The Relationship of Tree Overstory and Herbaceous Understory Vegetation

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Highlight

For study of the effect of trees on understory vegetation a good mathematical equation is very helpful. This article presents an equation which fits overstory-understory data better than previously used equations.

Trees adversely affect the growth of herbaceous plants around them; clearings in a forest produce much more herbaceous material than do similar areas with a dense tree cover. Because of competition for light, water, and nutrients, and possible antagonistic chemical effects, this inverse relationship is entirely reasonable and has often been reported in the literature. A few examples are the ponderosa pine *(Pinus ponderosa)*[2] ranges of South Dakota (Pase, 1958), Oregon (McConnell and Smith, 1965), and Arizona (Reynolds, 1962; Pearson, 1964); southern pine ranges (Gaines et al., 1954; Halls and Schuster, 1965); hardwood areas in Missouri (Ehrenreich and Crosby, 1960); and chaparral and woodland ranges of Arizona (Pond, 1961; Arnold et al., 1964). Mathematical expressions of the relationship between trees and the herbaceous understory do not point out the basic causes of the relationship; nevertheless, they have many useful applications.

Several investigators have fitted regression lines to their data. The measurement of trees is taken as the independent variable (x) and the measurement of herbage as the dependent variable (y). The relationship between these variables is clearly curvilinear, and mathematical models published include $\log y = a + bx$, $y = a + b \log (x + 1)$, and $y = a + bx + cx^2$. The model $y = a + b \log (Kx + 1)$ has also been suggested (Batschelet, 1966). Other models could also be fitted; for example, $y = a + bx + cx^2 + dx^3$ gives a good fit in some cases.

All of these models were tried with three sets of Arizona data, and none were satisfactory. The simpler models generally gave a poor fit with the data, especially as x approached zero. The polynomial models were illogical, a fact which became very apparent as the computed lines were extended beyond the limits of the data.

Recently, Grosenbaugh (1965) included as one of several generalized growth functions a 5-parameter transition sigmoid growth curve given by

$$Y = H + A\left(1 - e^{-B(X-G)}\right)^{M+1}$$

where X is the independent variable, Y is the estimated value of the dependent variable, and H and A are the upper and lower asymptotes, respectively. B provides the necessary curvature, M adjusts the inflection point, and G adjusts the value of X so that $X - G = O$ when $Y = H$.

For overstory-understory relationships, the X origin may be taken as zero so that $G = O$. Also the sigmoid shape $(M > O)$ may not be necessary, so that values of $M > -1$ were allowed, that is, $(M + 1) > 0$. For $0 < (M + 1) < 1$ the inflection point has a negative abscissa value, and the curves are concave upward in the first quadrant.

Three sets of data were used for computation. The collection of two of the sets was described by Pearson (1964). These data were collected in a ponderosa pine forest in northern Arizona. Basal area of trees was measured with a 10-factor prism using the plotless "Bitterlich" method (Grosenbaugh, 1952). Basal area ranged from 10 ft^2 through 200 ft^2/acre. Tree canopy cover was also measured at each point with a canopy mirror (Lemmon, 1956). In addition, 30 points were taken at random in a cleared area. At each point all herbaceous vegetation from a 9.6-ft^2 circular plot was clipped to ground level, ovendried at 104 C for 48

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[1] *Research reported here was conducted at the Station's project headquarters at Flagstaff, in cooperation with Northern Arizona University; central headquarters are maintained at Fort Collins in cooperation with Colorado State University.*

[2] *Nomenclature follows Kearney and Peebles (1960).*

hr, and weighed. About 36% of the weight of the herbaceous material was made up of Arizona fescue *(Festuca arizonica)* and 49% of mountain muhly *(Muhlenbergia montana)*. The remaining 15% included 4 species of grass, 1 sedge, and some 40 forbs.

The results of these clippings were first averaged for each basal area class, and expressed as total pounds of herbage per acre. The data were then regrouped by canopy classes, and the average herbage weights for each class were determined for the second set of data.

The third set of data was from Arnold et al. (1964). These data were collected at 14 locations in the pinyon-juniper (*Pinus edulis, Juniperus* spp.) type in northern and central Arizona. A total of 220 50-ft transects were measured. Tree cover was measured with the line intercept technique of Canfield (1941). Herbage samples were obtained by clipping a 4-inch strip along each transect. Important herbaceous species included blue grama (*Bouteloua gracilis*) and herbaceous portions of snakeweed (*Gutierrezia sarothrae.*) The results of these clippings were grouped by cover classes, and means of each canopy class were calculated.

A computer program[3] was designed to approximate values of B and M + 1 in the equation by iteration, and solve for H and A in the usual least squares procedure for regression equations. For the three sets of data, the best fit, with the equations, is shown in Fig. 1. The curve for pine basal area (Fig. 1A) was the only one that was sigmoid.

When X = O the maximum departure of Y from the actual plot values was 9 lb/acre, and the curve fit the data well along the rest of the lines. Since the curves do fit the data well, this model is suggested as a general model for overstory-understory relationships.

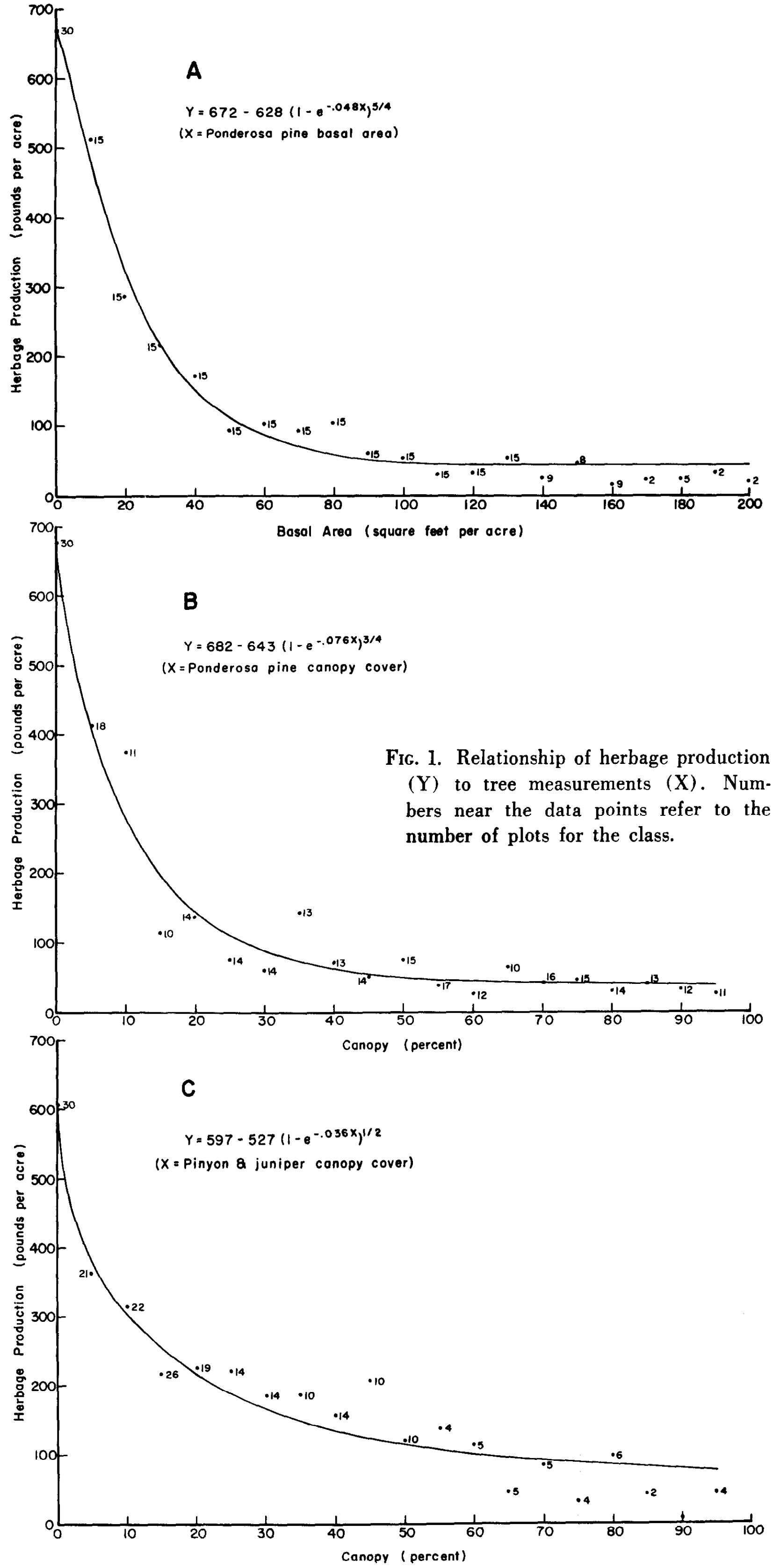

FIG. 1. Relationship of herbage production (Y) to tree measurements (X). Numbers near the data points refer to the number of plots for the class.

[3] *The computer program was written in FORTRAN II-D for the IBM 1620, 20 K storage. Copies of the program can be obtained from the author, although other available programs can also be used.*

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