From: Husch, B.; T.W. Beers, and J.A. Kershaw, Jr.
2003, 4th Ed. Forest Mensuration. John Wiley
and Sons, Inc., New York. 443 p.

10

NONTIMBER FOREST VEGETATION PARAMETERS

As a result of the increased need for more comprehensive information on natural resources, forest inventories have expanded their scope from only the measurement of timber quantities to other parameters of interest. Forests are not only sources of wood for traditional timber products but also for wood fiber for new industrial products. In addition, forest resources play an important role with respect to wildlife habitat, plant diversity, nutrient recycling, biogeochemical interchange, and repositories for carbon. This emphasizes the need for forest mensuration to consider measurements beyond those of traditional timber quantities. Schreuder and Geissler (1998) have indicated that the following variables associated with forest resources are measurable and useful for forest vegetation and inventory monitoring:

1. Forest vegetation
   a. Trees: number of trees, tree basal area, length, diameter, and frequency of down woody material, tree mortality and regeneration, number of diseased and insect-infested trees, removals by species
   b. Understory: number, mortality, height, percent seedlings, percent saplings, and percent mature shrubs by species
   c. Forbs, grasses: number of species, aerial extent
2. Soil
   a. Depth of organic matter, depth of A-horizon, soil series, soil quality (SQ), pH
   b. Other characteristics: erosion rate, slope, and aspect

3. Animals, relative abundance of:
   a. Birds
   b. Small ground vertebrates (mammals, reptiles, and amphibians)
   c. Ground insects
4. Water
   a. Quality, depth, and extent

In this chapter we concentrate on the forest vegetation parameters employed in multiple resource inventories, forest health monitoring, and biomass and carbon estimation which are not covered in other chapters: understory vegetation, regeneration, dead standing trees and woody detritus, total forest biomass, and carbon quantities. For description and measurement of nonvegetation parameters (soils, animals, water, air, etc.) the reader should consult references dedicated to those topics (e.g., Sutherland, 1996).

10-1. UNDERSTORY VEGETATION

Understory or lesser vegetation consists of species of nontimber value: mosses, lichens, ferns, herbs, shrubs, and natural tree regeneration. Information on the amount and characteristics of regeneration and other understory vegetation and its biomass is required for forest management decisions, evaluating forest health, and for the estimation of total vegetation biomass and its carbon content. These components are generally not measured in operational forest inventories to estimate timber quantities.

The most important characteristics of understory vegetation to measure are:

- Species composition
- Relative cover by species or species groups
- Density (number of stems or plants per unit area)
- Frequency (the proportion of samples in which a species occurs)
- Abundance (number of stems or plants per sample)
- Sizes (height, diameter), especially for tree regeneration

Table 10-1 summarizes the sampling techniques commonly applied to understory vegetation. In this chapter we review some of the more common techniques employed in estimation of these parameters. For a more complete treatment of understory vegetation measurement and sampling, refer to Kershaw and Looney (1985), Bonham (1989), or Sutherland (1996). Examples of integrated multiresource forest inventories and their design and analysis can be found in O'Brien and Van Hooser (1983), Schreuder et al. (1993), and Tallent-Halsell (1994).

TABLE 10-1. Methods[a] for Sampling Understory Vegetation

Method	Vegetation Type					
	Saplings	Seedlings	Shrubs	Herbs and grasses	Bryophytes	Fungi and Lichen
Counts						
Fixed-area plots	*	*	+	?	–	–
Point samples	+	?	?	?	–	–
Transects	*	*	*	*	?	?
Distance sampling	*	*	*	?	?	?
Cover						
Visual estimation	*	*	*	*	*	*
Frame quadrats	+	*	+	*	*	*
Point quadrats	–	+	+	*	*	*
Point samples	?	?	*	*	–	–
Transects	*	*	*	*	*	*
Biomass						
Harvesting	+	*	*	*	*	*
Reference units	+	+	+	?	?	–
Allometric relationships	*	*	*	*	?	?

Source: Adapted from Bullock (1996).

[a] *, Usually applicable; +, often applicable; ?, sometimes applicable; –, generally not applicable

10-1.1 Estimation of Frequency and Density

Frequency is based on the presence or absence of a species in sample units (plots, transects, or points) and is defined as the number of times a species is present in a given number of sample units (Raunkiaer, 1934). Frequency is usually expressed as a percentage of the total number of sample units. Percent frequency is sometimes referred to as the *frequency index* (Bonham, 1989). Density is a quantitative expression of the number of plants per unit area. Depending on the size of the plants, density is expressed as number of individuals/ft^2 or individuals/m^2 for small plants and number of individuals/acre or individuals/hectare for larger plants.

The most common method for estimating understory vegetation frequency or density utilizes fixed-area square or circular plots which can vary in size, depending on the class of vegetation to be studied. For example, Cain and de Oliveira Castro (1959) suggested the following plot areas: for the moss layer, 0.01 to 0.1 m^2; for the herb and small seedling layer, 1 to 2 m^2; for tall herbs and low shrubs, 4 m^2; for tall shrubs and low trees, 10 m^2; and for trees, 100 m^2. However, the selection of an appropriate plot size for measurement is a subjective decision and should be based on the size and spacing of individuals of a species (Bonham, 1989). Curtis and McIntosh (1950) proposed that a plot should be no larger than one or two times the mean area per individual of the most common species. Bartlett (1948) determined the most efficient size of plots for density estimation corresponded to a 20 percent absence rate (frequency = 80 percent). A number of researchers have examined efficiency in terms of sampling error and time requirements for various plot sizes and shapes (e.g., Evans, 1952; Van Dyne et al., 1963; Eddlemann et al., 1964; Hyder et al., 1965). Frequencies and densities can also be estimated using line transects (Section 11-2.2) and distance methods (Section 11-4). Density estimates for larger shrubs and small trees may be obtained using point sampling techniques (Section 11-3 and Chapter 14).

For frequency estimates, only the presence of a species on a plot needs to be noted. For density estimates, all individuals within the plot boundary need to be counted. Plot counts are expanded to per unit area counts using the ratio of unit area to plot area:

$$\text{expansion factor} = \frac{\text{unit area}}{\text{plot area}} \tag{10-1}$$

For example, if the number of individuals on 5-ft^2 plots are counted, the number of individuals/ft^2 is obtained by multiplying the count by 0.2 (1 ft^2/5 ft^2). If 100-m^2 plots are used, the number of individuals per hectare is obtained by multiplying the count by 100 [(10,000 m^2/ha)/(100 m^2/plot)].

To estimate density, each individual plant on a plot needs to be identified and counted. One of the greatest difficulties in estimating density of understory vegetation is identification of individual plants (Bonham, 1989). Strickler and

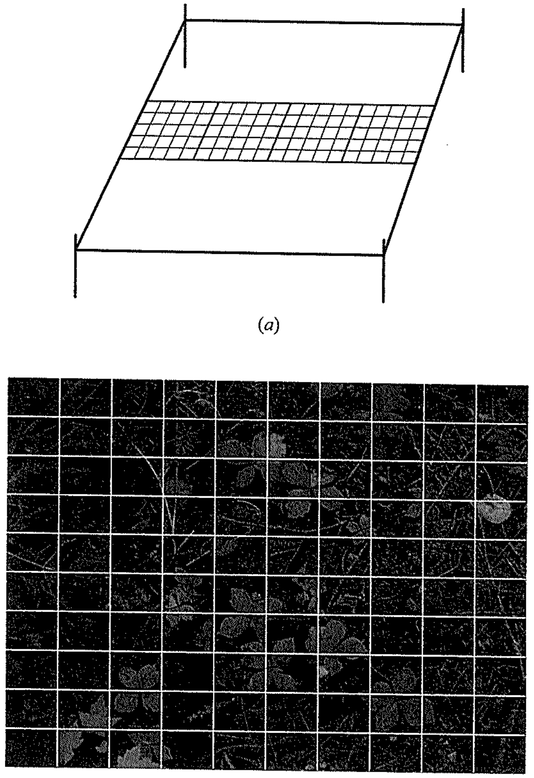
Stearns (1962) defined an individual as the aerial parts corresponding to a single root system. For single stem species, like most trees and annuals, this definition is simple to apply; however, for many grass species, clonal herbs, and multistemmed shrubs, where the number of individual plant stems per root system vary considerably, this definition is not easily applied. While the only practical counting unit for density estimation is the individual, the value of carefully defining the individual depends on the purpose of the study, definition of the unit, and precision of the count (Bonham, 1989). The number of individual stems or shoots may be more highly correlated with other parameters of interest, such as biomass and cover, than with the number of individual plants.

10-1.2 Estimation of Cover

The simplest definition of *cover* is the percentage of ground surface covered by vegetative material. Cover is generally expressed as a fraction or percentage of total area. Cover of a species or life-form expressed as a percentage of total vegetation is referred to as *relative cover*. Cover is generally measured as the vertical projection of vegetative material on to the ground surface (see Fig. 5-17 for an example of crown projection area). Cover is one of the most commonly measured vegetation parameters. Because cover is an expression of vertical projection, its measurement does not require identification of individual plants, thus estimation of cover is generally easier than estimation of density. Cover also has the advantage of being able to express measures of different life-forms (e.g., mosses, grasses, forbs, shrubs, and trees) in comparable terms. If the vegetation occurs in distinct layers (e.g., trees, shrubs, and undergrowth), then depending upon the objectives of the sample, cover of each species can be measured separately by layer (Bonham, 1989).

Cover may be estimated by measuring plant dimensions and applying formulas for regular geometric shapes. For example, crown area is often calculated by measuring crown diameter along one or more axes and applying the formula for a circle (see Section 5-5.1). For understory vegetation, cover is often estimated visually using small fixed-area plots. A frame quadrat (Fig. 10-1*a*) can be used to facilitate visual estimation. A frame quadrat divides a larger fixed-area plot into smaller subplots. The example illustrated in Fig. 10-1*a* has divided the larger plot into 100 equal-area subplots. Cover can be estimated visually for each subplot, or the subplot can be classified as either covered or not covered by a species. Cover for the larger plot is then obtained by summation of the cover values of the smaller plots.

Photographic frame quadrats (Fig. 10-1*b*) are an efficient method of estimating cover. Vertical photographs are obtained at a constant height above the vegetation or ground. A grid is superimposed on the image either by using a filter at the time of image capture or by manually overlaying a grid on the developed image. As with the normal frame quadrat, cover can be estimated visually for each subplot, or the subplot can be classified as covered or not covered. For example, a subplot can be considered covered if 50 percent of its area is occupied by a given species. Using this definition, the number of subplots in Fig 10-1*b* covered by bunchberry (*Cornus canadensis*) is 16 and the percentage cover is estimated to be 100(16/100) = 16 percent. The availability of reasonably priced high-quality digital cameras and powerful image analysis software makes photographic frame quadrats an easier and less time consuming method of obtaining cover estimates.


(*a*)

(*b*)

FIG. 10-1. Frame quadrat method for estimating vegetation cover: (*a*) frame quadrat; (*b*) photo frame quadrat.

Visual estimation of cover has the disadvantages of potential variation among different observations and the potential for high observer bias (Bonham, 1989). A number of intercept methods have been developed which eliminate much of the potential observer variation and bias. Two commonly employed intercept methods are the point intercept technique and the line intercept technique.

The *point intercept technique* involves lowering a pin through the vegetation canopy and recording the number of hits (interceptions) by species (Fig. 10-2). Percent cover is obtained by dividing the number of hits by the total number of pins. For example, in Fig. 10-2*b*, a forb is hit by 4 out of 10 pins; therefore, the percent cover for forbs is 100(4/10) = 40 percent. Similarly, grass had one hit, representing 10 percent cover, and bare ground had 5 hits, representing 50 percent cover. The point intercept technique can also be applied to vertical photographs (Fig. 10-3). As with the photo frame quadrat, a dot grid can be superimposed on the photograph and the number of dots falling on a given species counted. In Fig. 10-3, 13 dots fall on bunchberry, thus the percentage cover is estimated as 100(13/100) = 13 percent.

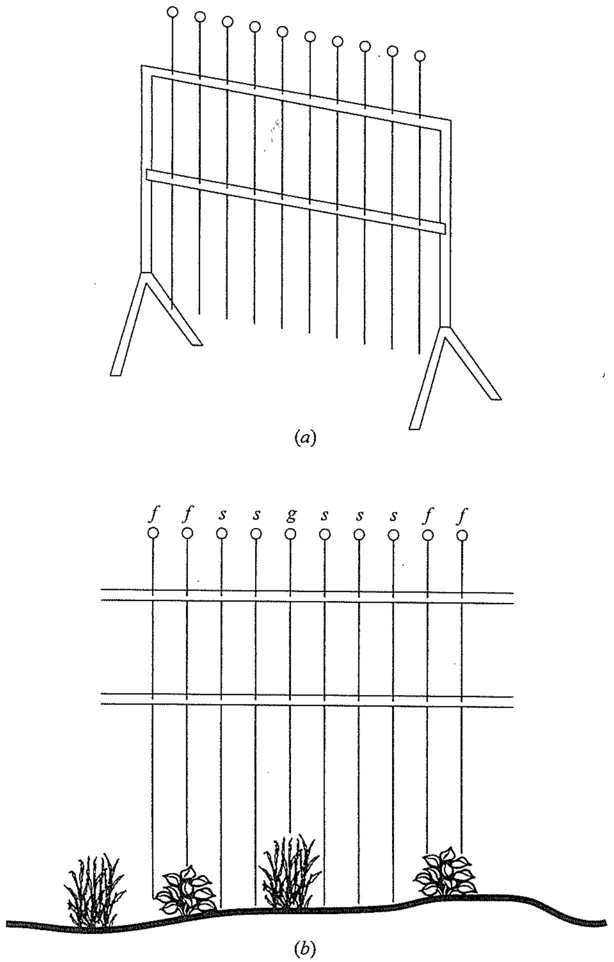


FIG. 10-2. Point intercept method for estimating cover: (*a*) point frame with 10 pins; (*b*) point frame intersections. *f*, First hit on forb; *g*, first hit on grass; and *s*, first hit on soil.

FIG. 10-3. Photographic point intercept method.

The *line intercept technique* utilizes a transect and measures the length of the transect intercepted by the vertical projection of a species (Fig. 10-4*a*). The percentage cover is estimated as the ratio of interception length to total transect length:

$$\text{percent cover} = 100\frac{\sum I}{L} \tag{10-2}$$

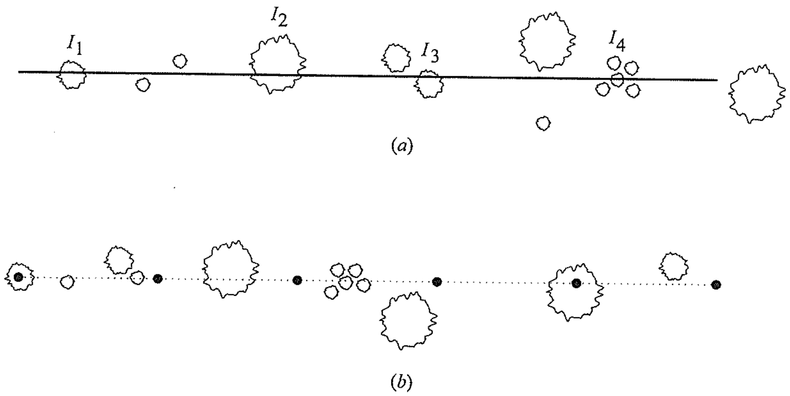


FIG. 10-4. (*a*) Line intercept technique for cover estimation; (*b*) point transect method.

where I = interception length
L = total transect length

For some species, such as trees and larger shrubs, the determination of intercepted distance can be difficult and subject to observer bias (Bonham, 1989). A point transect (Fig. 10-4*b*) is a modification of the line intercept technique.

The *point transect technique* is similar to the point intercept technique. Points along a transect are established at predetermined intervals. Each point is assessed to determine if it is covered or not covered. The percent cover is estimated as the number of covered points divided by the total number of points.

Bonham (1989) describes another technique for estimating cover using a modification of sampling with probability proportional to size (Section 14-1). An angle gauge (Fig. 10-5*a*) is built using two sticks. The gauge constant is determined from the ratio of stick length to crossbar length:

$$K = \frac{L}{I} \tag{10-3}$$

where K = gauge constant
L = stick length
I = crossbar length

This gauge constant, K, is the reciprocal of the gauge constant k used in horizontal point sampling (Section 11-3.1). Plants are counted if the diameter of their associated crown cross section is greater than the projected crossbar length (Fig. 10-5*b* and *c*). The percent cover represented by each plant counted is determined from the ratio of the area of a circle whose diameter equals the crossbar length to the area of a circle whose radius equals the stick length:

$$\text{percent cover} = 100\frac{\pi(I/2)^2}{\pi L^2} = 100\frac{I^2}{4L^2} = 25\frac{I^2}{L^2} = \frac{25}{K^2} \tag{10-4}$$

If $K = 5$, each plant counted represents 1 percent cover. Total cover is obtained by counting all plants in a 360° search around the sample point.

10-1.3 Estimation of Biomass

Interest in *understory biomass* has increased because of its role in biodiversity, global climate change, carbon sequestering, wildlife habitat evaluation, and forest fuel assessment. Understory biomass may be measured directly using harvest techniques or measured indirectly using a variety of nondestructive measurements and regression equations relating biomass to these measures.

Harvest methods may employ either complete removal of vegetation within a sample unit or some sort of proportional harvesting scheme. When using complete removal methods, all vegetation within a predefined sample area is removed. Often, the plot boundaries are projected vertically and only vegetation within the plot space is removed. Portions of plants rooted within the plot boundary but projecting out of the plot space are discarded from the sample. Similarly, parts of plants not rooted within the plot boundary, but projecting into the plot space, are counted. The clipped vegetation may be weighed fresh or dried and may be separated into components (foliage, branches, stems), depending on the requirements of the survey. In some surveys, clipped vegetation may be weighed fresh in the field and a fixed proportion of the material selected and dried. A ratio between the fresh weight and dried weight of the subsample is then used to estimate dried weight for the entire sample. Biomass per unit area is obtained by expanding the plot measurement to per unit area values using an appropriate expansion factor [eq. (10-1)].

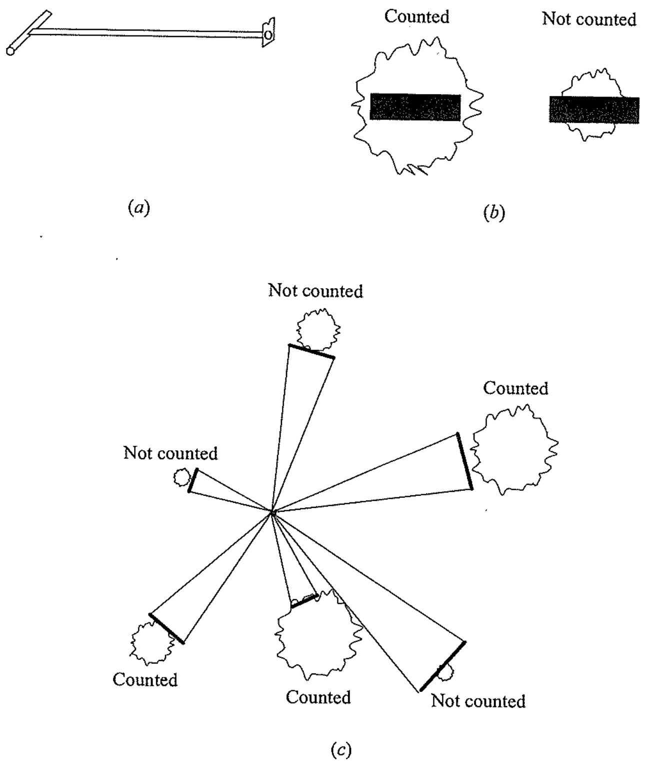


FIG. 10-5. Sampling cover with probability proportional to size: (*a*) angle gauge; (*b*) counting cover; (*c*) cover point sample. (Adapted from Bonham, 1989.)

If individuals are randomly distributed (i.e., Poisson distributed), $I_H = 1$. If $I_H < 1$, the distribution is more systematic (i.e., equally spaced). The smaller the value of I_H, the more regular the spacing. If $I_H > 1$, the distribution is clustered.

Vertical sampling (Section 11-3.4) is an overlooked alternative to using small fixed-area plots to obtain regeneration counts. Descriptions of the application of vertical sampling to regeneration assessment are found in Beers and Miller (1976) and Eichenberger et al. (1982).

In the *stocked-quadrat method*, a sample plot is stocked if it has at least one seedling of the species of interest. The presence or absence of a tree on the plot, not the total number, is the primary focus of the stocked-quadrat method. The method emphasizes the evaluation of tree distribution rather than tree density. The basic idea is to divide an area into small squares of a size such that one tree per square represents full stocking at maturity. Stein (1984b) pointed out that the size of the quadrat can be determined as the reciprocal of the number of stems per unit area that constitute full stocking. Thus, if full stocking is 250 stems per acre, the presence of trees should be checked on plots 1/250 acre in size; if full stocking is 2000 stems per hectare, plot size should be 1/2000 ha. Plot size can also be determined from ideal spacing. For example, if full stocking is 2500 stems per hectare, the ideal tree spacing is $\sqrt{10{,}000/2500} = \sqrt{4} = 2\,\text{m}$. The corresponding plot size is $(\text{spacing})^2$. However, Kershaw (in review) found that circular quadrats, where size is determined as the reciprocal of full stocking density, significantly underestimated stocking percentage. Circular plots with a radius equal to half of the diagonal spacing (spacing $\times \sqrt{2}/2$) were the optimal size for obtaining an unbiased estimate of stocking percentage.

The number of stocked quadrats in relation to the total number of plots gives the *stocking percentage*:

$$\%\ \text{stocking} = 100\,\frac{\text{number of stocked quadrats}}{\text{total number of quadrats}} \tag{10-6}$$

A regression of the form $Y = b_0 + b_1X^2$ can be prepared where Y is the seedlings per unit area, X the stocking percentage, and the b values are constants. With this function the percentage of stocked quadrats can be used to estimate the number of seedlings per unit area.

Dennis (1984) describes *distance-sampling methods* as an alternative to the use of fixed-area sample plots for evaluating forest tree regeneration. He summarized the several forms of distance sampling as:

1. Measuring the distance from a randomly located point to the nearest tree
2. Measuring the distance from a randomly selected tree to its nearest neighbor

3. Measuring the point-to-tree distance as in form 1, then measuring the distance to the nearest neighbor lying beyond a line through the first tree drawn perpendicular to the original point-tree line (*T-square sampling*)
4. Measuring the distances from a randomly located point to the first, second, third, . . . , jth nearest tree

All of these methods require several repetitions to obtain an adequate sample size. These distance methods permit estimation of the number of trees per unit area (density) and an assessment of the spatial pattern of the trees. The use of distance methods for estimation of density and other stand parameters is discussed in Section 11-4.

Regeneration can also be obtained from initial plantation establishment. The original density of a plantation (number of stems per unit area) is determined by the spacing used in planting. The density is

$$N = \frac{A}{LR} \tag{10-7}$$

where N = number of plants per unit area
A = size of area unit (hectare = $10{,}000\,\text{m}^2$; acre = $43{,}560\,\text{ft}^2$)
L = distance between plants in a row (m or ft)
R = distance between rows (m or ft)

For example, the density per acre for spacing of 6 ft × 6 ft is

$$N = \frac{43{,}560}{6(6)} = 1210\ \text{plants/acre}$$

Estimation of the survival or density of the plantation at some age can be determined by sampling as described in Chapter 13. Tree nurseries may require an inventory of the total number of seedlings and their health or condition. Estimates can be made using small sample plots and counting the number of seedlings, measuring their heights, and determining their health and their suitability for planting. From the sample plots, estimates can be made of total amounts in the nursery.

10-2. WOODY DETRITUS

The Forest Inventory Assessment (FIA) field guide (FIA, 2001) has emphasized that down woody debris is an important component of forest ecosystems of interest to wildlife biologists, ecologists, mycologists, foresters, and fuel specialists. Information on down woody debris helps describe:

- Quality and status of wildlife habitats
- Structural diversity within a forest
- Fuel loading and fire behavior
- Carbon sequestration—the amount of carbon stored in dead wood
- Storage and cycling of nutrients and water—important for site productivity
- Quantity available for possible commercial utilization

Harmon and Sexton (1996) have prepared guidelines for measurements of woody detritus in forest ecosystems. They recommend that the terms *woody detritus* and *woody debris* include all forms of dead woody material above- and belowground. Aboveground woody detritus can be divided into coarse or fine fractions. Minimum dimensions for coarse woody detritus are usually 10 cm diameter at the large end and 1.5 m in length. Smaller pieces than these are usually considered fine woody detritus. *Coarse fractions* can in turn be divided into *snags* (or *standing dead*) and *logs* (or *dead and downed*).* The separation of snags from logs is usually at a 45° angle. In addition to snags, stumps should be recognized in managed settings. They recommend that the short vertical pieces resulting from natural processes always be called snags, and that the term *stump* be reserved for short vertical pieces created by cutting. *Fine fractions* can also be divided into suspended or downed fractions. In the case of suspended fine wood, one must distinguish between that attached to living woody plants and that attached to dead woody plants. Woody branches, twigs, and bark pieces less than 1 cm in diameter can be very numerous and are treated as fine litter. They recommend that dead fine roots be separated from dead coarse roots at a diameter of 1 cm. Belowground woody detritus has rarely been studied, but they recommend that it be divided into buried wood (very decayed material in the mineral soil or forest floor) and dead coarse roots.

10.2.1 Fixed-Area Plots

Fixed-area plots are the simplest and most direct method of inventorying woody detritus, although line intercepts and variable radius plots have been used (see Harmon and Sexton, 1996). The volume of coarse woody detritus consisting of snags, stumps, logs, and piles of decomposed bark and wood accumulated at the base of snags (referred to as *blobs*) can be measured on fixed-area plots of from 0.05 to 0.20 ha, depending on the forest type. For logs, the diameters at both ends and midpoint and length are measured to calculate volumes (hollows are deducted). For snags, the dbh is measured for intact boles and the diameters at the base and top and length for boles that have broken. The base and top diameters and length are recorded for stumps (or a midpoint diameter). The diameter at the base is measured for blobs. These volumes must be converted to weight using estimates of wood specific gravity (g/cm^3). Downed fine wood can be weighed directly on portable scales and samples taken to estimate moisture content for conversion of the field weights to dry weight. Harmon and Sexton (1996) give detailed instructions for the estimation of attached dead wood, buried wood, and dead coarse roots.

10-2.2 Line Intersect Sampling for Woody Debris

Line intersect sampling (LIS) was developed initially to estimate the amount of woody debris or slash; for example, residue after logging, or to estimate the amount of fuel wood and inflammable material on the ground. As Shiver and Borders (1996) explain, the procedure to carry out a line intersect sample for this purpose consists of two steps:

1. Establish a line of a given length across the area of interest.
2. Traverse the line, maintaining the initial direction and record the diameter(s) of every piece of woody material that intersects the line. Diameter(s) may be measured at the midpoint of the piece, at both ends, or where the line crosses the piece.

With this procedure, the estimate of total amount $\hat{T}$ (number, volume, or weight) of material per unit area is

$$\hat{T} = \frac{\pi}{2L} \sum_{i=1}^{n} \frac{x_i}{l_i} \qquad (10\text{-}8)$$

where L = length of sample line
l_i = length of ith intersecting sample element
x_i = characteristic of interest on ith sample element

If l_i and L are measured in feet, $\hat{T}$ estimates x per square foot. If l_i and L are measured in meters $\hat{T}$ estimates x per square meter. If the characteristic of interest is cubic volume, the cubic volume of the ith element is

$$x_i = \pi \left(\frac{d_i}{2}\right)^2 l_i \qquad (10\text{-}9)$$

where x_i = cubic volume of ith element
d_i = diameter of ith element where it intersects line
l_i = length of ith element (note that d_i and l_i are measured in the same units, feet or meters)

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*Salvageable dead trees are dead trees with intact bark. This does not include snags that have lost their bark and for the most part contain no solid wood. Nevertheless, dead snags of unusable timber must also be included in the biomass.

Substituting eq. (10-9) into eq. (10-8) and simplifying, the total volume of material per unit area (square foot or square meter) is

$$\hat{T} = \frac{\pi}{2L}\sum \frac{\pi(d_i/2)^2 l_i}{l_i} = \frac{\pi^2}{8L}\sum_{i=1}^{n} d_i^2 \qquad (10\text{-}10)$$

The volume of woody debris per acre (ft^3/acre) is obtained by multiplying $\hat{T}$ by 43,560 (1 acre = 43,560 ft^2):

$$\hat{T}/\text{acre} = 43{,}560\hat{T} = 43{,}560\frac{\pi^2}{8L}\sum_{i=1}^{n} d_i^2 = \frac{5445\pi^2}{L}\sum_{i=1}^{n} d_i^2 \qquad (10\text{-}11)$$

where $\hat{T}$/acre = cubic feet of woody debris per acre
d_i = diameter of ith element (ft)
L = transect length (ft)

If d_i is measured in inches and L in feet, the volume of woody debris per acre (ft^3/acre) becomes

$$\hat{T}/\text{acre} = \frac{5445\pi^2}{L}\sum_{i=1}^{n}\left(\frac{d_i}{12}\right)^2 = \frac{5445\pi^2}{144L}\sum_{i=1}^{n} d_i^2 = \frac{373.2}{L}\sum_{i=1}^{n} d_i^2 \qquad (10\text{-}12)$$

The volume of woody debris per hectare (m^3/ha) is obtained by multiplying $\hat{T}$ from eq. (10-10) by 10,000 (1 ha = 10,000 m^2):

$$\hat{T}/\text{ha} = 10{,}000\hat{T} = 10{,}000\frac{\pi^2}{8L}d_i^2 = \frac{1250\pi^2}{L}\sum_{i=1}^{n} d_i^2 \qquad (10\text{-}13)$$

If d_i is measured in centimeters and L is measured in meters, the estimate becomes

$$\hat{T}/\text{ha} = 10{,}000\hat{T} = 10{,}000\frac{\pi^2}{8L}\sum_{i=1}^{n}\left(\frac{d_i}{100}\right)^2 = \frac{10{,}000\pi^2}{80{,}000L}\sum_{i=1}^{n} d_i^2$$
$$= \frac{\pi^2}{8L}\sum_{i=1}^{n} d_i^2 = \frac{1.2337}{L}\sum_{i=1}^{n} d_i^2 \qquad (10\text{-}14)$$

where $\hat{T}$/ha = cubic meters of wood debris per hectare
d_i = diameter of ith element (cm)
L = transect length (m)

As it happens, eq. (10-14) for m^3/ha is the same as eq. (10-10) for m^3/m^2; the difference is that d is measured in centimeters in eq. (10-14) and in meters in eq. (10-10). For detailed treatment of this method of sampling and an estimate of variance, see Shiver and Borders (1996).

The FIA (2001) method measures coarse and fine woody debris using transects established on each subplot of a four-plot cluster. Each transect starts at the subplot center and extends to the edge of the subplot (58.9 ft). Each transect is segmented according to the length of different condition classes. Individual pieces of coarse and fine woody debris are tallied or counted if they meet the rules for these types of debris. The diameters and lengths of coarse woody debris that is crossed by the transect are measured. On the fine woody debris transects, counts are made of three size classes. Depth measurements are made of the duff and litter layers and fuel bed at two points along each transect. In addition, a microplot (6.8 ft radius) is established in each of the four subplots. On microplots, the percent cover and height of live and dead shrubs, live and dead herbs, and litter are measured.

10-2.3 Other Methods

Gove et al. (2001) describe a *point relaskop sampling* (PRS) method for sampling that portion of coarse woody debris consisting of downed logs. The method is analogous to horizontal point sampling with an angle gauge. In PRS the angle gauge at a sampling point is sighted on the downed log lengths to determine whether a log is "in" or "out." The angle of the gauge determines a squared length factor (L) such that each "in" log represents L square units (feet or meters) of squared length per unit area.* Any quantity that can be associated with a log can be expanded to a per unit area estimate. For PRS, the equation for the estimate $\hat{y}$ (quantity per unit area) on any given sample point where m logs have been found to be "in" is

$$\hat{y} = L\sum_{i=1}^{m}\frac{y_i}{l_i^2} \qquad (10\text{-}15)$$

where L = squared length factor for angle of gauge
y_i = quantity of interest (number, volume, biomass) of ith log
l_i = length of ith "in" log

A simple relaskop can be constructed from a wooden slat and two nails (Fig. 10-6a). The relaskop angle v is formed from the ratio of reach length r and

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*Logs are selected with probability proportional to the square of their length. This is analogous to horizontal point sampling (Section 11-3), where standing trees are selected with probability proportional to their basal area (i.e., diameter squared).