Jurnal Ilmu Kehutanan
Volume IV No. 1 - Januari 2010

ALLOMETRIC EQUATIONS FOR ESTIMATING ABOVE GROUND BIOMASS OF SENGON (*Paraserianthes falcataria*) IN THE COMMUNITY FOREST OF BATEH VILLAGE, MAGELANG

RIS HADI PURWANTO[1]* & MUHAMMAD TAFAKUR AZIM[2]

[1]Department of Forest Management, Forestry Faculty, UGM, Yogyakarta
[2]Alumnus of Dept. of Forest Management, Forestry Faculty, UGM, Yogyakarta

ABSTRACT

*The above ground biomass of Sengon (*Paraserianthes falcataria*) in the community forest of Bateh Village were estimated by developing allometric equations. To establish the allometric equations, 400 sample trees were measured to determine the relationships between tree height (H) and stem diameter at breast height (D). Eighteen trees of various sizes were cut to measure the above ground biomass (stem, branch and leaves). The results showed that a diameter of 1.3 m above the ground (D) alone was a good predictor of tree height (H). When D was combined with H, r^2 was improved somewhat for stem, branch and leaves biomass. The relationships among measured tree dimensions drew a simple linear in log-log scale diagrams with r^2 over 0.9699, suggesting the growth patterns of tree dimensions were closely interdependent, whereas the allometric equations between D and H was approximated by the hyperbolic relation with r^2 over 0.9141. The individual tree equations appear to be applicable over a wide area of sengon in the community forest of Bateh Village, Magelang, Central Java.*

Keywords: *Allometric equations, biomass, Paraserianthes falcataria, community forests.*

*Corresponding author: *E-mail:* risuhadi@yahoo.com , Tel: 0274-512102; Fax: 0274-550541

INTRODUCTION

Total biomass is the amount of standing organic matter per unit area at a given time, which is related to a function of productivity system, stand age, organic allocation, and exportation strategies (Clintron & Novelli, 1984). The estimation of total biomass not only provides increasingly valuable means for evaluating worldwide productivity patterns (Rodin and Bazilevich 1967), but is also very important for the study of the functional aspects of forest such as primary productivity, nutrient cycling and energy flow (Hasse *et al.*, 1985). Consequently, biomass data is important in order to understand forest ecosystem characteristics to establish the proper management system based on the sustainable yield principles.

The most common procedure for estimating tree biomass is through the use of allometric equations. Trees are chosen through an appropriate selection procedure for destructive sampling, and weights or mass of the components of each tree are determined and related by regression to one or more dimensions of the standing tree. The tree is normally separated into two above ground components: (1) bole or main stem, (2) crown (branches and leaves), and occasionally, (3) below ground component (leaf biomass).

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The process of collecting data and developing biomass relationships falls under the subject of allometry, the measure and study of growth or size of a part in relation to an entire organism (Parresol, 1999). The term of "allometry" was defined as an exponential or logarithmic relationship that characterizes harmonious growth with changing proportions. In practice a set of sample trees are cut down and subjected to intensive measurement, so that biomass, production, and other dimensions (as dependent variables) can be related to diameter (or other independent variables) in logarithmic regressions (Whittaker & Marks,1975). The amount of dry weight for above and/or belowground components of standing tress can be estimated non-destructively using appropriate equations for each component or proportional relationships with total biomass previously developed or determined through destructive sampling mentioned above.

Sengon (*Paraserianthes falcataria*) as one of multipurpose dominant species in private forest landowners in Java has been planted since 1974 through reforestation programs by government. Extensive areas of these forests are being felled for lumber, raw material for pulp and paper, and firewood. Regenerating sengon forests in private landowners has been carried out successfully under agroforestry systems by traditional cultivation.

Although sengon forests have been grown in a large scale by traditionbal farmers, a database on sengon biomass in Java is lacking. This paper presents the results of allometric equations for estimating biomass of planted sengon (*Paraserianthes falcataria*) on private forest landowners in Magelang Regency, Central Java.

MATERIALS AND METHODS

Study site

The study area is located at Desa Bateh, Magelang Regency (7°11'13"S - 7°04'11"S, and 109°43'10"E - 110°04'40"E) in Central Java, and is being planted on private landowners by farmers in Magelang Regency. The total area of Desa Bateh is ca. 445 ha. Sengon forests of various ages grow on brownish latosol soil in altitude of 600 m above sea level. The private forest landowners in Desa Bateh are predominantly sengon plantations, and many remnant species such as *Swietenia* spp, *Acacia* spp, *Tectona grandis*, *Casia siamea*, *Leucaena glauca*, *Dalbergia* spp. are commonly found as mono or mixed plantations. The climate is monsoonal with two distinct seasons; a dry season (May-September) and rainy season (October-April). Air temperature is relatively stable throughout the year with a range of 24 - 30°C. Mean annual precipitation during the past 7 years was 2,746 mm, ranging from 1,616 - 3,996 mm. On Whitmore's map of rainfall types for the tropical Far East, the area is classified into types C or as a seasonal type (Whitmore, 1984).

Tree sampling

This research aimed to develop allometric equations for planted sengon forests which grown on private landowners. A total of 400 sengon trees from the private forest landowners were measured to develop the relationships between stem diameter at

1.3 m above the ground (D) and tree height (H). The tree sizes were various in stem diameter and height spanned nearly the complete range of this species.

For establishing the allometry equations, 18 sample trees were measured to determine allometric relationships between D and stem weight (W_S), branch weight (W_B), and leaf weight (W_L). Field studies were conducted during in November to December of 2006. Eighteen sample trees of various stem diameters (ranging from 3.0 - 37.5 cm) were felled and divided into leaves, branches and stem. The total fresh weight of each component was measured in the field. Representative sub-samples of all the plant components were brought back to the laboratory and oven-dried at 105°C for 48 hours to obtain constant weight. The total dry-weight of each component was calculated from the ratio of dry weight to fresh weight of the corresponding sub-samples.

Estimation method of biomass

It is well known that the allometry formulates the quantitative correlation between two different parts of a plant. When one part of an individual plant is Y as the dependent variable and X for another part of the independent variable, the relationships between both parts is usually satisfied by the allometric equation of

$$Y = aX^b \quad \text{(Eq. 1)}$$

where, a and b are constant, and b is known to be relatively growth constant. The equation can be expressed linear regression on logarithmic scale. Whereas, the relation of H to D was tentatively approximated by the hyperbolic relation as proposed by Ogawa and Kira (1977) and Ogawa *et al.* (1965), as follow:

$$\frac{1}{H} = \frac{1}{AD^b} + \frac{1}{B} \quad \text{(Eq. 2)}$$

where, H (tree height, m), D (diameter at 1.3 m above the ground, cm), h, A, and B are coefficients specific to the forest. Thus, a quantity of each component of individual sengon tree was estimated by the allometric relationships calculated by Eq. (1), and for the relation of H to D, was estimated by Eq. (2).

RESULTS

The quantities estimated were tree height (H), stem dry weight (W_S), branch dry weight (W_B), and leaf dry weight (W_L) per tree. The relation of tree height (H, m) to stem diameter at 1.3 m above ground

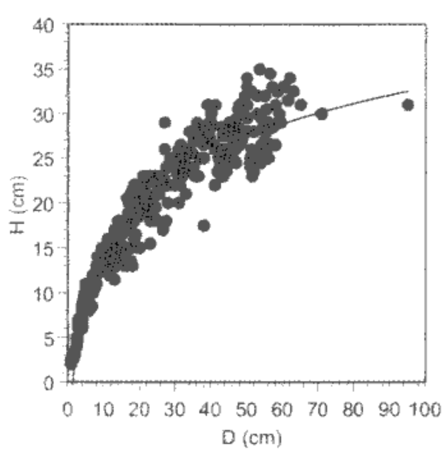

Figure 1. Hyperbolic relationships between stem diameter at 1.3 m aboveground (D) and tree height (H) for planted *Paraserianthes falcataria* forest on private lands in the study area.

(D, cm) was determined by the hyperbolic relation (Ogawa *et al.*, 1965; Ogawa & Kira 1977) as follows:

$$\frac{1}{H} = 0.4444\frac{1}{D} + \frac{1}{36} (n = 400, r^2 = 0.9141) \quad \text{(Eq. 3)}$$

Stem diameter of a tree was an excellent predictor of tree height, as shown in Figure 1, explaining more than 91% of the variability in tree height. The remaining variability might be attributed to the inherent characteristics of tree, stand (densities and age class distribution), and/or site condition (soil and hydrological parameters).

Stem dry weight (W_S, kg) is correlated most closely with the square of stem diameter at 1.3 m above ground (D, cm) multiplied by their height (H, m), as shown in Figure 2. The regression was written as

$$Ws = 0.0161 (D^2H)^{0.9367} (n = 18, r^2 = 0.9957) \quad \text{(Eq.4)}$$

The exponent of D^2H was so close to 1.0 that stem dry weight may be regarded as being proportional to D^2H. The D^2H is expected to be proportional to the volume or weight of stem, if the stem is approximately cone-shaped. In fact, the allometry constant (0.9367) in Eq. (4) has a close unity. The relation

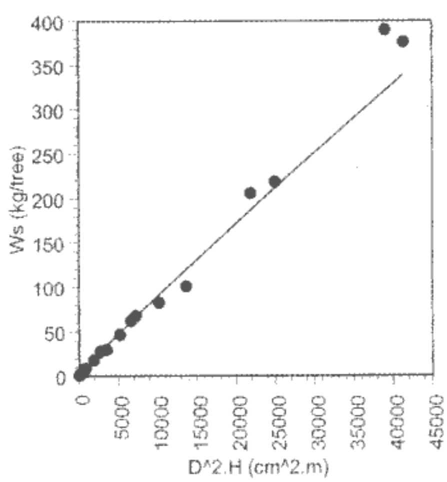

Figure 2. Relation between stem dry weight (W_s kg/tree) and the product of the square of stem diameter (D) and tree height (H) or D^2.H (cm^2.m)

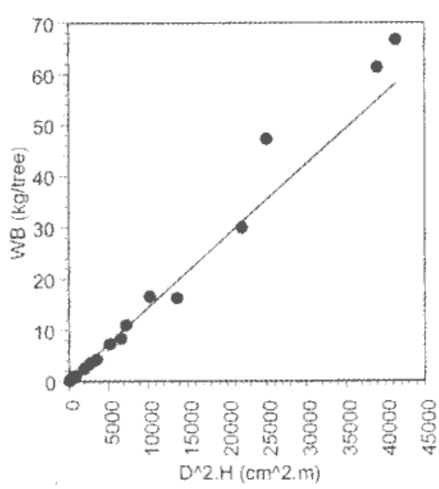

Figure 3. Relation between branch dry weight (W_B kg/tree) and the product of the square of stem diameter (D) and tree height (H) or D^2.H (cm^2.m)

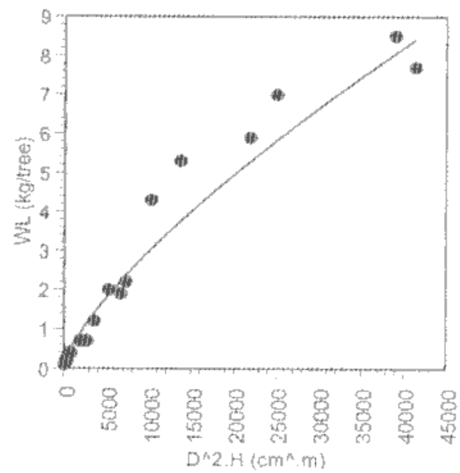

Figure 4. Relation between leaf dry weight (W_L kg/tree) and the product of the square of stem diameter (D) and tree height (H) or D^2.H (cm^2.m).

between branch dry weight (W_B, kg) and D^2H per tree was approximated by the equation:

$$W_B = 0.0017 (D^2H)^{0.9833} (n = 18, r^2 = 0.9940) \quad \text{(Eq. 5)}$$

The exponent of (D^2H) indicates a gradual increase in the ratio of branches to the D^2H as tree size increases, as shown in Figure 3.

The relation between leaf dry weight (W_L, kg) and D^2H per tree was approximated by the equation:

$$W_L = 0.0036 (D^2.H)^{0.7285} (n = 18, r^2 = 0.9699) \quad \text{(Eq. 6)}$$

The exponent of (D^2H) indicates a gradual increase in the ratio of leaf to the D^2H as tree size increases, as shown in Figure 4.

DISCUSSION

To establish allometric equations for estimating biomass of planted sengon (*Paraserianthes falcataria*) on private forest landowners in the Magelang Regency, Central Java, Indonesia, Eq. (3) - (6) were formulated. Usually in planted forests, allometric relationships appear to be independent of site quality (Assmann, 1970; Drew & Flewelling, 1977). Site quality does not affect the relationship between average size and density, but it does effect the growth (Jack and Long, 1996). Miller (1981) applied this concept in his model about the effect of fertilization on forest stand development: fertilization increases yield by accelerating stand development temporally. This effect has been confirmed in slash pine (*Pinus elliottii*) where fertilization had little effect on dimensional relationships (Jokela *et al.*, 1989; Colbert *et al.*, 1990). However, that allometries differ between genetic families of Loblolly Pine (*Pinus taeda* L.), especially at young ages (Lee, 1989). This raises the question whether Eqs. (3) - (6) are applicable for estimating plant biomass in the planted sengon on private forest landowners in the Magelang Regency, Central Java, Indonesia.

Regarding the D-H relation of Eq. (3) obtained the data for the sample trees have a similar dispersion around the regression curve of Fig. 1. Thus, Eq. (3) seemed to be applicable to the sengon plantations on private forest landowners in the Magelang Regency, Central Java, Indonesia. The equation showed that a considerable portion of forest trees grow up with the relative elongation rates similar than the rates of stem thickening (h=1) in the initial stage of sengon forest growth. In trees of the smallest size class the tree height increases in proportion to the stem diameter, but it approaches a plateau in very large trees. Using the equation, the maximum height was estimated as 36 meters.

To obtain stem biomass (W_S), an exponential model Eq. (4) was used, in which diameter at 1.3 m aboveground (D) and tree height (H) were used as the independent variables. Such equations and the proportional relationships are based on easily measured parameters such as tree diameter. Despite the fact that measuring tree height (H) is more time consuming, inclusion of height in the independent variable mostly as D^2H (Ogawa *et al.*, 1965; Ogawa & Kira, 1977) generally contributes to a much better explanation of the variation. In the research, D^2H as independent variables were used to estimate stem, branch and leaf biomass. The D^2H - W_S, D^2H - W_B, and D^2H - W_L relations are stable and did not generally differ among the planted forests. Furthermore, the trajectory of Eq. (4) - (5) in the log D^2H - log W_S, and D^2H - log WB diagram, respectively, seemed to be similar to the log D^2H - log W_S, and D^2H - log W_B relations obtained by Ogawa *et al.* (1965) at tropical rain forest in Thailand, as follows:

$WS = 0.0396\,(D^2H)^{0.9326}$, and

$WB = 0.0060\,(D^2H)^{1.0270}$, respectively.

CONCLUSION

1. The height of sengon (*Paraserianthes falcataria*) in the community forest of Bateh Village can be estimated by measuring stem diameter. Correlation between height (H) and stem diameter of the tree (D) was approximated by the hyperbolic relation in the following equation:

$$\frac{1}{H} = 0.4444\frac{1}{D} + \frac{1}{36} \quad (n = 400, r^2 = 0.9141)$$

2. The above ground biomass of sengon in the community forest of Bateh Village can be estimated through measuring D and H in the following formulas:

$Ws = 0.0161\,(D^2H)^{0.9367}$ (n = 18, r^2 = 0.9957)

$W_B = 0.0017\,(D^2H)^{0.9833}$ (n = 18, r^2 = 0.9940

$W_L = 0.0036\,(D^2H)^{0.7285}$ (n = 18, r^2 = 0.9699)

3. The individual tree equations appear to be applicable over a wide area of sengon in the community forest of Bateh Village, Magelang, Central Java.

REFERENCES

Assmann E., 1970. The principles of forest yield study. Permon, Oxford. 506 pp.

Clintron G & Novelli YS. 1984. Methods for studying structure. *In*: Snedaker SC & Snedaker JG (eds.). The Mangrove Ecosystem: Research Methods: **91-113**. UNESCO, Paris.

Colbert SR, Jokela EJ, & Neary DG. 1990. Effect of annual fertilization and sustained weed control on dry matter partitioning, leaf area, and growth efficiency of juvenile loblolly and slash pine. *For. Sci.* **36**: 995-1014.

Drew TJ & Flewelling JW. 1977. Some recent Japanese theories of yield density relationships and their application to Monterey pine plantations. *For. Sci.* **23**: 517-534.

Hasse H, Foelster & Lindheim, M. 1985. On the accuracy of estimating aboveground tree biomass in an evergreen forest near Manaus, Brazil. A simulation study. *Biotropica* **17(3)**: 191-195.

Jack SB & Long, JN. 1996. Linkages between silviculture and ecology: an analysis of density management diagrams. *For. Ecol. Manage.* **86**: 205-220.

Jokela EJ, Harding RB, & Nowak CA. 1989. Long-term effects of fertilization on stem form, growth relations, and yield estimates of slash pine. *For. Sci.* **35**: 832-842.

Lee JT. 1989. Basal area growth response to competition among improved families of Loblolly pine (*Pinus taeda* L.) in a 20-year-old Row Plot Progeny Trial, College Station, TX. 41pp. M.S. Thesis, Texas A & M University.

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Volume IV No. 1 - Januari 2010

Miller HG. 1981. Forest fertilization: some guiding concepts. *Forestry* **54**: 157-167.

Ogawa H. & Kira T. 1977. Methods of estimating forest biomass. *In*: Sidei T & Kira T (eds). Primary productivity of Japanese forests, JIBP Synthesis 16, 16 pp. 15-25. Univ. of Tokyo Press, Tokyo.

Ogawa H, Yoda K, Ogino K, & Kira T. 1965. Comparative ecological studies on three main types of forest vegetation in Thailand. II. Plant biomass. *Nature and Life in Southeast Asia* **4**: 49-80.

Parresol BR. 1999. Assessing tree and stand biomass: A review with examples and critical comparisons. *For. Sci.* **45(4)**: 573-593.

Rodin LE & Bazilevich NI. 1967. Production and mineral cycling in terrestrial vegetation. Oliver-Boyd, London. 288pp.

Whitmore TC. 1984. Tropical rain forests of the Far East, 2nd. Clarendon press, Oxford. 352pp

Whittaker RH & Marks PL. 1975. Methods of assessing terrestrial productivity. *In*: Lieth H & Whittaker RH (eds.), Primary productivity of the biosphere. Springer-Verlag, New York. p. 55-118.