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MEASUREMENTS OF CROWN DIAMETER AND CROWN COVER AND THEIR ACCURACY FOR 1:12,000 PHOTOGRAPHS*

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ABSTRACT

The standard error of individual crown diameter measurements made with either the shadow wedge or with a dot transparency is between 3 and 4 feet. The results obtained with a calibrated shadow wedge are free of systematic errors, while the use of the dot transparency may lead to systematic errors amounting to about 1 or 2 feet. Measurements of crown cover percentage made with a dot grid or a crown density scale are affected by highly significant systematic errors or interpreter's bias. The maximum of these systematic errors is between 5 and 10 per cent. The standard error of an individual measurement for a given interpreter is equal to 10 per cent. Measurements made with the dot grid method are somewhat more objective and subject to smaller systematic errors than the measurements based on comparisons with a crown density scale.

TIMBER stand volumes of upland oak forests in Pennsylvania have been successfully correlated with various expressions of tree height, relative crown cover and visible crown diameter, variables which can be conveniently measured on 1:12,000 aerial photographs. Of these three variables, only tree height can be precisely measured on the ground, allowing an objective determination of the systematic as well as the accidental errors of measurement.[5] The visible crown diameters of trees in mixed hardwood stands as measured on aerial photographs cannot be checked by ground measurements. Multiple stem trees, interlocking crowns, shadow variations, all contribute to wide discrepancies between visible crown diameters measured on photographs and actual crown diameters measured from the ground. Similarly, relative crown cover in these stands usually expressed as a percentage of complete crown coverage, cannot be directly related to any particular determination of crown cover made on the ground. For these reasons only the relative accuracy of such measurements can be investigated, namely the variation in the measurements made by a single observer and the variation in the measurements between observers. In other words, it is only possible to ascertain the relative consistency of photo measurements between and within different photo interpreters. The photo measurements used in this investigation were all made on 1:12,000, photographs taken with an $8\frac{1}{4}$

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inch focal length camera using a minus blue filter with infrared film. The accuracies of these measurements are of special interest when compared with similar data for large scale (1:1,200 and 1:7,200) panchromatic photographs made for perdominantly coniferous forest types as reported by Losee[2].

Visible Crown Diameter

Preliminary measurements of clearly defined images of high contrast such as buildings, sidewalks and streets, made with a calibrated shadow wedge indicated standard errors of measurements of about 1½ feet. The systematic errors of different observers were likewise small, amounting to less than one foot. Subsequently, the crown diameters of 36 trees were measured by three experienced photo interpreters using two different measuring aids, namely the calibrated shadow wedge, and the ordinary dot size transparency. The shadow wedge is calibrated to the nearest 0.001 inch; its design and use are fully described by Spurr,[4] and Jensen.[1] The dot size transparency consists of a series of dots, the smallest 0.005 inches in diameter. The design and use of these transparencies are described by Jensen,[1] With the shadow wedge the largest and smallest crown dimension of each tree was measured, the average of the two readings being recorded. The measurements with the dot transparency are obtained by comparing the photo image with various size dots and by recording the dot size closest to the visible crown diameter. All measurements were made under a lens stereoscope on the image nearest to the principal point. Each crown diameter was measured twice by each of the three observers. With 36 trees measured this gave a total of 432 measurements.

By subjecting the data to a statistical analysis, it was found that there existed no significant differences in the accuracy of crown measurements for different types of trees such as hardwoods or softwoods, or trees of different size. However, it was found that the standard error of measurement of the individual observers amounted to 4.2 feet for open grown trees and 3.0 feet for forest grown trees. The average standard error was equal to 3.7 feet. This difference is statistically significant, but for all practical purposes it is sufficient to state that the standard error of visible

Table 1

Average Visible Crown Diameter of 36 Trees

Instrument	Interpreter (1)	Interpreter (2)	Interpreter (3)	Average
	feet	*feet*	*feet*	*feet*
Dot size	27.2	30.4	28.5	28.8
Wedge	28.3	28.3	28.3	28.3
Average	27.7	29.5	28.4	28.6

crown diameter measurements made by a single observer is equal to 3 or 4 feet.

In order to determine if different observers are liable to systematic errors, that is, of measuring crown diameters consistently too high or too low, the averages of all measurements by instruments and observers were calculated as shown in Table 1. The averages given for each observer and instrument combination are based on 72 measurements and their standard error is therefore equal to $3.7/\sqrt{72} = \pm 0.4$ feet.

The results obtained with the two different measuring aids were essentially the same, since all the differences with the exception of one can be ascribed to accidental errors of measurement. Interpreter (2) obtained slightly larger crown diameter values when using the dot transparency than when using the wedge. In view of the perfect consistency between observers using the wedge, it appears, however, that inconsistencies or systematic errors of measurement occur only when using the dot comparison method of measurement. A more detailed analysis of the data made by considering separately the results obtained for open grown and forest grown trees confirms this contention. None of the differences between observers using the wedge were significant. On the other hand, when using the dot transparency, differences between observers as large as five feet were obtained from open grown trees while the maximum difference of forest grown trees was 2.4 feet.

The conclusion that more accurate results are obtained with the shadow wedge than with the dot comparison method may be explained by the simple fact that the dots cover the object to be measured while the wedge does not. Furthermore, when measuring irregularly shaped open grown trees it is rather difficult to make a choice between the two dots most closely approximating the size of a given crown.

Crown Cover Per Cent

Next to height, relative crown cover expressed as a percentage is probably the most important stand characteristic which can be measured on aerial photographs. Used in connection with height, or in connection with height and crown diameter, stand volume can be estimated with the help of established stand volume tables. Two different methods have been used for the determination of relative crown cover, namely the dot grid method and the crown density scale Spurr[4]; Moessner.[3] A regularly spaced grid of small dots superimposed on a photograph permits the counting of dots falling on crowns. This number in per cent of the total number of dots appearing over a given area represents the crown cover percentage.

When crown cover is determined for individual sample plots of about $\frac{1}{5}$ acre in size, the dot grid and the individual dots must necessarily be quite small. The measuring aid used in this investigation was constructed as follows: A square hole, with sides equal to the diameter of the circular plot used, is cut into a first piece of acetate. This forms a plot opening which enables the interpreter to have a clear view of the entire plot. Five dots of about 0.004 inches in diameter are printed in a line on a second piece of acetate, each dot separated from the next by $\frac{1}{5}$ the distance of the plot diameter. This dot tab is placed about $\frac{1}{5}$ of the plot diameter below the upper edge of the square delineating the plot. The dots falling on tree crowns are counted in this first position of the tab. Moving the tab down a second fifth of the plot diameter, the count is continued. The process is repeated for a third and a fourth possible position of the tab. In this way a maximum of 20 dots can be counted, each dot accounting for a crown cover percentage of 5. By multiplying the total number of dots falling on tree crowns by 5, the relative crown cover percentage of the plot is immediately obtained.

A similar objective method for determining relative crown cover has been described by Losee.[2] The use of an ordinary acreage grid for this type of work is not practical since the dots of such grids are too large. In addition, it would be very cumbersome to move the stereoscope from one dot to the next while obtaining in each position only a single observation. It should also be pointed out that when using aerial stand volume tables giving the volume per plot for different tree heights, crown diameters and crown cover percentages, these values should be determined individually by plots and not for a stand as a whole.

Crown density scales consist of gradually differing patterns of systematically or randomly distributed dots covering from 5 to 95 per cent of an area. The individual dots approximate the size of visible crowns. The crown cover per cent of a timber stand is estimated by comparison with these gradually differing density patterns. While the comparison method with crown density scales is considerably faster than the dot grid method, it probably lacks the objectivity required for an accurate crown density estimate.

The accuracy of the measurement of crown density was determined by measuring 93 plots of $\frac{1}{5}$ acre previously used for the construction of an aerial stand volume table for upland oak forests. The crown cover percentages of these plots varied from 10 to 100 but the majority of the plots had a crown density above 50 per cent. Using both the dot count and the crown density scale, each of three interpreters measured every plot twice, this amounted to 558 measurements made with the dot grid and 558 measurements with the density scale, a total of 1,116 measurements. All measurements were made under a lens stereoscope on the plot image nearest to the principal point.

With a balanced experiment as outlined above, it was possible to make a statistical analysis of the data to determine the standard error of a given interpreter from one measurement to another. This accidental error of measurement was found to be 9.5 per cent for the dot grid method and 10.4 per cent for the comparison method using the crown density scale. The two errors are not significantly different from each other, and it can simply be stated that the standard error of a single estimate of relative crown cover for a given observer is equal to 10 per cent.

When comparing the average crown cover per cent obtained by each observer for all 93 plots measured, it is at once evident that significant systematic errors

TABLE 2

AVERAGE CROWN COVER PERCENTAGE OF 93 PLOTS

Instrument	Interpreter (1)	Interpreter (2)	Interpreter (3)	Average
	per cent	*per cent*	*per cent*	*per cent*
Dot grid	73.2	65.7	70.8	69.9
Density scale	71.5	79.1	67.5	73.9
Average	74.2	72.4	69.2	71.9

are made by each observer. As shown in Table 2, the averages for each interpreter-instrument combination varies from 65.7 up to 79.1 while the standard error of the various averages due to accidental errors of measurement is only $10/\sqrt{186} = \pm 0.73$ per cent. Evidently, individual observers have a tendency to either over estimate or underestimate the relative crown cover of a stand. When using the crown density scale this is easily understandable, but the systematic errors are more difficult to explain for the supposedly objective dot count method. It is true that the differences between interpreters are somewhat smaller for the dot count method (7.5, 2.4, 5.1 as compared to 4.0, 7.6, 11.6 per cent), but they are still highly significant. The differences probably arise from the many doubtful cases when a point falls close to the edge of a crown. One observer may have a tendency to not count such a dot as covering the crown, while another observer will consistently make the opposite decision. One must therefore admit the possibility that crown cover estimates may be affected by systematic errors of 5 to 10 per cent. These errors may be positive or negative. It is quite possible that through practice and refinements in the method of measurement, the systematic error of an interpreter could be substantially reduced, perhaps to the extent that the maximum systematic error would not be larger than 5 per cent. The use of the dot grid method seems to be better suited for such a refinement of the measuring technique.

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NEWS NOTES

NEW ACTIVITY OF FAIRCHILD CAMERA

A new activity, which will concentrate on design, research and production of special, rapid film processing equipment for military and commercial application has been activated by Fairchild Camera and Instrument Corporation.

To be known as the "Processing Equipment Section," the new activity has established headquarters at Fairchild's Hicksville, N. Y. facility under the direction of Charles N. Edwards, formerly chief engineer of Fairchild's Systems Division.

ACADEMY AWARD PRESENTED TO BAUSCH & LOMB OPTICAL CO.

An "Oscar" has been presented to the Bausch & Lomb Optical Co. for its scientific contributions to the motion picture industry.

The gold statuette symbolic of the award was given to Carl S. Hallauer, president of Bausch & Lomb, at the annual awards night ceremonies in the RKO Pantages Theater in Hollywood, on Wednesday, March 30.

The coveted motion picture industry award was made to the Rochester, N. Y., firm largely in recognition of its accomplishments in producing CinemaScope camera and projection lenses. A round-the-clock development and manufacturing program at B&L in 1953 and 1954 produced the lenses that made possible the CinemaScope revolution in motion pictures.