Comparison of Alternatives to Measuring Crown Diameters with Logger's Tapes

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Abstract. *The direct measurement of crown diameters with logger's tapes adds significantly to the cost of forest inventories. We undertook a study of 100 trees to compare the traditional method to four alternatives - two field instruments, ocular estimates, and regression models. Using the taping method as the standard of comparison, accuracy of the tested alternatives was adequate for softwood species, but short of the specified measurement quality objective for estimating the mean crown diameter of hardwoods. Due to savings in field costs, ocular estimation and regression models were the best alternatives to direct measurement with logger's tapes.*

Tree crown condition can be used as an indicator of general tree health, vigor, and growth potential. Trees with large, full crowns usually have a high potential for carbon fixation and, consequently, net primary production. When natural or anthropogenic stresses impact a forest, the first signs of deterioration may be observed in the tree crowns. Crown diameter is an important variable in the calculation of composite crown variables such as crown volume and crown surface area.

Forest Health Monitoring (FHM) field crews traditionally have measured crown diameters by measuring (with logger's tapes) the horizontal length of the widest axis of each crown, plus the dimension perpendicular to the widest axis. The two tape measurements are then averaged to obtain mean crown diameter. Depending on the understory vegetation and percent slope, crown-diameter measurements often average more than one minute per tree, and easily can add an hour to a field crew's daily workload. Taping crown diameters also increases foot traffic on the plot, thus increasing exposure to erosion and understory trampling. For these reasons, crown diameter measurements were dropped when the Forest Inventory and Analysis (FIA) and FHM programs merged in 2000. This Poster describes a study designed to investigate alternative methods for measuring crown diameters that require less time and potential damage to plots.

FIELD ALTERNATIVES

Three Field Methods

Three alternative field methods were tested against the traditional method. The first is the calibrated cross (figure 1), which is based on similar ratios calibrated to total tree length. It consists of a vertical axis scaled from 0 to 100 percent, with a similarly scaled horizontal axis. The observer visually aligns the vertical axis with total tree length until the vertical scale reads 100 percent (AB). Crown diameter (in percent) is then read from the scale on the horizontal axis (DC). The result is then multiplied by total tree length (feet) to calculate crown diameter (feet):

$$D = R_h (L) \qquad (1)$$

where

R_h = the horizontal ratio (in percent) read from the calibrated cross when the vertical ratio is aligned with total tree length (L) at 100 percent, and

L = total tree length (feet).

The second alternative is a type of optical fork. With the observer's eye as the vertex (F), the angle formed by the left and right edge of a tree crown (EFG) is read from an angle gauge (figure 2). Slope distance from the observer to the point on the bole where the angle was viewed (FH) is then measured with a laser. Assuming the axis of the crown is perpendicular to the slope distance (forming a right angle), crown diameter is computed as:

$$D = 2 (\tan (\theta / 2)) S \qquad (2)$$

where

θ = the angle read from an angle gauge, and

S = the slope distance (feet) from the observer to the point on the bole where the angle was read.

The third alternative is the ocular method, where crown diameters are visually estimated (without instrumentation) to the nearest foot. For all alternatives, observations were taken from the two perspectives that offered the best view of each tree crown. Each method thus produced a crown-diameter estimate for each tree that was averaged from two perspectives.

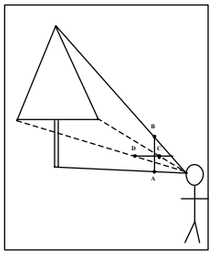

Figure 1. Reading ratios with a calibrated cross.

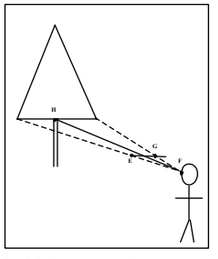

Figure 2. Reading an angle and slope distance for the optical fork method.

Results of the Field Study

100 trees were measured at five different sites in and around the Bent Creek Experimental Forest near Asheville, NC. Three two-person crews took part in the study, each of which measured about one-third of the trees. "Ground truth" was obtained by measuring crowns with logger's tapes in the traditional manner after all other readings were recorded. Seventeen different tree species were encountered.

Each of the three alternatives reduced the amount of foot traffic on the plot because crown diameters could be obtained from the same position where field crews measure other crown parameters (e.g., vertical crown ratio). None of the alternatives required extra walking to measure crown diameters, as does the traditional method.

The time required for the traditional taping method averaged 66 seconds per tree. The alternative methods averaged between 16 and 57 seconds per tree (table 1). Ocular estimation was by far the quickest, taking about one-fourth the time required for the traditional method.

The FHM measurement quality objective (MQO) for crown diameter is ±5 feet, or 10 percent (whichever is larger). All three field alternatives are approximately equivalent in accuracy (table 1). The optical fork attained the desired MQO 80 percent of the time, compared to 79 percent for ocular estimates and 74 percent for the calibrated cross. Considering accuracy, bias, and measurement time, ocular estimation proved to be the best field alternative tested. The inability of the two instruments to outperform ocular estimation is attributed largely to difficulty viewing crown outlines obscured by brush and other trees.

		---------- Evaluation statistics ----------					
Species group / method	N	Bias[a]	RMSE[b]	AD[c]	PAD[d]	MQO[e,f]	Time[g]
		-------(feet)-------			-----(percent)-----		(seconds)
Hardwood species							
Calibrated cross	62	-2.9	5.4	4.1	18	65 (53-76)	31
Optical fork	62	-2.1	6.0	4.5	19	71 (60-82)	53
Ocular estimate	62	-0.4	5.0	3.7	17	74 (63-85)	18
Regression model	62	-2.4	5.2	4.0	19	68 (56-79)	0
Softwood species							
Calibrated cross	38	-1.6	3.4	2.7	21	89 (80-99)	33
Optical fork	38	-0.5	2.7	2.2	19	95 (88-100)	64
Ocular estimate	38	2.0	3.5	2.9	27	87 (76-98)	12
Regression model	38	-0.1	3.0	2.3	19	92 (84-100)	0
All species							
Calibrated cross	100	-2.4	4.7	3.6	19	74 (65-83)	32
Optical fork	100	-1.5	5.0	3.6	19	80 (72-88)	57
Ocular estimate	100	0.5	4.5	3.4	21	79 (71-87)	16
Regression model	100	-1.5	4.5	3.4	19	77 (69-85)	0

[a] mean deviation
[b] square root of mean squared deviation
[c] mean absolute deviation
[d] mean percent absolute deviation
[e] percent of observations within the ±5 feet (or 10 percent) measurement quality objective
[f] 95-percent confidence interval for MQO is in parentheses.
[g] mean measurement time per tree.

Table 1. Comparison of traditional crown-diameter measurements to alternative methods for 100-tree Special Study, by species group.

Hardwood crowns are generally larger, more likely to be intermingled with other trees, and more variable than softwood crowns. As a result, all three field alternatives performed better for softwoods than hardwoods. For softwood species, the percentage of measurements that achieved the desired measurement quality was 89 percent with the calibrated cross, 95 percent with the optical fork, and 87 percent with ocular estimation. The corresponding figures for hardwood species were 65, 71, and 74 percent, respectively.

Taped crown diameters were used as the standard of comparison in this analysis, but there is also measurement error associated with this method. A national quality-assurance (QA) study of 1999 FHM data that includes blind checks of 1,376 taped crown measurements indicates that field crews using the traditional method attained the desired MQO 83 of the time—88 percent for softwoods and 76 percent for hardwoods. These results imply that a target MQO of 90 percent may be unrealistic for hardwood species, regardless of method.

CROWN-DIAMETER MODELS

In 1999, FHM field crews measured crown diameters from trees on 1,413 FHM plots distributed across 32 states. Data from a subset of these plots (i.e., plots with the species of interest) were used to develop models to predict crown diameters for the 17 species encountered in the Bent Creek field study. From a variety of potential models, the following was judged to fit the FHM data best:

$$D = b_0 + b_1 (dbh) + b_2 (R_v) \qquad (3)$$

where

D = mean crown diameter (feet),

dbh = tree diameter (inches) at breast height (minimum 5.0 inches),

R_v = uncompacted vertical crown ratio, and

b_i = regression parameters estimated from the data.

Adjusted R-squares from model solutions ranged from 0.16 for sourwood to 0.70 for shortleaf pine. In general, the models performed especially well for shade-intolerant overstory species such as pines, oaks, and hickories; but relatively poorly for shade-tolerant understory hardwoods such as red maple, sourwood, and blackgum. When applied to the 100 trees sampled in the Bent Creek study, the regression models produced results that were approximately equivalent to the three alternative field methods. Models attained the target measurement quality 77 percent of the time (table 1). As with the field alternatives, model predictions were noticeably better for softwoods than hardwoods (92 percent MQO vs. 68 percent, respectively).

Upon further investigation of model performance using all data from the 1999 production data set and fitting regressions to all available species (31,911 trees and 117 species), we found that 83 percent of the model predictions attained the desired measurement quality—90 percent for softwoods and 76 percent for hardwoods. Of the 117 species for which regressions were solved, models for 32 species achieved the target 90 percent MQO.

Based on these results, crown-diameter models offer a tempting alternative to the field measurement of crown diameter. However, in monitoring applications such as FHM, sole reliance on models to predict crown diameter and associated attributes (e.g., crown volume) has the potential to mask spatial or temporal trends involving these attributes. Models should be applied with the understanding that the same functional relationship between dependent and independent variables must be assumed for the predicted trees as for the trees from which the models were developed. If this functional relationship is altered by a change in forest health, poor predictions could result in the failure to detect a problem.

CONCLUSIONS

When measurement of crown diameters with logger's tapes is the standard of comparison, all of the tested alternatives are adequate for softwood species, but none achieve the 90-percent measurement quality objective for hardwoods. If crown diameters are important to the goal of an inventory or monitoring program, the most prudent course of action is direct measurement with logger's tapes—unless quality objectives can be relaxed (particularly for hardwood species). FHM QA data suggest that the 90-percent target may not be realistic for hardwood species, even when the taping method is used. Due to reduced field costs, regression models and ocular estimation are the most appealing alternatives to measurement with logger's tapes. Models are not recommended for forest health monitoring due to the possibility that models may mask a temporal or spatial trend. If it is not feasible to measure crown diameters with logger's tapes on plots used for monitoring purposes, ocular estimates are recommended.

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