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

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ABSTRACT

In 1992, canopy photos were taken from the same forest health monitoring points as in 1991 at the same timing in June, July and August. Photos were also taken three times in defoliated hemlock stands to compare canopy cover before and after leaf flush. All photos (Ektachrome slides) were computer-analysed to determine percent canopy cover. Canopy cover values for forest health monitoring plots in late August were similar to 1991, but June values were significantly lower ($p<0.01$) than 1991 due to cool weather and slower leaf flush. Canopy cover in two heavily defoliated hemlock stands increased 32 and 42 percent, respectively, between May and October compared to 11 percent for a lightly defoliated stand.

INTRODUCTION

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. This was the second year of a two-year project to develop a method to quantify canopy cover and provide short-term assessments as well as long-term objective documentation of changes within permanent forest plots.

METHODS

Photography

Using a 35mm camera with a 17mm wide angle lens, Ektachrome slides (IS0200) were taken beneath tree crowns by orienting the camera vertically over 141 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.

4. Forest Health Monitoring VMC2200 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 addition, photos were taken at ten points in each of three hemlock stands in southeastern Vermont on May 21, July 6 and October 6. Two of these stands had been heavily defoliated by hemlock looper the previous autumn, and the third had been lightly defoliated.

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, equipped with a right-angle view finder, was mounted on the tripod with the lens facing up and the base of the camera facing 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 compass should not be placed on the camera for this set-up, as a bad reading may result.

The camera tripod was erected over the photo point 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 magnify error in portions of the image from the upper canopy.

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 foliage to be removed. Haphazard observation of this rule will result in images of poor comparability.

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, 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. It was helpful to make occasional identifying notes (such as "big snag," or "solar disc used") as insurance against mix-ups of film roll # during processing, etc.

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 in 1991. The term, canopy cover, is used here to refer to the percent of sky obscured by vegetation, including woody tree parts. The computer analysis system (Swathkit) was so efficient that it was exclusively used in 1992.

The Swathkit is an image analysis/weather monitoring system which integrates data collected during 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.

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 properly illuminate 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 from the camera, light from the light table surrounding the slide was masked out. The camera lens was always positioned the same distance from the slide and set at the same f-stop.

Swathkit software requires that complex gray-level images be partitioned into two-tone black-and-white images through a thresholding procedure before measurements are made. We were concerned that there would be many slides containing canopy elements, such as light, sunlit foliage, which would be ambiguous, that is, in the same gray level range as parts of the sky.

In order to improve discrimination and hence the accuracy of the sky/canopy ratio for each slide, we explored several color filters as options for improving contrast. In 1991, a preliminary trial showed that a Wratten #35 filter (dark purple-blue) placed behind the slide on the light table improved contrast and reduced the variance in scores of 25 slides taken over a two-day period from a single photo point, when compared with scores of the same slides without a filter.

In 1992, we ran a comparison of eight filters with the same set of 25 photos. Shades of blue (Wratten #s 35, 38A, 45, 45A, 47, 78AA) performed the best and yellow the worst. Filter #45 (blue) yielded the least variance in the 25 readings, and was selected for all 1992 slides, as well as a re-analysis of all 1991 slides to maintain comparability.

The Swathkit measures the density of an image as the proportion of dark area in an image (below threshold) to the rest of the image in the image window. To determine what score the Swathkit would give to a 100% dark image behind the mask, an opaque slide was used. That score was then used as a standard to determine the percent density of actual canopy slides.

RESULTS

VT NAMP and FHM photosurveys: 1991/1992 comparisons.

The two study years, 1991 and 1992, were distinguished by contrasting growing season temperature profiles (Figure 1), which were reflected directly in canopy cover estimates for the first two survey periods of each year. In 1991, monthly temperature averages from February through May were all at least four degrees above normal, and all other months were above normal until September. 1992 temperatures were mostly close to normal except for a below normal June and a cold July.

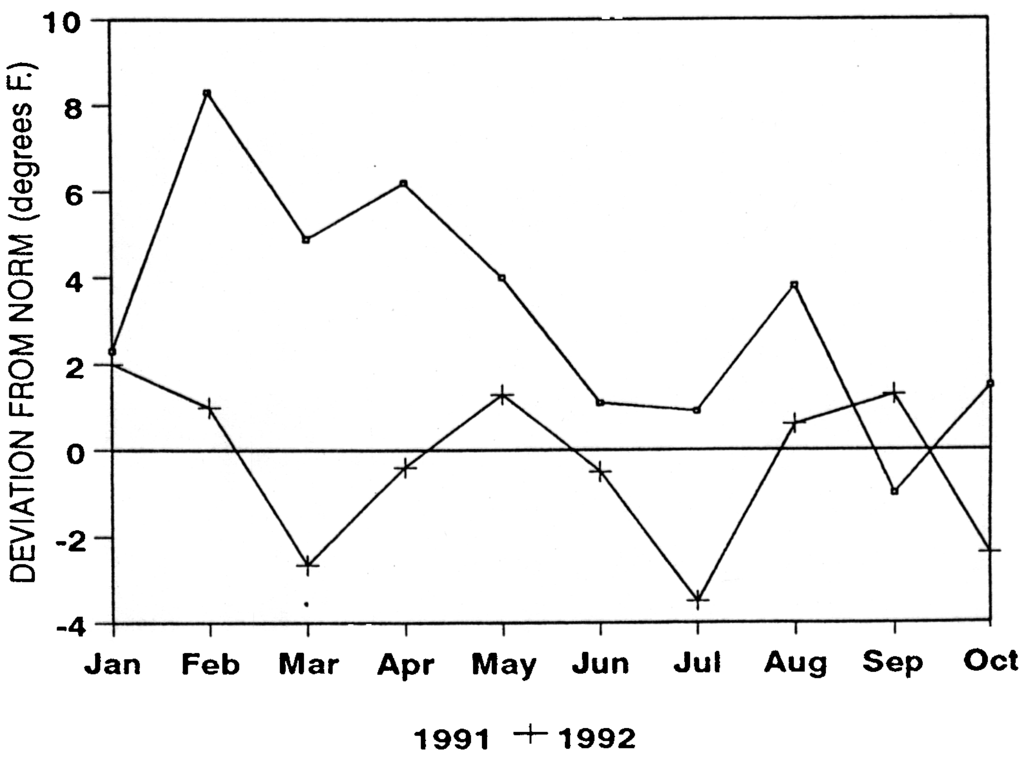

Figure 1. Monthly temperature deviation from normal in degress F for 1991 and 1992 at Burlington International Airport. Data from NOAA Climatological Data, Monthly Summary.

According to our computer-assisted image analysis, all forest health monitoring plots combined had significantly lower June 1992 readings compared to 1991 ($p<0.01$) and correspondingly greater increases in canopy cover from June to July compared to 1991. The impact of the different growing season profiles for these two years is illustrated by canopy cover data from the NAMP site in Underhill (Figures 2 and 3).

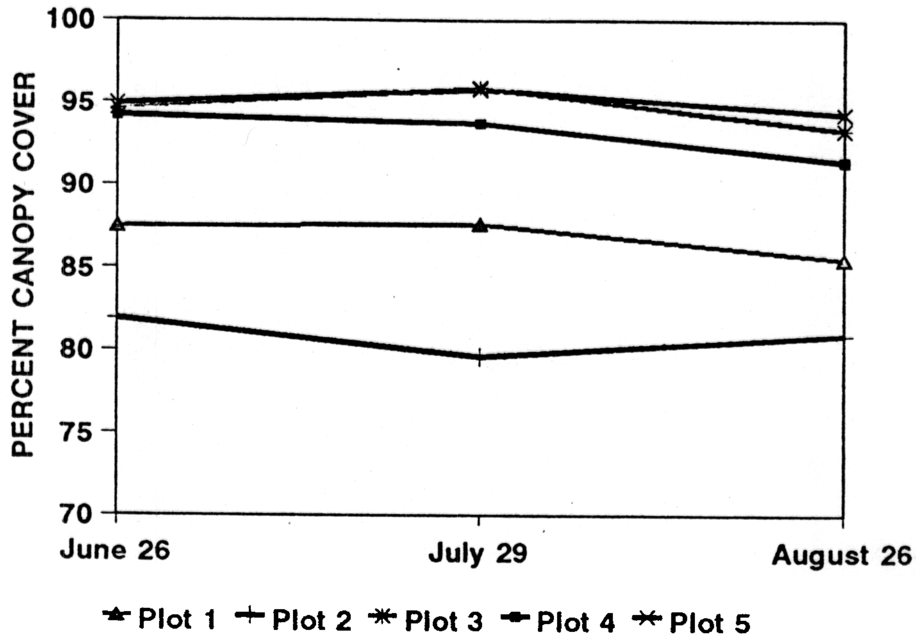

Figure 2. Canopy cover estimates obtained by Swath Kit analysis for a North American Maple Decline Project site at three sampling times in 1991. Each plot estimate is the mean of 9 photo points. Site is in Underhill, VT.

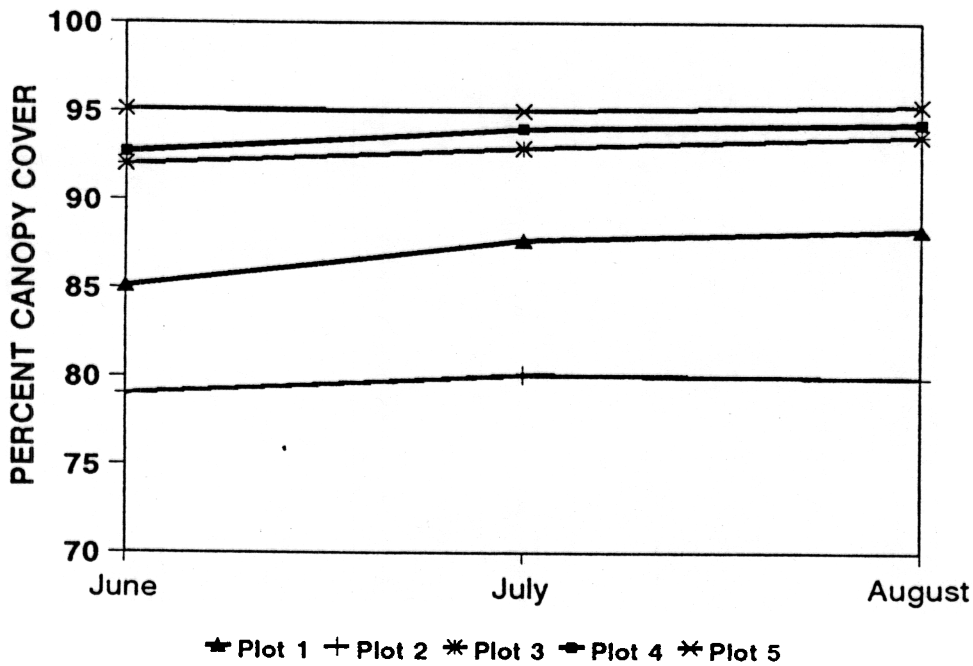

Figure 3. Canopy cover estimates obtained by Swath Kit analysis for a North American Maple Decline Project site at three sampling times in 1992. Each plot estimate is the mean of 9 photo points. Site is in Underhill, VT.

Another higher elevation (600 m) FHM plot on Mt. Mansfield shows even greater delayed foliage development from June to July in 1992 (Figure 4).

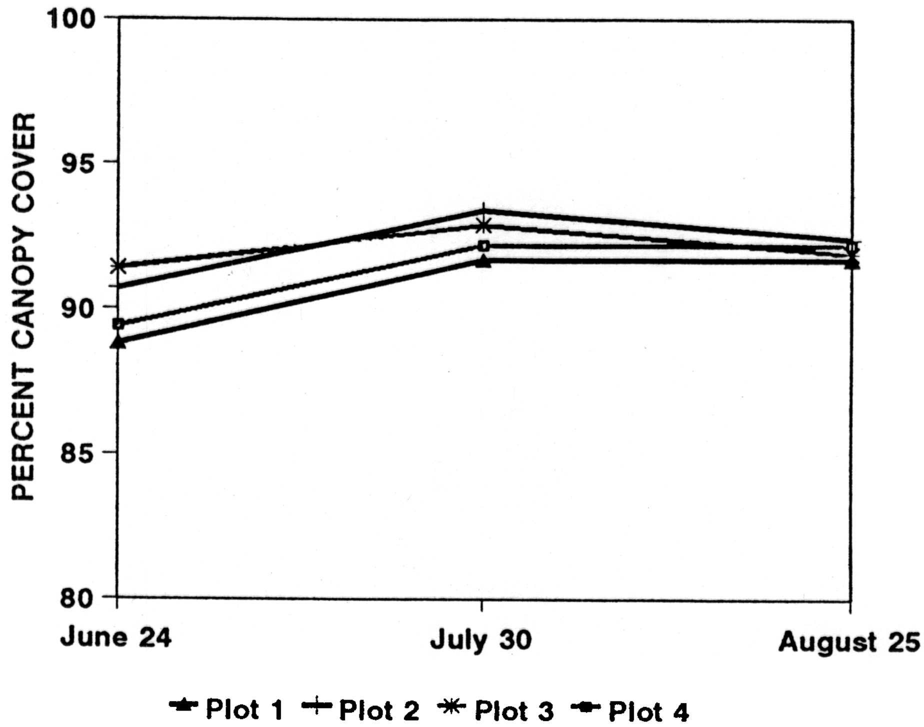

Figure 4. Canopy cover estimates obtain by Swath Kit analysis for a Forest Health Monitoring site at three sampling times in 1992. Each plot estimate is the mean of 8 photo points. Site is in Underhill, VT.

<u>1992 Hemlock defoliation photosurvey.</u>

Results from the 1992 season in three Vermont hemlock stands demonstrate that the film/Swathkit system can provide useful documentation of changes in canopy condition in a softwood species. At Ft. Dummer, based on a mean of ten photo point scores, canopy cover increased from 83.5 percent in May to 88.5 in July and 92.3 percent in early October, for an overall increase of 10.5 percent (Figure 5). This site had received little or no defoliation in 1991.

At Schmidt's, which had moderate-high defoliation in 1991, canopy cover increased from 67.4 percent in May to 83.4 percent in July and 89 percent in October, for an overall increase of 32 percent. At Crossman's, which suffered severe defoliation in 1991, canopy cover went from 60.1 percent in May to 74.2 in July and 85.1 in October for an overall increase of 41.6 percent.

In evaluating these figures, one should remember that a completely defoliated hemlock stand would still have a base "canopy" score consisting of those tree parts (boles, branches, dense twig systems) which appear within the analyzed zone of the image.

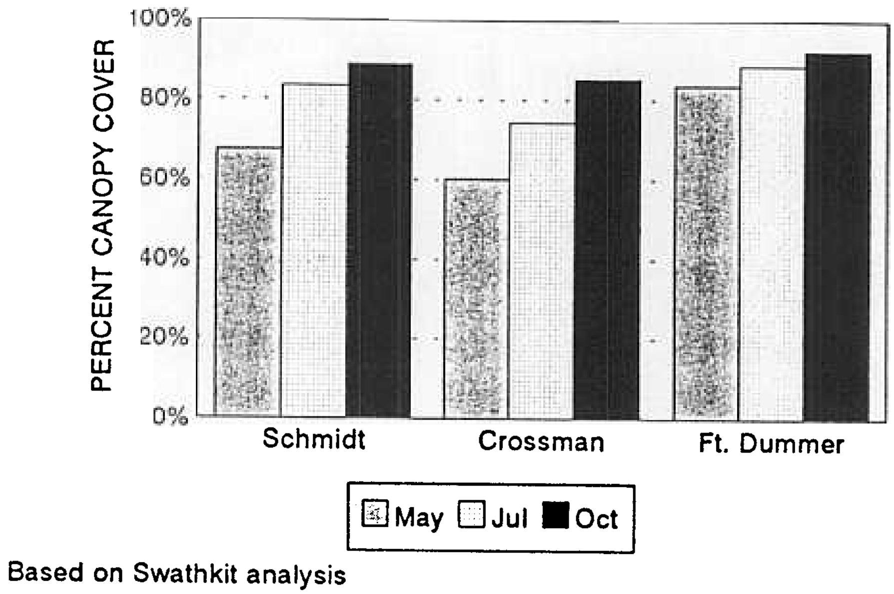

Figure 5. Percent canopy cover in three hemlock stands in Windham County, VT for three months, 1992.

DISCUSSION

Those having access to a Swathkit can expect this system or similar computer analysis systems to generate canopy cover estimates which have consistency and which can detect subtle changes in condition. The film/Swathkit system and its variations are well suited for monitoring objectives which include (1) the maintenance of a long-term record of pictures, e.g., photographs, which document canopy condition from fixed photo points and (2) periodic quantitative and repeatable assessments of canopy cover in integrated surveys of forest health. Electronic radiation-measuring tools such as the Ceptometer and the LI-COR LAI-2000 Plant Canopy Analyser (which were tested but not reported on here) are better suited to situations where neither stored images nor permanent plots are required.

Not to be overlooked is the adaptability of computer image-analysis systems for a spread of management and research objectives. The Swathkit system, although dedicated to a particular use, could be conveniently adapted not only to read canopy slides but also to measure individual leaf areas when needed. Such versatility could make the system more appealing to a wider group of users interested in acquiring and sharing new systems.

Off-the-shelf computer image analysis systems are available in a variety of forms and prices. Slide-scanning hardware is marketed as well as video camera/copy stand setups such as we have used here. Useful software features include masks which can be designed and saved to disc as permanent references. A color analysis capability is costlier at present but is likely to become standard. While color analysis of individually-customized slides will usually yield more accurate results than gray-level analyses of ambiguous images, time input will tend to be greater for both image-grabbing and tinkering in color systems. Large numbers of images collected under a variety of light conditions will tend to defy the application of standard, time-saving color enhancement programs (i.e, "macros").

Advances in film/compact disc technology will bear watching. Kodak's Photo CD system utilizes 35 mm cameras with conventional film, but the processing differs in that a compact disc is produced to store images for viewing on TV, etc. Proper computer interfacing promises to make these images accessible by image analysis software. For our purposes, advantages of this approach are a storage medium in which image aging can be minimized and from which image files can be readily pulled for analysis without further transcription. High relative cost per image is a drawback at the moment. Still video cameras with standard 35 mm lens options offer an avenue for development which is more appealing because the output is an image file which is ready for analysis, enhancement, etc.

For most users, basic requirements for any system will be the ability to mesh with other equipment and with operator skills, the potential for multiple applications, i.e., versatility, and, not least, a low probability of immediate obsolescence. Most important, long-term data comparability requires that any method be upgradable to the next generation. For now, the film/Swathkit system exploits mainstream technologies which meet this need.

FUTURE PLANS

The forest health monitoring photo points will be photographed once annually in late July, to obtain archiveable images that can be compared with data obtained in 1991 and 1992. Data analyses shows that the number of points per plot can be reduced to 5 or 6, with little change in variation. A field manual detailing the procedures for this system is being prepared and will be field tested in 1993 by two Forests, Parks and Recreation employees using NAMP plots.

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.