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A COMPARISON OF THE SPHERICAL DENSIOMETER AND OCULAR METHODS OF ESTIMATING CANOPY COVER

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ABSTRACT.—Percent tree canopy cover in a ponderosa pine (*Pinus ponderosa*) forest of northeastern California was estimated by the point intercept spherical densiometer and ocular methods. Estimates derived by the two methods were similar ($P > .05$). The ocular method is recommended when understory vegetation is tall or clumped instead of randomly distributed, or if available field time limits sample size.

Canopy cover, or percent canopy cover, refers to the proportion of an area covered by the vertical projection of plant crowns to the ground surface (Gysel and Lyon 1980). The measurement of cover provides information on the structure of vegetation. Several instruments and methods have been used to measure canopy cover, including photometers, light meters, photographic methods, densiometers and ceptometers, vertical crown projection methods, ocular estimations, point intercept, line intercept, and the Bitterlich method (Lemmon 1956, Mueller-Dombois and Ellenberg 1974, Hays et al. 1981).

Robinson (1947, cited in Lemmon 1956) was one of the first researchers to use a densiometer; he used a flat mirror to estimate relative area of crown coverage. This method required use of both a large mirror and a large number of samples. Lemmon (1956) improved the method by using a spherical densiometer and reported that at probability levels of 70, 95, and 99%, average measurements of the same overstory area could be expected to be within ±1.3, ±2.4, and ±3.1%, respectively. Strickler (1959) recommended limiting use to 17 points in a wedge-shaped area on the densiometer to avoid multiple counting of intercepts. Dealy (1960) used a densiometer in conjunction with the line intercept method to measure canopy cover in tall shrub–small tree vegetation types.

Densiometer measurements were found to be highly correlated with measurements taken by a canopy camera (Hoffer 1962, cited in Hays et al. 1981). The amount of open canopy in the east, south, and west directions, as measured with the spherical densiometer, accounted for the largest proportion of the variance in light penetration in an Arizona ponderosa pine forest (McLaughlin 1978). Total understory, shrub, and forb production was correlated with canopy cover measured with a spherical densiometer, but not with tree basal area, stand height, or number of trees/ha in the grand fir (*Abies grandis*)/ myrtle boxwood (*Pachistima myrsinites*) habitat type of north central Idaho (Pyke and Zamora 1982).

The ocular method estimates cover "by eyeball" over a sample area that is laid out on the ground. Proponents of its use include Braun-Blanquet (1932) and Daubenmire (1959). These scientists used cover classes (e.g., 0–5%, 5–25%, etc.). Steele et al. (1981) used the ocular method to estimate canopy coverage of all vascular plant species by classes and recommend it from the standpoint of efficiency. Hays et al. (1981) stated that the ocular method can be "moderately accurate." They recommended use of the line intercept or point intercept techniques when greater accuracy is desired.

I compared estimates of tree canopy cover obtained by the ocular method to estimates obtained by the point intercept spherical densiometer on the same study plots to determine if the ocular method could be used as a reliable estimate of percent overstory canopy in a ponderosa pine forest in northeastern California.

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STUDY SITE

Tree canopy cover was estimated on plots in the Blacks Mountain Experimental Forest in northeastern California (Lassen County). Approximately half of the study area was in a gently rolling basin; the rest extended up moderate slopes to the north and east. Elevations ranged from 1,700 to 2,100 m.

The forest vegetation was characteristic of the Interior Ponderosa Pine type (Eyre 1980). Dominant were ponderosa pine and Jeffrey pine (*Pinus jeffreyi*), as well as white fir (*Abies concolor*) and incense cedar (*Calocedrus decurrens*) at higher elevations. The understory was often open, with scattered shrubs, forbs, and grasses, along with clumps of sapling and pole-sized conifer thickets. Bitterbrush (*Purshia tridentata*) and big sagebrush (*Artemisia tridentata*) were abundant in the understory at lower elevations. Typical understory species at higher sites were snowberry (*Symphoricarpos oreophilus*) and pennyroyal (*Monardella odoratissima*).

METHODS

Conifers greater than 1.5-m height were considered to be trees. Ocular estimates of tree canopy cover were made for 25-m^2 circular microplots (2.82-m radius) in June 1983. An initial training exercise was conducted in which canopy cover was also estimated using 40 points located within the plot in the four cardinal directions for the first 10 microplots. Later, with two-thirds of the sampling completed, an estimate on another 10 microplots was used as a check. Results were compared with paired t-tests. A total of 330 sample points were located along 33 transects. Each of the transects was about 400 m long and contained 10 randomly located microplots. Twenty-six transects were located in experimental units that were logged approximately 40 years ago, and the remaining 7 were located in units cut within the past 10 years.

Tree canopy cover was remeasured with a spherical densiometer on all 330 plots in June 1984 without the data sheets from the previous year in hand. The densiometer measurements served as a standard to which the ocular estimates could be compared. Paired t-tests were used to compare the ocular estimates to those derived using a spherical densiometer. Normality of distribution was tested using the Kolomogorov D statistic (SAS 1982).

Hallin (1959) stated that these 40-year-old experimental units were cut using a randomized block design to study the effects of six harvest treatments on tree growth. The treatments ranged from no harvest (control) to removal of all trees larger than 29.5 cm dbh. Analysis of variance (ANOVA) was used to test for treatment effects on mean canopy cover estimated by the ocular method and by the spherical densiometer for the 26 transects in the older cuts (SAS 1982). Normality of distribution was tested using the Shapiro-Wilk statistic, W (SAS 1982).

RESULTS

The difference in canopy cover between paired observations was less than 41% for 90% of the observations, less than 28% for 80% of the observations, and less than 12% for 50% of the 330 observations.

The t value was -1.60 ($P = .11$). The data (paired differences) were not distributed normally (Kolomogorov $D < 0.01$). The data were not further analyzed using the nonparametric Wilcoxon's signed-rank test because of large sample size, robust nature of the t-test, and nonsignificance of the results using the parametric test.

The data were further sorted into three categories to examine for differences due to plant community and length of time after timber harvest (limited to recent cuts or 40-year-old cuts). The paired t-test results for the differences between the two methods of estimating canopy cover were not significant for any of these categories (Table 1). Both methods of estimating cover provided similar ANOVA results (Table 2). The six timber harvest treatments did not have significant effects on total tree canopy cover 40 years after harvest as measured by the two methods. This was due to the natural heterogeneity in forest structure. The forest was composed of a variety of small, even-aged groups of trees of various ages. The overstory was broken by groups of smaller-sized trees or scattered, older residuals in younger stands. The age classes were not evenly distributed spatially, but instead formed a mosaic of small, homogeneous units that varied in size from a fraction of a hectare to 4 ha (Hallin 1959).

TABLE 1. Differences between ocular and densiometer estimates of tree canopy cover by age of cut and plant community.

Category	t value	P	Number of samples
Recent cuts (4–10 yrs)	−1.95	0.06	70
Older cuts (40 yrs)	−0.81	0.42	260
Lower-elevation community (ponderosa pine and bitterbrush)	1.18	0.24	100
Higher-elevation community (ponderosa pine, white fir, incense cedar, and snowberry)	−0.02	0.80	160

TABLE 2. Analyses of variance of effect of treatment and block on tree canopy cover as measured by densiometer and ocular methods.

	Ocular[a]				Densiometer[b]		
Source	df	F value	P	Source	df	F value	P
Treatment	5	0.91	0.51	Treatment	5	0.94	0.48
Block	4	1.58	0.23	Block	4	1.77	0.18

[a]Macroplot means were distributed normally ($Pr<W = 0.47$).
[b]Macroplot means were distributed normally ($Pr<W = 0.43$).

The two checks on the ocular method showed that this method did not deviate significantly from cover estimated from the 40 points within the plot ($t = -1.40$, $P = .18$; normality test, $P = .34$).

Discussion

The results of the paired t-tests and ANOVA do not indicate significant differences between estimates of canopy cover obtained from a spherical densiometer and from the ocular method. The choice of methods is dependent upon time available in the field, needed accuracy, range of tree sizes, nature of understory, and species of trees.

The ocular method is quicker and is fairly accurate with a trained observer. The densiometer takes several more minutes at each plot and is subject to error in counting of intercept points by the observer. The ocular method works well in all size classes of vegetation and probably does a better job of estimating canopy cover as defined by drip lines of trees rather than canopy cover in terms of light penetration, although the latter is probably of greater biological significance. Light penetration through loose ponderosa pine foliage is difficult to estimate either visually or with a spherical densiometer.

The spherical densiometer is most effective in stands of medium to large trees (> 10 m tall) where there is little understory greater than 1 m in height. In some cases the plot center was located under a tall seedling or sapling. In these instances densiometer estimates of cover were too high for the 25-m^2 plot. Also, it was sometimes difficult to get readings in four directions with the densiometer in low, dense vegetation. Estimates of cover obtained by a densiometer at the plot center did not include cover provided by small trees at the edge of the plot; the lesser the tree height, the smaller the portion of the canopy reflected in the mirror. In these cases, the ocular estimate of cover was superior to that obtained using a spherical densiometer at the plot center. The densiometer uses the point intercept method; hence measurements at the plot center cannot be extrapolated to a large plot without additional measurements within the plot.

The paired t-test for recently cut areas was almost significant ($P = .06$, Table 1). The vegetation in these areas was dominated by sapling and pole-sized trees, and densiometer estimates taken at plot center were probably less accurate for coverage estimates of the 25-m^2 plot. Differences between the ocular and densiometer methods were least significant ($P = .80$) in older harvest areas at higher elevations where there were large trees with dense foliage, such as white fir and incense cedar. The degree of nonsignificance drops ($P = .24$) in the more open ponderosa pine and bitterbrush community. Here, densiometer estimates may be more accurate where large trees dominate over a low understory. The method suggested by Dealy (1960) for low shrubs and small trees may work better where a tall understory is present, but it requires use of the more time consuming line intercept method.

Weather conditions may also impact the accuracy of densiometer readings. Looking into the mirror can be blinding when the sun is overhead. Wind movement of foliage can make determination of point intercept in the mirror difficult.

CONCLUSIONS

Ocular estimates provided an estimate of tree canopy coverage that was not statistically different from that estimated using a spherical densiometer. Use of the spherical densiometer and line intercept methods is probably more accurate under certain conditions but may yield erroneous results if understory vegetation is tall, if vegetation is clumped instead of randomly distributed, or if available field time limits sample size. In the latter case, the lower accuracy of the ocular method may be more than compensated by the larger sample sizes. Observers using the ocular estimating method should be initially trained with and periodically checked against a reliable mechanical cover estimation method.

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