FOREST CANOPY HEALTH: DEVELOPMENT OF A STANDARD METHOD FOR LONG-TERM MONITORING AND EVALUATION

by
Luke Curtis, University of Vermont
Ronald Kelley, Vermont Department of Forests, Parks & Recreation

OBJECTIVES

Forest canopy assessments related to tree health have historically been obtained by visual evaluations done by field personnel trained in how to evaluate such things as dieback, defoliation, and crown transparency. Such procedures lack permanent documentary records such as photographs, from which future investigators can make comparisons, or check procedures. The purpose of this project is to develop a method to quantify forest canopy cover for short-term assessments, as well as long-term objective documentation of changes within permanent plots.

METHODS

Using a 35mm camera with a 17mm wide angle lens, Ektachrome slides (IS0200) were taken beneath tree crowns by orienting the camera vertically over 107 permanent points established within the following northern hardwood forest health monitoring sites in Underhill, Vermont:

1. North American Maple Project (NAMP) 014, Proctor Maple Research Center (PMRC) in Underhill - 45 points.

2. Forest Health Monitoring (FHM) 2 at PMRC - 32 points.

3. Forest Health Monitoring 4 at Underhill State Park - 32 points.

Photo points were arrayed 10 m apart on the NAMP grid for each subplot, and were at a different, but comparable, spacing in the FHM systems. Photo points were marked by an orange fiberglass stake.

In order to evaluate the performance of this system for characterizing softwood canopies, a series of nine photo-points, 10 m apart, was surveyed on a transect in a red pine plantation in Salisbury, VT.

Photography:

With certain modifications, field procedure was based on a method developed by the Institute for Ecosystems Studies (Fergione, 1985).

No weather criterion was applied, except to avoid rain and excessive breeze. The objective has been to keep the procedure user-friendly and not restricted by narrow weather windows, particularly in regions like Vermont where weather conditions can change quickly. Although cloudy or highly diffuse light conditions are ideal for obtaining good canopy silhouettes, these conditions can change without notice and could frustrate efficient data collection if strictly required.

The camera was mounted on the tripod with the lens oriented toward the zenith. For consistency of orientation, the base of the camera always faced true east. This arrangement, with the long axis of the film parallel to the true north-south axis, minimized the period at midday during which the sun might appear in the image.

The camera tripod was erected over each photopoint such that a plumb bob hung directly under lens center would be within 2.5 cm of the base of the photo point stake. This tolerance (about 1 in) was allowed because it would be within the ability of many field workers to estimate and was not likely to translate into significant errors in canopy estimates.

Camera height was 1 m from the base of the stake to the optical center of the lens (about 2 cm from the lens front). A meter stick was carried for this purpose. The camera was leveled with a plate-mounted bubble level that was placed on the lens. This adjustment is the most critical for repeated comparisons of images taken from the same point, as small variations in leveling tend to be magnified in portions of the image from the upper canopy.

The camera was equipped with a right-angle viewfinder and a cable release.

All foliage up to 1 m from the camera lens was removed in an arc containing the image. This distance was standardized to permit highly obstructive close foliage to be removed.

After set-up was complete, three exposures were taken: one at the camera meter's setting, one a full stop over, and one a full stop under. This procedure gives protection against small errors in the camera's automatic exposure calculation. In addition, Ektachrome has enough latitude to make all three exposures useful. Overexposures tend to show better color and are more revealing of damage and disease conditions. Underexposures afford more sky/canopy contrast and are more suitable for image scoring.

In cases in which the sun appeared in the picture, it was blocked out with a device consisting of a film canister cap mounted on a wire. While exposures were being made, it was positioned such that the disc, at a distance of 60-70 cm from the lens, blocked out the sun.

Complete notes were taken for each set of exposures, including photo point ID, time of day, an estimate of cloud cover to the nearest 10 percent, f-stop, shutter speed, and exposure number.

Video:

To compare computer analyses of photographic and video images, video images were taped in August at 18 NAMP photo points on the same day that slides were taken. Video images were taken using a regular VHS video camera (Panasonic WDV 5000), equipped with an 8x autofocus lens with a focal length of 10.5-84mm. The field of view with video cameras is actually four to five times as narrow as that of a 35mm camera lens of the same focal length. This video camera has a field of view that is four times as narrow, making the lens at 10.5mm the equivalent of a 42mm lens on a 35mm camera. Wide angle lenses that screw onto the front of video lenses are available that would more closely approximate the field of view of the 17mm lens and could be tried in the future.

Techniques described for setup and placement of the 35mm camera above each point were also followed for the video camera, with its optical center at the same height. Understory foliage within 1 meter of the camera lens was also removed. The video camera was operated using automatic exposure, taping for about 15 seconds at the wide-angle setting, and then slowly zooming up to the telephoto (84mm) setting to capture closeup images of foliage and any visible foliar damage.

Image Analysis

In order to develop a scoring procedure for canopy cover on the slides, we compared a manual/visual method and a computer image analysis. The term canopy cover is used here to refer to the percent of sky obstructed by vegetation, including woody tree parts.

Slide Grid Projection:

A radial grid was drawn on white paper to include 144 intersections formed by 12 concentric circles and 12 equally spaced radial lines. The concentric circles were spaced to sample 12 concentric bands, equal in arc degrees, partitioning the field of view from the zenith to 30 degrees from the zenith. This samples an area equal to a circle of approximately 20 mm diameter on the slide. At a height of 25 m, this circle represents an area of canopy 48 m in diameter. The frame of the grid was proportional to a slide and has dimensions of 75 x 50 cm. Grid lines were drawn as fine as possible, so as not to obscure detail, while permitting easy viewing from a distance of about .5 m.

This custom screen was hung on a wall and the projector positioned 2.84 m from lens front to screen. While this relatively short distance resulted in only fair focus at the edges of the image, it was good within the target region. Careful adjustment was made to ensure that the slide fit the screen borders. If, because of variation in mount size in different brands, slides did not register consistently on grid borders, all slides were projected so that left-hand corners were filled and even.

Each slide was read with a set routine, scoring intersections on successive circles beginning with the innermost. The number of grid intersections falling on visible sky were tallied to obtain raw scores, since in plots of normal canopy density it is much faster to count sky than tree. Processed data, however, were expressed as percent canopy cover.

For scoring, we consistently used the slide least exposed of the three taken for each photo point on each occasion, as contrast was best in this case.

Scoring time with the manual/visual system varies according to crown density, with the less dense images taking longer. We estimate about 3-4 minutes turnaround time with the 144 intersection grid.

Swathkit:

The Swathkit is an image analysis/weather monitoring system used in the calibration of spray systems for aerial applications. While primarily designed for determining the number and size of spray droplets on a card held to a small lighted port, the Swathkit can do area measurements of the sort needed to discriminate regions of different density, as found in canopy photos.

Photography: it was desirable to remove the B&W video camera from the Swathkit "blue box" and put it on a copy stand for several reasons. Its focal length and position within the box prevented it from reading the proper amount of slide and mask for comparison with the grid projection method. It was much easier to illuminate properly the slide when placed on a copy stand. The mask has the dimensions of a slide mount and has a 20 mm diameter hole in its center. It is cut from 26 gauge sheet metal and spray painted with a white enamel. Slight illumination has to be provided to the white mask from above for the camera to pick it up, since the Swathkit must see the area of interest as having a white border in order to make a correct measurement.

Best results from the lighting standpoint were obtained by replacing the 50mm lens (supplied with camera) with a 105mm lens. Focusing was simpler, the right amount of mask was readily obtained, and an even light effect was achieved. It was also far enough from the slide (.5 m) to enable the operator to see the slide in color and easily adjust the initial threshold level. Both slide and mask were held on the light table, with the mask on top, in a plexiglass holder made large enough to accommodate the largest slide (there is some variation in slide mounts). Mask and slide were always oriented the same way and any slack removed by aligning them in the same corner of the holder each time. To prevent glare in the camera, light from the light table surrounding the slide was masked out.

Using the striped test pattern, which is slightly less than 50 percent black on white, the threshold was set at 120. The area measurement is given as a percent of the total area which the Swathkit scans. A solid black piece of paper was placed behind the mask to yield a percent representing the total area within the mask. The percent crown cover is derived as a ratio of the image reading to the total possible within the mask.

A series of 25 images taken over two days from one photo point was run at threshold 120, and then with a blue/purple filter at threshold 53. The filter reduced the variance in crown canopy readings, it was used with all 1991 slides measured with the Swathkit. The threshold was not changed during this process. Scoring time with the Swathkit was about 1 minute/slide when a series of slides was run at a single threshold.

<u>Video:</u> Because the Swathkit was designed to read spray droplets on white cards, the software was programmed to eliminate any images that are contiguous with the edge of the screen and, therefore, of unknown dimension. This prevented accurate processing of video frames with crown, or sky contiguous with the edge. For that reason, video frames were modified by use of a MIPS (Map and Image Processing System, Microimages, Inc.) program at the U.S. Forest Service Methods Application Group Office in Fort Collins, Colorado. One wide-angle frame was grabbed for each point and reduced in size a little so that it was surrounded by a black mask. It was then copied back onto videotape, allowing about 30 seconds per frame. To process the video frames, the modified videotape was played on a video cassette recorder, the signal was fed directly into the frame-grabber of the Swathkit, and each frame was grabbed while viewing the tape on a monitor.

Largely due to the narrower field of view for video, the size of the image captured was only 45 percent as large as the area analyzed for 35mm slides, although the images shared a common center. The black and white image as seen by the Swathkit was reversed during analysis to give a white border around each frame. Future video images could be mechanically masked during the recording process by use of a reducing ring or similar attachment screwed on to the front of the video camera lens.

RESULTS AND DISCUSSION

Photography:

Preliminary data suggest that grid projection and Swathkit scoring methods agreed rather well in these hardwood stands (Figures 1,2 and 3). Swathkit results produce more stable plot canopy density averages between months than grid projection.

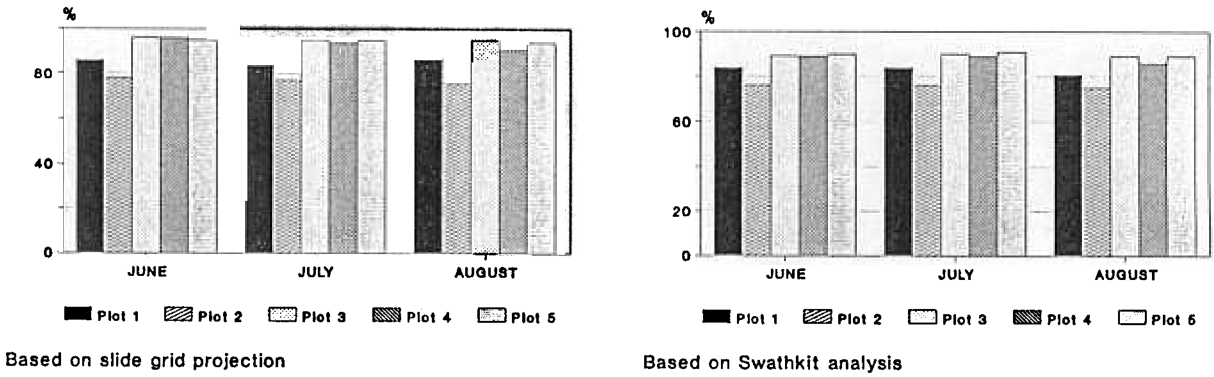


Figure 1. Percent Canopy Cover in 1991 for the NAMP Plot at Proctor Maple Research Center Based on Two Analysis Methods.

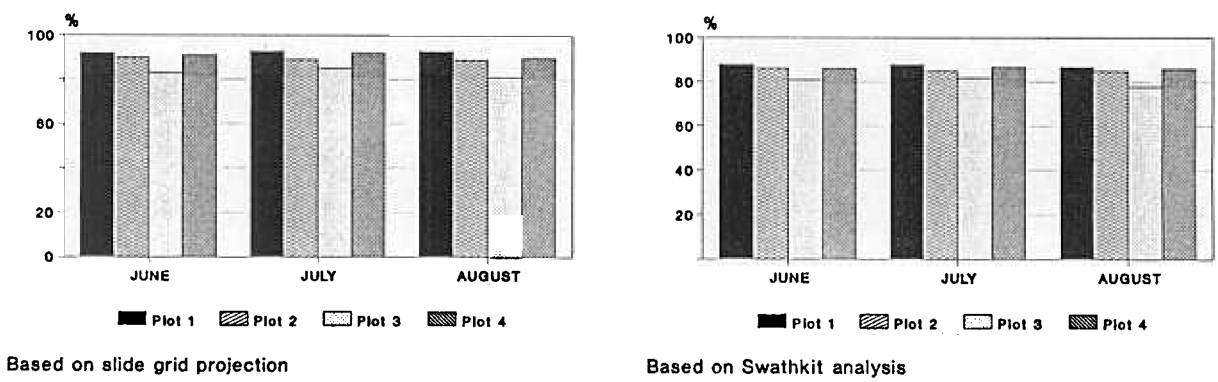
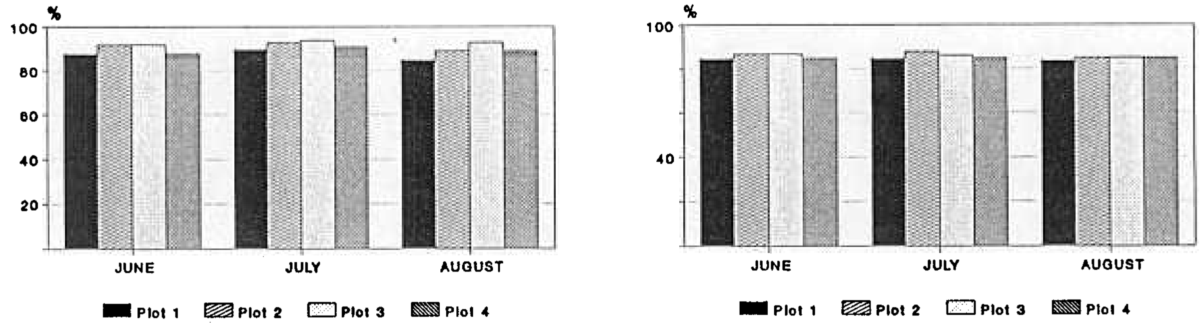


Figure 2. Percent Canopy Cover in 1991 for the FHM Plot at Proctor Maple Research Center Based on Two Analysis Methods.



Based on slide grid projection

Based on Swathkit analysis

Figure 3. Percent Canopy Cover in 1991 for the FHM Plot at Underhill State Park Based on Two Analysis Methods.

The trial in the red pine plantation, in which the nine photo-point transect was traversed four times on an overcast morning, again showed good agreement between the two scoring methods (Figure 4). Although the stand was of uniform composition and thus displayed less variation than we would have liked for a good comparison, we believe that those needing evaluations in softwood forests will find hope in this procedure.

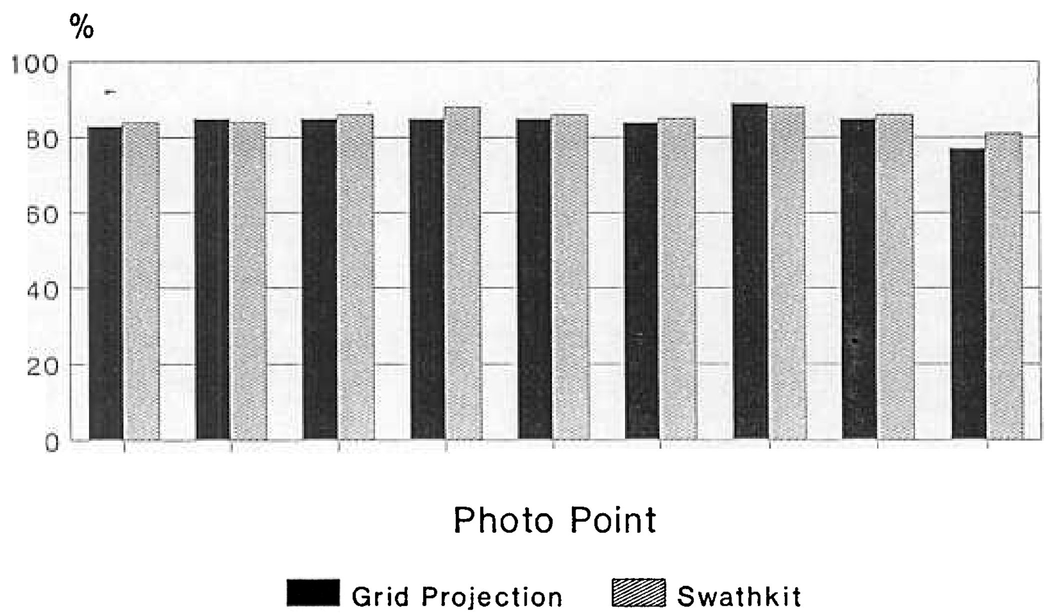


Figure 4. Percent Canopy Cover for Individual Photo Points in a Red Pine Plantation Based on Two Analysis Methods.

The Swathkit analysis appears to be quite sensitive in detecting small changes in canopy cover due to light to moderate defoliation. Within the NAMP plots there were no significant changes in percent canopy cover between June and July, but there were significant drops within three of the plots (1,4,5) between July and August, associated with light to moderate defoliation by the maple leaf cutter, a late-season defoliator (Table 1). None of the permanent plot trees in Plot 1 were rated as having moderate defoliation, but this plot contains a lot of sugar maple regeneration under 4 inches in diameter that was noted as having light to moderate leaf cutter. Except for one small maple near the center, all the rated trees in this plot are near the perimeter on one side of the plot. Plots 2 and 3 had no significant drop in canopy cover and no leaf cutter damage recorded. Plots 4 and 5 had the most highly significant drop in canopy cover and both had at least some moderate defoliation. Although Plot 5 had only one tree with moderate defoliation, maple leaf cutter damage was noted as being present throughout the plot.

Table 1. Percent Canopy Cover Change Within NAMP Plots from July to August and Late Defoliation by Maple Leaf Cutter.

Plot	Canopy Cover Change (%)	Percent and No. of Maples with Mod. Defol.*		Sig. Level
	-3.1	0	(0/4)	.04
2	+1.3	0	(0/3)	N.S.
3	N.C.	0	(0/7)	N.S.
4	-3.1	47	(7/15)	.00005
5	-2.2	5	(1/21)	.0003

*Sugar maple 4.0" DBH or greater (# moderately defoliated/total#).

A comparison of 25 slides taken in hardwood from one photo point over two days in different light conditions showed a lower variance in density when read by the Swathkit through a blue filter than with no filter (.0005 vs .0009, means 86.9 and 87.6 respectively). Other filters of similar hue should be explored to determine if we can improve on this result, before more large groups of slides are run. Similarly, good test patterns for areas of various sizes need to be developed to evaluate the linearity of Swathkit measurements.

The Swathkit is quite promising for rapid black-and-white analysis and generating average density characterizations and comparisons. Reliable individual photo point comparisons, particularly concerning factors producing less than 5 percentage points difference in canopy cover, may ultimately require the hand-tuning that is found in more versatile image analysis equipment.

Comparisons of NAMP results obtained with the two different methods show a tendency of grid projection to estimate higher than the Swathkit at high densities. Because the grid tends to sample heavily toward the center due to its assumptions and light-study applications, we feel that chance foliage clumping near the zenith could have had this effect. A rectangular grid may be more appropriate for comparisons with Swathkit estimates. We cannot yet rule out the possibility that the Swathkit needs more precise calibration (by the operator) for high density images.

One advantage of the grid projection system over image analysis is the ability to compare density at different angles with sensors like the LiCor, which reads in five concentric rings. A comparison of this sort is projected for 1992.

Video:

Swathkit analysis of the video images resulted in plot averages for percent canopy cover that were similar to photography, despite the fact that the video images were of a much reduced area of view. Video images for Plots 2 and 5 averaged 75.3 and 93.7 percent canopy cover, respectively, compared to 75.7 and 89.1 percent for color slides taken from the same points.

From this limited test, video appears to offer a low cost alternative to photography for capturing similar information. The separate video camera and recorder used in this project to capture the original canopy images was cumbersome compared to photography, but the variety of small camcorders and still video cameras available today offer light-weight alternatives. The short life of most video recorder batteries must be considered if images from many points need to be captured in a single day.

Photographic transparencies can be easily modified with filters, masks, etc. in the analysis process whereas video images are difficult to manipulate without complex, expensive computer systems.

FUTURE PLANS

Photography for June, July and August will be repeated in 1992 using the same photopoints and methods. Slides obtained will be processed with the Swathkit and will be used for year to year, as well as seasonal comparisons. Additional ground information on tree transparency ratings will be obtained to help explain any changes in canopy cover expected from defoliation by maple leaf cutter, or other insects. Processing of the data will be fine-tuned, and cost and efficiency information will be obtained, including determination of the minimum number of points needed for reasonable precision.

Light sensors such as the LiCor Plant Canopy Analyzer and Sunfleck PAR Ceptometer are now available for measuring light, or photosynthetically active radiation beneath tree canopies. We hope to compare the utility of one of these methods to the photographic method.

FUNDING SOURCE

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REFERENCES

Fargione, Michael J., 1985, an estimation procedure for determining canopy densities from hemispherical photographs. Unpublished Rept. Institute of Ecosystem Studies, Milbrook, N.Y.