Common Regressions to Estimate Tree Biomass in Tropical Stands

Note by T. R. Crow

ABSTRACT. Regression analysis is often used to estimate tree biomass as a function of tree dimension, but most regressions are developed for a specific species and site. Broader applications may be valid in some cases. Regressions developed in Thailand for estimating bole weight and branch weight as a function of D^2H were found to be applicable to the rain forest of Puerto Rico. These results suggest that common regressions also exist for estimating aboveground biomass and total tree biomass. FOREST SCI. 24:110–114.

ADDITIONAL KEY WORDS. Dimensional analysis, allometry, standing crop, Puerto Rico, rain forest.

RECENTLY THERE HAS BEEN an increased utilization of biomass as a unit of measure in forestry. Weight tables for forest trees are now available (Young and others 1964) and forest yields have been estimated in terms of weight or biomass (Burkhart and Strub 1973, Schlaegel 1973). Biomass estimates are also a prerequisite for studies of ecosystem function such as nutrient cycling and energy flow (e.g., Whittaker and others 1974).

A common method used to estimate biomass is the technique termed dimensional analysis by Whittaker and Woodwell (1968) or allometry by Kira and Shidei (1967) in which dry weight is determined from destructive sampling and related by regression analysis to easily measured tree dimensions such as dbh or a combination of dbh and tree height. Many such regressions now exist, but in most cases these equations were developed for specific applications. A study to test for broader applications of existing regressions for tropical forests is reported here.

Procedures.—Data published by Ovington and Olson (1970) were used to test regressions developed elsewhere in the humid tropics for estimating tree biomass in the rain forest at El Verde, Puerto Rico. As the basis for their predictive equations, Ovington and Olson (1970) harvested 102 trees within the El Verde area. For each sample tree, they list: total height; dbh; leaf area; oven-dry weight of leaves, branches, bole, fruit, flowers, roots, and total plant; oven-dry weight of epiphytes. Unfortunately, most samples were seedlings and saplings. To avoid giving undue emphasis to small trees and to make the size class distributions and size ranges more comparable among sample populations, all trees less than 5.0 cm dbh were eliminated from the El Verde data set and new regressions calculated. These new regressions, based on 25 individuals of 19 different species, were compared with regressions developed by Ogawa and others (1965) as part of a comprehensive biomass study in three principal types of climax forest vegetation in Thailand: savanna forest, monsoon forest, and tropical rain forest. In most regressions, dry weight was expressed as a function of dbh squared times tree height (D^2H) in the linear form of the allometric function.

The statistical procedure used for comparing regressions is described by Freese (1967). First the regressions were tested by ANOVA for common slopes, and if the slopes differed significantly, the regressions were different and no further testing was necessary. If slopes were not significantly different, Y-intercepts (level) were then compared, and a significantly different intercept in this case also indicated different regressions. All statistical differences are reported at the 5 percent probability level.

Results and Discussion.—Ogawa and others (1965) found that a single allometric regression between bole weight $\sim$ dbh squared times tree height (D^2H) was accurate for

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the three principal types of forests in Thailand, and our study found no significant differences between the bole weight ~ D^2H regression in Thailand and that based on El Verde data (Fig. 1). These studies suggest that this function may have a wide application. It follows that since stem volume = f (diameter, height) and stem weight = f [(diameter, height) × (wood density)], species with similar wood density and stem form will have a common estimator. Many species in the tropics do have similar form and dense wood is a common characteristic. The fact that a bole weight ~ D^2H regression for sugar maple (*Acer saccharum* Marsh.), a temperate species with relatively dense wood, did not differ significantly from either of the two regressions for the tropical woods (Fig. 1) adds support to the hypothesized commonality.

Error terms associated with estimates of branch and leaf weight are much greater than those for stem weight. Unlike the common regression for the estimation of bole weight, Ogawa and others (1965) used different regressions for the estimation of branch weight in the deciduous forest and the rain forest in Thailand; both had the same slope but different intercepts. Restricting our comparison to rain forest data, no significant differences were found between branch weight ~ D^2H regressions for Thailand and Puerto Rico (Fig. 2).

For estimating leaf biomass in the rain forest, Ogawa and others (1965) found a hyperbolic relationship between leaf weight ~ bole weight to be the best estimator. Asymptotic values were reached in the vicinity of 40 kg dry-weight, meaning leaf biomass does not exceed this amount regardless of tree size. Over the range of values for the El Verde rain forest, the linear form of the allometric function provided the best fit (Fig. 3). With Ogawa's data, the same model over the same range as the El Verde data (< 30 kg oven-dry leaf weight) was significantly different from the El Verde regression (Fig. 3). Thus, a common regression for the estimation of leaf biomass does not exist for these two rain forests. This incompatibility is not surprising in view of the sensitivity of leaf mass to such factors as light intensity, stand density, tree age, and species.

Because of the variability associated with leaf and branch weight, regression estimates

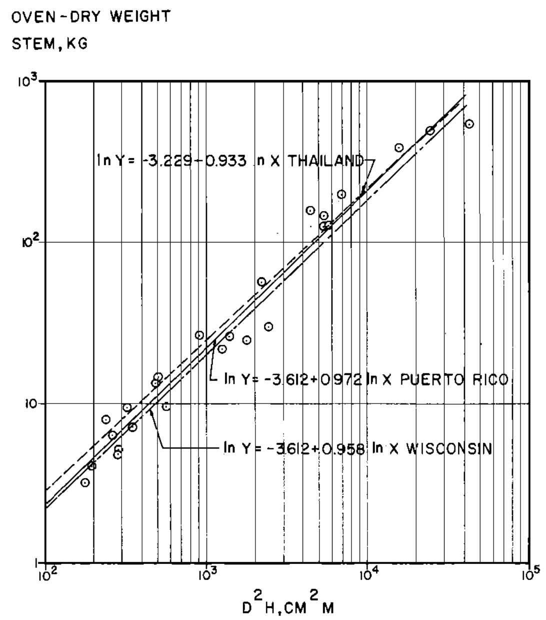

FIGURE 1. Comparison of three regressions for the estimation of stem weight as an allometric function of D^2H. Regressions for Thailand and Puerto Rico were based on multiple species. The curve for Wisconsin was derived from data given by Crow (1977) for *Acer saccharum*. Plotted circles represent the 25 samples from which the Puerto Rico regression was obtained.

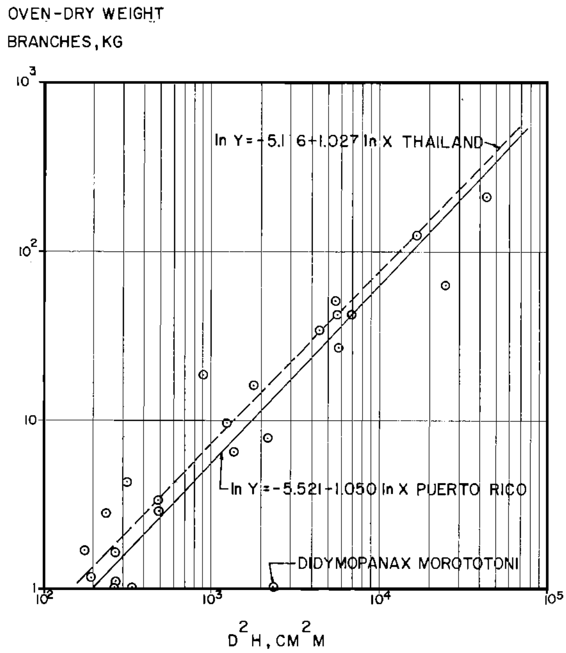

FIGURE 2. Comparison of regressions for the estimation of branch weight as an allometric function of D^2H. Plotted circles represent Puerto Rico data.

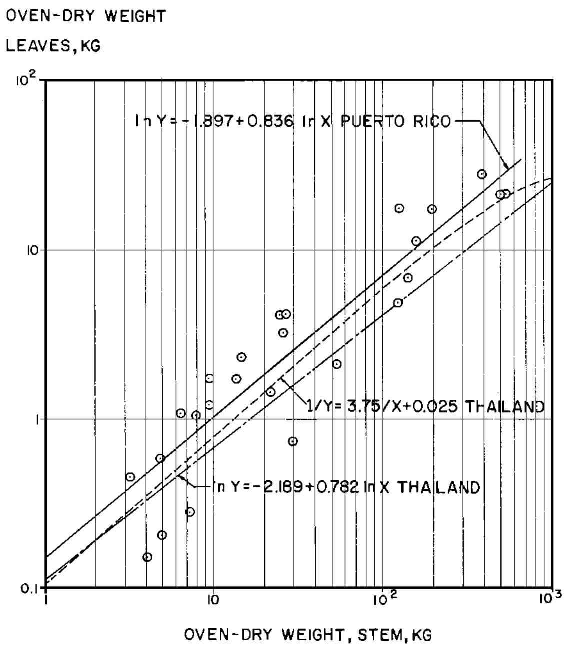

FIGURE 3. Relation between leaf weight and stem weight in the rain forests of Thailand and Puerto Rico. Plotted circles are Puerto Rico data.

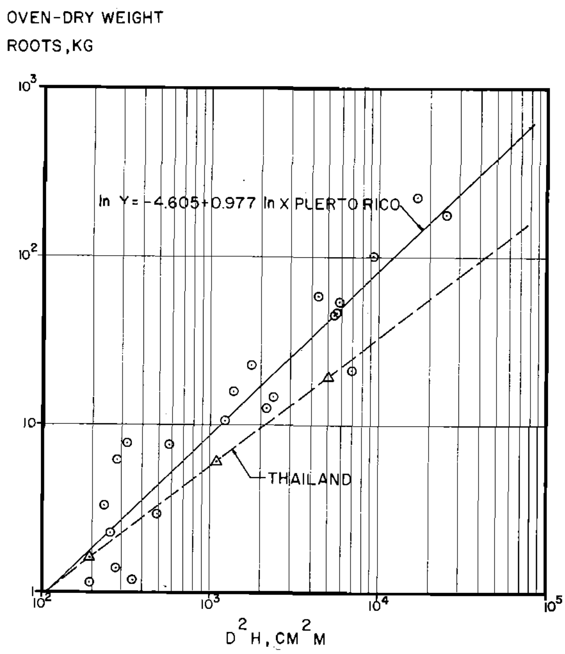

FIGURE 4. Root weight expressed as an allometric function of D^2H. Plotted circles represent Puerto Rico data; triangles are data reported by Ogawa and others (1965) from Thailand.

for individual trees can have substantial error. In the Puerto Rican rain forest, for example, *Didymopanax morototoni* (Aubl.) Decne. & Planch. is unbranched below, but has a shallow umbrella-like crown in the uppermost part of the tree with only a few branches (Little and Wadsworth 1964). Obviously, the unique physiognomic features of this species do not lend themselves to a common regression among species or sites, and so *Didymopanax* was omitted from the least-squares calculations for the regression in Fig. 2 for Puerto Rico. These exceptions are obvious and good sense should dictate caution.

A comparison of functions for the estimation of root biomass is meaningless since the curve plotted by Ogawa and others (1965) is based on only three points (Fig. 4). Ogawa cites the enormous amount of labor needed to sample this component. This point is valid for the determination of biomass for all tree components. Because data are few and sampling difficult and expensive, there is a need for better use of existing data in a search for common regressions.

Conclusions.—Results of this study indicate that regressions developed in Thailand for estimating bole weight and branch weight as a function of D^2H can be applied to the rain forest of Puerto Rico. Because these components comprise ~ 95–98 percent of the aboveground biomass and ~ 75 percent of the total tree biomass, it is presumed that common predictors would also exist for the estimation of aboveground and total tree biomass.

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Air Pollution—Phytotoxicity of acidic gases and its significance in air pollution control

By Robert Guderian. 1977. Translated from German by C. Jaffrey Brandt, 127 p. Springer-Verlag, New York. Price $24.80.

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This is volume 22 in a series entitled "Ecological Studies." It is concerned with the effect of hydrogen fluoride, sulfur dioxide, and hydrogen chloride on vegetation. Both the novice and experienced investigator should find it valuable. The book provides a more complete coverage of HCl than anything available and a superior review of the European literature on SO_2.

The first chapter gives explicit directions for conducting fumigations with HF, SO_2, or HCl in the field or in a controlled chamber. Explanatory schematic diagrams accompany the descriptions. The author cites various plant responses that might be examined in such studies, including growth, yield, quality, gas exchange, pollutant accumulation, and changes in ultrastructure. The next chapter, which is the most extensive, focuses on the factors that determine the effect of a pollutant on vegetation. Some apply to the pollutant (dosage, continuous vs. intermittent exposure, combinations), others to the environment (temperature, humidity) and to the plant (leaf age, nutrition, developmental stage). In chapter 3 the functions of fluorine, sulfur, and chlorine in plant metabolism are discussed and also the accumulation of these elements in plant tissue in relation to pollutant dosage and also to plant damage. The often repudiated but still used term "hidden damage" is given some attention. The closing chapter develops the theme that plants are biological indicators of air quality and are valuable in deriving air quality standards.

The book contains a good portion of experimental data effectively displayed in 40 figures that are unusually graphic and in 26 tables. Four colored plates show typical HF, SO_2 and HCl damage on sensitive plants. Over 350 references are cited, and approximately one-half are from German or French literature.