Comparing spherical densiometry and hemispherical photography for estimating canopy closure

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Introduction

Forest canopy closure (Fig. 1) is an important component of wildlife habitat, which is quantified for management and monitoring purposes. For example, most definitions of northern spotted owl habitat in Washington require a minimum canopy closure of 70 percent (*1,7,14*). The definitions usually do not specify how to measure canopy closure. There are a number of ground-based methods for its estimation, including: line-intercept, moosehorn, convex and concave spherical densiometers, and hemispherical photography. Canopy closure estimates vary considerably depending on the instrument used and/or analysis applied (*2,3,4,8,13*).

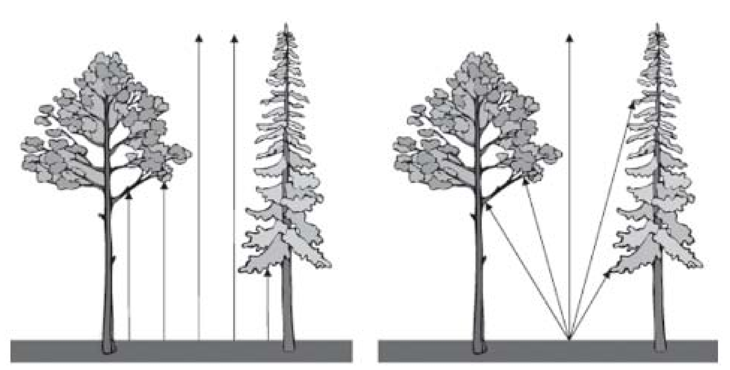

Figure 1. Canopy cover (left) is always measured in vertical direction, whereas canopy closure (right) involves an angle of view (image and caption from Korhonen et al., 2006).

Objectives

1. Compare two ground-based techniques for estimating canopy closure: a convex spherical densiometer and digital hemispherical photography. Since both methods are used at the Washington Department of Natural Resources (DNR), a reliable translation of their estimates is needed.
2. Examine the effect of different image processing software settings on canopy closure estimates obtained through hemispherical photography.

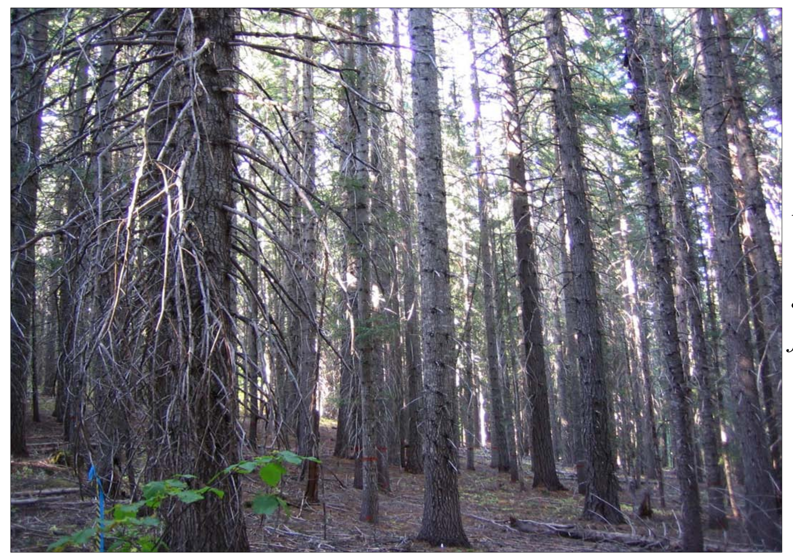

Figure 2. Study site. 90-year-old stand, grand fir and Douglas fir, 425 trees/hectare (172 trees/acre).

Methods

The study was located on DNR-managed lands in Klickitat County, WA (Fig. 2). Hemispherical photos and densiometer readings were taken 1.2 m (4 ft) above the ground at the same 39 sample points spaced at least 25 meters apart.

Densiometer – Measurements from a hand-held convex spherical densiometer (*10*) were averaged over the four cardinal directions. The densiometer's angle of view was calculated at 82.7 degrees (see Englund et al., 2000 for methodology).

Hemispherical photos – A Nikon CoolPix 4500 digital camera with a FC-E8 fisheye lens was mounted on a leveled tripod. Photos were analyzed with Gap Light Analyzer (GLA) 2.0 (*5*) using the blue color pane and polar projection distortion. To match the densiometer's estimated angle of view (82.7 degrees), and compare three additional angles of view, topographic masks were applied (Fig. 3).

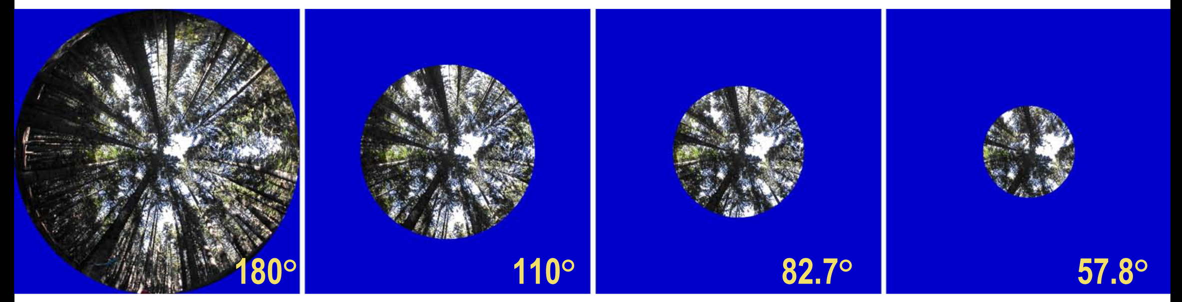

Figure 3. A canopy photo with various topographic masks applied to compare reported densiometer angles of view: 180 degrees (full range); 82.7 (our estimate); 110 and 57.8 degrees (Englund et al. 2000).

The threshold used to convert the color image into black and white (canopy and sky) was determined automatically for each photo using SideLook 1.1 (*11*). To assess the effect of different thresholds, the automatic threshold was compared with the GLA default (128) and a manual (user-determined) threshold (Fig. 4).

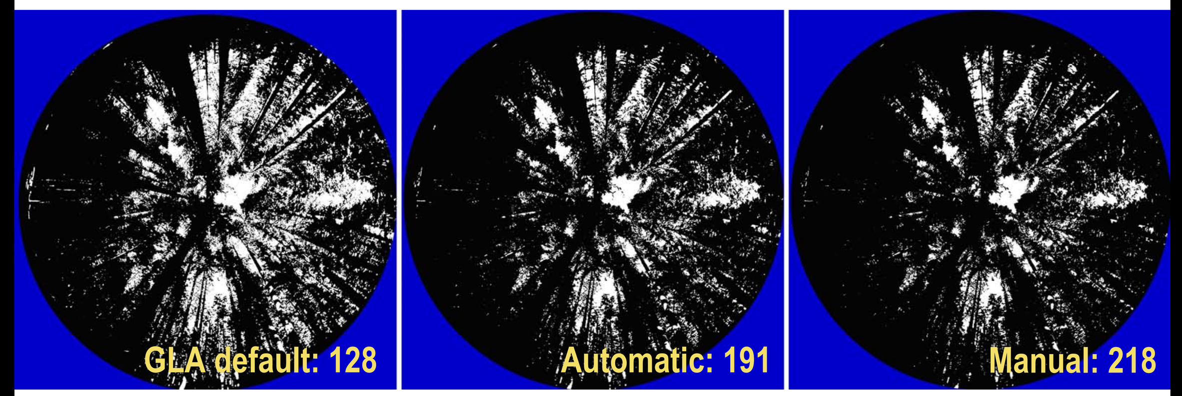

Figure 4. One canopy photo with varying thresholds.

Densiometer and photo estimates were compared with a paired t-test. The effect of the varying angles of view and thresholds on canopy closure estimates was assessed with the nonparametric Friedman test.

Results

Densiometer estimates were consistently and significantly higher than estimates from photo images with matching angles of view (mean paired difference = 19.3%, t= 60.9, df=38, p<0.001).

Comparisons of canopy closure estimates obtained from photographic images with four different angles of view indicate that two or more were significantly different (Friedman test $\chi 2$=117, df=3, p<0.001; Fig. 5). The estimates increased while variation decreased with increasing angles of view.

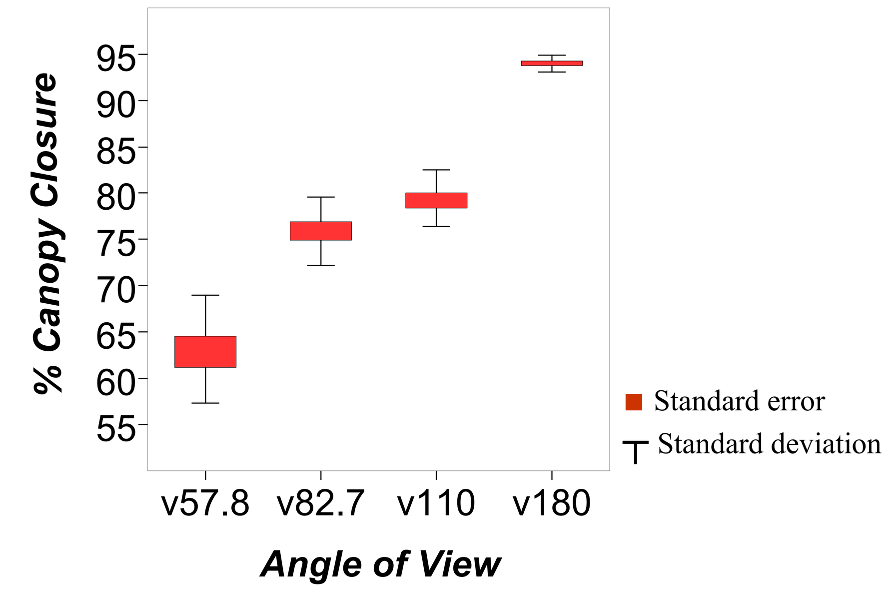

Figure 5. Differences in percent canopy closure estimates with varying angles of view.

Applying different thresholds to distinguish sky from canopy in the photos resulted in significantly different canopy closure estimates (Friedman test χ^2=76.1, df=2, p<0.001). The default threshold provided the lowest closure estimate while manual produced the highest (Fig. 6 and Table 1). The automatic threshold resulted in the lowest variance.

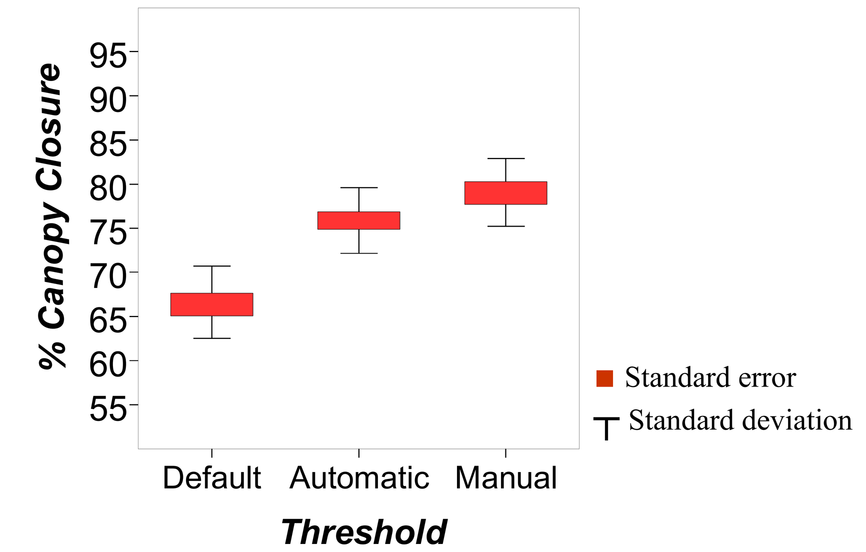

Figure 6 and Table 1. Differences in percent canopy closure estimates with varying thresholds.

Thresholds	Mean paired difference (% canopy closure)	t	df	p
Automatic - Default	9.5	36.9	38	<0.001
Automatic - Manual	2.7	10.4	38	<0.001
Manual - Default	12.3	33.0	38	<0.001

Conclusions

Higher densiometer estimates may be related to the instrument's low resolution (a large canopy area reflected on a small mirror area). Thus only relatively large canopy gaps are considered openings compared with the photo analysis where each white pixel counts as sky. At least one study (*4*) comparing 180 degree photos with a densiometer's smaller angle of view did not reveal significant differences. In our opinion, such a comparison is not valid because different canopy areas were considered and as a result the effect of the photo's wider angle of view obscured the higher densiometer estimates.

Our finding that as the angle of view increased, canopy closure estimates increased and stand-level variability decreased is consistent with other authors (*e.g. 2,4*).

Many studies report that manually applied thresholds during photo analysis introduce error (*3,6,13*). Our analysis confirmed and quantified this effect. We recommend using an automatic threshold as it is reproducible, faster, and less subjective compared with manual thresholding (see also *12*).

Given the magnitude of our reported differences, one should not directly compare canopy closure estimates when recorded with different techniques. Regression equations for conversion among methods may be applied (*4*). It is important to specify the instrument, angle of view, and analysis settings used.

Literature Cited

1. Buchanan, J. B. 2004. In my opinion: managing habitat for dispersing northern spotted owls – are the current management strategies adequate? Wildlife Soc. B. 32(4):1333-1345.
2. Bunnell, F. L., & D. J. Vales. 1990. Comparison of methods for estimating forest overstory cover: differences among techniques. Can. J. Forest Res. 20:101-107.
3. Englund, S. R., J. J. O'Brian, and D. B. Clark. 2000. Evaluation of digital and film hemispherical photography and spherical densiometry for measuring forest light environments. Can. J. Forest Res. 30:1999-2005.
4. Fiala, A. C. S., S. L. Garman, A. N. Gray. 2006. Comparison of five canopy cover estimation techniques in the western Oregon Cascades. Forest Ecol. Manag. 232:188–197.
5. Frazer, G.W., C. D. Canham, and K. P. Lertzman. 1999. Gap Light Analyzer (GLA), Version 2.0: Imaging software to extract canopy structure and gap light transmission indices from true-colour fisheye photographs, users manual and program documentation. Simon Fraser University, Burnaby, B. C., and the Institute of Ecosystem Studies, Millbrook, NY.
6. Frazer, G.W., R.A. Fournier, J.A. Trofymow, and R.J. Hall. 2001. A comparison of digital and film fisheye photography for analysis of forest canopy structure and gap light transmission. Agr. Forest Meteorol. 2984:1–16.
7. Hanson, E., D. Hays, L. Hicks, L. Young, and J. Buchanan.1993. Spotted owl habitat in Washington: a report to the Washington Forest Practices Board. Olympia, WA.
8. Jennings, S. B., N. D. Brown, & D. Sheil. 1999. Assessing forest canopies and understorey illumination: canopy closure, canopy cover and other measures. Forestry 72(1):59-73.
9. Korhonen, L., K. T. Korhonen, M. Rautiainen, & P. Stenberg. 2006. Estimation of forest canopy cover: a comparison of field measurement techniques. Silva Fenn. 40(4):577-588.
10. Lemmon, P. E. 1957. A new instrument for measuring forest overstory density. J. Forest. 55(9):667-669.
11. Nobis, M. 2005. SideLook 1.1 - Imaging software for the analysis of vegetation structure with true-colour photographs; http://appleco.ch.
12. Nobis, M., & U. Hunziker. 2005. Automatic thresholding for hemispherical canopy-photographs based on edge detection. Agr. Forest Meteorol. 128:243-250.
13. Teti, P. A., & R. G. Pike. 2005. Selecting and testing an instrument for surveying stream shade. BC Journal of Ecosystems and Management 6(2):1-16.
14. WADNR. 1997. Final Habitat Conservation Plan. Washington State Department of Natural Resources. Olympia, WA.

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