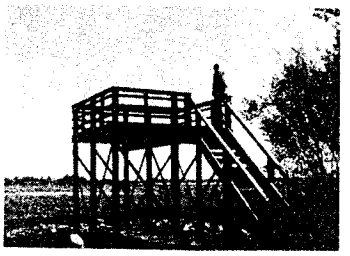
US Army Corps of Engineers



ENVIRONMENTAL LABORATORY

ENVIRONMENTAL IMPACT RESEARCH PROGRAM

TECHNICAL REPORT EL-95-24

PRISM SAMPLING

Section 6.2.3, U.S. ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL

by

Wilma A. Mitchell

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

H. Glenn Hughes

Pennsylvania State University–DuBois
DuBois, Pennsylvania 15801

and

Larry E. Marcy

U.S. Fish and Wildlife Service
900 Clay Street, Vicksburg, Mississippi 39180-2975

July 1995

Final Report

Approved For Public Release; Distribution Is Unlimited

Prepared for DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under EIRP Work Unit 32420

The contents of this report are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products.

PRINTED ON RECYCLED PAPER

PREFACE

This work was sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), as part of the Environmental Impact Research Program (EIRP), Work Unit 32420, entitled Development of U.S. Army Corps of Engineers Wildlife Resources Management Manual. Mr. Dave Mathis was the EIRP Coordinator at the Directorate of Research and Development, HQUSACE. The Program Monitors for the study were Dr. John Bushman, Mr. F. B. Juhle, and Mr. Forrester Einarsen, HQUSACE.

This report was prepared by Dr. Wilma A. Mitchell, Stewardship Branch (SB), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES); Dr. H. Glenn Hughes, School of Forest Resources, Pennsylvania State University (DuBois campus), DuBois, PA; and Mr. Larry E. Marcy, U.S. Fish and Wildlife Service, Vicksburg, MS. Dr. Hughes and Mr. Marcy were assigned to EL under an Intergovernmental Personnel Act agreement during the development of this report. Mr. Chester O. Martin, SB, was principal investigator for the work unit. WES review was provided by Messrs. Martin, Michael Waring, and Darrell Evans, SB.

The report was prepared under the general supervision of Mr. Hollis Allen, Acting Chief, SB, EL; Dr. Robert M. Engler, Chief, Natural Resources Division, EL; and Dr. John W. Keeley, Director, EL. Dr. Russell F. Theriot, WES, was the EIRP Program Manager.

At the time of publication of this report, Dr. Robert W. Whalin was Director of WES. COL Bruce K. Howard, EN, was Commander.

This report should be cited as follows:

Mitchell, Wilma A., Hughes, H. Glenn, and Marcy, Larry E. 1995. "Prism sampling: Section 6.2.3, U.S. Army Corps of Engineers Wildlife Resources Management Manual," Technical Report EL-95-24, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

NOTE TO READER

This report is designated as Section 6.2.3 in Chapter 6 -- CENSUS AND SAMPLING TECHNIQUES, Part 6.2 -- VEGETATION SAMPLING TECHNIQUES, of the U.S. ARMY CORPS OF ENGINEERS WILDLIFE RESOURCES MANAGEMENT MANUAL. Each section of the manual is published as a separate Technical Report but is designed for use as a unit of the manual. For best retrieval, this report should be filed according to section number within Chapter 6.

PRISM SAMPLING

Section 6.2.3, U.S. ARMY CORPS OF ENGINEERS
WILDLIFE RESOURCES MANAGEMENT MANUAL

TECHNIQUE SELECTION 4
SAMPLING CONCEPT 4
STUDY DESIGN 6
Site Selection 6
Sampling Design 6
BAF Selection 7
EQUIPMENT 8
PREPARATION 8
USE OF THE WEDGE PRISM 9
Procedure 9
Alternative Procedures 10
Prism Calibration 11
MEASUREMENT OF TREE DIAMETER . . 12
Diameter Tape 12
Biltmore Stick 13
Irregular Trees 14
PROCEDURE FOR DATA COLLECTION . . 16
RECORDING 17
Species Names 17
Diameter Classes 18
DATA ANALYSIS 18
Data Summary 18
Basal Area 20
Density 24
Average Diameter 27
Volume 28
SOURCES OF ERROR 28
Wedge Prism 28
Borderline Trees 29
Boundary Overlap 29
LITERATURE CITED 31
APPENDIX A: RELATIONSHIP OF SIGHTING ANGLE, PLOT RADIUS, AND BAF A1
APPENDIX B: DETERMINATION OF PLOT RADIUS B1
APPENDIX C: CALIBRATION OF THE WEDGE PRISM C1
APPENDIX D: PRISM SAMPLING DATA FORMS D1

Prism sampling is a vegetation sampling technique used to determine basal area, species composition, density, and timber volume of trees. It has numerous applications in forestry, wildlife management, and other natural resources disciplines. Prism sampling is fast, easily applied, and particularly well suited for reconnaissance inventories. This report describes the sampling concept, procedure for application, and data analysis.

The prism sampling technique is also called point sampling, the Bitterlich method, and variable radius plot sampling. The concept of prism sampling is based on a variable-radius plot, rather than a fixed-area plot; it was developed and first reported in 1948 by Walter Bitterlich, a forest engineer of Salzburg, Austria (Avery 1967). In this report, the technique will be called prism

sampling because the wedge prism is the primary instrument for its performance as described herein. Use of this name also prevents confusion with point sampling methods designed to estimate ground cover.

TECHNIQUE SELECTION

Prism sampling is an efficient technique for large-scale surveys of forest stands. Time and costs are reduced because plot boundaries do not have to be established, equipment is inexpensive, and data can be collected by one individual if necessary.

Personnel requirements usually depend upon the intensity of sampling. Information on basal area and species composition is readily collected by 1 person, but more detailed information on diameter, height, and tree quality requires 2 or 3 people. Although 1 person can conduct prism sampling, data collection is more efficient when a second crew member records data.

Prism sampling is used to acquire forest stand information essential for natural resources management. This sampling method has traditionally been applied by foresters to determine stand stocking and volume and to develop harvesting schedules. However, the technique is highly appropriate for the evaluation of vegetation associated with wildlife habitat. The procedure described in this report emphasizes basal area, density, and average tree diameter, which are major parameters sought in vegetation analyses of wildlife habitat. A first-time survey may be used to collect data for a specific study or to establish a baseline for future reference. The establishment of permanent sample points allows for subsequent surveys to determine changes within a stand over time.

SAMPLING CONCEPT

In its most elementary form, prism sampling is a method of selecting trees to be sampled on the basis of their sizes rather than by their frequency of occurrence (Avery 1967). In conventional plot sampling, fixed-area plots are established within a stand, and the probability of sampling a species is proportional to its frequency of occurrence. Prism (variable-radius plot) sampling is based on the premise that each tree has an imaginary circular plot whose radius is directly proportional to the tree's stem diameter. Sample points are established throughout the stand, and trees whose associated plots contain a point are sampled (Fig. 1). The probability of an individual tree being

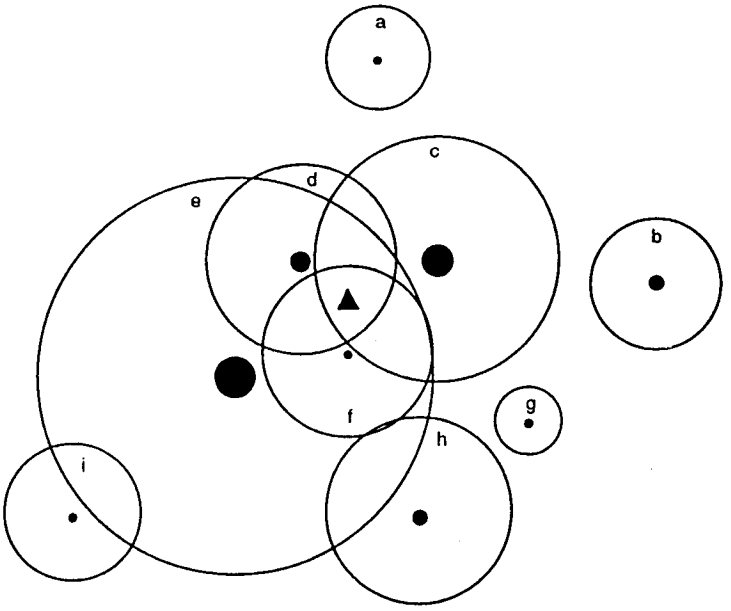


Figure 1. Imaginary plots of trees with various diameters. Letters refer to individual trees and associated plots. In this example, only trees c, d, e, and f would be measured at the sample point, which is represented by the black triangle (from Hovind and Rieck 1970)

sampled is proportional to the diameter of its stem; therefore, the larger, more dominant members of the forest community are emphasized in an inventory.

A wedge prism is a ground glass sighting device used to ascertain the trees to be sampled. This instrument creates a sighting angle that defines the ratio of stem diameter to plot radius and, thus, the plot size for each sample tree. The prism allows the data collector to visually determine whether the sample point is "inside" or "outside" a tree's plot. If the point is inside the plot, the tree is sampled; i.e., the stem diameter is measured at 4.5 ft (referred to as diameter-at-breast-height, or dbh).

Regardless of its size or position relative to the sampling point, each sample tree represents a fixed amount of basal area per acre. Basal area is the cross-sectional area of a tree stem measured at dbh. The sighting angle of a prism has a unique BA/acre value, termed the Basal Area Factor (BAF). It is this value that allows determinations of BA/acre, an important forest stand parameter from which other parameters, such as density, stocking, and volume, may be calculated. The relationships of sighting angle, plot radius, and basal area factor are discussed in detail and illustrated in Appendix A.

STUDY DESIGN

Site Selection

Aerial photographs should be studied and a ground reconnaissance should be conducted to determine the size and characteristics (e.g., terrain, forest heterogeneity) of the study area. The sites to be sampled should be selected and located on a map of the study area prior to data collection. If the area is large with fairly homogeneous forest stands, sites should be randomly selected. However, if the study area consists of diverse forest types (e.g., hardwood, coniferous, and mixed), it may be preferable to select sites representative of these types in proportion to the amount of area occupied by each.

Sampling Design

Sample points. Completely random sampling, in which sample points are located independently of one another, minimizes bias and satisfies statistical assumptions. However, random sampling is more difficult and time consuming than other sampling designs. Systematic (grid) sampling is probably the easiest design, in which points are located at predetermined intervals along transects evenly spaced throughout the stand. However, these points are not randomly located for purposes of statistical analysis. As a compromise, a design consisting of a combination of random and systematic sampling may be used to locate sample points. Points may be randomly spaced along fixed lines, or fixed points may be located on randomly spaced lines. It can then be assumed that the trees sampled represent overall stand conditions.

There is no standard spacing for sampling points on a transect. However, points should be located far enough apart to prevent sampling overlap and yet adequately cover the entire study area.

Sampling procedure. At each point, the trees to sample are determined with a wedge prism, each sample tree is identified to species, and its dbh is measured. Basal area, density, and average tree diameter are then calculated from these data. Timber volume can also be determined but is not included in this discussion because it has limited application in wildlife habitat analysis. Tree height may be read with a clinometer for each sample tree but cannot be calculated from diameter data.

Standard methods for sampling borderline trees and compensating for boundary overlap should be established and used throughout the study. This will help to eliminate bias and reduce error in the final results. Suggestions are given for these procedures in the section SOURCES OF ERROR.

Sample size. Sample size can be calculated if data are separated by points. A formula commonly used to calculate sample size (Snedecor 1950) is

$$N = \frac{s^2 t^2}{d^2}$$

where,

N = number of sample points required

s = standard deviation

t = t-value with n-1 degrees of freedom

d = allowable error (i.e., arithmetic mean of the sample total times the designated percent accuracy)

Standard deviations are larger for prism sampling than for fixed area sampling within the same stand; therefore, more points are required to obtain an adequate sample. However, the speed of prism sampling usually compensates for the increased sample size (Burkhart et al. 1984).

The number of sampling points will depend upon a combination of stand size and vegetation characteristics. Beers and Miller (1973) recommended the following guidelines based on acreage for prism sampling in mixed hardwoods of the central United States:

If area in acres is	Number of points required is
<10	10
11-40	1 per acre
41-80	20 + 0.50 (number of acres)
81-200	40 + 0.25 (number of acres)
>200	(Use sample size formula above)

The number of points needed per acre may vary in other forest types or regions, and stand characteristics such as tree density, stand age, and species composition may influence sample size. For example, fewer sampling points will be required in homogeneous stands, in which trees are of approximately the same age and size, than in heterogeneous stands, where there is great diversity in tree ages and sizes.

BAF Selection

To ensure maximum sampling efficiency and statistical accuracy, the basal area factor (BAF) should match the stand size and density. Prisms should have BAFs based on the average diameter of trees in the stands to be sampled (Avery

and Burkhart 1983, Chambers and Brown 1983). Small BAFs are effectively used in scattered stands to create larger plot radii and thus ensure sufficient sampling. Large-diameter trees require larger BAFs to reduce the chance of excessively large field samples. Grosenbaugh (1952) suggested using BAF 10 or larger. However, Avery and Burkhart (1983) recommended using BAF 10 for second growth sawtimber or dense pole timber and BAF 5 for sparse stands of pole timber. BAF 20 should be used for large-diameter timber, but extremely large timber may require BAFs of 30 to 60 (Dilworth and Bell 1979).

EQUIPMENT

A diameter tape (D-tape) and Biltmore stick are needed to measure tree diameters, and a wedge prism is required to determine the trees to sample. A 20-ft dbh tape (76-in. diameter) with claw hook is recommended; one with black graduations on white enameled steel line is easiest to read. The Biltmore stick should be calibrated for a 25-in. (64-cm) reach and be capable of measuring diameters to 74 in. Wedge prisms of various sizes and shapes may be used; the two most likely to be chosen are those with BAF 10 or 20. A marker is needed to identify the sample point so personnel can properly position the prism. Stake wire flags are highly recommended because they are lightweight and convenient to transport.

These inexpensive items can be purchased from forestry retailers. The approximate costs are: $50.00 for a diameter tape with leather case, $35.00 each for a Biltmore stick and a clear wedge prism with leather case, and $20.00 for 100 stake wire flags and flag carrier (1994 prices).

PREPARATION

Obtaining accurate results with prism sampling depends on proper use of the equipment, especially the wedge prism. Field personnel should learn to use the prism, dbh tape, and Biltmore stick before initiating fieldwork. This will increase efficiency and eliminate bias resulting from inexperience during early sampling. Instructions for use of these instruments are provided below under USE OF THE WEDGE PRISM and MEASUREMENT OF TREE DIAMETER.

Valuable time can be saved if identification of trees is learned prior to fieldwork, especially if the area encompasses a large number of species. The data collector should learn to identify trees by the bark, twigs, and growth form as well as the foliage, since it may be difficult to see individual leaf shapes on tall trees in dense forests.

Several trial runs should be conducted in the forest types to be sampled before actual fieldwork begins. This will provide opportunity for field personnel to gain proficiency in tree identification, use of the prism, and measurement of dbh before initiating data collection.

USE OF THE WEDGE PRISM

A wedge prism is a tapered wedge of glass that bends or deflects light rays at a specific offset angle. When a tree stem is viewed through the prism, the bole (trunk) appears to be displaced, as if seen through a camera range finder. The amount of displacement determines whether the point is inside or outside the tree's plot, and subsequently whether it will be sampled.

Procedure

Correct use of the prism is critical in obtaining accurate data with the prism sampling technique. Instructions for using the prism are provided below.

1. Hold the prism over the sample point and sight on all trees within 360 deg of the point. The prism should be held at a comfortable and consistent distance from the eye and viewed at breast height (4.5 ft above the base of the tree) (Fig. 2a). The prism should be held vertically (i.e., perpendicular to the ground surface) and not tilted or dipped away from that plane (Fig. 2b).

Figure 2. The wedge prism should be held (a) a consistent and comfortable distance from the eye; and (b) vertically over the sample point

2. Use a systematic approach to sighting trees. For example, you may face due north to start and rotate clockwise until you have returned to the first tree sighted. Be careful to keep the prism over the sample point as you change your body position.

3. Determine the trees to sample:

   a. A tree is sampled if the image of the tree viewed through the prism is not completely offset (Fig. 3b). This means that the sample point is inside the tree's plot.

   b. A tree is not sampled (the point is outside the plot) if the image is completely offset (Fig. 3a).

   c. A borderline tree is one in which the image is not definitely overlapping or offset (neither inside nor out of the plot) (Fig. 3c). Whether this tree is sampled or not depends upon the sampling design. A frequently used method is to sample every other borderline tree.

Alternative Procedures

Obstruction. Problems may be encountered in obtaining a clear image of a tree and its offset image. The major difficulties involve tree density and vegetative obstruction. In a dense stand, the large number of trees sometimes makes it difficult to see the image associated with only one tree. When the

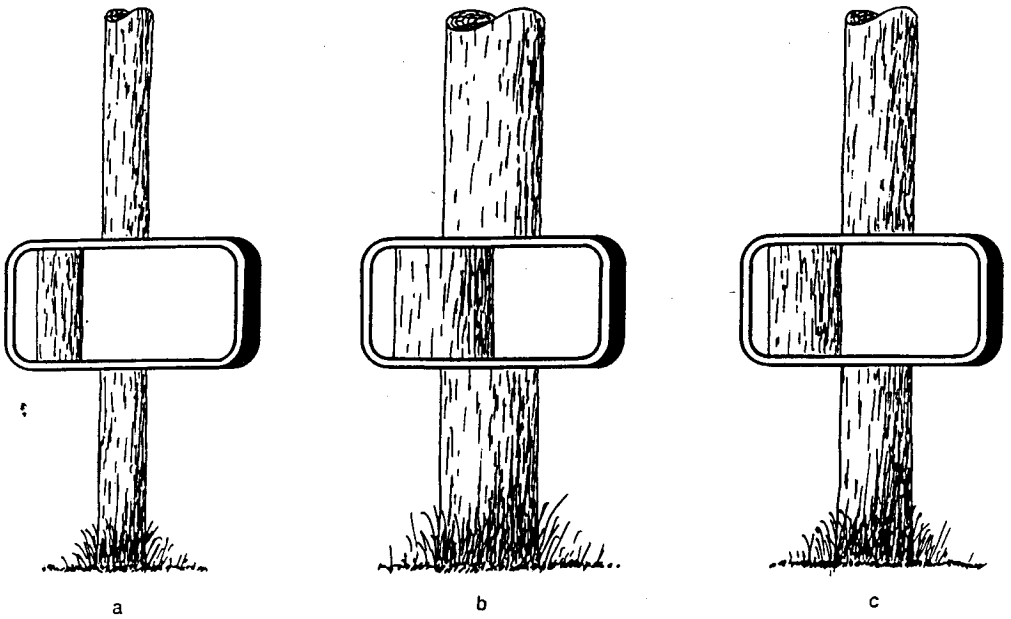


Figure 3. The wedge prism indicates that a tree (a) is not sampled if the image is completely offset; (b) is sampled if the image is overlapping; (c) is considered borderline if the image is neither definitely offset nor overlapping

sighting path to a tree is blocked, the data collector should move away from the sampling point until the tree can be distinguished from others; however, the prism must be kept the same distance from the tree that it would be at the sampling point.

Foliage, underbrush, or vines surrounding a tree trunk can also preclude a clear image. In such situations, a standard point higher than 4.5 ft may be used to sight on the trunk. If the image is not completely offset, the tree is sampled. If the image is completely offset and the data collector cannot obtain a better view, the plot radius can be calculated and compared with the distance to the tree, thus determining whether that tree is to be sampled. To speed up fieldwork, a table of plot radii (limiting distances) has been prepared for a specified BAF by using the plot radius factor (PRF) of the prism and varying the dbh. Instructions for finding the plot radius and a table showing limiting distances for a 10 BAF prism are provided in Appendix B.

Leaning trees. If a tree leans to the right or left when viewed from the sampling point, the prism should be turned parallel to the vertical axis of the tree to ensure that a proper image is obtained (Avery and Burkhart 1983). Trees that lean severely toward or away from the sampling point and are not obviously sample trees should be treated similarly to obstructed trees. That is, the distance to the tree and the dbh of the tree should be measured and compared with the appropriate plot radius (limiting distance) value. The center of this type of leaning tree is considered to be a point projected 4.5 ft vertically above the center of the tree at groundline (Avery and Burkhart 1983).

Slope. Corrections must be made when slope is 15 percent or greater; i.e., a 15-ft rise or drop in elevation per 100 ft (horizontal) (Stage 1959). Compensation for slope can be made by tilting the top edge of the prism through the estimated slope angle so that the prism is held at a right angle to the ground (Avery 1967).

Prism Calibration

Precision-tested prisms are recommended whenever feasible because the BAF value of exact numbers (e.g., 5, 10, or 20) allows faster computations than values with decimals, such as 4.5, 9.8, or 19.3. Prisms ground to within 1 min of a specified angle usually result in a maximum error of only 2 percent for a BAF 10 prism. However, inexpensive prisms, whose exact BAFs are unknown, should be carefully calibrated. It may even be desirable to calibrate all instruments, regardless of price or stated precision, because individual eyesights vary

appreciably. The procedure for calibrating wedge prisms is provided in Appendix C.

MEASUREMENT OF TREE DIAMETER

Diameter at breast height is the variable most frequently collected for trees during prism sampling. It is measured at 4.5 ft above ground level. Procedures for using the diameter tape and Biltmore stick are provided below.

Diameter Tape

Circumference is the variable actually measured with a diameter tape. The tape graduations, based on the relationship between the circumference and diameter of a circle, give direct readings of tree diameter, usually to the nearest 0.1 in. If a steel diameter tape is level and pulled taut, it is the most consistent method of measuring dbh (Avery 1967).

The tape is wrapped around the tree trunk and secured with the claw hook if the trunk has a large diameter. It is read to the nearest inch, where the first marker line on the tape overlaps the number of inches (Fig. 4).

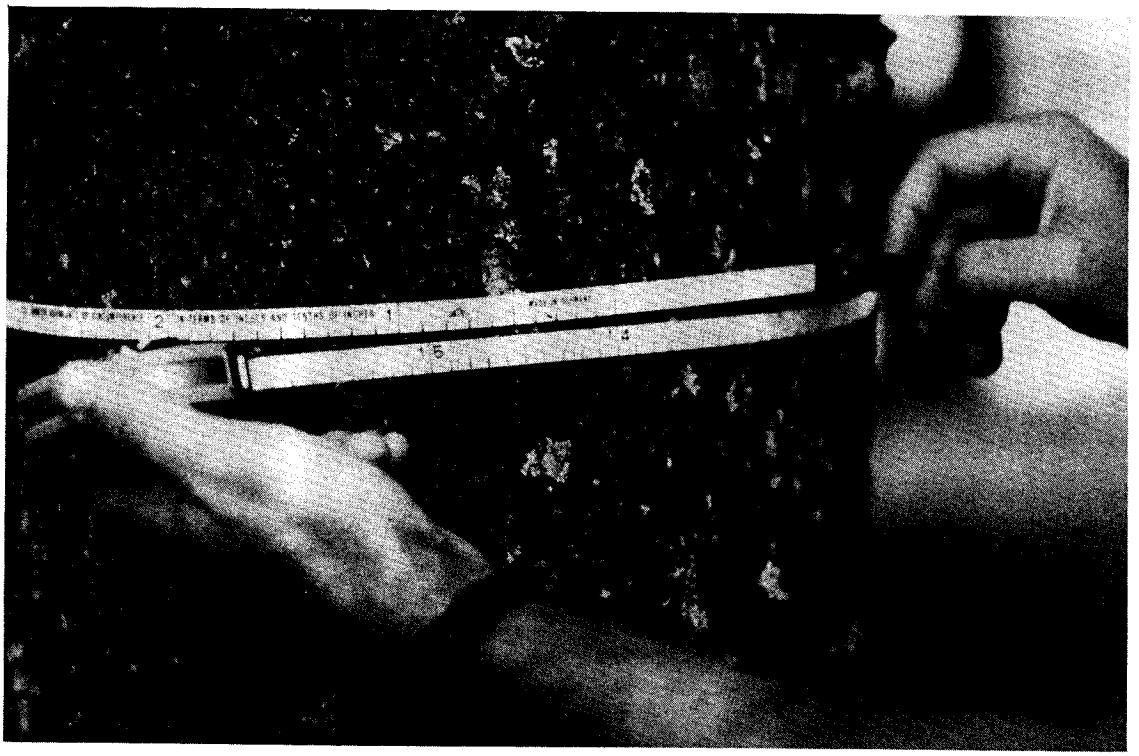


Figure 4. The dbh of this tree is exactly 14 in.

Biltmore Stick

The Biltmore stick is a straight wooden stick specially graduated for direct readings of dbh on trees with large diameters. The graduations on the stick are usually based on a fixed distance of 25 in. from the observer's eye to dbh. Because of difficulty in maintaining the proper distance from eye to tree, the Biltmore stick is considered a rather crude measuring device (Avery 1967). However, most trees are recorded in 1- or 2-in. classes, and the stick is usually adequate for these measurements. It is especially useful in preventing contact with vines such as poison ivy (*Toxicodendron radicans*) that may be present on the stem.

The Biltmore stick should be grasped near the middle, placed horizontally against the tree trunk at breast height, and held perpendicular to the line of vision (Fig. 5). With one eye closed, the observer aligns the stick so that its center is the appropriate distance from the eye (usually 25 in.) and the zero end of the scale coincides with the edge of the trunk. The diameter is read as the number (to the nearest inch) that aligns with the other side of the tree trunk (Fig. 6).

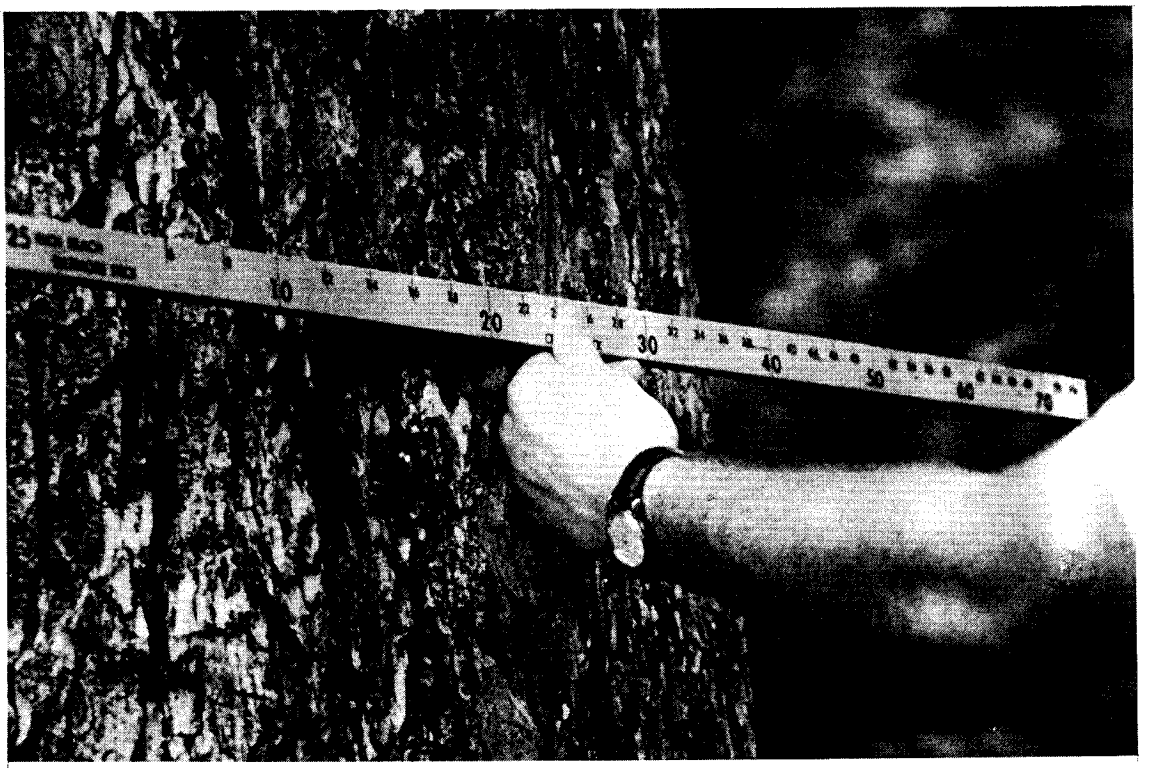


Figure 5. The Biltmore stick can be used to measure large stems

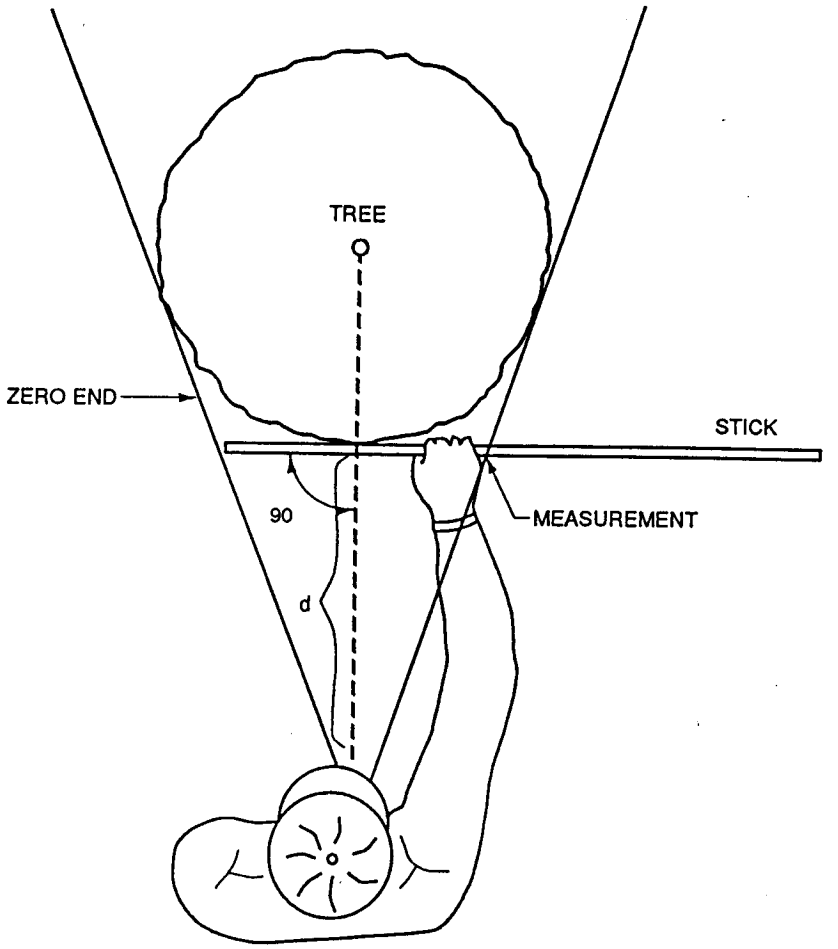


Figure 6. Use of the Biltmore stick to estimate the dbh of a tree (from Hays et al. 1981)

Irregular Trees

It is critical that trees be measured exactly at 4.5 ft above ground (Fig. 7a). Otherwise, a high degree of error will be introduced during data collection. When diameters are measured under heavy snow cover or swampy conditions, a 4.5-ft pole should be used to locate true ground level and thus prevent the measurement from being made too high up the stem (Avery 1967). Arational deviation from dbh must be used for trees on sloping ground or for those with irregular stems.

Figures 7b-7g illustrate suggested methods for maintaining consistency in diameter measurements. For trees growing on slopes, dbh should be measured at

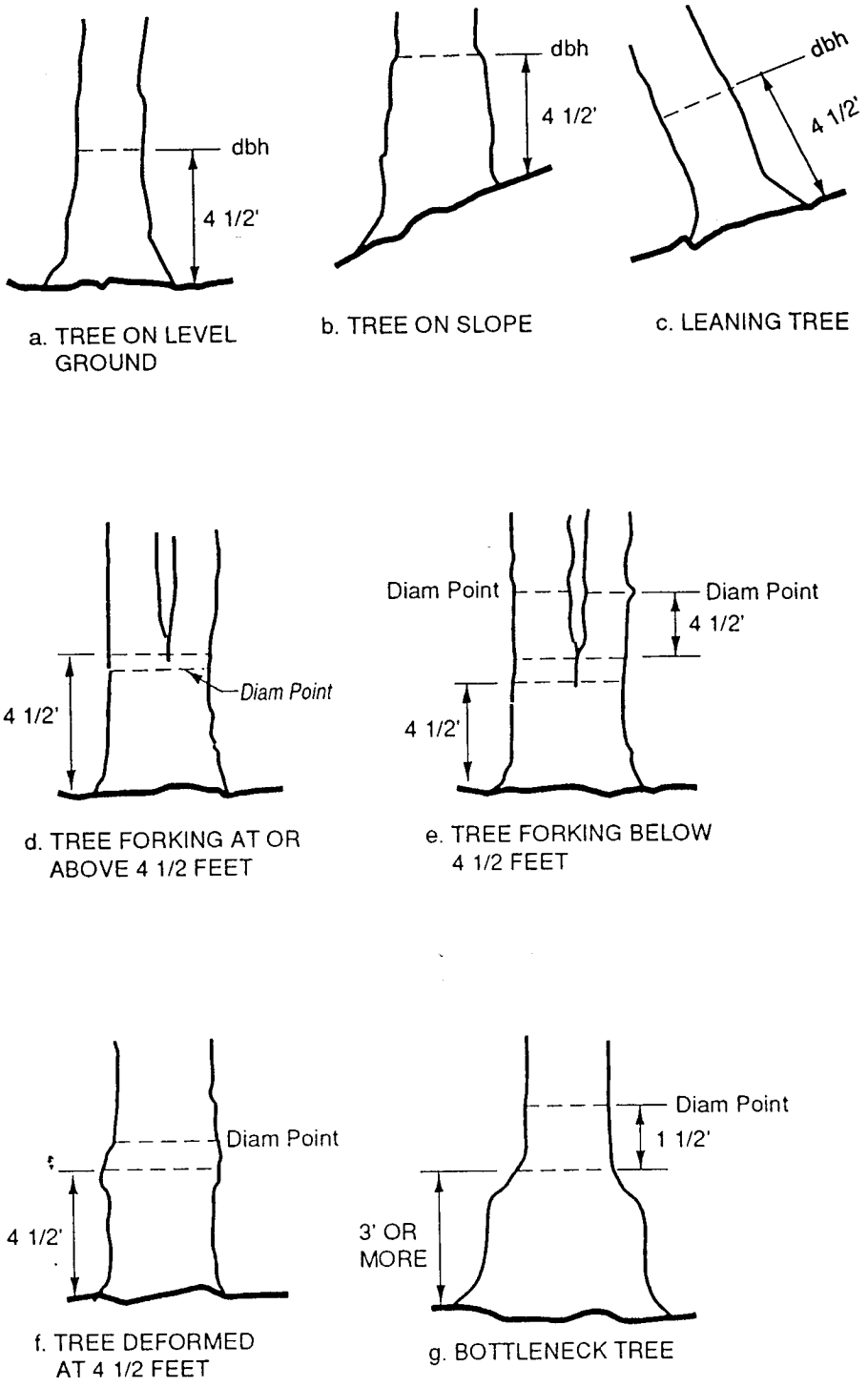


Figure 7. Points of dbh measurement for sloping ground and irregular tree stems (from U.S. Forest Service 1964)

4.5 ft above ground on the uphill side of the tree (Fig. 7b). Dbh for a leaning tree is measured at a right angle to an imaginary perpendicular line that is parallel to the side of the tree leaning away from the data collector (Fig. 7c). If a tree forks immediately above dbh, it is measured just below the swell resulting from the double stem (Fig. 7d). Stems that fork below dbh are considered to be separate trees, and diameters are measured approximately 3.5 ft above the fork (Fig. 7e).

When swellings, bumps, depressions, or branches occur at 4.5 ft above ground, diameters are usually taken just above the irregularity at a point where the irregularity ceases to affect normal stem form (Fig. 7f). Trees such as baldcypress (*Taxodium distichum*) and tupelo gum (*Nyssa sylvatica*) are measured 1.5 ft above the pronounced swell or "bottleneck," if the swell is more than 3 ft high (Avery 1967) (Fig. 7g). Such measurements are usually referred to as normal diameters and are abbreviated dn.

PROCEDURE FOR DATA COLLECTION

After the techniques of reading a prism and measuring tree diameters have been mastered, data collection will proceed rapidly. The procedure for collecting data at each sample point is given below.

1. A stake flag marker should be placed at the sampling point. The prism should be held over this point during the entire procedure, unless the observer is using an alternative procedure discussed above.

2. One person stands at the sampling point and reads the prism to determine which trees to sample (Fig. 8). It is usually helpful to flag the first tree measured in a dense homogeneous stand.

3. One crew member measures or estimates the dbh of each sample tree, for hich species name and diameter are recorded. Every other borderline tree is sampled unless otherwise dictated by the study design.
   Note: To increase efficiency of this procedure, the data collector should learn to estimate dbh. This can be accomplished within a few days' time by comparing estimates with actual measurements. A D-tape and/or Biltmore stick is still needed to measure the occasional tree of unusual size.

4. When data have been collected on all sample trees, the field crew moves to the next sampling point and repeats the procedure.

Figure 8. Data collection at a sampling point

RECORDING

Several methods are available for recording field data. As shown in this report, items of data may be handwritten onto prepared forms. However, use of a device such as a hand-held computer or tape recorder will greatly increase the efficiency of data collection.

Blank data recording and analysis forms are provided in Appendix D. The form "Prism Sampling: Field Data Sheet" is used for recording field data. The station number is recorded for station number is recorded for the first tree measured at each point, and the species name and dbh are recorded for each tree sampled.

Species Names

An abbreviated name or code number is usually assigned each species. Names may be coded in various ways, but the same coding system should be consistently used throughout the study. Three methods of species name coding are suggested below:

1. Mnemonic system, in which the initial letters of common names identify the species (e.g., BC = black cherry). This system is used in the examples given in this report.

2. Numerical system, in which each species is assigned a coded value (e.g., 01 = black cherry). This system is especially useful for data entered into a field computer.

3. Scientific name abbreviation, a four-letter system in which the first two letters of the generic and specific names are recorded (e.g., PrSe = *Prunus serotina*, the scientific name of black cherry).

Diameter Classes

Diameter may be recorded to the nearest 0.1 in., but it is usually recorded in dbh classes of 1 to 2 in. If 1-in. classes are used, it is customary to use the lower value when diameters fall exactly halfway between inch graduations. For example, the class limits for 8-in. trees are 7.6 in. to 8.5 in.; the 9-in. class ranges from 8.6 to 9.5 in. (Avery 1967). When the 2-in. diameter classes are used, the 8-in. class boundaries commonly range from 7.000 to 8.999+ in.; the 10-in. class spans from 9.000 to 10.999+ inches. In the examples provided below, diameters were recorded to the nearest inch, then tallied and analyzed by 2-in. categories.

A sample data sheet with actual prism sampling data from an Allegheny hardwood forest is shown in Figure 9. The data from Station 1 show that 16 trees were sampled and dbh was recorded to the nearest inch. The mnemonic system was used to record species name. The first tree sampled at Station 1 was black cherry (*Prunus serotina*); it had a diameter of 12 in.

DATA ANALYSIS

Forest stand parameters that can be determined from data collected in the above procedure include the following:

1. Basal area (square feet of cross-sectional area per acre).

2. Density (number of trees per acre).

3. Average diameter.

Data analysis forms are provided in Appendix D. On each form, the dbh categories should be entered in the first column on the left, and the tree species names should be entered in the row of blocks under the "Species" heading.

Data Summary

Procedure. Data from the Field Data Sheet should be summarized on the "Prism Sampling: Stand Tally Sheet" in the following manner:

1. Tally the trees sampled by species and dbh class.

PRISM SAMPLING: FIELD DATA SHEET

AGENCY/OWNER: USFS PROPERTY: Allegheny Nat'l For. DATE: 19 July 90

COUNTY: Warren COMPARTMENT/UNIT: 38 ACREAGE: 34 OBSERVER: Hanlon

FOREST TYPE: Allegheny Hardwoods BAF: 10 STAND NUMBER: 16 NO. POINTS: 20

Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh
1	BC	12	(2 con't)	NRO	18	(3 con't)	BC	19
	EH	19		SM	14	4	SM	21
	BC	12		AB	15		BC	17
	BC	11		BC	11		SM	16
	BC	14		S	8		BC	19
	BC	19		SM	8		SM	20
	BC	25		RM	18		SM	11
	BC	19		BC	12		SM	13
	BC	18	3	S	8		BC	17
	BC	27		WA	11		SM	20
	BC	17		EH	6		SM	20
	SM	11		BC	14		SM	17
	SM	8		SM	16	5	S	5
	WA	14		BC	17		BC	17
	SM	7		S	10		BC	15
	BC	22		BC	18		BC	12
2	EH	14		S	10		BC	10
	BC	21		AB	9		BC	15
	BC	21		RM	18		BC	11
	AB	7		SM	18		BC	15
	BC	20		BC	18		BC	13
	BC	15		BC	14		BC	14
	S	6		BC	16		BC	16
	SM	20		BC	16		BC	29

PAGE 1 OF 4

Figure 9. Sample data sheet used to illustrate the recording of data collected in the field

2. Count the number of trees of all species in each dbh class and enter the totals in the right-hand column (Total dbh Class).

3. Add the number of trees in the right-hand column (No. 2 above) and enter the total number of trees sampled in the space at the bottom of the column.

4. Count the number of trees of each species in all dbh classes and enter at the bottom of each column. (The total number of trees in this row should equal the total number of trees in the right-hand column.)

Example. Actual data from an Allegheny hardwood stand (see RECORDING) have been used in this and subsequent examples to illustrate the steps of data analysis for each parameter. The lower limit of dbh classes is 6 in. in all examples.

Information transferred from the Field Data Sheets (only page 1 shown in Fig. 9) to the Stand Tally Sheet (Fig. 10) was summarized as suggested in the steps above.

1. The Stand Tally Sheet shows that 20 black cherry trees in the 16-in. dbh class were sampled in this stand.

2. The data in the right-hand column indicate a total of 42 trees in the 16-in. class.

3. The summation of numbers in the right-hand column shows that a total of 257 trees were sampled in this stand.

4. The tally for all dbh classes of each species in the last row (Total) shows a total of 113 black cherry trees, 50 sugar maples (*Acer saccharum*), 14 American beeches (*Fagus grandifolia*), and 1 black birch (*Betula lenta*).

Basal Area

Procedure. Basal area/acre can be determined for each dbh class, species, or all trees sampled by following the steps outlined below. All calculations should be entered on the data analysis form entitled "Prism Sampling: Basal Area Per Acre." The numbers of trees used in the calculations are taken from the Stand Tally Sheet. The general equation for basal area/acre is

$$\text{BA/acre} = \frac{(\text{Total number trees sampled})(\text{BAF})}{\text{Total number of sample points}}$$

Use the following steps to calculate basal area:

PRISM SAMPLING: STAND TALLY SHEET
(Number of trees sampled)

AGENCY/OWNER: USFS PROPERTY: Allegheny Nat'l. For. COUNTY: Warren DATE: 19 July 90

COMPARTMENT/UNIT: 38 STAND NUMBER: 16 ACREAGE: 34 OBSERVER: Hanlon

FOREST TYPE: Allegheny Hardwoods BAF: 10 NO. POINTS SAMPLED: 20 PAGE: 1 OF 1

dbh (In)	Number of Trees by Species										Total dbh Class
	BC	RM	SM	EH	WA	AB	YB	BB	NRO	BW	
6		I	I	I		I					4
8		I	~~IIII~~	III	I	III					3
10	II	~~IIII~~	~~IIII~~ III	III		II	I	I			22
12	~~IIII~~ ~~IIII~~	~~IIII~~	~~IIII~~ ~~IIII~~ II	II	II		I				32
14	~~IIII~~ ~~IIII~~ I	~~IIII~~ IIII	~~IIII~~ III	IIII	II	I	I			I	37
16	~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~	~~IIII~~ ~~IIII~~ I	~~IIII~~ I	I		III	I				42
18	~~IIII~~ ~~IIII~~ ~~IIII~~ I	~~IIII~~ I	~~IIII~~	I		III			I		32
20	~~IIII~~ ~~IIII~~ ~~IIII~~ IIII	~~IIII~~ I	IIII	III	II	I					35
22	~~IIII~~ ~~IIII~~ ~~IIII~~ II	IIII	I								22
24	~~IIII~~ ~~IIII~~										10
26	IIII										4
28	II										2
30	II										2
32											
34											
TOTAL	113	48	50	18	7	14	4	1	1	1	257

Figure 10. Sample data form illustrating the tallying of tree species from the Field Data Sheet shown in Figure 9

1. Find the BA/acre for each species by dbh class ($BA_{sp\text{-}dbh}$/acre)

$$BA_{sp\text{-}dbh}/acre = \frac{(\text{Total number trees}_{sp\text{-}dbh})(BAF)}{\text{Total number of sample points}}$$

2. Find the BA/acre for each species (BA_{sp}/acre)

$$BA_{sp}/acre = \Sigma BA_{sp\text{-}dbh}/acre$$

3. Find the BA/acre for each dbh class (BA_{dbh}/acre)

$$BA_{dbh}/acre = \frac{(\text{Total number trees}_{dbh})(BAF)}{\text{Total number of sample points}}$$

or

$$BA_{dbh}/acre = \Sigma BA_{dbh}/acre$$

4. Find the total BA/acre

$$\text{Total BA/acre} = \Sigma BA_{dbh}/acre$$

or

$$\text{Total BA/acre} = \Sigma BA_{sp}/acre$$

Example. Data from the Stand Tally Sheet (Fig. 10) are used to calculate BA/acre on the Basal Area Per Acre Table shown as Fig. 11. BA/acre is found by substituting in the general equation given in step 1.

1. BA/acre for each species dbh class: In this sample the BA/acre of 16-in. red maple (*Acer rubrum*) trees is

$$BA_{sp\text{-}dbh}/acre = \frac{(11)(10)}{20}$$

$$= 5.5 \text{ ft}^2$$

2. Total BA/acre for each species: The BA/acre for sugar maple trees is

$$BA_{sp}\backslash acre = \frac{(50)(10)}{20}$$

$$= 25 \text{ ft}^2$$

3. BA/acre for each dbh class: The BA/acre for all 16-in. trees is

$$BA_{dbh}/acre = \frac{(42)(10)}{20}$$

$$= 21 \text{ ft}^2$$

4. Total BA/acre for area sampled: BA/acre for the study area is

$$\text{Total BA/acre} = \frac{(257)(10)}{20}$$

$$= 128.5 \text{ ft}^2$$

or

$$\text{Total BA/acre} = \Sigma BA_{sp} \text{ or } \Sigma BA_{dbh} = 128.5 \text{ ft}^2$$

PRISM SAMPLING: BASAL AREA PER ACRE

AGENCY/OWNER: USFS PROPERTY: Allegheny Natl. For. COUNTY: Warren DATE: 19 July 90

COMPARTMENT/UNIT: 38 STAND NUMBER: 16 ACREAGE: 34 OBSERVER: Hanlon

FOREST TYPE: Allegheny Hardwoods BAF: 10 NO. POINTS SAMPLED: 20 PAGE: 1 OF 1

dbh (In)	Species Basal Area per acre (BA/acre)										BA/Acre dbh Class
	BC	RM	SM	EH	WA	AB	YB	BB	NRO	BW	
6		0.5	0.5	0.5		0.5					2.0
8		0.5	2.5	1.5	0.5	1.5					6.5
10	1.0	2.5	4.0	1.5		1.0	0.5	0.5			11.0
12	5.0	2.5	6.0	1.0	1.0		0.5				16.0
14	5.5	4.5	4.0	2.0	1.0	0.5	0.5			0.5	18.5
16	10.0	5.5	3.0	0.5		1.5	0.5				21.0
18	8.0	3.0	2.5	0.5		1.5			0.5		16.0
20	9.5	3.0	2.0	1.5	1.0	0.5					17.5
22	8.5	2.0	0.5								11.0
24	5.0										5.0
26	2.0										2.0
28	1.0										1.0
30	1.0										1.0
32											
34											
BA/AC	56.5	24.0	25.0	9.0	3.5	7.0	2.0	0.5	0.5	0.5	128.5

$$\text{BA/Acre} = \frac{\text{(Number trees sampled) (BAF)}}{\text{Total number of points sampled}}$$

Figure 11. Sample data analysis form illustrating the determination of basal area/acre

Density

Procedure. Density (trees per acre) is more difficult to calculate than basal area because of the inability to precisely determine the amount of area sampled. The sampling concept is based on the premise that each tree has a plot, the radius of which is directly proportional to its diameter. Therefore, the amount of acreage sampled will vary according to the size of the trees sampled. Small trees represent small areas sampled, whereas large trees represent much larger areas sampled.

Since trees are categorized by diameter, the plot area for an individual tree is calculated at the midpoint of each dbh class. Based on this area, a "per acre conversion factor" (PACF) is used in density determinations. The PACF represents the number of plots for a tree of a given diameter that would occupy 1 acre. The conversion factor varies by diameter class because different diameter classes have different sizes.

All calculations should be entered on the data analysis form entitled "Prism Sampling: Density." The numbers of trees used in the calculations are taken from the Stand Tally Sheet. The following steps show how to calculate density:

1. Use Table 1 to find the PACF for each diameter class and enter the values in the second column (PACF) of the data sheet. For trees with dbhs that exceed 40 in., calculate the PACF by using the class midpoint and the plot radius factor (Appendix A) in the equation

$$PACF = \frac{43{,}560\ ft^2/acre}{pi\ (dbh \times PRF)^2}$$

2. Calculate the density (D) for trees of each species in each dbh class ($D_{sp\text{-}dbh}$) with the equation

$$D_{sp\text{-}dbh} = \frac{(\text{Number trees sampled})(PACF)}{\text{Total number of points}}$$

3. Calculate the total density for each dbh class (D_{class}) with the equation in step 2 or by adding the densities for all species (D_{sp}) of that diameter class.

$$D_{class} = \sum D_{sp}$$

4. Add each column to find the total density for each species.

$$D_{sp} = \sum D_{sp} \text{ for all dbh classes}$$

5. Add the dbh class densities in the last column to obtain total tree density D_{tree}.

$$D_{tree} = \sum D_{class} \text{ for all dbh classes}$$

Table 1. Per acre conversion factors for BAF 10 and BAF 20

Diameter Class	PACF	
	BAF 10	BAF 20
2	458.6	917.1
4	114.7	229.2
6	50.9	101.9
8	28.6	57.3
10	18.5	36.7
12	12.7	25.5
14	9.4	18.7
16	7.2	14.3
18	5.7	11.3
20	4.6	9.2
22	3.8	7.6
24	3.2	6.4
26	2.7	5.4
28	2.3	4.7
30	2.0	4.1
32	1.8	3.6
34	1.6	3.2
36	1.4	2.8
38	1.3	2.5
40	1.1	2.3

Example. The Stand Tally Sheet (Fig. 11) provides numbers of trees used in density calculations, which are entered in the Density Stand Table (Fig. 12).

1. The Per Area Conversion Factor (PACF): Obtained for each dbh class from Table 1 or by using the equation given in step 1 above.

The PACF for trees in the 16-in. dbh class is

$$\text{PACF} = \frac{43{,}560 \text{ ft}^2/\text{acre}}{3.14\ (16 \times 2.75)^2}$$

$$= \frac{43{,}560 \text{ sq ft}}{3.14\ (1936)}$$

$$= \frac{43{,}560}{6079}$$

$$= 7.2$$

PRISM SAMPLING: DENSITY

AGENCY/OWNER: USFS PROPERTY: Allegheny Nat'l For. COUNTY: Warren DATE: 19 July 90

COMPARTMENT/UNIT: 38 STAND NUMBER: 16 ACREAGE: 34 OBSERVER: Hanlon

FOREST TYPE: Allegheny Hardwoods BAF: 10 NO. POINTS SAMPLED: 20 PAGE: 1 OF 1

dbh (In)	PACF	Species Density (Trees per acre)										Density dbh Class
		BL	RM	SM	EH	WA	AB	YB	BB	NRO	BW	
6	50.9		2.54	2.54	2.54		2.54					10.2
8	28.7		1.43	7.17	4.31	1.43	4.31					18.6
10	18.5	1.85	4.62	7.40	2.78		1.85	0.92	0.92			20.3
12	12.7	6.35	3.18	7.62	1.27	1.27		0.63				20.3
14	9.4	5.17	4.23	3.76	1.88	0.94	0.47	0.47			0.47	17.4
16	7.2	7.20	3.96	2.16	0.36		1.08	0.36				15.1
18	5.7	4.56	1.71	1.43	0.28		0.86			0.28		9.1
20	4.6	4.37	1.38	0.92	0.69	0.46	0.23					8.1
22	3.8	3.23	0.76	0.19								4.2
24	3.2	1.60										1.6
26	2.7	0.54										0.5
28	2.3	0.23										0.2
30	2.0	0.20										0.2
TOTAL DENSITY		35.3	23.8	33.2	14.1	4.1	11.3	2.3	0.9	0.3	0.5	125.8

DENSITY = $\frac{\text{(Number trees sampled)(PACF)}}{\text{Total number of points}}$

Figure 12. A sample data analysis form illustrating the determination of density

2. The density, D, of each species in each dbh class: Using the equation in Step 2 above, the density of 16-in. American beech trees in this sample is

$$D_{sp\text{-}dbh} = \frac{(3)(7.2)}{20}$$

$$= 1.1 \text{ beech trees/acre}$$

3. The total density for each dbh class: The density of all 16-in. trees is

$$D_{class} = \frac{(42)(7.2)}{20}$$

$$= 15.1 \text{ 16-in. dbh trees/acre}$$

4. Individual species densities: In the summation row at the bottom of the Density Stand Table, the density of black cherry trees is 35.3 trees/acre.

5. Total density: The summation of dbh class densities (last column) shows a total tree density of 125.8 trees/acre in the Allegheny hardwood stand.

Average Diameter

Procedure. The average diameter is calculated from the tree of average basal area ($\overline{BA}$) by the following procedure.

1. Find the tree of average basal area ($\overline{BA}_{tree}$) by using the equation

$$\overline{BA}_{tree} = \frac{\text{Total BA/acre}}{\text{Total number trees/acre}}$$

where

Total number trees/acre = density as calculated (from Density Stand Table), not just the number of trees sampled/acre;
therefore,

$$\overline{BA}_{tree} = \frac{\text{Total BA/acre}}{\text{Density}}$$

2. Calculate the dbh of the tree of average basal area with the equation

$$BA = (0.005454)(D^2)$$

where

D = dbh

therefore

$$\overline{D} = \sqrt{\frac{\overline{BA}}{0.005454}}$$

Example. Information from the Basal Area Per Acre Stand Table (Fig. 11) and Density Stand Table (Fig. 12) are used to calculate the average stand diameter with the equations given above.

1. Average BA/acre = $\frac{\text{Total BA/acre}}{\text{Total Density}}$

$$\overline{BA/acre} = \frac{128.5 \text{ ft}^2/\text{acre}}{125.8 \text{ trees/acre}}$$

$$= 1.02 \text{ ft}^2$$

2. Since BA = 0.005454 d^2, then

$$\overline{D} = \sqrt{\frac{BA/acre}{0.005454}}$$

$$= \sqrt{\frac{1.02}{0.005454}}$$

$$= 13.7 \text{ trees/acre}$$

Volume

Timber volume can be estimated from prism sampling data by using stem density or basal area data with volume tables. Volume is not a major parameter describing wildlife habitat; therefore, these methods are not discussed in this report. Information on calculating timber volume can be found in Avery and Burkhart (1983), Smalley and Bower (1968a,b), and Edminster et al. (1980, 1982).

SOURCES OF ERROR

Wedge Prism

The principal sources of error in applying the prism sampling technique involve improper use of the wedge prism. Errors can result from holding the prism incorrectly (e.g., tilted), not holding it directly over the sampling point, turning more or less than 360 deg around the sampling point, not correcting for slope, and using a noncalibrated prism. Because prisms can be

ground for either metric or standard measurements, it is necessary to know which is being used.

Borderline Trees

Inaccurate classification of borderline trees is a potentially significant source of error. Errors may result from improper use of the prism or from lack of precision in measuring dbh, especially in a stand with thick undergrowth that obscures trees. Inattention to borderline trees can cause significant problems when volume is being estimated. Wiant (1987) found that a single misclassified tree of 30-in. dbh on a 250-acre stand in West Virginia produced stumpage value errors of $625 and $839 for BAF 10 and 20, respectively.

A standard method for determining borderline trees should be established in the study design. Since volume determinations are not needed for habitat evaluations, every other borderline tree is usually sampled in a vegetation survey. The method suggested for finding the plot radius (Appendix B) may be used to determine whether a tree obscured by brush or other trees is a borderline tree.

Boundary Overlap

Boundary overlap is a source of bias that should be addressed in the study design. Overlap occurs when a sampling point falls close enough to the stand or tract boundary so that the plot of one or more sample trees falls partially outside the stand. When this happens, the probability of a plot including the sample point is less than the corresponding probability for similar trees whose plots are completely within the stand boundaries.

Bias is reduced if the forest conditions outside the boundary approximate those inside the tract (Burkhart et al. 1984). Bias is essentially negligible if the stand or tract is large and the proportion of edge is small. However, small or narrow stands have a high proportion of edge; therefore, bias can be high.

In large stands with a low percentage of edge, the common solution is to designate a buffer zone around the tract boundary in which no points are established (Burkhart et al. 1984). The width of this zone should equal the plot radius for the largest tree dbh expected in the stand. Although this solution can introduce an edge-effect bias because the edge zone is not sampled, it is not usually of practical significance in large homogeneous stands.

Several methods have been suggested to compensate for boundary overlap in small or narrow stands with a high percentage of edge (Grosenbaugh 1958, Barrett

1964, Beers 1977). Avery and Burkhart (1983) suggested using the "Mirage" method of boundary overlap correction. With this method, the distance (D) from the sample point to the edge of the stand is determined if boundary overlap might occur. The observer proceeds beyond the stand boundary by distance D, establishes a correction point, and sights back toward the trees sampled from the original point. If this point is "in" the plot, the trees in question are counted twice; the correction point is not counted as a sampling point.

LITERATURE CITED

Avery, T. E. 1967. Forest Measurements. McGraw-Hill, New York. 290 pp.

Avery, T. E., and H. E. Burkhart. 1983. Forest Measurements. McGraw-Hill, New York. 331 pp.

Barrett, J. P. 1964. Correction for edge effect bias in point-sampling. For. Sci. 10:52-55.

Beers, T. W. 1977. Practical correction of boundary overlap. South. J. Appl. For. 1:16-18.

Beers, T. W., and C. I. Miller. 1973. Manual of Forest Mensuration. Purdue Univ., West Layette, Indiana. 153 pp.

Burkhart, H. E., J. P. Barrett, and H. G. Lund. 1984. Timber inventory. Pages 361-411 In K. F. Wenger, ed. Forestry Handbook, 2nd ed. John Wiley and Sons, New York. 1335 pp.

Chambers, J. C., and R. W. Brown. 1983. Methods for vegetation sampling and analysis on revegetated mined lands. USDA For. Serv. Gen. Tech. Rep. INT-151. 57 pp.

Dilworth, J. R., and J. F. Bell. 1979. Principles of Silviculture. 2nd ed. McGraw-Hill, New York. 500 pp.

Edminster, C. B., R. T. Beeson, and G. E. Metcalf. 1980. Volume tables and point-sampling factors for ponderosa pine in the front range of Colorado. USDA For. Serv. Res. Pap. RM-218. 14 pp.

Edminster, C. B., H. T. Mowrer, and T. E. Hinds. 1982. Volume tables and point-sampling factors for aspen in Colorado. USDA For. Serv. Res. Pap. RM-232. 16 pp.

Grosenbaugh, L. R. 1952. Plotless timber estimates--new, fast, easy. J. For. 50:32-37.

Grosenbaugh, L. R. 1958. Point-sampling and line-sampling: Probability theory, geometrics implications, synthesis. USDA For. Serv., South. For. Exp. Station Occas. Pap. No. 160. 34 pp.

Hays, R. L., C. Summers, and W. Seitz. 1981. Estimating wildlife habitat variables. U.S. Fish and Wildl. Serv. FWS/OBS-81/47. 111 pp.

Hovind, H. J., and C. E. Rieck. 1970. Basal area and point-sampling: Interpretation and application. Wis. Conserv. Dep. Tech. Bull. No. 23 (Rev. ed.). 51 pp.

Smalley, G. W., and D. R. Bower. 1968a. Volume tables and point-sampling factors for shortleaf pines in plantations on abandoned fields in Tennessee, Alabama, and Georgia highlands. USDA For. Serv. Res. Pap. 50-39. 13 pp.

Smalley, G. W., and D. R. Bower. 1968b. Volume tables and point-sampling factors for loblolly pines in plantations on abandoned fields in Tennessee, Alabama, and Georgia highlands. USDA For. Serv. Res. Pap. 50-32. 13 pp.

Snedecor, G. W. 1950. Statistical Methods. Iowa State Univ. Press, Ames. 485 pp.

Stage, A. R. 1959. A cruising computer for variable plots, tree heights, and slope correction. J. For. 57:835-836.

U.S. Forest Service. 1964. Forest survey handbook. Washington, D.C. 90 pp.

Wiant, H. V., Jr. 1987. Misclassifying trees. J. For. 85:40-41.

APPENDIX A

RELATIONSHIP OF SIGHTING ANGLE, PLOT RADIUS, AND BAF

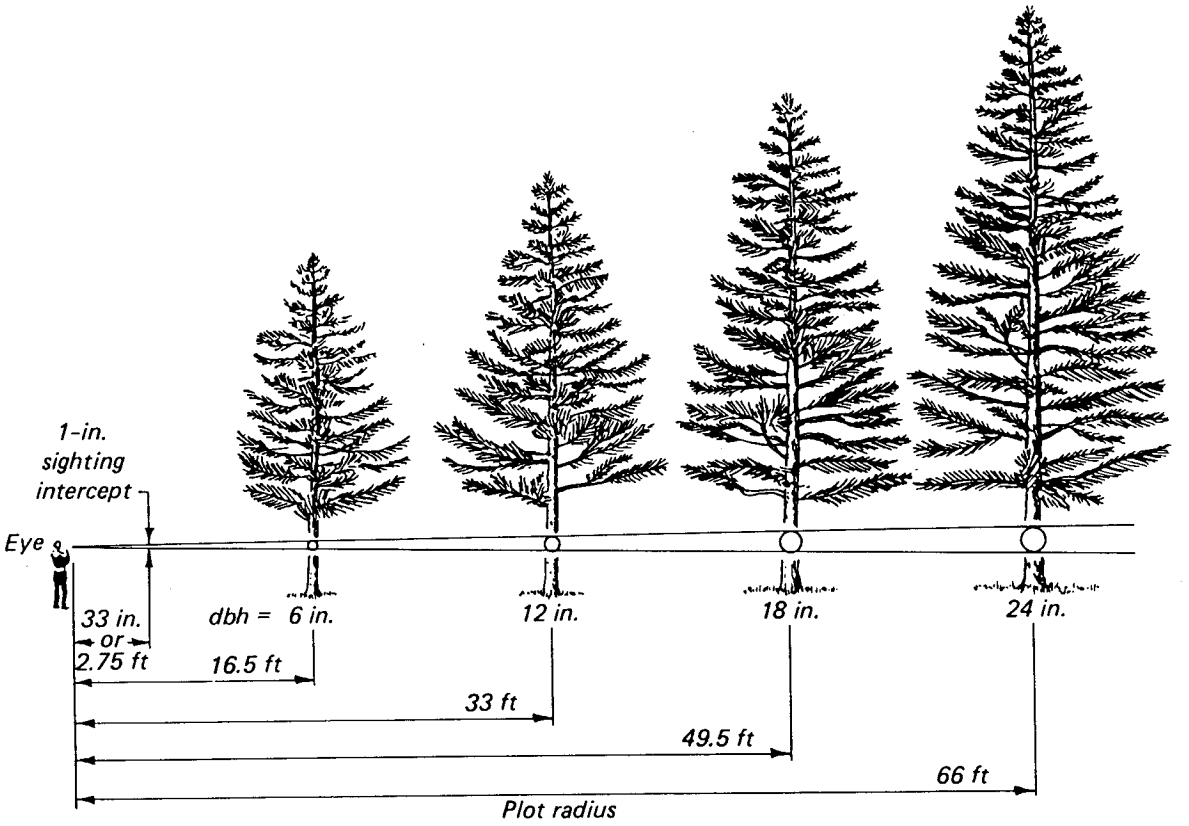
RELATIONSHIP OF SIGHTING ANGLE, PLOT RADIUS, AND BAF

A prism creates a sighting angle that has a constant ratio of stem diameter to plot radius. Sighting angles are generally expressed as basal area factors (BAFs) because each tree sampled, regardless of its diameter, represents a fixed cross-sectional area called "basal area" (expressed as ft^2/acre or m^2/ha). For example, if the BAF of a prism is 10, each tree sampled would represent 10 ft^2 of area per acre.

For a given sighting angle (BAF), the plot radius increases as the stem diameter increases. The example in Figure A1 illustrates the constant ratio of tree diameter to plot radius for a sighting angle of 104.18 min, or BAF 10. When the various tree diameters (in feet) are divided by the respective plot radii (in feet), each ratio is 1:33. Smaller sighting angles result in larger plot radii relative to tree diameter than do larger angles (Fig. A2); thus, more trees will be sampled with smaller sighting angles.

Sighting angles commonly used range from 32.94 min for BAF 1 to 255.23 min for BAF 60 (Table A1). A circle has 360 deg, and each degree is subdivided into 60 min. Therefore, sighting angles range from approximately 0.5 to 4.25 deg, respectively, for these BAFs (i.e., 60 min per degree divided by 32.94 min is 0.51 deg).

Because the ratio of stem diameter to plot radius is constant and known, the plot radius for any sized tree can be calculated from its diameter. For BAF 10, the tree diameter:plot radius ratio is 1 in.:2.75 ft; thus, the plot radius for a 1-in.-diam tree is 2.75 ft. This diameter is called the plot radius factor (PRF) and can be used to calculate the plot radius of any-sized diameter tree when a prism of BAF 10 is used. The tree diameter is multiplied by the PRF of 2.75, and the result is the respective plot radius (in feet) for the tree in question. Each BAF has a different PRF; for example, the PRF for BAF 20 is 1.944. Table A1 gives angle sizes, tree diameter to plot radius ratios, and PRFs for the more common English BAFs.



Ratio (tree dbh to plot radius) $= \frac{0.5'}{16.5'} = \frac{1.0'}{33.0'} = \frac{1.5'}{49.5'} = \frac{2.0'}{66.0'} = 1:33$

Figure A1. Tree sizes and plot radii for a 1:33 prism (BAF 10) (from Avery and Burkhart 1983)

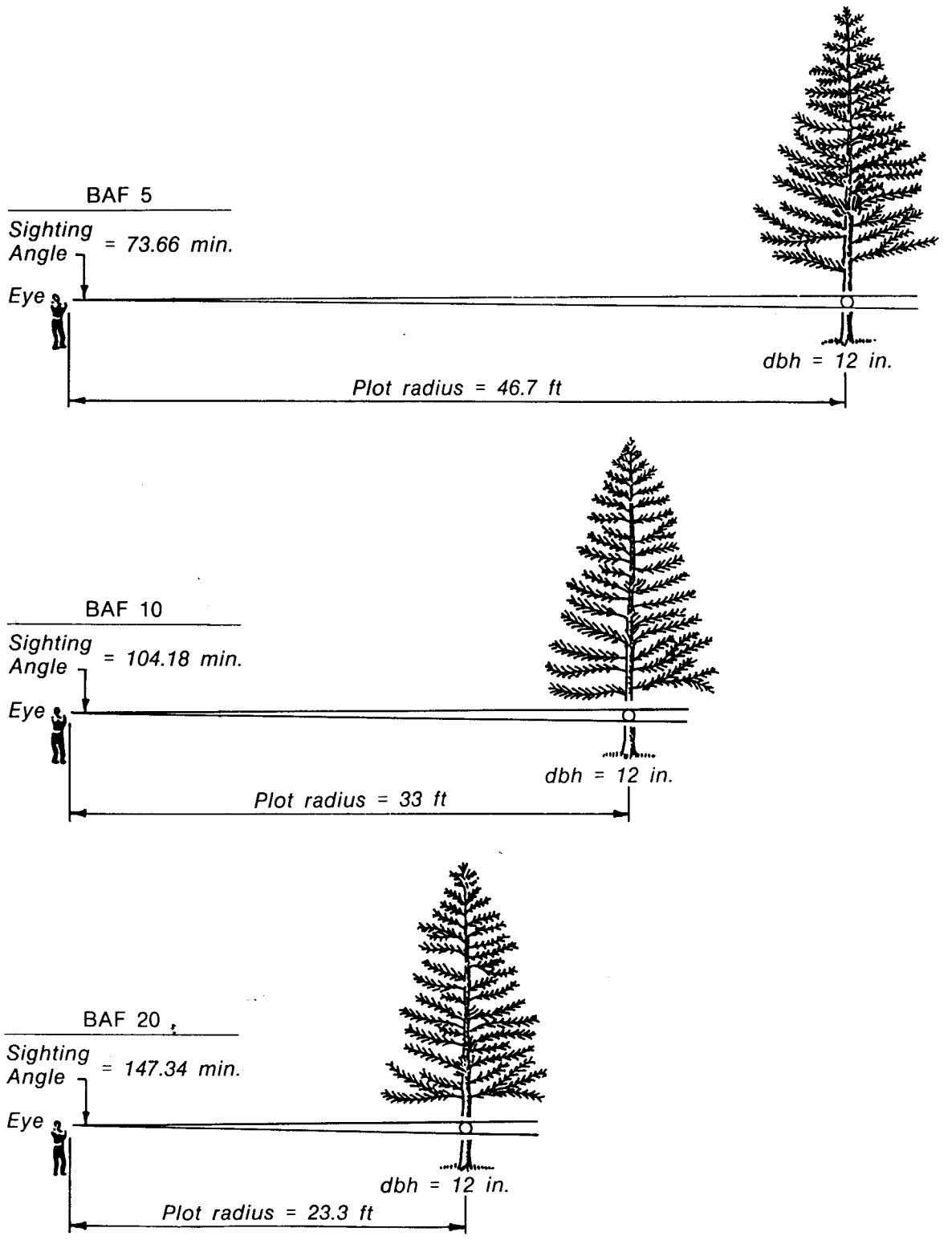


Figure A2. Plot radii for 12.0-in. dbh trees when using prisms with BAF 5, BAF 10, and BAF 20, respectively

Table A1. Common basal-area factors and angle sizes used in prism sampling (Hovind and Rieck 1970)

Basal-Area Factor	Angle Size min	Ratio Tree Diameter to Plot Radius	Plot Radius Factor
1	32.94	1:104.4	8.696
2	46.59	1:73.8	6.149
3	57.06	1:60.2	5.021
4	65.89	1:52.2	4.348
5	73.66	1:46.7	3.889
10	104.18	1:33.0	2.750
15	127.59	1:26.9	2.245
20	147.34	1:23.3	1.944
25	164.73	1:20.9	1.739
30	180.46	1:19.0	1.588
35	194.92	1:17.6	1.470
40	208.38	1:16.5	1.375
50	232.99	1:14.8	1.230
60	255.23	1:13.5	1.123

APPENDIX B

DETERMINATION OF PLOT RADIUS

DETERMINATION OF PLOT RADIUS

Procedure

The following procedure can be used to find the plot radius (limiting distance) and determine whether to sample a tree:

1. Measure the diameter, **d**, of the tree.
2. Measure the point-to-plant distance, **M**, from the sample point to the middle of the tree trunk width.
3. Calculate the plot radius, **r**, of the tree using the plot radius factor (PRF) in the equation

   $$r = (d)(PRF)$$

   where

   PRF = 2.750 for BAF 10 and 1.944 for BAF 20.

If the measured distance is less than the plot radius (limiting distance), the tree should be sampled; if **M > r**, the tree should not be sampled.

Example

The following example is provided to illustrate this procedure. Substitute in the above equation for a tree with a dbh of 12 in. that is being viewed with a prism of BAF 10. The distance from the sample point to the tree is 30 ft. To find the radius of the tree:

$$r = 12 \text{ in. } (2.750)$$

$$r = 33 \text{ ft}$$

Since **M < r** (i.e., 30 ft < 33 ft), this tree would be sampled because the sampling point fell within the circumference of the plot determined by its radius.

Plot Radius Table

Table B1 has been prepared for BAF 10 by varying the dbh in the above equation. To quickly find the plot radius for a given tree, locate its dbh (inches) in the left-hand vertical column and read across the row dbh (tenths of an inch). For example, the plot radius for a 5.4-in. tree is 14.85 ft. This is the greatest length that the tree's radius can be for the sampling point to lie within the tree's plot. Since the plot radius determines the tree's plot, it is also referred to as the "limiting distance" from tree to sampling point.

Table B1. Plot radii (ft) for trees of various diameters using BAF = 10 (from Avery and Burkhart 1983)*

	Plot Radius (ft)									
dbh in.	0.0 in.	0.1 in.	0.2 in.	0.3 in.	0.4 in.	0.5 in.	0.6 in.	0.7 in.	0.8 in.	0.9 in.
5	13.75	14.02	14.30	14.57	14.85	15.12	15.40	15.67	15.95	16.22
6	16.50	16.77	17.05	17.32	17.60	17.87	18.15	18.42	18.70	18.97
7	19.25	19.52	19.80	20.07	20.35	20.62	20.90	21.17	21.45	21.72
8	22.00	22.27	22.55	22.82	23.10	23.37	23.65	23.92	24.20	24.47
9	24.75	25.02	25.30	25.57	25.85	26.12	26.40	26.67	26.95	27.22
10	27.50	27.77	28.05	28.32	28.60	28.87	29.15	29.42	29.70	29.97
11	30.25	30.52	30.80	31.07	31.35	31.62	31.90	32.17	32.45	32.72
12	33.00	33.27	33.55	33.82	34.10	34.37	34.65	34.92	35.20	35.47
13	35.75	36.02	36.30	36.57	36.85	37.12	37.40	37.67	37.95	38.22
14	38.50	38.77	39.05	39.32	39.60	39.87	40.15	40.42	40.70	40.97
15	41.25	41.52	41.80	42.07	42.35	42.62	42.90	43.17	43.65	43.72
16	44.00	44.27	44.55	44.82	45.10	45.37	45.65	45.92	46.20	46.47
17	46.75	47.02	47.30	47.57	47.85	48.12	48.40	48.67	48.95	49.22
18	49.50	49.77	50.05	50.32	50.60	50.87	51.15	51.42	51.70	51.97
19	52.25	52.52	52.80	53.07	53.35	53.62	53.90	54.17	54.45	54.72
20	55.00	55.27	55.55	55.82	56.10	56.37	56.65	56.92	57.20	57.47
21	57.75	58.02	58.30	58.57	58.85	59.12	59.40	59.67	59.95	60.22
22	60.50	60.77	61.05	61.32	61.60	61.87	62.15	62.42	62.70	62.97
23	63.25	63.52	63.80	64.07	64.35	64.62	64.90	65.17	65.45	65.72
24	66.00	66.27	66.55	66.82	67.10	67.37	67.65	67.92	68.20	68.47
25	68.75	69.02	69.30	69.57	69.85	70.12	70.40	70.67	70.95	71.22
26	71.50	71.77	72.05	72.32	72.60	72.87	73.15	73.42	73.70	73.97
27	74.25	74.52	74.80	75.07	75.35	75.62	75.90	76.17	76.45	76.72
28	77.00	77.27	77.55	77.82	78.10	78.37	78.65	78.92	79.20	79.47
29	79.75	80.02	80.30	80.57	80.85	81.12	81.40	81.67	81.95	82.22
30	82.50	82.77	83.05	83.32	83.60	83.87	84.15	84.42	84.70	84.97

* Find the measured dbh and read the appropriate radius (limiting distance) from the table. A tree of this dbh located farther than the limiting distance should not be tallied.

APPENDIX C

CALIBRATION OF THE WEDGE PRISM

CALIBRATION OF THE WEDGE PRISM

Procedure

Prism calibration may be accomplished by using the following procedure (Burkhart et al. 1984):

1. Set up a paper target of known width (e.g., 12 in.) outdoors. It should be a circular cross section, not a flat target. Otherwise, the formula will not be exact.

2. Holding the prism at a comfortable distance from the eye, back away until the target becomes borderline.

3. Measure the exact distance from the prism to the target (repeat several times and average).

4. Compute the prism BAF with the following formula:

$$BAF = \frac{43,560}{1 + 4\left(\frac{D}{W}\right)^2} \qquad (C1)$$

where

W = target width in feet

D = distance from prism to target in feet

Example

In calibrating a prism of BAF 10, the observer has to move 34 ft away from a 12-in. target. Substituting in the above equation,

$$BAF = \frac{43,560}{1 + 4\left(\frac{34}{1}\right)^2}$$

$$= \frac{43,560}{1 + 4(1156)} \qquad (C2)$$

$$= \frac{43,560}{4625}$$

$$= 9.4$$

The correct BAF to use in all calculations for trees collected in a survey using this prism would be 9.4 rather than 10.

APPENDIX D

PRISM SAMPLING DATA FORMS

PRISM SAMPLING: FIELD DATA SHEET

AGENCY/OWNER:_____ PROPERTY:_____ DATE:_____

COUNTY:_____ COMPARTMENT/UNIT:_____ ACREAGE:____ OBSERVER:_____

FOREST TYPE:_____ BAF:_____ STAND NUMBER:_____ NO. POINTS: _____

Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh	Sta. No.	Sp.	dbh

PAGE ____ OF ____

PRISM SAMPLING: STAND TALLY SHEET
(Number of trees sampled)

AGENCY/OWNER:_____ PROPERTY:_____ COUNTY:_____ DATE: _____

COMPARTMENT/UNIT: _____ STAND NUMBER: _____ ACREAGE:_____ OBSERVER:_____

FOREST TYPE:_____ BAF:_____ NO. POINTS SAMPLED:_____ PAGE:____ OF _____

dbh (In)	Number of Trees by Species										Total dbh Class
TOTAL											

PRISM SAMPLING: BASAL AREA PER ACRE

AGENCY/OWNER:_____ PROPERTY:_____ COUNTY:_____ DATE: _____

COMPARTMENT/UNIT:_____ STAND NUMBER:_____ ACREAGE:_____ OBSERVER:_____

FOREST TYPE:_____ BAF:_____ NO. POINTS SAMPLED:_____ PAGE:_____ OF _____

dbh (In)	Species Basal Area per acre (BA/acre)										BA/Acre dbh Class
BA/AC											

$$\text{BA/Acre} = \frac{\text{(Number trees sampled) (BAF)}}{\text{Total number of points sampled}}$$

PRISM SAMPLING: DENSITY

AGENCY/OWNER:_____ PROPERTY:_____ COUNTY: _____ DATE:_____

COMPARTMENT/UNIT:_____ STAND NUMBER:_____ ACREAGE:_____ OBSERVER:_____

FOREST TYPE: _____ BAF:_____ NO. POINTS SAMPLED:_____ PAGE:_____ OF _____

dbh (In)	PACF	Species Density (Trees per acre)									Density dbh Class
TOTAL DENSITY											

DENSITY = $\frac{\text{(Number trees sampled)(PACF)}}{\text{Total number of points}}$

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	July 1995	Final report

4. TITLE AND SUBTITLE
Prism Sampling: Section 6.2.3, U.S. Army Corps of Engineers Wildlife Resources Management Manual

5. FUNDING NUMBERS
EIRP WU 32420

6. AUTHOR(S)
Wilma A. Mitchell, H. Glenn Hughes, Larry E. Marcy

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station, 3909 Halls Ferry Road, Vicksburg, MS 39180-6199;
Pennsylvania State University-DuBois, DuBois, PA 15801;
U.S. Fish and Wildlife Service, 900 Clay Street, Vicksburg, MS 39180-2975

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report EL-95-24

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers, Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Prism sampling (also called variable radius plot, Bitterlich, or point sampling) is a method commonly used to inventory woody vegetation, particularly trees. It is easily applied with an optical wedge prism and is appropriate for determining basal area and density, as well as for assessing volume and stand structure. This report provides biologists and natural resource managers with a description of the method for use on project lands.

Topics include sampling concept, guidelines for technique selection and study design, preparations for sampling, procedure for data collection, sources of bias, and data analysis. Detailed instructions are given for recording and analyzing data; these are accompanied by numerical examples that illustrate each step of the calculations. Reproducible data forms are provided for project use.

14. SUBJECT TERMS	15. NUMBER OF PAGES
See reverse.	49
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		

14. (Concluded).

Basal area factor
Forest inventory
Prism sampling
Rapid sampling technique
Tree basal area
Tree density
Tree diameter
Variable radius plot
Vegetation sampling
Wedge prism