Fish and Wildlife Service
Fuel and Fire Effects Monitoring Guide

This documents include excerpts related to Cover --
Full Guide available at: www.fws.gov/fire/downloads/monitor.pdf

The ***Fuel and Fire Effects Monitoring Guide*** is a U.S. Fish and Wildlife Service information resource for integrating fuels treatment and fire effects monitoring into an overall management program. Information in the Guide is designed to facilitate adaptive management when evaluating:

- The effectiveness of fuels management projects identified in approved refuge Fire Management Plans.
- Whether fuels management projects may be compromising refuge resource management goals and objectives defined in approved refuge land management plans.

The Guide supplements the monitoring standards and protocols being developed under Fulfilling the Promise WH-8, WH-10, and WH-14 action items.

Successful fuels treatment and fire effects monitoring starts with planning.

The challenges of successful monitoring involve efficient and specific design, and a commitment to implementation of the monitoring project, from data collection to reporting and using results. Rather than develop a standard approach, this reference attempts to provide guidance that will assist field offices think through the many decisions that they must make to specifically design monitoring projects for their site, resources, and issues. The Fuel and Fire Effects Monitoring Guide is not a step-by-step guide on how to implement a monitoring project, but a compilation of monitoring information that you need to choose among and put together for your particular situation and issues. Local managers and specialists understand their issues and resources best and, therefore, are best able to design a monitoring project to meet their specific needs.

"Methodology is the last refuge of the sterile mind."

That may be an odd statement to find in a methods guide, but the success of a monitoring project does not start with choosing methods. On the contrary, the probability of failure increases as the investigator's thinking becomes method rather than problem oriented.

Planning is the selection and prearrangement of events for the predictable attainment of an objective. Planning is the most difficult and even tedious aspect of a project. It requires mental discipline and exercise, which can be frustrating and exhausting even for practiced minds. The investigator must often draw from principles of unfamiliar disciplines, such as business management and statistics. Meanwhile, the romance and excitement of data gathering and a sense of expedience entice the investigator to get busy with something familiar and tangible; they lure you into the "activity trap".

Fire Works!

COVER

1. **Description** Cover is an important vegetation and hydrologic characteristic. It can be used in various ways to determine the contribution of each species to a plant community. Cover is also important in determining the proper hydrologic function of a site. This characteristic is very sensitive to biotic and edaphic forces. For watershed stability, some have tried to use a standard soil cover, but research has shown each edaphic site has its own potential cover.

Cover is generally referred to as the percentage of ground surface covered by vegetation. However, numerous definitions exist. It can be expressed in absolute terms (square meters/hectares) but is most often expressed as a percentage. The objective being measured will determine the definition and type of cover measured.

a. Vegetation cover is the total cover of vegetation on a site.

b. Foliar cover is the area of ground covered by the vertical projection of the aerial portions of the plants. Small openings in the canopy and intraspecific overlap are excluded.

c. Canopy cover is the area of ground covered by the vertical projection of the outermost perimeter of the natural spread of foliage of plants. Small openings within the canopy are included. It may exceed I 00%.

d. Basal cover (area) is the area of ground surface occupied by the basal portion of the plants. Ecologists and range managers typically use a height close to the ground (e.g., about 1 in; 2.5 cm); foresters typically use "breast height" (4.5 ft; 1.4 m).

e. Ground cover is the cover of plants, litter, rocks, and gravel on a site.

2. **Advantages and Limitations**

a. Ground cover is most often used to determine the watershed stability of the site, but comparisons between sites are difficult to interpret because of the different potentials associated with each ecological site.

b. Vegetation cover is a component of ground cover and is often sensitive to climatic fluctuations that can cause errors in interpretation. Canopy cover and foliar cover are components of vegetation cover and are the most sensitive to climatic and biotic factors. This is particularly true with herbaceous vegetation.

c. Overlapping canopy cover often creates problems, particularly in mixed communities. If species composition is to be determined, the canopy of each species is counted regardless of any overlap with other species. If watershed characteristics are the objective, only the uppermost canopy is generally counted.

d. For trend comparisons in herbaceous plant communities, basal cover is generally considered to be the most stable. It does not vary as much due to climatic fluctuations or current-year defoliation.

3. **Techniques**

- Primary attributed that the technique collects.
  - **Daubenmier**
  - **Line Intercept**
  - **Step Point**
  - **Point Intercept**
    - **Spherical Densiometer**
  - **Cover Board**
  - **Biltmore Stick**
  - **Bitterlich Method**
- Secondary attributed that can be collected or calculated
  - **Frequency**
  - **Calculated Cover**

DAUBENMIRE METHOD

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1. General Description The Daubenmire method consists of systematically placing a 20- x 50-cm quadrat frame along a tape on permanently located transects. The following vegetation attributes are monitored using the Daubenmire method·

A. Canopy cover
B. Frequency
C. Composition by canopy cover

It is important to establish a photo plot and take both close-up and general view photographs. This allows the portrayal of resource values and conditions and furnishes visual evidence of vegetation and soil changes over time.

2. Areas of Use This method is applicable to a wide variety of vegetation types as long as the plants do not exceed waist height. It tends to be inexpensive. Estimates can be made very quickly. It is necessary for the plants' canopies to be distinct.

3 . Advantages and Limitations This method is relatively simple and rapid to use. A limitation is that there can be large changes in canopy cover of herbaceous species between years because of climatic conditions, with no relationship to the effects of management. In general, quadrats are not recommended for estimating cover. This method cannot be used to calculate rooted frequency.

This method can be moderately accurate. Where greater accuracy is required, Line Intercept or Point Intercept techniques can be used.

4. Equipment The following equipment is needed.

A. Study Location and Documentation Data form
B. Daubenmire forms (Daubenmire form and Daubenmire Summary form).
C. Hammer
D. Permanent yellow or orange spray paint
E. Two stakes: 3/4 - or 1 -inch angle iron not less than 16 inches long
F. Tape: 100- or 200-foot, delineated in tenths and hundreds, or a metric tape of the desired length.
G. Steel pins (reinforcement bar) for marking zero, mid, and end points of the transect
H. Frame to delineate the 20- x 50-cm quadrats
I. Compass
J. Steel post and driver

5. Training The accuracy of data depends on the training and ability of the examiners. Error arises simple from inadequate training, but can be minimized by making quantitative measurements of cover using other techniques (e.g., line intercept). Examiners must be able to identify the plant species. They must receive adequate and consistent training in laying out transects and making canopy coverage estimates using the frame.

6. Establishing Studies Careful establishment of studies is a critical element in obtaining meaningful data.

A. **Site Selection** The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to run the study. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the critical or key areas (see Section III).

B. **Pilot Studies** Collect data on several pilot studies to determine the number of samples (transects or observation points) and the number and size of quadrats needed to collect a statistically valid sample.

C. **Number of Studies** Establish a minimum of one study on each study site; establish more if needed (see Section II.D and III.B).

D. **Study Layout** Data can be collected using the baseline, macroplot, or linear study designs. The linear technique is the one most often used.

(1) Align a tape (100-, or 200-foot, or metric equivalent) in a straight line by stretching it between the transect location and the transect bearing stakes. Do not allow vegetation to deflect the alignment of the tape. A spring and pulley may be useful to maintain a straight line. The tape should be aligned as close to the ground as possible.

(2) Drive steel pins almost to the ground surface at the zero point on the tape and at the end of the transect. A pin may also be driven into the ground at the midpoint of the transect.

E. **Reference Post or Point** Permanently mark the location of each study with a reference post and a study location stake.

F. **Study Identification** Number studies for proper identification to ensure that the data collected can be positively associated with specific sites on the ground.

G. **Study Documentation** Document pertinent information concerning the study on the Study Location and Documentation Data form.

7. Taking Photographs Establish photo plots.

8. Sampling Process In addition to collecting the specific studies data, general observations should be made of the study sites.

A. **Cover Classes** This method uses six separate cover classes. The cover classes are:

Cover Class	Range of Coverage	Midpoint of Range
1	- 5%	2.5%
2	5- 25%	15.0%
3	25 - 50%	37.5%
4	50 - 75%	62.5%
5	75 - 95%	85.0%
6	95 - 100%	97.5%

B. **Ten Cover Classes** Where narrower and more numerous classes are preferred, a ten-cover class system can be used.

C. **Collecting Cover Data** As the quadrat frame is placed along the tape at the specified intervals, estimate the canopy coverage of each plant species. Record the data by quadrat, by species, and by cover class on the Daubenmire form. Canopy coverage estimates can be made for both perennial and annual plant species.

(1) Observe the quadrat frame from directly above and estimate the cover class for all individuals of a plant species in the quadrat as a unit. All other kinds of plants are ignored as each plant species is considered separately.

(2) Imagine a line drawn about the leaf tips of the undisturbed canopies (ignoring inflorescence) and project these polygonal images onto the ground. This projection is considered "canopy coverage." Decide which of the classes the canopy coverage of the species falls into and record on the form.

(3) Canopies extending over the quadrat are estimated even if the plants are not rooted in the quadrat.

(4) Collect the data at a time of maximum growth of the key species.

(5) For tiny annuals, it is helpful to estimate the number of individuals that would be required to fill 5% of the frame (the 71 - x 71 -mm area). A quick estimate of the numbers of individuals in each frame will then provide an estimate as to whether the aggregate coverage falls in Class I or 2, etc.

(6) Overlapping canopy cover is included in the cover estimates by species; therefore, total cover may exceed 100 percent. Total cover may not reflect actual ground cover.

9. **Calculations** Make the calculations and record the results in the appropriate columns on the

Daubenmire and Daubenmire Summary forms.

A. **Canopy Cover** Calculate the percent canopy cover by species as follows:

(1) On the Daubenmire form count the number of quadrats in each of the six cover class (by species) and record in the Number column on the Daubenmire Summary form.

(2) Multiply this value times the midpoint of the appropriate cover class.

(3) Total the products for all cover classes by species.

(4) Divide the sum by the total number of quadrats sampled on the transect.

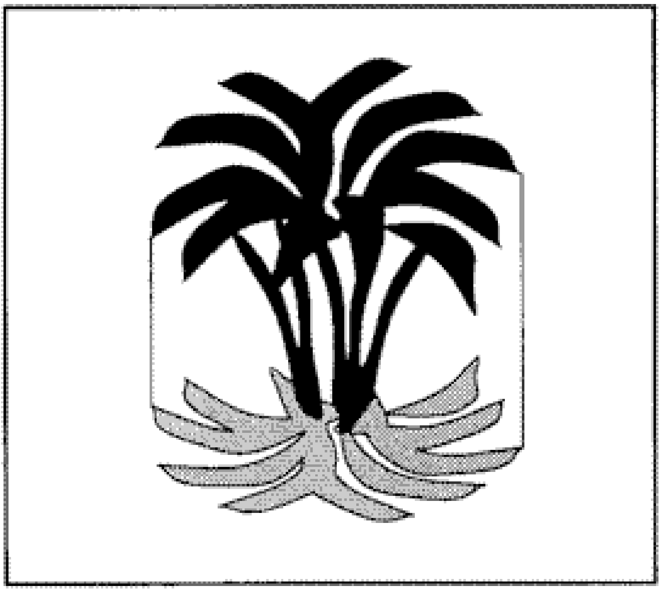
(5) Record the percent cover by species on the form.

B. **Frequency** Calculate the percent frequency for each plant species by dividing the number of occurrences of a plant species (the number of quadrats in which a plant species was observed) by the total number of quadrats sampled along the transect. Multiply the resulting value by 100. Record the percent frequency on the form.

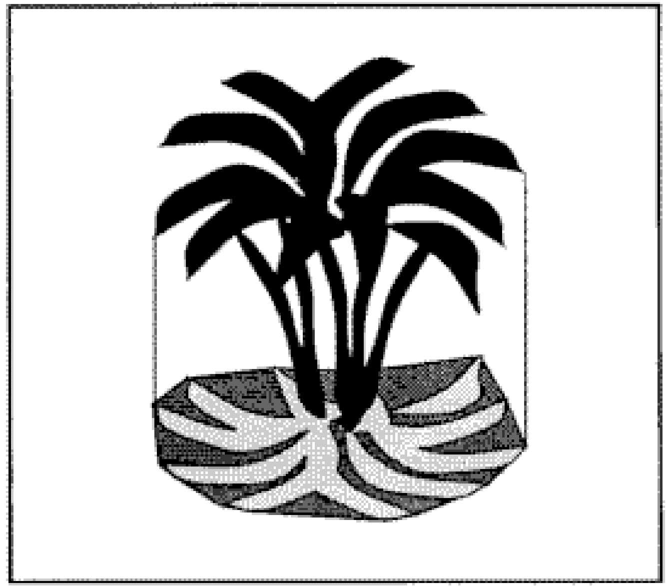
C. **Species Composition** With this method, species composition is based on canopy cover of the various species. It is determined by dividing the percent canopy cover of each plant species by the total canopy cover of all plant species. Record the percent composition on the form.

10. Data Analysis Tests should be directed at detecting changes in cover of the species and/or in major ground cover classes. Tests for changes in minor species will have low power to detect change. If quadrats are spaced far enough apart on each transect so as to be considered independent, the quadrat can be analyzed as the sampling unit. Otherwise, the transects should be considered the sampling units. If the transects are treated as the sampling unit, and given that the transects are permanent, either the paired t-test or the nonparametric Wilcoxon signed rank test should be used to test for change between two years. Repeated measures ANOVA can be used to test for differences between 3 or more years. If the quadrats are treated as the sampling units, care must be taken to ensure they are positioned the same along each transect in each year of measurement. A paired t-test, Wilcoxon signed rank test, or ANOVA is then used as described above for transects.

11. Cost About 5-25 min/10 quadrats.



Foliar cover.



Canopy cover.

LINE INTERCEPT METHOD

1. General Description The Line Intercept method consists of horizontal, linear measurements of plant intercepts along the course of a line (tape). It is designed for measuring grass or grass-like plants, forbs, shrubs, and trees. The following vegetation attributes are monitored with this method:

A. Foliar and basal cover
B. Composition (by cover)

It is important to establish a photo plot and take both close-up and general view photographs. This allows the portrayal of resource values and conditions and furnishes visual evidence of vegetation and soil changes over time.

2. Areas of Use This method is best suited for conditions in which it is easy lay out straight lines. This implies a relatively open vegetation at a height of less than 2 m.

The Line Intercept method is applicable to vegetation ranging from low herbaceous growth to the tallest forests. It is necessary to modify the length of the transect line and the precision with which the intercept points are recorded under these various conditions. For low or herbaceous vegetation, it is often desirable to use lengths of about 10m. Data should be recorded to the nearest cm. In shrubby vegetation and in forests, it if often desirable to use transects of > 100 m length. Data should be recorded to the nearest 10 cm. For vegetation with multiple strata, it is often desirable to run separate transects to deal with the different layers. The layers measured can be defined arbitrarily.

3. Advantages and Limitations The Line Intercept method is best suited where the boundaries of plant growth are relatively easy to determine. It can be adapted to sampling varying densities and types of vegetation. It is not well adapted, however, for estimating cover on single-stemmed species, dense grassland situations, litter, or gravel less than 1/2 inch in diameter. It is best suited to estimating cover on shrubs.

This technique gives quite accurate results. Accuracy is highest if the plants measured have the same growth form and similar crown diameters. Accuracy is lower when it is difficult to set up a straight line using a stretched tape. It is also necessary to be able to clearly see the projection of the canopy (or basal area) of the plant on the line. As for other techniques for examining canopy cover, if canopies intermingle or are highly irregular, it becomes difficult to say precisely where the margin of the plant's canopy is and, consequently, accuracy is affected. It is desirable to use multiple line transects, rather than a single line, to insure adequate coverage of the site and a random sample.

4. Equipment The following equipment is needed.

A. Study Location and Documentation Data form
B. Line Intercept form
C. Hammer
D. Permanent yellow or orange spray paint
E. Two stakes: 3/4 - or 1 -inch angle iron not less than 16 inches long.
F. Two tapes: 100- or 200-foot, delineated in tenths and hundredths, or a metric tape of the desired length
G. Compass
H. Steel post and driver

5. Training A minimum of training is needed to make sure the examiners understand how to lay out baselines and transects and how to make the measurements. The examiner must also be able to identify the plant species. One-half hour training and 1 day of practice to obtain consistency is adequate.

6. Establishing Studies Careful establishment of studies is a critical element in obtaining meaningful data.

A. **Site Selection** The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to run the study. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the critical or key areas.

B. **Pilot Studies** Collect data on several pilot studies to determine the number of samples (transects or observation points) and the number and size of quadrats needed to collect a statistically valid sample.

C. **Number of Transects** Establish the minimum number of transects to achieve the desired level of precision for the key species in each study site.

D. **Length of Transect** The length of a transect is based on the density and homogeneity of the vegetation. If the vegetation is sparse, a longer transect is needed. Transects may be any length (eg. 100 feet, 200 feet, or even longer). For low or herbaceous vegetation, it is often desirable to use lengths of about 10m. Data should be recorded to the nearest cm. In shrubby vegetation and in forests, it if often desirable to use transects of > 100 m length. Data should be recorded to the nearest 10 cm. For vegetation with multiple strata, it is often desirable to run separate transects to deal with the different layers. The layers measured can be defined arbitrarily.

E. **Study Layout** Line Intercept data can be collected using either the baseline or linear study design. The baseline technique is the recommended study design.

(1) The study location stake is placed at the beginning of the baseline. After determining the

bearing of the study, a stake is placed at the end of the baseline. Transects are run perpendicular to and at random distances along the baseline. Transect location stakes are placed at the beginning and end of each transect. The distance between the stakes dependents on the length of the transect. The height of the stakes depends on the height of the vegetation.

Transect location stakes may be left in place as permanent markers or removed at the conclusion of the study. Permanently marking transects will result in greater power to detect change.

(2) Stretch the transect tapes between stakes as close to the ground as possible, with the zero point of the tape aligned on the baseline (the beginning point of the transect). Do not allow vegetation to deflect the alignment of the tape.

F. **Reference Post or Point** Permanently mark the location of each study with a reference post and a study location stake.

G. **Study Identification** Number studies for proper identification to ensure that the data collected can be positively associated with specific sites on the ground.

H. **Study Documentation** Document pertinent information concerning the study on the Study Location and Documentation Data form .

7. Taking Photographs Establish photo plots.

8. Sampling Process In addition to collecting the specific studies data, general observations should be made of the study sites.

Proceed down the tape stretched along the transect line and measure the horizontal linear length of each plant that intercepts the line. Measure grasses and grass-like plants, along with rosette-forming plants, at ground level. For forbs, shrubs, and trees, measure the vertical projection of the foliar cover intercepting one side of the tape. Be sure not to inadvertently move the tape to include or exclude certain plants. If the measurements are made in 10ths and 100ths of feet, the totals are easily converted to percentages. The measurements are recorded by species on the Line Intercept form.

9. Calculations Make the calculations and record the results on the Line Intercept form.

A. **Cover**

(1) Calculate the percent cover of each plant species by totaling the intercept measurements for all individuals of that species along the transect line and convert this total to a percent.

(2) Where the measurements are made in 10ths and 100ths of feet along a 100-foot transect, the totals for each species are the cover percentages.

(3) Calculate the total cover measured on the transect by adding the cover percentages for all the species. This total could exceed 100% if the intercepts of overlapping canopies are recorded.

B. **Composition** With this method, species composition is based on the percent cover of each species. Calculate percent composition by dividing the percent cover for each plant species by the total cover for all plant species.

10. Data Analysis It is important to realize that each transect is a single sampling unit. For trend analysis permanent sampling units are suggested. If permanent transects are monitored, use the appropriate paired analysis technique. Use either a paired t-test or the nonparametric Wilcoxon signed rank test when testing for change between years. When comparing more than two sampling periods, use repeated measures ANOVA. If the transects are not permanently marked, use the appropriate nonpaired test.

11. Cost Approximately 1 hour per 25 intercepts. This can be a 10 m transect in herbaceous vegetation to a 250 m transect in a forest.

STEP POINT METHOD

1. General Description The Step-Point Method involves making observations along a transect at specified intervals, using a pin to record cover "hits." It measures cover for individual species, total cover, and species composition by cover.

It is important to establish a photo plot and take both close-up and general view photographs. This allows the portrayal of resource values and conditions and furnishes visual evidence of vegetation and soil changes over time.

2 . Areas of Use This method is best suited for use with bare ground, litter, grasses, forbs, as well as low shrubs, but can be used large shrubs and trees. The greater the structure to the community, the more difficult it becomes to determine "hits" due to parallax, observer bias, wind, etc. This method is good for an initial overview of an area not yet subjected to intensive monitoring.

3 . Advantages and Limitations. This method is relatively simple and easy to use as long as careful consideration is given to the vegetation type to which it is applied. It is suitable for measuring major characteristics of the ground and vegetation cover of an area. Large areas can easily be sampled, particularly if the cover is reasonably uniform. It is possible to collect a fairly large number of samples within a relatively short time.

A limitation of this method is that there can be extreme variation in the data collected among examiners when sample sizes are small. Tall or armored vegetation reduces the ability to pace in a straight line, and the offset for obstructions described in the procedures adds bias to the data collection by avoiding certain components of the community. Another limitation is that less predominant plant species may not be hit on the transects and therefore do not show up in the study records. The literature contains numerous studies utilizing point intercept procedures that required point densities ranging from 300 to 39,000 in order to adequately sample for minor species. One major consideration in the use of this method is to assure that a sharpened pin is used and that only the point is used to record "hits." Pins have finite diameters and therefore overestimate cover (Goodall 1952). Another limitation of this method is that statistical analysis of the data is suspect unless two and preferably more transects are run per site.

This method is rather crude. Errors in pacing the transect invariably occur, usually resulting in underestimation of shrubs and other obstacles. In addition, its is often hard to eliminate errors caused by moving vegetation out of its original position. A sharpened pin may diminish some of this bias. Estimation of taller vegetation (e.g., trees) by line of sight is even less accurate than the results for low grasses and forbs, but using the vertical rod to project upward will give results whose accuracy is comparable to those for herbs. Error can also result for the uniform spacing of points. This can be minimized by using several short transects, rather than one or two long ones.

4. Equipment The following equipment is needed.

A. Study Location and Documentation Data form
B. Cover Data form
C. Permanent yellow or orange spray paint
D. Tally counter (optional)
E. One stake: 3/4- or l -inch angle iron not less than 16 inches long
F. 3-foot long, 3/16th-inch diameter sharpened pin
G. Compass
H. Steel post and driver

5. Training A minimum amount of training is needed for this method. The technique can be learned in less than 1 hr. A 1/2 hr practice session in the field is usually adequate. Complex communities may require 4 hr of practice. Examiners must be able to identify the plant species, be familiar with the ground-level cover categories, know how to collect canopy or foliar cover data, and know how to collect cover data using a pin and notch in the boot.

6. Establishing Studies Careful establishment of studies is a critical element in obtaining meaningful data.

A. **Site Selection** The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to run the study. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the critical or key areas.

B. **Pilot Studies** Collect data on several pilot studies to determine the number of samples (transects or observation points) and the number and size of quadrats needed to collect a statistically valid sample.

C. **Number of Transects** Establish the minimum number of transects to achieve the desired level of precision.

D. **Study Layout** Data can be collected using either the baseline or linear study designs. The linear technique is the one most often used.

E. **Reference Post or Point** Permanently mark the location of each study with a reference post and a study location stake.

F. **Study Identification** Number studies for proper identification to ensure that the data collected can be positively associated with specific sites on the ground.

G. **Study Documentation** Document pertinent information concerning the study on the Study Location and Documentation Data form.

7. Taking Photographs Establish photo plots.

8. Sampling Process In addition to collecting the specific studies data, general observations should be made of the study sites

A. **Running a Transect** Determine the transect bearing and select a prominent distant landmark such as a peak, rocky point, etc., that can be used as the transect bearing point.

(1) Start a transect by randomly selecting a point along the transect bearing and reading the first hit (observation point).

(2) Read hits at specified intervals by placing the heel of the boot on the ground with the sole of the boot at a 30-degree angle to the ground. Place the pin into the 3/16th inch wide by 1/8th inch deep notch in the toe of the boot and vertically lower the pin until it either intersects an herbaceous plant or the ground for the specified number of hits. It is recommended that the interval be a minimum of 5 paces. To lengthen the transect, increase the distance between hits (10 paces, 20 paces, etc.) -

(3) When obstructions such as trees, cactus, ledge rock, etc., are encountered, sidestep at 90' from the transect line and continue pacing parallel to the transect to avoid the obstructions. Return to the original transect line as soon as possible by sidestepping at 90' in the opposite direction. Continue pacing along the transect bearing. If the obstruction is determined to be a highly important component of the community, this information can be recorded qualitatively on the back of the form.

(4) In most cases, do not count hits along portions of a transect that have been unnaturally disturbed, such as roads or trails. When such areas are encountered, proceed three paces past the disturbance before resuming the reading of hits along the transect line.

B. **Collecting Cover Data** At each observation point, identify the ground level or basal hit with the point of the pin and record the data by dot count tally by category and/or plant species code in the appropriate section of the Cover Data form . If there is a vegetation canopy layer, lower the pin through the vegetation until a basal or ground level hit is determined. Record the basal or ground level hit and any subsequent vegetation layers that intersect the pin. For vegetation structure above 3-feet (length of pin), a visual observation of plant intercepts above the notch in the boot can be made and recorded as additional canopy or foliar level hits on the data form.

(1) Ground-level or basal hits

(a) Ground-level hits (excluding basal vegetation hits) will fall into four cover categories. They can be redefined and/or additional categories added, depending on the data needed. The four categories are:

L - Litter
B - Bare ground
G - Gravel (particle sizes between 1/12 inch and 10 inches)

S - Stone (greater than 10 inches)

(b) Record the ground-level hits by dot count tally by ground-level cover category in the Ground-Level Cover section of the form, except where there are ground-level and, basal or canopy cover hit combinations. In this situation, use the Basal and Canopy/Foliar Cover section of the form.

(c) Basal hits on live vegetation are identified by species (includes mosses and lichens more than 1/16 inch thick). To count as a basal hit on live vegetation, the plant crown at or below a 1-inch height above the ground MUST be intercepted by the pin.

(d) Enter the appropriate plant species code in the Basal or Ground-Level Column in the Basal and Canopy/Foliar Cover section of the form.

(e) Enter a dot count tally for each basal hit on a species in the Dot Count Column in the Basal and Canopy/Foliar Cover section of the form when the plant species code is first entered on the form. Enter an additional dot count tally each time there is a basal hit on that species on the transect, except where there are basal and canopy/foliar cover hit combinations.

(2) Ground-level or basal and canopy/foliar cover hit combinations

(a) Identify the ground-level or basal hit, as well as any canopy cover hit(s) below 3 feet in height, intercepted at each point by the pin. For canopy cover above 3 feet, use line-of-sight observations directly perpendicular to the notch in the boot.

(b) Enter the appropriate ground-level cover category code and/or plant species code for each level of hit (up to four levels) in the appropriate columns in the Basal and Canopy/Foliar Cover section of the form .

(c) Enter a dot count tally for each ground-level or basal and canopy/foliar cover hit combination when it is first entered on the form and each time this same combination is encountered on the transect.

(d) Enclose plant species codes for vegetation cover hits more than 20 feet above ground level in brackets [ ].

9. Calculations Calculate the percent cover for each cover category by dividing the number of hits for each category by the total number of hits for all categories, including hits on vegetation.

A. **Ground Cove**r Ground cover is determined by dividing the total number of hits for all categories except bare ground by the total number of hits (including bare ground).

B. **Canopy/Foliar Cover** Canopy/Foliar cover is determined by dividing the total number of hits on vegetation (includes all basal and canopy/foliar hits) by the total number of hits.

C. **Basal Cover** Basal cover is determined by dividing the number of basal hits by the total number of hits.

10. Data Analysis

A. When transects are the sampling units: For trend analysis, permanent sampling units are suggested. If permanent transects are monitored, use the appropriate paired analysis technique to compare change in average cover by species and cover class. When comparing more than two sampling periods, use repeated measures ANOVA. If the transects are not permanently marked, use the appropriate nonpaired test.

B. When points are the sampling units: To determine if the change between sampling periods is significant, use Chi Square analysis of variance for cover data.

11. Costs One-half to 1 hr per 200 m transect.

POINT-INTERCEPT METHOD
Sighting Devices, Pin Frames, and Point Frames

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1. General Description The Point-Intercept method consists of employing a sighting device or pin/point frame along a set of transects to arrive at an estimate of cover. It measures cover for individual species, total cover, and species composition by cover. Point-Intercept is the method used in the NPS Fire Monitoring Handbook to estimate cover.

It is important to establish a photo plot and take both close-up and general view photographs. This allows the portrayal of resource values and conditions and furnishes visual evidence of vegetation and soil changes over time.

2. Areas of Use This method is suited to all vegetation types less than about 1.5 meters in height. This is because sighting devices and pin/point frames require the observer to look down on the vegetation from above in a vertical line with the ground. If the sighting device allows upward viewing, the method can also be used to estimate the canopy cover of large shrubs and trees.

3 . Advantages and Limitations Point interception measurements are highly repeatable and lead to more precise measurements than cover estimates using quadrats. The method is more efficient than line intercept techniques, at least for herbaceous vegetation, and it is the best method of determining ground cover and the cover of the more dominant species. Given the choice between sighting devices and pin/point frames, the optical sighting device is preferable.

A limitation of point-intercept sampling is the difficulty in picking up the minor species in the community without using a very large number of points. In addition, wind will increase the time required to complete a study because of the need to view a stationary plant.

One limitation that is specific to the use of point frames is that a given number of points grouped in frames gives less precise estimates of cover than the same number of points distributed individually. In fact, single-pin measurements require only one-third as many points as when point frames are used . Another problem with frames is that they overestimate the cover of large or dumped plants because the same plant is intercepted by different points on the same frame. This problem is overcome with the method described here by treating the frames as the sampling units (rather than using the individual points as sampling units). However, this approach doesn't change the fact that more points must be read than when the points are independent.

Use of a pin frame device (as opposed to a grid frame made of crossing strings) will result in overestimation of cover because the pins have finite diameter. The use of a sharpened pin will greatly reduce overestimation when only the point of the pin is used to record a hit or a miss.

4. Equipment The following equipment is needed.

A. Study Location and Documentation Data form
B. Cover Data form
C. Sighting device (A sighting device is available commercially from ESCO, P.O. Box 18775, Boulder, Colorado 80308)
D. Tripod for mounting sighting device
E. Panhead for tripod (makes possible rapid positioning of sighting device)
F. Pin or point frame. This can be a pin frame usually with 10 pins or a point frame , consisting of two superimposed string grids mounted one above the other on three adjustable legs.
G. Hammer
H. Permanent yellow or orange spray paint
I. Tally counter (optional)
J. Two stakes: 3/4 - or I -inch angle iron not less than 16 inches long
K. Compass
L. Steel post and driver
M. Tape: 50-, 100-, or 200-foot delineated in tenths and hundreds or a metric tape of the desired length.

5. Training A minimum of training is needed to make sure the examiners understand how to lay out baselines and transects and position and read the specific sighting device or pin/point frame being employed. The examiners must learn what constitutes a "hit". The technique should take about 1/2 hr training instruction and 1 day of practice to develop consistency. The examiners must also be able to identify the plant species.

6. Establishing Studies Careful establishment of studies is a critical element in obtaining meaningful data.

A. **Site Selection** The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to run the study. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the critical or key areas (see Section III).

B. **Pilot Studies** Collect data on several pilot studies to determine the number of samples (transects or observation points) and the number and size of quadrats needed to collect a statistically valid sample.

C. **Number of Studies** Establish a minimum of one study on each study site; establish more if needed (see Section II.D and III.B).

D. **Study Layout** Data can be collected using the baseline, macroplot, or linear study designs. The baseline technique is the recommended procedure.

E. **Reference Post or Point** Permanently mark the location of each study with a reference post and a study location stake.

F. **Study Identification** Number studies for proper identification to ensure that the data collected can be positively associated with specific sites on the ground.

G. **Study Documentation** Document pertinent information concerning the study on the Study Location and Documentation Data form.

7. Taking Photographs Establish photo plots.

8. Sampling Process In addition to collecting the specific studies data, general observations should be made of the study sites.

A. **Transects** Run a series of transects perpendicular to the baseline in both directions. The beginning points for each transect are randomly selected points along the baseline and the direction of each transect is also randomly determined.

To ensure that both transects and points/point frames are independent, spacing between transects and between points/point frames on each transect should be greater than the average diameter of the largest plants likely to be sampled. (If only basal cover is to be sampled, this diameter is the basal diameter; otherwise, it is canopy diameter.)

B. **Sampling along Transects** The first point/point frame read on each transect should be randomly determined. After the first point/point frame is read, all others are spaced the predetermined interval from the first point. If a tape is used for the transects, always read on the same side of the tape. (One of the devices manufactured by ESCO employs a mounting arm that is exactly 0.5 m long from tripod pivot to the axis of point projection. With this device, two points along each transect can be read with each placement of the tripod (assuming that I m is the selected interval between points). If this device is used, the tripod is placed at 2 m intervals along the tape (or at a number of paces approximating 2 m if no tape is used), the arm is rotated toward the baseline, the intercepted object is recorded, the arm rotated 180 degrees, the next intercepted object is recorded, and so on.)

(1) **Sighting Device** Determine hits by sighting through the device and recording the cover category in the cross hairs.

(2) **Pin/point frames** Determine hits by recording the cover category intercepted by each of the points. For pin frames, this is the cover category hit by each pin; for grid frames, this is the cover category determined by sighting through the "cross hairs" formed by each of the intersections of strings.

Hits are recorded on the Cover Data form in the following categories: vegetation (by plant species), litter, gravel, stone, and bare ground. Prior to recording data, the examiner needs to determine if canopy/foliar cover or basal cover (or both) will be recorded and if hits will be recorded in more than one canopy layer. For sighting devices and some pin/point frames, recording hits in more than one canopy layer requires that upper layers be temporarily moved out of the way to provide a direct line of sight to the lower canopy layers.

C. **Paired Samples** If the data are to be analyzed as paired samples, each transect should be permanently marked the first year at both ends. In each subsequent year of measurement, a tape should be run from one end to the other and the points/point frames read at the selected intervals along the transect. This process should then be repeated for each transect.

D. **Independent Samples** If the data are to be analyzed as independent samples, the transects do not have to be permanently marked. In this case, it is sufficient to pace each transect, taking measurements at each specified pace interval. The observer must ensure, however, that no bias is introduced by subconsciously "choosing" the point to be read. Such bias can be avoided by looking at the horizon when placing the tripod down.

9. Calculations Make the calculations and record the results on the Cover Data form.

A. **Cover of Individual Plants, Litter, Gravel, Stone, and Bare Ground**

(1) **Paired samples** Calculate the percent cover of each species along each transect by totaling all of the "hits" for that species along the transect, dividing the hits by the total number of points along the transect, and multiplying by 100. Calculate the total percent cover for the species in the sampled area by adding together all the transect cover values for the species and dividing by the number of transects. Do the same for litter, gravel, stone, and bare ground.

When point frames are used, the point frames themselves can be analyzed as sampling units. In this case, percent cover of each species is calculated for each point frame. Percent cover is calculated by totaling all of the "hits" for that species in one frame, dividing the hits by the total number of points in that frame, and multiplying by I 00. In this situation, cover data for each frame must be recorded separately on one form or on separate forms.

(2) **Independent samples: Sighting device and Pin frames** Calculate the percent cover of each species in the study area as a whole by totaling all the "hits" for that species along all of the transects, dividing by the total number of points in the study, and multiplying by 100. Do the same for litter, gravel, stone, and bare ground.

(3) **Independent samples: Point frames** For independent samples, the frames themselves can be considered the sampling units. Calculate the percent cover of each species in each point frame by totaling all the "hits" for that species in the frame, dividing the hits by the total number of points in the frame, and multiplying by 100. Calculate the total percent cover for the species in the sampled area by adding together all of the point frame cover values for the species and dividing by the number of point frames. Do the same for litter, gravel, stone, and bare ground.

(4) **Total vegetation cover** Calculate total vegetation cover by adding the study area cover percentages for all plant species. This total could exceed 100 percent if multiple hits (overlapping canopies) were recorded at each point along the transect.

B. **Species Composition** Species composition is based on the percent cover of the various species. Calculate percent composition by dividing the percent cover for each plant species by the total cover for all plant species.

10. Data Analysis The method of data analysis depends upon whether or not the transects are permanent.

A. **Permanent Transects** If the transects are permanent, the transects or point frames are the sampling units. Either a paired t test or the nonparametric Wilcoxon signed rank test is used to test for significant change in average cover between two sampling periods. Repeated measures analysis of variance is used to test for significant change in average cover between three or more sampling periods.

B. **Transects Not Permanent** If the transects are not permanent, that is, if they are randomly located in each sampling period, then the samples are independent and the points can be treated as the sampling units.

Sighting Devices: Analysis consists of a Chi Square contingency table analysis to test for significant change between years in numbers of "hits" on the key species, other plant species, or cover classes.

Point Frames: Analysis consists of testing for significant changes in average cover between sampling periods using the independent sample t test or the nonparametric Mann Whiitney U test. Independent sample analysis of variance or the nonparametric Kruskal-Wallis test is used to test for significant changes in average cover between three or more years.

11. Cost Ten minutes per 10 pins (for a 10 pin frame).

POINT INTERCEPT-SPHERICAL DENSIOMETER

1. Variables Estimated

Canopy and foliar cover of the very tall shrubs and trees (pp. 5, 7).

2 Description

In summary, a spherical densiometer is set up at randomly located sampling locations in the site. The densiometer optically identifies a series of points in the canopy above the sampling location. The observer records what each point hits.

Random sampling locations should be selected. At each location, the densiometer is set up following the manufacturer's instructions. The crew then sequentially looks at each of the points on the densiometer and records sky or the kind of plant which is intercepted. For foliar cover, if a point falls on a plant, the species should be recorded. If the point hits plant parts from more than one species, all should be recorded as hits. For estimates of canopy cover, the crew must judge where the outer perimeter of the canopies of individual plants lie, and then record for each sample point whether or not it falls within a plant's perimeter. The only data that need to be recorded are the total number of points intercepting each category of interest; e.g., trees by species, and sky. Data are most easily collected by sequentially observing in four directions (north, east, south, west) at a sample location.

To calculate cover for a particular category of data (e. g. , plant species X), the following equation is used:

Cx = Nx/Ên (100)

where
Cx = cover of X (%)
Nx = number of dots intercepting X
Ên = total number of dots sampled

This formula may be applied for either foliar cover or canopy cover, depending upon how the data were collected. Commercially available densiometers use a 96 dot grid. Approximate measures of cover may be made by assuming one dot equals 1%, on the average. This will give an error of less than 5% due to the difference between 96 and 100.

3. Accuracy

Spherical densiometer consistently produces accurate measurements regardless of the operator. Densiometer measurements were found to be highly correlated with those taken with a canopy camera.

4. Application notes

This technique can be applied by one person. It is particularly appropriate to use where vegetation is dense and the user wants to estimate cover by species (e.g., mixed deciduous forest). It is also relatively easy to use in highly uneven terrain where the Line Intercept technique is difficult to apply. Where canopies do not overlap, and canopy cover is the desired variable, Line Intercept, Bitterlich Method, or Daubenmier are often preferred techniques.

5. Training

Instructions included with the instrument are adequate. However, field experience is necessary to improve operator consistency. Fifteen minutes instruction and 0.5 hr practice is adequate.

6. Equipment

Spherical densiometer (about $47, Forest Densiometers 1980). Two types are available: convex and concave. Measurements from the two types should be calculated separately, because slightly different results can occur.

7. Cost

Three minutes per sample location (four directions) for sparse communities; 12 minutes per sample location for dense communities.

COVER BOARD METHOD

1. General Description The Cover Board method uses a profile board or density board to estimate the vertical area of a board covered by vegetation from a specified distance away. This technique is designed to evaluate changes in the vegetation structure over time. The following vegetation attributes are monitored using this method:

A. Vertical cover
B. Structure

It is important to establish a photo plot and take both close-up and general view photographs. This allows the portrayal of resource values and conditions and furnishes visual evidence of vegetation and soil changes over time.

2. Areas of Use This method is applicable to a wide variety of vegetation types. It should be used with those that show potential for changes, such as woody riparian vegetation.

3 . Advantages and Limitations The Cover Board technique is a fast and easily duplicated procedure. The size of the board can be modified to meet the purpose of the study.

It is moderately accurate for measuring vertical cover. However, the vertical cover is usually used to measure something else such as "perceived sight distance" for a given wildlife species, or for estimation of the quantity of vegetation at a give height in a stand. Its accuracy under these conditions becomes largely a function of the extent to which there is a direct relationship between the measured vertical cover and the variable of which it is used as an indicator. Precision is largely a function of one's ability to ocularly estimate the amount of the board which is obscured. (For characterizing a site, precision also becomes a function of the sample size.)

The major sources of error include selecting points which are not truly random (e.g., avoiding standing in briar patches when the randomly selected location would put the examiner there), not moving along the same direction in a straight line, and errors in the ocular estimation of the amount of the board which is covered. The error in ocular estimation can be minimized by using a "comparator". It is probably minimal in the variable distance approach.

4. Equipment The following equipment is needed.

A. Study Location and Documentation Data form
B. Density or Profile Board Method forms
C. Cover board
D. One stake: 3/4- or 1 -inch angle iron not less than 16 inches long
E. Hammer
F. Permanent yellow or orange spray paint

G. Compass
H. Steel post and driver

5. Training The accuracy of the data depends on the training and ability of the examiners. They must receive adequate and consistent training in laying out transects. A minimum of training is needed to make sure the examiners understand how to position the cover board and estimate percent cover. Examiners must also be able to identify plant species if estimates are to be made be species.

6. Establishing Studies Careful establishment of studies is a critical element in obtaining meaningful data.

A. **Site Selection** The most important factor in obtaining usable data is selecting representative areas (critical or key areas) in which to run the study. Study sites should be located within a single plant community within a single ecological site. Transects and sampling points need to be randomly located within the critical or key areas (see Section III).

B. **Pilot Studies** Collect data on several pilot studies to determine the number of samples (transects or observation points) and the number and size of quadrats needed to collect a statistically valid sample.

C. **Number of Studies** Establish a minimum of one study on each study site; establish more if needed (see Section II.D and III.B).

D. **Study Layout** Data can be collected using either the baseline or linear study designs described in Section III.A.2 beginning on page 8. The linear technique is the most often used procedure.

(1) **Linear transect**

(a) Determine the transect bearing and select a prominent distant landmark such as a peak, rocky point, etc., that can be used as the transect bearing point.

(b) Randomly select an observation point along the transect. The cover board will be placed 15 feet from this observation point in a random direction. One way to select a random direction is by using the second hand on a standard watch. Look at the watch and note the direction the second hand is pointing. Another way is to randomly select a three digit number between 0 and 360 from a random number table to represent the degrees on a compass. After taking the initial reading, remain at the observation point on the transect and take three additional readings at 90-degree angles from the original bearing and at the same distance (15 feet). Additional observation points can be established at specified intervals from the initial observation point along the transect bearing. A piece of angle iron or rebar should be placed at each observation point for easy relocation.

(c) Be sure to record the bearing from the observation point to each cover board location on the

Cover Board form.

(2) Center location

(a) An alternative method of establishing a transect is to randomly select a center point within an area to be sampled. Set angle iron or rebar at four randomly selected points 15 feet from the center point. Place the cover board at each rebar, facing the center post. Take readings and photographs of the cover board from the center point. Additional center points can be established as needed.

(b) Be sure to record the bearing and distance to each center point location from the reference post on the Cover Board form (see Illustrations 18 and 19).

E. **Reference Post or Point** Permanently mark the location of each study with a reference post and a study location stake.

F. **Study Identification** Number studies for proper identification to ensure that the data collected can be positively associated with specific sites on the ground.

G. **Study Documentation** Document pertinent information concerning the study on the Study Location and Documentation Data form.

7. Taking Photographs Establish photo plots.

8. Sampling Process In addition to collecting the specific studies data, general observations should be made of the study sites.

Position the cover board in the appropriate locations 15 feet from the observation point. Record the cover class from the modified Daubenmire cover classes (see Table 2) for each segment of the cover board (see Illustration 20). Depending on the objectives, vegetative cover can be recorded by species or simply for the total of all species. Cover can also be recorded as a straight percentage.

Cover Class	Range of Coverage	Midpoint of Range
0	0%	0%
T	< 1%	0.5%
1	1 to 5%	3.0%
2	5 to 25%	15.0%
3	25 to 50%	37.5%
4	50 to 75%	62.5%
5	75 to 95%	85.0%

6	95 to 100%	97.50%

9. Calculations for Vertical Canopy Cover Calculate the average "cover score" by layer. The midpoint of each cover class is used to calculate the average cover for each layer or for the entire transect when using cover classes. If actual percentage estimates are made, calculate an average cover value by averaging cover for each layer. For a total cover average, the calculation involves summing the cover values for all layers and dividing by the number of layers.

1**0. Data Analysis** For trend analysis, permanent sampling units are suggested. If permanent transects are monitored, use the appropriate paired analysis technique. If the transects are not permanently marked, use the appropriate nonpaired test. When comparing more than two sampling periods, use repeated measures ANOVA.

BILTMORE STICK

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1. Variable Estimated

Stem diameter of an individual tree.

2. Description

In summary, the diameter of an individual tree stem is estimated using a stick graduated with a special scale. The stick is held against the tree, and the estimated diameter is read directly off the stick.

If the desired variable is the average for the trees on a site, the tree to be measured should be chosen randomly.

On approaching the tree, one should estimate its diameter and grasp the Biltmore stick near the middle. Place the stick horizontally against the tree trunk at the height to be measured (usually "breast height", 1.4 m or 4.5 ft, Fig. 7). The stick should be perpendicular to the eye. With one eye closed, one aligns the stick so that the center of the stick is the appropriate distance from the eye (usually 64 cm or 25 in.) with the zero end of the scale aligned with the edge of the tree trunk. Without moving one's head, read the number off the scale which aligns with the other side of the tree trunk.

3. Accuracy

This technique is crude. Sources of error include deviations of the tree from circular in cross section and, most importantly, errors in holding the stick horizontally, perpendicular to the eye, and precisely the specified distance from the eye. Accuracy increases as tree size decreases. Diameter readings for small trees can be measured to about the nearest 2 cm.

4. Application Notes

This technique is inexpensive. It is usually the best technique if 10 accuracy is acceptable. One person can apply the technique without difficulty. It is appropriate except where tree growth form deviates radically from circular.

5. Training One-half hour.

6. Equipment Biltmore stick ($20-$25; Forestry Suppliers, Inc. 1980).

BITTERLICH METHOD

VARIABLE PLOT SAMPLING, PRISM CRUISING, OR THE SHRUB ANGLE GAUGE

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1. Variables Estimated

Basal cover of trees and tall shrubs, canopy cover of shrubs.

2. Description

In summary, random points are selected in the plot. From each point, a count is made of all plants larger than a certain critical size (which is a function of the diameter of the plant and its distance from the sample point).

Within the site, a random point is selected. The observer stands close to the point, and turns 360' while keeping the gauge directly over the sample point. Each plant seen as the observer turns is inspected using an angle gauge (see equipment section, below). The plant is usually viewed at breast height (1.4 m or 4.5 ft) for trees, or at the widest point for canopy cover of shrubs. If the tree or shrub viewed is sufficiently large or sufficiently close to be wider than the critical angle, it is counted. (See instructions with the gauge used). It is necessary to be careful not to count the first plant twice. The procedure is repeated at several sample points.

For accurate results, it is important that these measurements be made horizontally or corrected for slope (see below). If the observer is measuring low shrubs, it may be necessary to stoop or lie down to get a horizontal measurement. If one is making measurements on a slope, calculated cover will be less than actual cover. For best results, a slope-correcting angle gauge (such as the Relaskop) should be used. If one is not available and small errors are acceptable, ignoring gentle slopes is justified. If the slope is less than 171, the error due to ignoring slope will be less than 5%. For accurate results, the count at each sample point should be divided by the cosine of the slope angle at that point (i.e., multiplied by the secant). The gauge must be perpendicular to the line of sight and vertical (not tilted to the left or right). When small errors are acceptable, individual plants that fall precisely on the critical angle should be counted as one half (Fig. 11). When accurate results are needed, borderline plants should be examined by measurement. When measuring, a plant should be counted if:

Percent	Metric	English
$D^2 <= (0.174\ W^2) / BAF$	$D^2 <= (0.25\ W^2) / BAF$	$D^2 <= (75.625\ W^2) / BAF$

where
D = distance from sample point to center of plant (m for percent and metric, ft for English)
W = width (diameter) of plant (cm for percent and metric, in for English)

BAF = basal area factor (percent cover/plant, Ml/ha plant, or ft2 /ac plant)

It is more accurate to count as "in" all plants that clearly are, and to measure D and W for each plant that is "borderline.11

No plant should be counted more than once from a single sample point, even though it may be more than twice as wide as the critical angle. From different sample points, however, it should be counted every time it is larger than the critical angle.

Basal cover is calculated with the following formula. The angle gauge's "basal area factor" (BAF) must be known. (If unknown, this may be determined as described in the Equipment section below).

B = (Ên)/p (BAF)

where
B = basal area (M2 /ha or ft2 /ac)
Ên = total number plants counted at all sample points
p = number of sample points
BAF = basal area factor (M2 /ha plant, or ft2 /ac plant)

Basal area in M^2 /ha or ft^2/ac can be converted to basal cover in percent by multiplying by a conversion factor. The conversion factor for basal area expressed in ml/ha = 100/10,000 = 0.01. The conversion factor for ft^2 /ac = 100/43,560 = 0.0023.

3. Accuracy

This technique can be moderately accurate. The principal sources of error are in systematic errors in using the angle gauge (e.g., systematically including more plants than should be included, or an inaccurate gauge) and deviations of the plants from circular cross section. Error can be introduced if sample points are not selected randomly. In dense stands, errors can arise by one plant being behind another. Sampling on slopes introduces error if no correction is made. If the observer stands on the sample point, rather than holding the gauge over the point, an error of about +4% results.

4. Application Notes

This technique is inexpensive. One person can apply the technique. It is particularly applicable in vegetation that is relatively open at eye level. Basal area of the trees in dense forest can be handled if there is relatively little understory growth to obscure the line of sight.

Shrub cover can be measured provided the density of the shrubs is not so great that some individuals are partially obscured by closer individuals, and provided the shrub canopies are nearly circular.

For measuring basal cover of trees 9 the Bitterlich Method is usually preferred because of its accuracy and low cost. For measuring shrub canopy cover, the Bitterlich Method is a rapid but crude technique. For low shrubs, the Daubenmire Method may be nearly as accurate but faster, especially if quadrats are needed anyway to estimate density or cover by herbs. For accurate results, the Line Intercept is preferred. Of course, RS: Crown Density Scale or RS: Ocular Estimation of Cover is often much less expensive.

5. Training Instruction and field practice require about 4 hr.

6. Equipment

There are several types of angle gauges on the market for measuring basal areas of trees. These include: glass prism ("cruising prism"); Relaskop; the Cruz-all; and others (Forestry Suppliers, Inc. 1980). The instrument should be accompanied by its specified BAF. If not, the BAF may be calculated as follows: Set up a target of 0.5-1 m in width (e. g. , a horizontal board of appropriate length). Move directly away from the target until the angle gauge precisely measures or displaces the width of the target. Now measure the distance from the target to the eye. BAF is calculated as follows:

BAF (percent/plant)=0.174(W^2/D)

BAF (M2 /ha plant) = 0.25 (W^2/D)

BAF (ft'/ac plant) = 75.625 (W^2/D)

where
BAF = base area factor (M^2 /ha plant or ft^2 /ac plant)
W = width of target (cm for percent and metric, in for English)
D = distance to target (m for percent and metric, ft for English)

Foresters usually use a gauge with a BAF of 4 M^2 /ha plant (or 10 ft^2 /ac plant). In stands of large, old growth trees, a BAF of 8 M^2 /ha is preferable, while in open stands of small (pole-sized) trees, a BAF of 2 M^2 /ha plant should be used. This minimizes the number of borderline trees and the number of trees that should be counted which are hidden behind others.

The shrub angle gauge needs to be calibrated for each user. Cooper (1957) recommends a BAF of 0.5% plant. Convenient dimensions for the gauge are a 10 cm bar width and an eye-bar distance of about 70.7 cm. To adjust the gauge so it has a BAF of 0.5, set up a horizontal target 2 m wide and move directly away until the distance from the eye to the target is 14.14 m. The length of the chain should be adjusted until the target appears exactly "borderline." The observer should then check the calibration by moving toward the target, then slowly backing away until the target is "borderline," and then checking the distance. It is essential that each user recalibrate and readjust the shrub angle gauge to compensate for individual variation in the way the instrument is held.

Commercially available angle gauges cost from about $3 for the Cruz-all, $15-20 for prisms, and $600 for the Relaskop (Forestry Suppliers, Inc. 1980). The shrub angle gauge can be constructed for $2-3.

A low cost (i.e. , $2-3), but less convenient angle gauge for use in forests, can be constructed similar to the shrub angle gauge, but using a stick instead of a chain for determining the distance between the eye and the crossarm. Convenient dimensions are a 1 in crossarm and a 33 in stick. This gives a basal area factor of 10 ft/ac plant.

7. Cost

5 min per sample point.

CALCULATED COVER

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1. Variable Estimated

Canopy or Basal Cover of trees or shrubs.

2. Description

In summary, the results of a measurement of density and of mean canopy area or basal area for the same site are used to calculate cover.

If data are available on density (Techniques 3.20 or 3.21) and mean canopy or basal area for plants (Techniques 3.1 and 3.23) on the same site, these estimates can be combined to estimate cover. The following formula applies:

$$C = 100\ A*D$$

where
C = cover (%)
A = mean area per plant (area)
D = density of plants (number per unit area, where the area units are the same as area for A, above)

3. Accuracy

The accuracy of the calculated cover is a function of the accuracies of the constituent measurements of density and mean area . For basal area of trees, it is usually medium to low in accuracy. For canopy cover, it tends to have low accuracy, due to deviations of canopy shape from circular.

4. Application Notes

This technique is most appropriate where the separate measures of density and canopy or basal area are required for other purposes. A convenient sampling approach is to combine T-square Nearest Neighbor Sampling (p. 62) for density with Crown Diameter (p. 15) or Diameter Tape (p. 18) and Averaging (p. 69). Each plant measured for the T-square sampling can also be used for area measurement. If the average area per plant is not required, it is usually preferable to measure cover with the Line Intercept (p. 40), Bitterlich Method (p. 43), Point Intercept-Spherical Densiometer (p. 55), or RS: Crown Density Scale at the same time density is being measured. One convenient way to do this is by combining a Line Intercept (p. 40) for measuring cover with a belt Quadrat (p. 65) for measuring density. The line transect forms one side of the belt quadrat.