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ALLOMETRIC EQUATIONS FOR ESTIMATING THE ABOVE-GROUND BIOMASS OF CACAO STANDS IN THE EASTERN AMAZON BASIN

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Abstract

Allometric relationships are described for estimating cacao tree (*Theobroma cacao* L.) leaf, branch, bole, and total above-ground dry biomass from measurements of bole diameter and height, primary branch diameter, and maximum canopy height. Eight cacao trees in a 16 - 17-year-old plantation in Tomé-Açu, Pará, Brazil, in the eastern Amazon Basin, were measured and destructively sampled for component wet and dry weight determinations. Stepwise regression was used on log-transformed measures to develop equations of best fit; the best overall predictor of total and component dry biomass was the sum of the bole and branch diameters, (D_t). Correlation coefficients for allometric regressions of biomass variables on D_t were generally above 0.90, with over 98% of the variation in branch and total biomass accounted for by variation in D_t. The simply and rapidly measured sum of the stem and primary branch diameters should be useful for providing accurate estimates of above-ground dry cacao tree biomass in plantations in Amazonia, and perhaps elsewhere where management practices result in cacao trees with similar growth forms to those studied in Tomé-Açu.

Key words: *Theobroma cacao*, biomass, allometry

Equações alométricas para estimar a biomassa da parte aérea de stands de cacaueiros na bacia amazônica oriental

Resumo

São descritas relações alométricas para estimar as biomassas secas da folha, ramo, caule e biomassa total da parte aérea do cacaueiro *(Theobroma cacao* L.) a partir de medições do diâmetro e altura do caule, diâmetro do ramo principal e altura máxima da copa. Foram medidas e amostradas destrutivamente, no que se refere ao teor de umidade e peso seco, oito cacaueiros com 16-17 anos de idade em Tomé-Açu, Pará, na bacia amazônica oriental. Para desenvolver as equações de melhor ajuste, foi utilizada a regressão stepwise em medidas transformadas em logaritmo; a melhor previsão da biomassa seca total ou parcial foi obtida através da soma dos diâmetros do caule e dos ramos (D_t). Os coeficientes de correlação para regressões alométricas das variáveis de biomassa sobre D_t ultrapassaram, em geral, 0,90, com mais e 90% de variação das biomassas do ramo e total justificada pela variação em D_t. A soma dos diâmetros dos galhos e ramos principais, medida simples e rapidamente, poderia ser útil para proporcionar estimativas precisas da biomassa seca da parte aérea de plantações da Amazônia e, talvez, alhures, onde as práticas de manejo resultem em cacaueiros com formas de crescimento semelhantes às estudadas em Tomé-Açu.

Palavras-chave: *Theobroma cacao*, biomasssa, alometria

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Introduction

Accurate estimates of above- and below-ground biomass production in agricultural ecosystems are important for the determination of fertilizer input requirements, for ecosystem studies concerned with nutrient and energy flows, and for modeling of regional and global carbon cycling dynamics. Brazil was the major world producer of cacao, producing approx. 350 x 10^6 kg, or about 15% of the world's total, in the 1989-90 crop year (Oct. - Sept.) (Commodity Research Bureau, 1990). The majority of Brazil's cacao plantations are found in the state of Bahia in northeastern Brazil; however, the cultivation of cacao in Amazonian states has increased in importance over the past twenty years, contributing about 16% of Brazil's total production in 1987 (Anuário Estatístico do Brasil, 1988). Because it is a perennial tree native to the Amazon Basin, cacao has been thought to hold great promise for producing sustainable yields in Amazonia (Alvim, 1982; Hecht, 1982; Subler and Uhl, 1990).

Research has focused on environmental, edaphic and cultural influences on cacao growth and yield (Alvim, 1977), and on chemical analysis of leaves and other plant organs for determining fertilizer requirements (Eernstman, 1968). Alpízar et al. (1986) estimated cacao biomass in a plantation at Turrialba, Costa Rica using non-destructive techniques. However, few studies have been concerned with the development of relationships for the estimation above-ground biomass based on actual whole-plant weight determinations, and no such data are available for cacao plantations in Amazonia. Non-destructive allometric methods, involving an established relationship between plant biomass and some readily measured parameter, are used widely to estimate the biomass of forest trees (Whittaker and Marks, 1975; Causton, 1985). As a part of a larger study concerned with biomass production and mechanisms of nutrient retention and recycling in agricultural systems in Amazonia (Subler, 1993), I developed allometric equations useful for the estimation of above-ground biomass of cacao trees. This work is reported here.

Study Site

The study was conducted in a 16 - 17-year-old cacao plantation on a farm owned by Brazilians of Japanese descent in the municipality of Tomé-Açu (approx. 2°40'54" south, 48°16'11" west) in the state of Pará, Brazil. Tomé-Açu has been an important cacao producing area in Amazonia for the past 15 - 20 years (Florschütz, 1983). This region is primarily *terra firme* (never flooded) with highly weathered Oxisols characterized by low nutrient supplying and retention capabilites (Falesi, Santos and Vieira, 1964). The area annually receives an average of 2600 mm of rain and has a four month period (July - October) with reduced rainfall in which water deficits may occur in the soil (Bastos, 1972; Moraes and Bastos, 1972). In 1973-74, approximately 8 ha of previously abandoned black-pepper fields were planted to a "hybrid" variety of cacao distributed by CEPLAC (Comissão Executiva do Plano da Lavoura Cacaueira), the Brazilian governmental agency which was responsible for cacao development in Amazonia. Initial cacao spacing was 2.5 x 2.5 m, but in 1986 was thinned to 2.5 x 5.0 m in an attempt to reduce humidity and prevent outbreaks of "witches' broom" fungus (*Crinipellis perniciosa*). Annual pruning of suckers and infected limbs is required for continued disease control and tree maintenance. Shade trees in the plantation include *Erytrina poeppigiana* (Walp.) O. F. Cook, *Carapa guianensis* Aubl., *Cordia goeldiana* Hub., *Clitora racemosa* G.Don., and *Bertholletia excelsa* H.B. The plantation received an average of approx. 400 kg organic fertilizer (castor bean cake) and 680 kg chemical fertilizer (normally 9-18-26 NPK) per hectare per year. Annual yields average about 800 kg dried beans per hectare.

Methods

Four 25 x 25 m quadrats were located in separate, randomly selected lots in the 8 ha plantation (consisting of 14 approx. equal-sized lots). All cacao trees within the quadrats (177 trees) were measured for bole diameter at 50 cm height, height to primary jorquette (whorl), diameter of the base of each branch at the primary jorquette, and maximum canopy height (with a graduated pole). Eight trees were selected to represent the range of bole diameters seen in the sample, with six of the eight trees having bole diameters within one standard deviation of the sample mean (see Table 1). The eight trees were harvested and transported to a shaded work area where they were sorted into the following components: leaves, branches ("fine", < 2 cm; "intermediate", 2 - 5 cm, and "gross", > 5 cm), and stem (bole). Floral parts and fruits were removed from branches and stem and were not included in the analysis since the weight of the floral parts was insignificant relative to the rest of the plant components, and because total fruit production was previously determined through harvest records. Wet weights of all plant material within each component for each tree were determined to 0.01 kg on a 200 kg capacity standing balance. Three subsamples of material