THE ESTIMATION OF FOREST VEGETATION COVER DESCRIPTIONS USING A VERTICAL DENSITOMETER[1]

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ABSTRACT: The estimation of vegetation cover or canopy closure can be difficult and costly. The utilization of a vertical sampling tool, such as a canopy densitometer, along linear transects provides a reasonable means of generating reliable cover estimates. Estimates represent both the horizontal and vertical diversity of sample areas and may represent descriptions of species composition, size, and canopy structure as well as non-tree characteristics, such as ground surface conditions and shrub or herbaceous cover.

INTRODUCTION

The concept of ecosystem management is replacing the traditional approaches to forest management. The effects of land management practices are being monitored and evaluated to determine impacts on wildlife habitat, water quality, fisheries, aesthetics, and other forest ecosystem benefits, as well as timber inventory and harvest levels. One of the most important characteristics currently used as an indicator of the status and condition of the forest ecosystem is crown closure or vegetation canopy cover. Vegetation cover or canopy closure estimates are developed and used to characterize forest vegetation and enable the assignment of attributes or descriptive information regarding species type, composition, and even stand structure (Brown and Fox, 1992). Efforts using cover estimates are frequently associated with remote sensing/image processing efforts that involve aerial photography or satellite imagery. These efforts are significant in both the development of characteristics and the testing of map accuracy relative to ground truth (Hill, 1993). Without an accurate and reliable methodology for estimating vegetation cover, the development and accuracy assessment of cover-based vegetation databases is quite suspect.

The quantification of cover estimates may be accomplished in one of several ways: cover (versus non-cover) may be mapped; cover may be photographed, scanned, and image processed; cover may be estimated based on samples collected with a spherical densitometer; or cover may be estimated using data collected with a vertical point sampling device. Crown mapping may yield very precise and detailed estimates of cover characteristics, but it is not a methodology that may be applied on a very broad scale or at a low cost relative to sampling with spherical or vertical densitometers. Photo scanning and image processing may also be costly and subject to potential biases due to the non-vertical nature of the photo image. Species and tree size recognition may be difficult and the cost may be relatively high.

The spherical densitometer is useful for developing estimates based on only a few sample locations and therefore at a lower cost. However, these cover estimates also do not reflect a true vertical depiction of the cover characteristics, nor is it easy to differentiate the cover estimates by vegetation characteristics such as size or specie. The development of cover characteristics using a vertical densitometer relies on a greater number of sample points than the spherical densitometer, but requires a significantly lower amount of effort than crown mapping or photo scanning. Vertical sampling also enables the development of very detailed information regarding species composition, size, and stand structure with a high degree of reliability at a relatively low cost.

VEGETATION DATA COLLECTION USING THE CANOPY DENSITOMETER

The canopy-densitometer, when used with line-point transect sampling, combines horizontal and vertical stand sampling thereby enabling the collection of resource information across the landscape (horizontally) at different canopy levels (vertically) in the forest canopy. Stand characteristics are sampled in proportion to the differing amounts of cover that each characteristic contributes to the sample stand. For example, an individual large tree with a large crown area has a higher probability of being sampled than a small tree with a small crown area. However, a few large trees that encompass 10 percent cover will have as equal a probability of being sampled as a large number of small trees that also comprise ten percent cover.

This sampling methodology provides estimates of the cover contribution of the different characteristics measured at the transect (sample) points. Estimated distributions of species composition, tree size, age, crown diameter, and any other sampled characteristics are easily generated by dividing the number of points tallied for each recorded characteristic by the total number of sample points. For example, if 100 points are sampled along the transect and 29 of the sample points are covered by Douglas-fir trees, then the estimated cover of Douglas-fir is 29 percent. Other characteristics, such as the average diameter and crown width may also be recorded for sample trees. If 17 of the 100 sample points indicate cover is provided by trees equal to or greater than 36" dbh then the estimated cover of this size class is 17 percent. If 74 sample points indicate conifer cover and 9 points indicate hardwood cover then the total tree cover estimate is 83 percent (74+9) and the estimated percent conifer composition is 89.2 percent (74/(74+9)). An example of the stand estimates generated for an area sampled using this methodology is shown in Table 1.

Table 1
Training Area/ Accuracy Assessment Transect Summary

Transect Cover Density Summary:
Training Polygon: 154

Size Class: Species	0-5"	6-10"	11-23"	24-35"	36"+	Tree Cover	Non-Tree Cover	Total Cover
Doug-fir	10.0%	12.0%	0.0%	3.0%	4.0%	29.0%		28.9%
redwood	6.0%	10.0%	9.0%	2.0%	13.0%	40.0%		40.1%
white fir	0.0%	2.0%	3.0%	0.0%	0.0%	5.0%		5.1%
tanoak	2.0%	3.0%	4.0%	0.0%	0.0%	9.0%		8.9%
salal							1.0%	1.0%
vaccinium sp.							1.0%	1.0%
woody debris							3.0%	3.0%
bare soil							12.0%	12.0%
Total Cover	18.0%	27.0%	16.0%	5.0%	17.0%	83.0%	17.0%	100.0%
Total Tree Cover						83.0%		

Transect Tree Density Summary:
Training Polygon: 154

Size Class: Species	0-5"	6-10"	11-23"	24-35"	36"+	Tree Cover
Doug-fir	11.9%	14.4%	0.0%	3.6%	4.9%	34.8%
redwood	7.2%	12.0%	10.9%	2.4%	15.7%	48.3%
white fir	0.0%	2.4%	3.6%	0.0%	0.0%	6.1%
tanoak	2.4%	3.6%	4.8%	0.0%	0.0%	10.8%
Total Tree Cover	21.6%	32.4%	19.3%	6.0%	20.6%	100.0%

Transect Quadratic Mean DBH Summary:
Training Polygon: 154

Size Class: Species	0-5"	6-10"	11-23"	24-35"	36"+	Tree Cover
Doug-fir	3.9"	7.1"	0.0"	28.3"	41.1"	18.5"
redwood	3.7"	8.6"	14.3"	32.0"	43.6"	27.2"
white fir	0.0"	9.5"	15.7"	0.0"	0.0"	13.6"
tanoak	4.0"	9.4"	12.0"	0.0"	0.0"	9.8"
Quad Mean DBH	3.9"	8.1"	14.1"	29.9"	43.1"	22.3"
Quad Mean DBH - Con	3.8"	8.0"	14.7"	29.9"	43.1"	23.3"
Quad Mean DBH - Hwd	4.0"	9.4"	12.0"	0.0"	0.0"	9.8"

TRANSECT CONFIGURATION

The cover estimates generated using the canopy-densitometer are based on an evaluation of data collected at sample points evenly spaced on transects placed within sample areas. Transects of several different forms and lengths may be used, depending on the characteristics of the sample area. Shapes may be altered in an attempt to provide the most representative sample of the area subject to data collection goals. The transects are configured in either a straight line, triangle, or diamond shape (see Figure 1), depending on the size and shape of the sample area.

The transects are situated so that all the sample points fall within the sample area. The triangle shaped transects are used to sample smaller areas that the larger diamond shaped transect do not fit within. The straight line transects are typically used to sample the larger areas in which the triangle or diamond shaped transect might provide sample estimates that are too localized and potentially not representative of the sample area. Multiple transects, located randomly or systematically may be used to develop multiple estimates of stand characteristics, as well as stand estimates and variances. It is important that a given configuration be applied consistently to avoid any potential bias due to changing the form of the transect.

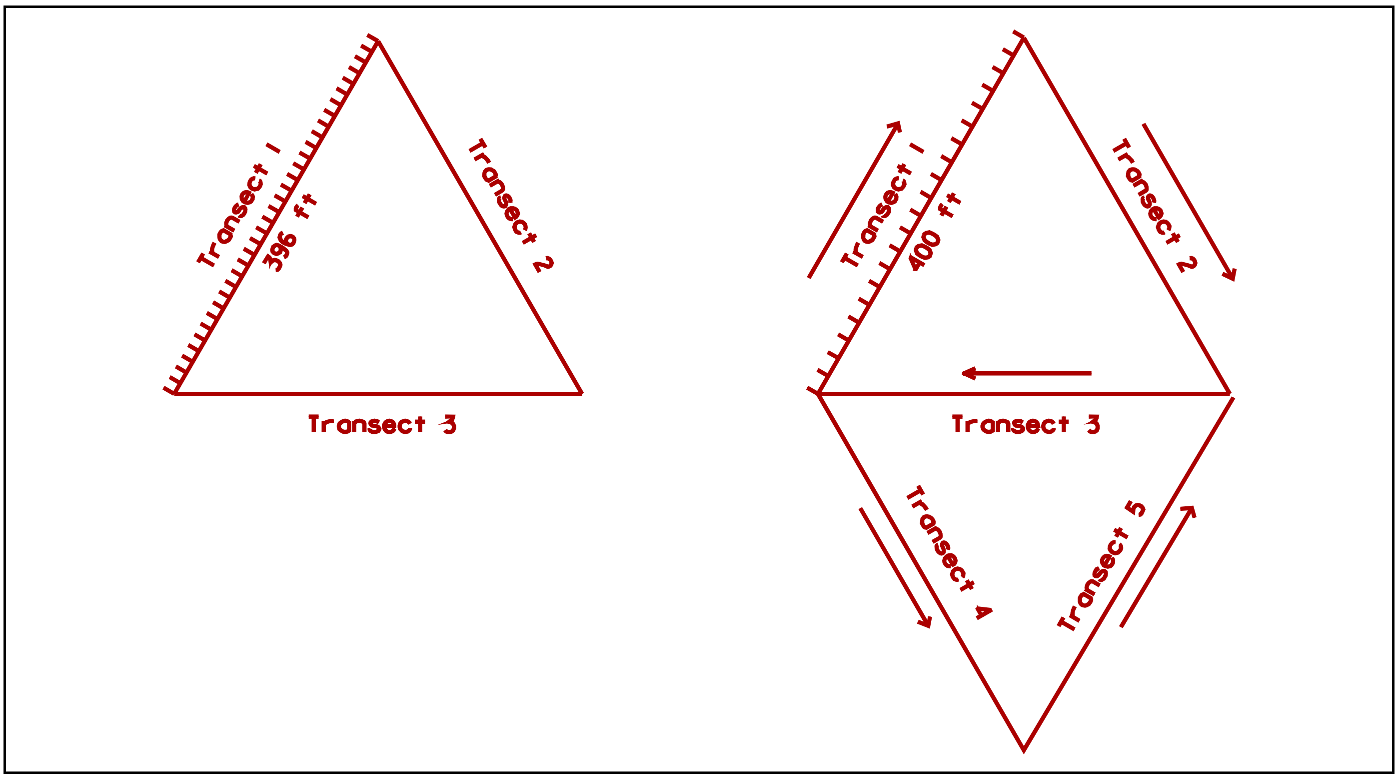

Figure 1. Transect configurations for triangular and diamond shaped transects.

In previous efforts, we have used transects of either 1188 feet or 2000 feet long. Sample data are collected along the transect at points spaced either twelve (12) feet (straight-line or triangle transect) or twenty (20) feet (diamond transect) apart. A total of one-hundred (100) transect points are sampled along each transect. More points may be collected by changing either the spacing of the points or the total length of the transect. A sample size of one-hundred points is by no means the optimal sample size but is based on sampling requirements that consider personnel, cost, and statistical reliability. Since the data being collected using this technique are binomially distributed (for each feature of interest there is a "yes" or "no" answer at every transect sample point), the statistical reliability of our sample, for different sample sizes, is known and is

95 Percent Confidence Interval (Two Standard Deviations)
Relative to Sample Size(n) and Population Estimate(p)

Sample Points	Population Estimate(p) 10%	20%	30%	40%	50%	60%	70%	80%	90%
10	20.0%	26.7%	30.6%	32.7%	33.3%	32.7%	30.6%	26.7%	20.0%
25	12.2%	16.3%	18.7%	20.0%	20.4%	20.0%	18.7%	16.3%	12.2%
50	8.6%	11.4%	13.1%	14.0%	14.3%	14.0%	13.1%	11.4%	8.6%
100	6.0%	8.0%	9.2%	9.8%	10.1%	9.8%	9.2%	8.0%	6.0%
200	4.3%	5.7%	6.5%	6.9%	7.1%	6.9%	6.5%	5.7%	4.3%
400	3.0%	4.0%	4.6%	4.9%	5.0%	4.9%	4.6%	4.0%	3.0%

Table 2: Estimated confidence interval width of sample data based on number of sample points and sample estimates.

shown in Table 2. A cover estimate based on a sample of one-hundred points will yield a 95 percent confidence interval of a width of between ± 6.0 percent and ±10.1 percent cover. An estimate based on 200 points will yield a 95 percent confidence interval width between ± 4.3 percent and ±7.1 percent cover.

The initial (starting) point of a sample transect should be located within each sample polygon in an unbiased manner. Locations should also be located on imagery, aerial photographs, corresponding digital maps, and/or orthophotography that are used to record data collection sites and assist field personnel in locating the transect starting points. During image processing and training and accuracy assessment projects, it is important that the field position of a transect is located as close as possible to the position identified on the image and photography. The improper location of sample transects can be a major source of error in the subsequent application of sample data to mapped vegetation conditions. If there is uncertainty regarding the accurate location of field data collection sites then Global Positioning System (GPS) devices should be used to properly locate sample sites and sample transects.

The direction of a sample transect is systematically determined so that, if possible, the transect falls entirely within the mapped boundaries of the study area. When this is not possible, the transect may be broken and an additional direction(s) may be selected for the remaining portion(s) of the transect to assure that all transect points fall within the boundaries of the sample area. If the sample area is too small to effectively locate the straight-line transect within, then a diamond-shaped or triangular shaped transect should be used. This transect layout avoids any potential bias and error that may result from the systematic orientation of the transect with respect to physiographic (terrain) features.

VEGETATION MEASUREMENT DETAILS AND STANDARDS

Both quantitative and qualitative data may be collected at all sample points along a transect. The presence or absence of any given vegetative cover characteristic is determined at each sample point along the transect using the vertical canopy-densitometer. A sighting is taken with the canopy-densitometer and the characteristics of that point are recorded. A tree that covers a sample point is a "cover" tree. Trees are determined to be "cover" trees by sighting through the canopy-densitometer and determining whether any portion of a tree crown intersects the vertical line of sight through the densitometer. The vertical line of sight is obtained by leveling both of the densitometer's vials and then sighting through the instrument so that the cross hairs are positioned between the sighting marks on the mirror.

Data are collected to be compatible with satellite imagery or aerial photo interpretation, methods that represent a "bird's eye" or top down view of the forest canopy. For transect points covered by tree crown(s), tree specific characteristics are recorded for the tree(s) providing the top level (as seen from above) of crown cover. Transect points covered by multiple trees of the same canopy position, but of different species or size, have multiple tree characteristics recorded, one for each of the "cover" trees.

The specific data that are collected at each transect point include the species code, dbh, crown diameter or area, and the canopy layer of the cover feature. Tree dbh is estimated using conventional forest inventory techniques and is recorded to the nearest inch. Tree crown diameter or area is estimated as accurately as possible using a tape and vertical canopy-densitometer; diameter is recorded to the nearest foot; while area, if recorded, is estimated to the nearest ten (10) feet. Sample point features that are definitely overstory contributors (top layer characteristics) are identified by recording an "**O**" (overstory) in the spectral contribution (SC) column. Those features that are definitely <u>not</u> contributors are identified by recording the proper canopy layer designation in this column (this information is useful for segregating the cover data that contribute to the spectral data of the satellite imagery and aerial photography from those characteristics that are covered and do not contribute to the spectral data as sensed from above the stand). Understory and ground vegetation features of the sample point are identified by using a species code that signifies the appropriate vegetation characteristic(s). Sampling at multiple layers of the forest stand is accomplished by noting the characteristics at different levels of the stand and designating the layer of the characteristic. Canopy layer classes, such as "**S**" and "**G**" are used to indicate subordinate and ground level layers of the stand. Any set of codes that would signify different types or levels of characteristics that are sampled can be recorded and used to summarize the sample data. Sample point data are recorded on the Transect Data Collection Form shown in Figure 2.

Many non-tree characteristics may also be recorded to provide a description of the non-tree characteristics of the sample area. Characteristics include such features as shrub and herbaceous cover and ground condition descriptions such as duff and litter, bare soil, soil-type, and exposed rock. Characteristics of duff and litter estimates may include an estimate of the depth of the organic layer and the size and decay status of dead and down woody debris if it intersects a transect point. Other information, such as parent material, if observable, may also be recorded at each point, as well as estimates of the landform such as ridge top, shoulder, valley bottom, concave slope, or alluvial fan.

Qualitative data are also observed and recorded. These are field observations that supplement the field measurements. Ocular estimates of vegetation type, quadratic mean tree size(dbh), canopy closure class, and stand age may be recorded for the area represented by each transect. Non-tree estimates involving the presence of understory vegetation, snags, litter/duff, woody debris, and parent material may also be indicated. These estimates reflect the field personnel's evaluation of the sample area and are based on their general impressions of the vegetation and non-vegetation characteristics of the area encompassing the transect(s) and of the general area that has been sampled. This information may be significant in understanding and interpreting the field data collected on individual transects and for the sample area as a whole. Individual transects may describe polygon variation and explain differences between map descriptions and field observations, thereby indicating horizontal diversity within the sample area. Other conditions of the sample transects, such as the logging history, slope percent, and aspect, also may be described.

SUMMARY

The vertical densitometer provides a useful means of collecting and estimating crown canopy closure estimates. The combination of the line-point transect sampling method and the collection of vegetation and non-vegetation characteristics at different positions within the forest canopy result in a sampling methodology that considers the horizontal diversity present across the landscape and the vertical diversity present within the sample area. Accurate and reliable estimates may be developed that include descriptions of species composition, cover by tree size, percent conifer and hardwood, and canopy structure.

LITERATURE CITED

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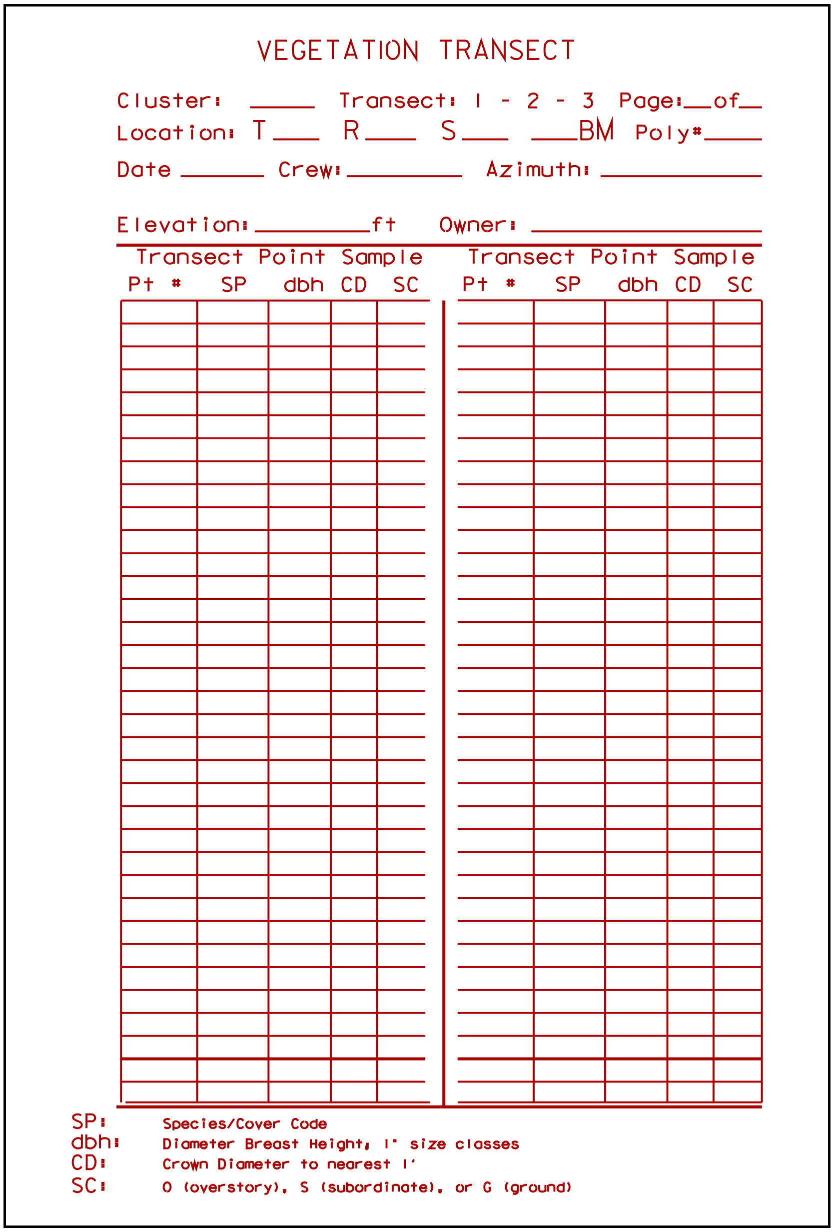

VEGETATION TRANSECT

Cluster: ______ Transect: 1 - 2 - 3 Page:__of__

Location: T____ R____ S____ ____BM Poly#_____

Date ________ Crew: __________ Azimuth: ______________

Elevation: __________ft Owner: ____________________

Transect Point Sample					Transect Point Sample				
Pt #	SP	dbh	CD	SC	Pt #	SP	dbh	CD	SC

SP: Species/Cover Code
dbh: Diameter Breast Height, 1" size classes
CD: Crown Diameter to nearest 1'
SC: O (overstory), S (subordinate), or G (ground)

Figure 2. Sample Area Transect Data Collection Form