NE-256
RN

FOREST SERVICE RESEARCH NOTE NE-256
1978

Northeastern Forest Experiment Station

FOREST SERVICE, U.S. DEPARTMENT OF AGRICULTURE, 370 REED ROAD, BROOMALL, PA. 19008

CORRELATIONS OF LEAF AREA WITH LENGTH AND WIDTH MEASUREMENTS OF LEAVES OF BLACK OAK, WHITE OAK, AND SUGAR MAPLE

—PHILIP M. WARGO

Research Plant Pathologist
Northeastern Forest Experiment Station,
Hamden, Connecticut

Abstract. Correlations of leaf area with length, width, and length times width of leaves of black oak, white oak, and sugar maple were determined to see if length and/or width could be used as accurate estimators of leaf area. The correlation of length times width with leaf area was high ($r > +.95$) for all three species. The linear equation $Y = a + bX$, where X = length times width, can be used to estimate leaf area where it is not possible or practical to make actual area measurements.

INTRODUCTION

Leaf area of trees is an important component of models of photosynthesis, growth, and primary productivity. Area measurements can now be made with portable electronic area meters, and are most easily made if the leaves are detached from the plant and passed through the meter. Measuring attached leaves with the electronic meter is cumbersome, not as accurate, and can be hazardous. However, for some experiments, it would be detrimental to the results of the study if leaves were removed.

An easier measurement to make on attached leaves is length or width. These measurements are highly correlated with leaf area in grape species (Manivel and Weaver 1974). Therefore, this study was made to determine if length and width were correlated highly enough with leaf area to be substituted as an accurate estimate of leaf area in species of forest trees.

MATERIALS AND METHODS

Three species of deciduous hardwoods were chosen: sugar maple, *Acer saccharum* Marsh, white oak, *Quercus alba* L., and black oak, *Q. velutina* Lamarck. Trees were 5 to 8 cm in diameter at 1.4 m, and were 5 to 7 m tall. The sugar maples were part of a thicket that had seeded into an abandoned field. The oaks were growing in a stand that had been recently cut over. All trees were 15 to 20 years old.

Ten leaf clusters were randomly selected from the upper two-thirds of the crown of each of 10 trees for each species. Leaf length was measured to the nearest .1 cm along the midrib. Width was measured perpendicular to the midrib between two points projected at the widest margins of the blade. Leaves were measured with an electronic leaf area meter. Each leaf was measured 10 times, and an average area in cm^2 recorded. If leaves were too large for the meter they were cut in half, each half was measured, and the areas were combined. Holes in leaves were covered with masking tape to prevent underestimates. Portions of the margin that were missing, but which could be projected, were cut from paper and attached to the leaf. Unfortunately many of the leaves had portions missing that could not be projected; these leaves were eliminated. This may have caused a bias. Leaves were treated as the unit of observation in the analysis.

Regression analyses were used to fit leaf area using functions of length and width. Linear, parabolic, and allometric models were tested and R^2 values compared. For the equation $Y = a + bX$ where X was the length times width, an analysis of variance was made to determine differences in slope and intercept among species, and to determine variance within and among trees. For the allometric regression model $Y = aX^b$, the values for a and b were determined by regression using the equation $\log Y = \log a + b \log X$. The R^2 value for the equation $Y = aX^b$ was then calculated with the formula $1 - \frac{S^2Y \cdot X}{S^2Y} = R^2$,

where $S^2Y \cdot X = \frac{\Sigma (Y - \hat{Y})^2}{n - 2}$ and

$$S^2Y = \frac{\Sigma (Y - \bar{Y})^2}{n - 1}$$

$\hat{Y}$ values were calculated with the equation $Y = aX^b$ using the b value and the antilog of the a value determined above by regression.

RESULTS

Correlations of length, width, and length times width with leaf area in black oak, white oak, and sugar maple were high (Table 1); the highest were with length times width.

The allometric model, $Y = aX^b$, and the parabolic model, $Y = a + bX + cX^2$, were compared with the linear model. The R^2 values of the linear model were similar to those of the other models (Table 1), and the linear model seems to be adequate. An analysis of variance was performed on the data using the linear equation with length times width as the independent variable.

The analysis indicated that the three species tested had a common intercept but significantly different slopes (Table 2). Slopes for white and black oak were not significantly different from each other, but they were significantly different from sugar maple ($P < .01$). Within-tree variance ($\hat{\sigma}_e^2$) was 72.595 $(cm^2)^2$ and the additional between-tree variance component ($\hat{\sigma}_T^2$) equaled 19.964 $(cm^2)^2$.

Table 1. Coefficients of determination (R^2) for three models relating leaf area (Y) to leaf length (L), width (W), and length times width (LxW) in black oak, white oak, and sugar maple

Species	Independent variable	Model		
		Linear $Y = a + bX$	Parabolic $Y = a + bX + cX^2$	Allometric $Y = aX^b$
Black oak	L	0.855	0.855	0.841
	W	.838	.850	.849
	LxW	.938	.939	.938
White oak	L	.881	.901	.897
	W	.858	.861	.858
	LxW	.942	.943	.942
Sugar maple	L	.856	.874	.873
	W	.880	.881	.855
	LxW	.918	.923	.915

Table 2. Estimates and precision of the intercept and slope for estimating leaf area for black oak, white oak, and sugar maple using the linear model Y = a + bX, where X equals length times width

Variable	Estimated	Standard error	Covariance with mean
Common intercept (a)	3.676	0.656	
Regression coefficient			
Black oak	.537	.00336	$-.122287\text{x}10^{-4}$
White oak	.514	.00780	$-.165082\text{x}10^{-4}$
Sugar maple	.490*	.00588	$-.170606\text{x}10^{-4}$

*Difference significant at $P < .01$.

For N_T randomly selected trees and N_L randomly selected leaves per tree of a given species, the area per leaf and its variance can be estimated by the following formulas, where

X = leaf length times width in centimeters,
Y = average leaf area in square centimeters,
i = tree index,
j = leaf index, within tree.

White oak:

$$\hat{Y} = 3.676 + \frac{.514}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.608062\text{x}10^{-6}\,\Sigma X_{ij}^2 - .330164\text{x}10^{-4}\,\Sigma X_{ij})$$

Black oak:

$$\hat{Y} = 3.676 + \frac{.537}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.113084\text{x}10^{-6}\,\Sigma X_{ij}^2 - .244594\text{x}10^{-4}\,\Sigma X_{ij})$$

Sugar maple:

$$\hat{Y} = 3.676 + \frac{.490}{N_L N_T} \Sigma X_{ij}$$

$$\hat{\sigma}^2(\hat{Y}) = \frac{72.5953}{N_L N_T} + \frac{19.9643}{N_T} + .43229 + \frac{1}{N_L N_T}(.345815\text{x}10^{-6}\,\Sigma X_{ij}^2 - .341212\text{x}10^{-4}\,\Sigma X_{ij})$$

DISCUSSION

The correlation of length times width with area in leaves from black oak, white oak, and sugar maple is high enough that length times width can be used as an accurate estimator of leaf area. In conjunction with a random sampling scheme, these equations can be used to estimate leaf area where the use of an area meter is not possible or when repeated measurements of the same leaf are needed and leaves cannot be detached.

LITERATURE CITED

Manivel, L., and R. J. Weaver.
1974. **Biometric correlations between leaf area and length measurements of "Grenache" grape leaves.** Hortsci. 9:27-28.

Acknowledgments

I thank Gerald Walton and Jay Homeyer for statistical assistance; Thomas Abbott, Michael Boutin, Robert Knapp, and Martha Potvin for technical assistance; and the New Haven Water Company, New Haven, Connecticut, for use of their forests.

MANUSCRIPT RECEIVED FOR PUBLICATION 26 OCTOBER 1977

☆U.S. GOVERNMENT PRINTING OFFICE: 1978— 703-112:29