.
Multiply by the area of each plot.
Divide by area of the stand.
Convert the figure to a percentage.

This percentage is the amount of the total stand area included in the sample.

((17 plots × 0.25 ac) / 40 ac) × 100 = 10.6% inventory

Figure 7: Example of a Systematic Line-Plot Sampling Layout for a 10-Percent Sample Using Fixed Plots in a 40-Acre Stand



Many features of point sampling and fixed plot sampling are identical.

- The number and location of plot centers are determined in the same manner.
- Methods for determining which borderline trees to sample are the same.
- Tree measurements (diameter, height, defects, etc.) are also measured or estimated by methods similar to those used in point sampling.
- The primary difference between the two methods is that fixed plot sampling requires measurement of plot dimensions. Also, fixed plots may be less efficient in stands with a large number of small trees, because of the additional time required to measure them.

Table 4: Commonly Utilized Dimensions for Fixed Plot Sampling, Showing Radii for Circular Plots

Plot Dimensions
1/1000-acre plot = 3.7-foot radius or 6.6 feet × 6.6 feet
1/500-acre plot = 5.3-foot radius or 9.3 feet × 9.3 feet
1/250-acre plot = 7.4-foot radius or 13.2 feet × 13.2 feet
1/100-acre plot = 11.8-foot radius or 20.9 feet × 20.9 feet
1/300 –acre plot = 6.8-foot radius or 12 feet × 12 feet
1/20-acre plot = 26.3-foot radius or 46.7 feet × 46.7 feet
1/10-acre plot = 37.2-foot radius or 66 feet × 66 feet
1/4-acre plot = 58.9-foot radius or 104.4 feet × 104.4 feet
1/5-acre plot = 52.7-foot radius or 93.3 feet × 93.3 feet
1/2-acre plot = 83.3-foot radius or 147.6 feet × 147.6 feet
1-acre plot = 118-foot radius or 208.7 feet × 208.7 feet

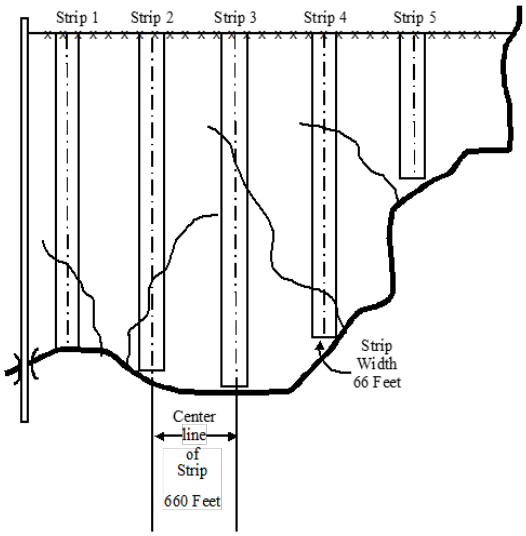
Strip Sampling

In strip sampling, the sample units are continuous strips of uniform width, spaced at a predetermined distance apart. The width of the strips and the distance between the centerline of the strips determines the percentage of the area sampled.

Strips are often used in tropical forests where there is such a dense understory that point sampling is limited by visibility.

These designs may also be useful in areas with strong environmental gradients, usually due to steep slopes, where they are oriented perpendiculuar to the slope. See figure 8 for an example of a strip sampling design.

Figure 8: Example Strip Sampling Layout



Tree Planting Inventory

Many factors can affect the postplanting success of tree and shrub establishment projects. Negative factors may include adverse weather conditions or livestock trampling, or other biotic and abiotic causes of mortality.

Regular inspections of tree planting sites or direct seeding sites are necessary to identify the many factors affecting survival and growth. Inspections help determine whether there are needs for replanting; additional weed control; moisture management; protection from deer, rabbits, or other herbivores; management of insect or disease problems; etc.

It is important to note that factors such as improper seedling shipping, handling, onsite storage, or planting procedures are elements of the actual tree planting project.

- These issues must be addressed in a properly designed job sheet, combined with the oversight of an experienced tree planting supervisor during the time of planting.
- These causes for failure are not the same as the ones that are the focus of tree planting inventories.
- The methods described in this section can be used to evaluate most newly planted tree and shrub establishment practices and very young plantations.

Timing for Inspections

Generally, survival should be assessed at 4 to 5 months after the initial planting and at least once a year until the trees and shrubs are established. This typically occurs within the first 3 years, but establishment may take longer in some geographic areas.

- For evergreen plantations, it may be easier to see small trees in the late fall or winter, when the brown ground cover or snow provides more contrast to their green foliage.
- For deciduous trees and shrubs, growing season (leaf-on) inspections may allow for better and easier species identification.
- If very adverse conditions, such as dry weather, high predation, or heavy weed competition, are noted, a second inspection in the fall may be recommended. End of the growing season (early fall) inspections can also make it easier to locate trees and shrubs with contrasting fall foliage colors.
- If deciduous trees and shrubs are inspected during dormancy, confirm survival by assessing the "suppleness" of the twig with presence of soft, current-year buds, or by scraping a very small patch to reveal green inner bark. Limit the number of scrapings by developing a general "feel" for which trees are alive.

Plot Sampling Methods for Tree Planting Inventory

- Circular Plots
  - This method is appropriate for all planting arrangements, including linear plantings, random spacing layouts, and direct seeding plantings.
    - Generally, a 1/100th acre circular plot will work for most typical tree and shrub plantings.
    - Larger 1/20th- and 1/5th-acre circular plots work well when tree plantings exceed a 10-foot by 10-foot spacing or for even wider spaced trees, such as those used in fruit and nut tree plantations (40-foot by 40-foot spacing).
    - Refer to table 4 for the radii commonly used to construct plots of various sizes. Choose a plot size large enough to inventory several planted trees per plot.
  - Count and inspect all seedlings within the plot. If desirable natural tree and shrub regeneration help meet planting objectives, include those plants in the tally. Count every other seedling that falls directly on the edge of the plot.
  - To calculate the average number of seedlings per acre, total the number of live seedlings in all plots, then divide by the total number of plots. Multiply the average number of seedlings per plot by 100 (for a 1/100th-acre plot) to obtain the average number of seedlings per acre.
- Linear Plots
  - Linear plots can be used for plantings that were installed with uniform row widths and evenly spaced trees and shrubs, (for example windbreaks, hedgerows, and other linear plantings). This method is often preferred in narrow plantings or under dense vegetation conditions, when a planting slit (or furrow) can be located.
  - Several variations of linear plots may be used depending on field conditions and planting scenarios. The two most common types of linear plots are assessing 10 consecutive seedlings in a row and assessing a row of seedlings over a distance of

100 feet. Variations of these two methods can be created by adjusting the number of seedlings counted in a row or the distance used within the row.

- Ten Consecutive Seedling Count Method
  - The 10 consecutive seedling count method is best used when all planted seedlings (live and dead) are present, planted at the original planned spacing, and natural tree and shrub regeneration will not be assessed.
  - For a 10 consecutive seedling row plot—
    - Follow one row and assess 10 consecutive (live and dead) planted trees and shrubs in that row.
    - After 10 planted plants have been inspected within that row, move over one or more rows and repeat the procedure until the required number of plots has been assessed.
  - To determine total number of surviving seedlings per acre—

    (# of live seedlings tallied ÷ # of plots) × 10 = % survival rate

    => (% survival rate × # of planted seedlings per acre) ÷ 100 = surviving seedlings per acre
- 100-Foot Row Seedling Count Method

  The 100-foot row seedling count method is best used when individual seedling spacing varies within a row but spacing between rows is relatively consistent. Much like the circular plot, this type of linear plot can be used to assess natural regeneration that may be occurring within planted rows. Include natural regeneration tallies only if it helps meet planting objectives. To use this method—
    - Count the number of seedlings in a 100-foot distance along the row. If desirable natural tree and shrub regeneration help meet planting objectives, include those plants in the tally.
    - Measure the width between rows.
    - After the 100-foot distance has been inspected, move over one or more rows and repeat the procedure until the required number of plots has been assessed.
    - To determine average number of surviving seedlings per acre—

      Average distance between rows, feet × 100 feet ÷ 43560 sq ft/acre = area sampled, acres—

      => total # of live seedlings tallied ÷ # of plots = average # of seedlings per plot

      => average seedlings per plot ÷ area sampled, acre = surviving seedlings per acre.

- Sampling Procedures
  - For any of the circular or linear plot methods, select plot locations in the planting area that best represent the variation of soils, topography, aspect, etc. Select a random starting spot (roughly 100 feet from the edge) in one corner of the planted area and install plots diagonally through the plantation. Alternatively, use two diagonals forming an "X" pattern. Record data on the "Tree and Shrub Planting Evaluation

Form," or a similar data collection form adapated to the setting (see fig. 9 in this section).

- To collect enough data for a reliable survival estimate, use at least the number of plots shown in table 5. For windbreaks and sites with highly variable soils, hydrology, etc., consider increasing the number of plots per acre, to increase the confidence level of the data collected.

Table 5: Minimum Number of Circular or Linear Plots Needed for Reliable Seedling Survival Estimates in Planted Areas of Different Sizes

Circular plots—1/100th acre	
Minimum number of circular plots needed	
≤ 5 ac.	5 plots
6 to 10 ac.	1 plot per ac.
> 10 ac.	10 plots + 1 plot/additional 5 ac.
Linear Plots	
Minimum number of linear plots needed*	
≤ 5 ac.	3 plots
6 to 10 ac.	1 plot per every 2 ac.
> 11 ac.	5 plots + 1 plot/additional 10 ac.
*Double the number of plots for windbreaks.	

Figure 9: Example Form for Recording Data During Tree or Shrub Survival Surveys

Tree and Shrub Planting Evaluation

Client:			Total acres in unit:		County:		Evaluation date:	
Tract #:		Field #:	Planned trees/ac. (a):		Planned spacing (ft.):	____X____	Evaluation by:	
Conservation practice:	☐Tree/Shrub Establishment (612); ☐Windbreak/Shelterbelt Establishment (380); ☐Riparian Forest Buffer (391); ☐Windbreak/Shelterbelt Renovation; ☐Other (specify):________________							

Assessment Method Used (check one):

☐ Circular Plots (1/100th ac.; radius 11.8 ft. (11’, 9½”))

☐ Linear Plots assessing 10 consecutive seedlings plot

☐ Linear Plots assessing 100 ft. row seedling plot

Important! Be sure to inspect several areas or rows in the plantation to ensure the sampled area is representative of the site.

Plot Number	# of Live	Spacing between rows	Additional Field Notes (species observed, improper planting technique, deer and rodent damage, weed competition, O&M needs, etc. Include plot numbers if note does not apply to the whole planting unit):
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
Totals # plots (b)	Total # live (c)	Average ft. (d)	

Circular 1/100th Plot Summary:

	÷		× 100 =		÷		=	%
Total # of live (c)		Total # of plots (b)		**Surviving trees/ac.**		Original # trees/ac. (a)		**Survival Rate**

Linear 10 Consecutive Seedling Plot Summary:

	÷		× 10 =	%	×		÷ 100 =	
Total # of live (c)		Total # of plots (b)		**Survival Rate**		Original # trees/ac. (a)		**Surviving trees/ac.**

Linear 100 ft. Row Seedling Plot Summary:

	× 100ft. ÷ 43,560 sq ft/ac =			÷		=	
Average row width, ft (d)		**Plot size in ac.**	Total # live (c)		Plot size in ac.		**Surviving trees/ac.**

This form is adapted from Michigan Technical Note Forestry #30, Evaluation of Tree and Shrub Establishment Practices, December 2011, developed by Tom Ward, NRCS retired.

Crop Tree Inventory and Demonstration

- Crop Tree Inventory
  - Crop tree management is a forest stand improvement treatment, also known as release, that provides potential crop trees with additional growing space, light, and air through opening the area around their crowns. It reduces competition from adjacent trees to promote survivial and more rapid growth of the desired crop trees, and in some cases can be used to increase seed production.
  - A crop tree can be any tree that has been identified as desirable and worth retaining, and may be selected for the purposes of wildlife habitat, economic value, water quality, aesthetics, etc., depending on landowner objectives.
  - Crop tree management is typically applied in multispecies forest stands, such as eastern and northern hardwoods (maple, oak, hickory, etc.), and bottomland hardwoods (elm, ash, cottonwood, silver maple, red maple, etc.).
  - Multiple purposes can be addressed through crop tree management. It can be used to create desired forest structure in stands that are primarily even-aged. See Perkey et al. (1994) for information on silvicultural aspects of crop tree selection and management.
  - Trees that are relatively young for their life spans, around 25 feet tall with large healthy crowns, are often good candidates for crop tree management.
  - Trees selected for economic value will have a desirable growth form.
  - Before commencing an inventory and demonstration, discuss crop tree management with the landowners to gauge interest and identify purposes.
  - Conduct a reconnaissance survey of the stand to determine whether crop trees that meet landowner objectives are present, and to identify representative stand conditions. Take point samples as described in the section “Point Sampling” on page 4 in this TN. At each point, use a tally sheet such as the one shown in figure 11 to record species and DBH (for all trees of 4 inches DBH or larger), and codes indicating whether the tree is a potential crop tree for one or more purposes. (e.g., “W” for wildlife, “T” for timber, “V” for visual quality, etc.). Also use codes to identify trees that compete with potential crop trees (“cut trees”).
- Crop Tree Demonstration
  - A demonstration plot is used to assist the landowners in deciding whether to manage for crop trees, and if so, how intensively.
  - One or more demonstration plots are located in representative portions of the forest stand.
    - A 1/5-acre plot is recommended; the plot may be circular with a radius of 53 feet or a square of 93 feet on a side.
    - Flag the plot boundaries sufficiently to allow the landowners to visualize plot dimensions. Within the plot—
      - Identify and flag high-value crop trees using criteria selected by the landowners.
      - Identify trees that are competing with crop trees for light (i.e., those with a crown that touches the crop tree crown).

        - Flag these competing trees with flagging of a different color; they are the "cut trees" that will be cut or killed to release the crowns of crop trees. Trees that do not contact a crop tree crown, or that are growing below a crop tree crown, are disregarded since they do not compete with crop trees.
        - Identify and flag competing trees on at least three out of four quadrats around the crop tree (fig. 10).
    - Determine whether the landowners are satisfied with the amount of cutting. If less cutting is desired, first reduce the number of crop trees and then reduce the cut trees associated with those crop trees. This ensures that all remaining crop trees are fully released.
    - Utilize information from the reconnaissance survey to calculate the number and average diameter of crop trees and cut trees, and the residual BA of the stand.
    - The average number of crop trees and cut trees per acre, and the average diameter of these trees, will help the landowners or forestry contractor determine the potential for a timber sale and estimate the workload to cut or kill competing trees. In typical cases, 20–75 crop trees will be released per acre (4–15 crop trees per 1/5-acre plot).
    - The calculation of residual BA will ensure that the stand remains fully stocked after crop tree management. See Perkey et al. (1994) for more information on crop tree management.

Figure 10: The crop tree crown in the center of this illustration has been separated into four quardrants. A free-to-grow rating is determined by evaluating each side for competition from neighboring crowns. This crop tree is free to grow on three sides (Wilkens 1994).

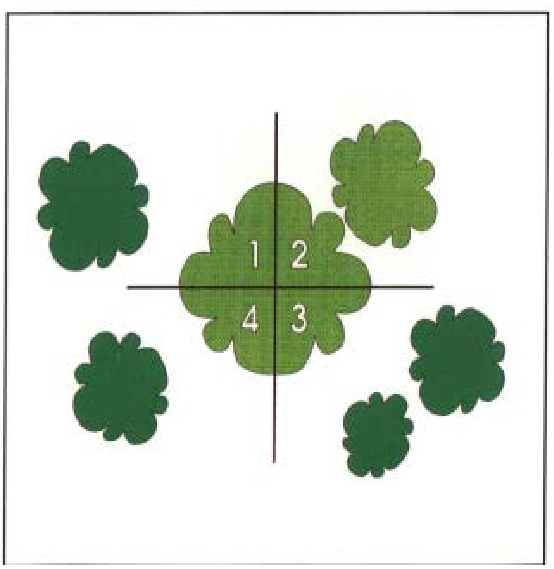


Figure 11: Example of a Crop Tree Tally Sheet, to be Adapted as Needed for Different Geographic Areas

CROP TREE TALLY SHEET

(Eastern Hardwoods and Bottomland Hardwoods)

LANDOWNER: **DATE:**

STAND HISTORY:

STAND NUMBER: **TYPE:** **APPROX. AGE:** **ACRES:**

LANDOWNER OBJECTIVES:

Plot No.	Species	DBH	Crop Tree [1] T,W, V, WQ	Cut Tree x

				AVG.
Basal Area - "leave" trees [4]				
Basal Area - cut trees				
TOTAL Basal Area [5]				

Crop Tree Totals				
Category	**Total [2]**	**# Plots**	**Avg. No. Trees/Ac. [3]**	**Avg. DBH**
Timber (T)				
Wildlife (W)				
Visual Quality (V)				
Water Quality (WQ)				
Total All Categories				
Cut Tree Totals				
Cut Trees (x)				

[1] Crop Tree Categories

T - Timber

W - Wildlife

V - Visual Quality

WQ - Water Quality

x - Cut Tree

1/5 acre plot radius = 53 feet

DBH - diameter breast height

[2] If a tree qualifies in more than one category (example: T & W) count it only once in the category where it makes the greatest contribution to to accomplishing the primary landowner objective.

[3] Ave. Number of Trees Per Acre = Total # Trees / # Plots X 0.2 acre

[4] "leave" trees are all trees that are not marked to be cut or killed, that is BOTH Crop Trees AND trees that are neither Crop Trees nor cut trees. BA reported in this space represents the total post-treatment BA. BA measurements should be made at 2 or 3 points near plot center.

[5] Total pre-treatment BA

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11/22/2006

Zig-Zag Transect Method

The zig-zag transect is best suited for even-aged, single-layer, and single-species forest stands of a uniform nature. These conditions would likely be encountered in a plantation type of stand. However, experienced users are also able to apply this method in measuring multilayered stands with a diversity of tree species.

The zig-zag method can be used to determine—

- Average tree diameter.
- Range of tree diameters.
- Stocking rates (TPA).
- Stand composition.
- Stand condition (health).

Information from the zig-zag transect can be used to derive an estimate of the BA of the sampled stand.

The zig-zag transect is performed by selecting a point in the stand where the transit will begin, along with determining a direction of travel (a general route which will best capture the stand attributes) (fig. 12). A compass and bearing are used to guide the route. The transect will normally be conducted along the contour when stands are on sloping topography.

A "starter tree" anchors the transect and is not measured. An imaginary 90^o quadrant, bisected by the direction of travel, is used to determine the area where the first sample tree will be selected.

- From the starter tree, select the next closest sample tree from within the 90^o quadrant. This provides a degree of randomness. Measure the distance from the starter tree to the first tree. Species, DBH, height, tree condition and other attributes of this first sample tree are recorded.
- The first tree that was sampled serves as the reference point in selecting the second tree. The same process that was used with the starter tree is repeated in order to select the next sample tree. Continue in this manner until 20 or more trees have been sampled.
- Be careful to exclude uncharacteristic openings. The true tree-to-tree distances will reveal the general stand density only if openings are excluded. The same logic applies to clumps of trees or other configurations that obviously do not represent the general stand structure. Figure 13 illustrates this concept.
- Collectively, these "atypical" conditions should occur infrequently within the stand. If they don't, and if these areas become significant in cumulative size, then the overall stand description must be revised to account for the openings or clumps.
- See Montana's Technical Note MT-22 for additional detail on the zig-zag transect method (Logar and Wiersum 2003).

Figure 12: Configuration of a Zig-Zag Transect Showing Tree Selection Sequence and Direction of Travel

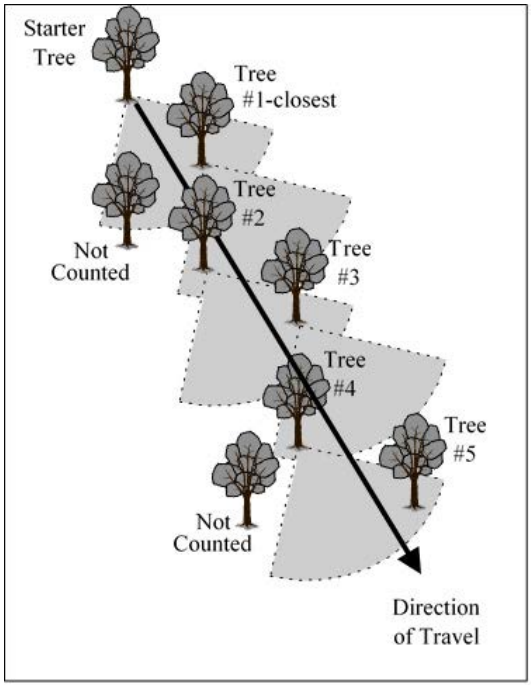
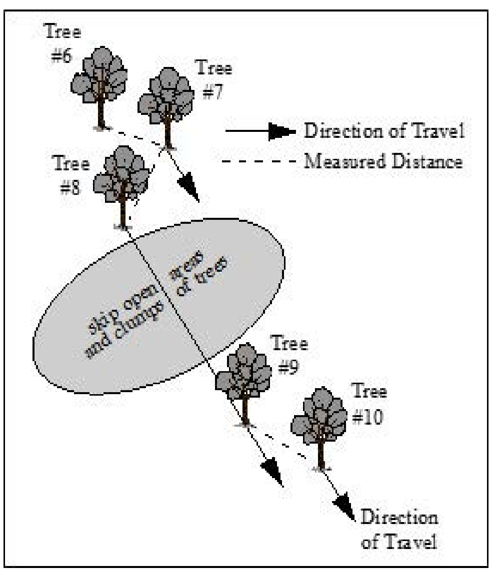


Figure 13: Using the Zig-Zag Method When Encountering Forest Openings or Clumps of Trees



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