Measuring Crown Cover in Interior Alaska Vegetation Types

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ABSTRACT: Tree-canopy cover is an important stand characteristic that can be estimated from aerial photography. Strong and weak points of various methods developed to aid this process are discussed. Several forest-canopy conditions common in interior Alaska are described; resource managers need to understand the limitations of the imagery they use and adjust their definition of canopy and cover stratifications accordingly.

INTRODUCTION

CROWN COVER is a useful stand characteristic estimated most easily by aerial photography. The estimates are useful because of the relations between crown closure, stocking, and stand volume. Estimates of crown or foliar cover of vegetation other than trees is useful in describing plant communities or biomass. Cover estimates from photographs are used instead of basal-area estimates or number of trees per acre when ground measurements are not possible or are limited by time or cost constraints (Moessner, 1964).

Although crown cover is estimated most easily from aerial photographs, the process is not as straight-forward as it might seem. Continued interest in the subject and the variety of ways to measure or estimate crown closure suggest that methods developed thus far are not completely satisfactory. In fact, many of these methods were developed with a small range of photo-scales and with specific questions to be answered at a particular precision. For the most part, the techniques do work well under the correct set of conditions.

Ocular estimation of crown closure has probably occurred since foresters began using aerial photographs. Pope (1960) formalized estimation of crown cover by documenting two methods that can be used to standardize the process: tree cramming and tree counting (Figure 1). No matter how standardized the process, however, these methods are still subjective; they only work well when individual tree crowns and the spaces between them can be seen clearly.

Comparison also has been a popular method of estimating crown closure. Moessner (1949) developed a crown-density scale for 1:20,000-scale photography, which incorporated three random crown-cover patterns for each of ten crown densities from 5 to 95 percent at 10 percent intervals. This scale can be used as a comparator to estimate crown density from aerial photos (Figure 2). Aldrich (1967) proposed a slightly different comparator that incorporates both a crown-density scale and crown-size scale. The objective of this comparator was to aid in stratifying photo plots into broad volume classes using crown closure and crown diameter as independent variables. The weak points of the comparator methods include subjectivity and the limitation of reproducing comparators for very large- or very-small scale photography.

Stereogram examples (e.g., Moessner, 1956; Hegg, 1967) have been used successfully, but they are difficult to adapt to conditions other than those for which they are designed. Stereogram examples or keys are developed by compiling actual aerial photo stereograms of particular vegetation patterns that have been visited and described on the ground. They are useful as photo interpreter training aids and can be made to depict *any* vegetation cover class of interest. But they are very unwieldy for everyday interpretive use.

Another method employed extensively with large-scale photography uses a dot grid or transect to count tree-crown hits and misses (Figure 3) (Losee, 1953, 1956). Both the dot grid and transect provide objective results if the counting criteria are well documented. Their use is limited to fairly large scales, however, and the actual counting can be quite tedious. Sampling errors are associated with the dot grid/dot transect methods.

A method formulated by Klier (1969) is based on the ingenious use of the Bitterlich principle. Tree crowns that are simultaneously cut or touched by both legs of a wedge with a specific angle are counted, as the wedge is turned around a sample point (Figure 4). Crown closure is calculated by formula. This method is limited to large-scale photography ($\geq$ 1:5000, depending on crown size); it can also be tedious, particularly where crowns overlap.

While photo-interpreters have been searching for the best way to estimate crown closure photography, they have also searched for ways to estimate crown closure on the ground.

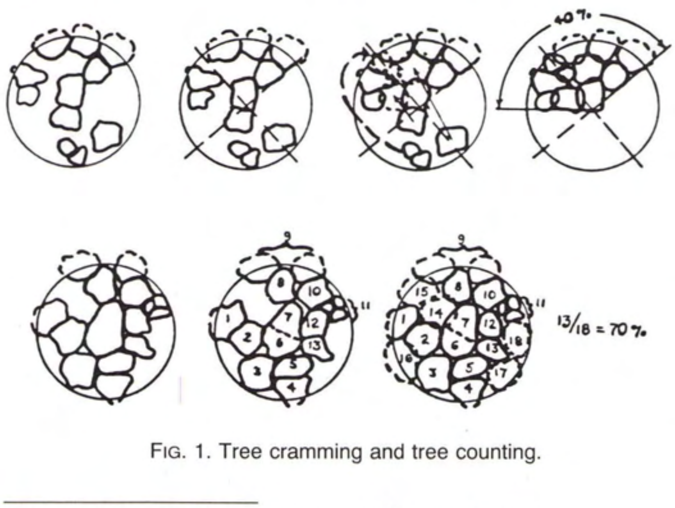

FIG. 1. Tree cramming and tree counting.

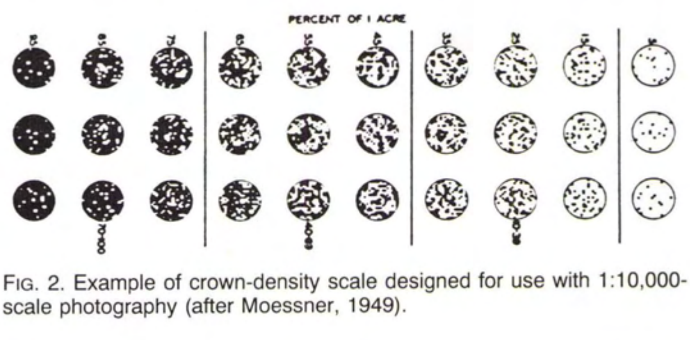

FIG. 2. Example of crown-density scale designed for use with 1:10,000-scale photography (after Moessner, 1949).

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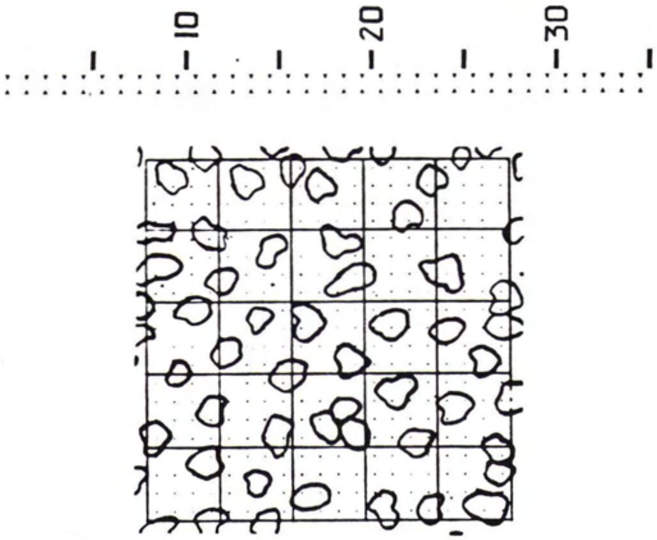

FIG. 3. Dot grid and dot transect. The dot grid was used to take 5 random cover samples of the tree pattern shown. The sample mean was 34.3% ± 3.5% (95% confidence limits). The actual measured cover is 32.65%. The dot transect is used by counting the imaginary lines between triangle apices hit by tree crowns and dividing by the total number of imaginary lines, in this case 35. It has the advantage of fewer "dots" to count and better visibility of the tree crowns being counted.

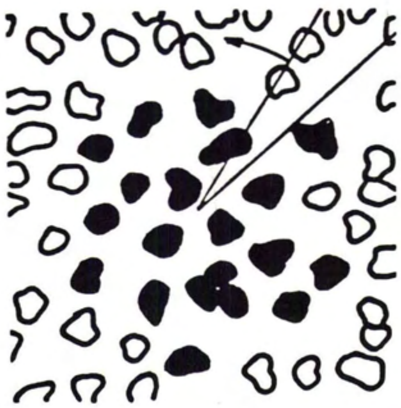

FIG. 4. Crown-area determination following the Bitterlich principle. Using a crown-density factor of 50 (16° 16' angle), six random cover samples were taken of the tree pattern. The sample mean was 36.7% ± 7.4% (95% confidence limits). In this example the 20 darkened trees were counted; 20 is divided by the crown-density factor of 50, resulting in a crown cover estimate of 40%. Other density factors suggested by Klier (1969) are 10 (36° 52' angle) and 100 (11° 26' angle).

Ground measurements must be made to determine correlation between photo and ground. At least as many ways exist to measure or estimate crown cover on the ground as there are on photography.

Ocular estimation of crown cover on the ground probably is the most commonly used ground observation method. It is also the most subjective and potentially inaccurate method. One of its main problems is observer perspective.

One of the most accurate methods of determining crown closure on the ground uses plane-table surveying to map the tree crowns. Plane-table surveying is time-consuming and, except for research, is usually unwarranted.

Most other methods use a grid sample of the overstory canopy (Robinson, 1947; Lemmon, 1956; Johansson, 1985). Several instruments developed for acquiring these data use mirrors and cross-hairs or grids superimposed on the instrument's field of view, allowing the observer to count the number of canopy hits and misses from below (Figure 5). All of the ground methods require a relatively large number of samples in each canopy-cover class to obtain a prescribed accuracy.

DISCUSSION AND RECOMMENDATIONS

What are some of the problems in estimating crown closure in interior Alaska from remotely sensed imagery? Can any of the methods mentioned above overcome these problems, or must the methodology or expectations be modified?

One of the primary problems encountered in trying to estimate tree-crown closure is the inability to see the trees on the imagery in use, particularly in interior Alaska where poor forest-site conditions are common. Spruce trees on these poor sites are small, with crown widths averaging about 1 metre. Caylor's proposed method for a rule-of-thumb to predict scale requirements for new special project aerial photographs of forest resource targets (presentation at the National Forest Applications Program Remote Sensing Workshop, 1986) suggests the use of the concept of Film Resolution Elements and Image Recognition Units to determine either the photo-scale needed to resolve a particular object size or the size of the object that should be detectable at a particular scale.

Using the formulas presented by Caylor, a scale of about 1:13,000 is necessary for practical detecting of trees with crowns that are about 1 metre in diameter. This scale is probably the limit with no shadows; when shadows are present, however, the scale is probably reduced somewhat. The shadow of a tree may cover a much larger area than the tree crown and contrast much better with the background than does the tree crown. In developing his formulas, Caylor assumed low contrast between subject and background – a reasonable assumption because the open, skimpy crowns of these trees produce little shadow.

FIG. 5. The moosehorn (Robinson, 1947) is an example of one of the tools developed to sample tree-canopy cover on the ground. The moosehorn estimates are often used as "ground truth." The correlation between them and corresponding photo estimates can be used to correct other photo estimates in similar cover types.

The size of objects that are practically detectable on 1:60,000-scale color infrared (CIR) imagery, commonly used for resource interpretation in Alaska, can be calculated using Caylor's formulas, to be about 4 metres. Nonetheless, most experienced photo interpreters will argue that they can estimate tree crown closure on 1:60,000 scale photogrpahy. These estimates are based more on color and texture than actually viewing individual trees, especially small-crowned trees.

Although color and apparent texture can be used as a basis for classifying crown cover on small-scale photography and satellite imagery, some ground truth is necessary to make this classification consistent.

When small-scale photography (≤ 1:60,000) is used to determine tree-crown cover, only ocular estimates and perhaps some form of comparison can be used. At these scales, ocular estimation and comparison are limited and based on color, texture, and experience rather than on seeing individual tree crowns. Expectations of accuracy in estimating crown cover must be reduced as photo-scale decreases. When small-scale photography is used, the number of crown-cover classes should be reduced to as few as two – open and closed – to maintain adequate precision of classification.

Another problem encountered in estimating crown cover in interior Alaska is related to the species composition of mixed needleleaf/broadleaf forest. Although a mixed forest might easily be classified as closed, composition may be difficult to determine accurately. The spruce component of a mixed forest is often not visible on even large-scale photographs because of the position of the spruce in the mixed-forest canopy. This problem was pointed out in an unpublished study (K.C. Winterberger, unpublished data, 1987), where two photo interpreters were asked to examine 1,273 photo points on 1:60,000-scale aerial photos. Interpreters were instructed to classify vegetation type by only what they could definitely see. Then, the interpreters were instructed to use intuition about the presence or absence of trees in classifying vegetation type. Nearly always, the proportion of photo points classified as conifers was underestimated by the interpreters and the number of points classed as broadleaf trees was overestimated. Using intuition improved the estimates, but the number of points containing conifers, namely small-crowned spruce trees, was still underestimated.

When spruce are dominant in the mixed-forest canopy, they usually are apparent on medium- and large-scale CIR photography. The spruce contribution to total canopy cover is estimated easily using any of the methods mentioned earlier. When small-scale photography is interpreted, distinguishing between individual spruce trees and shadowed openings in an otherwise broadleaf canopy is difficult, and ground observation is necessary to maintain precision.

When spruce are co-dominant in a mixed-forest canopy, they start to become invisible to the photo interpreter. On large-scale photography, ascertaining presence or absence may be possible, but spruce-cover estimates will usually be low. To determine the actual crown cover of canopy components, ground sampling is a necessity. Distinguishing this type of mixed forest from pure broadleaf forest may be impossible on medium- and small-scale photography.

A previous study by the authors (Winterberger and Larson, 1985) provides some data to confirm the problems of seeing these small crowned trees on photography of different scales. In interior Alaska, 14 million hectares were sampled on 1,343 small-scale (1:60,000) photo plots, subsampled on 331 large-scale (1:3,000) photo plots, and further subsampled on 88 ground plots. Assuming that the ground plots provide "truth" and that the proportion of cover types would remain the same for all samples, the authors found that more area was classified as broadleaf or mixed forest on small-scale photos. As the ability to see small conifer crowns increased on large-scale photos and on the ground, more area was recognized as coniferous forest.

The study points out that categories must be defined more broadly to maintain classification accuracy. For example, a forest stand examined on small-scale photography and classified as "broadleaf/mixed forest" can include both broadleaf and broadleaf/needleleaf mixed forest. Sorting out the invisible needleleaf component on small-scale photos is impossible. To be precise in classifying these particular stands, sampling with either larger photo scales or ground plots is necessary. In two-tiered stands, where the shade-tolerant spruce are growing beneath a broadleaf canopy, classifying the stand correctly by aerial photography is impossible. Again, the best solution is defining the category more inclusively or increasing precision through sampling.

The last problem is the actual definition of "canopy." Depending on the ultimate use of the canopy-cover estimates, the definition of canopy can vary greatly. Because of the resolution of the imagery that might be used, some canopy-cover classes may have to be defined to include two distinct canopy covers. For example, the canopy cover associated with small streams found in the intricate drainage networks in interior Alaska may be completely different from the canopy cover of vegetation found between these streams. On-low resolution imagery, these cover classes may not be separable. The canopy cover may have to be defined to include both. Canopy is sometimes defined to include only dominant and co-dominant vegetation. Other vegetation is not estimated no matter what its cover might be. Only the part of the canopy that is visible can be used to make accurate canopy-cover estimates.

CONCLUSIONS

Resource managers interested in estimating canopy cover by available remotely sensed imagery need to understand the limitations of the imagery they plan to use. They should understand the limitations of the aids and methodology commonly used in making the estimates. Their expectations of classification accuracy must accomodate these limitations, and the "canopy" of interest must be clearly defined.

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