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# DEVELOPMENT OF ALLOMETRIC EQUATION FOR BIOMASS OF RUBBER TREE (*Hevea brasilliensis*) SAPLINGS

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## ABSTRACT

Carbon is sequestered by plant through photosynthesis and stored as biomass in different parts of the tree including stems, branches, leaves and roots. The objective of this study is to determine the biomass in five different growth stages of rubber tree saplings and to develop the allometric equation for biomass estimation. Biomass of rubber tree saplings was measured for the growth stages of 45, 90, 135, 180 and 225 days with total number of samples used was 650 saplings. Biomass was determined by weighing the constant dry weight of the samples. Four candidate models were selected and evaluated and Model 4 appeared to be the best allometric equations for biomass estimation of rubber tree saplings in the form of $\log_{10} W = 0.184 + 0.007 \log_{10} D + 0.705 \log_{10} HT + 0.002 \log_{10} AG$, ($R^2$=0.96). The allometric equation developed in this study is useful for the estimations of biomass in rubber tree saplings.

**Key words:** Biomass, *Hevea brasilliensis*, destructive sampling, allometric equation

## INTRODUCTION

Rubber tree is the second largest agriculture tree crops in Malaysia in 2014 after palm oil. The study of ecosystem function of crop is crucial to determine the role of crop in mitigating climate change. Malaysia has signed the United Nation Framework Convention on Climate Change (UNFCCC) on 9 June 1993 and was classified into non-Annex 1. Since it is likely that climate change will have adverse effects over the next 50-100 years, following regional research finding on national climate change impacts, mitigation and adaptation options have primarily been suggested as the means to reduce the impact of climate change in Malaysia (Malaysian Meteorological Department, 2009).

Climate change has increased the need of information on the amount of forest biomass in different regions for climate policy definition. This requires reliable estimations of carbon pools in forest ecosystems (Brown, 2002; Justen *et al.*, 2004). Estimates of carbon stock are generally produced by measuring the total biomass of the population. Since carbon stock is typically derived from biomass by assuming that 50% of the biomass is made up by carbon (Montagnini and Porras, 1998; Basuki *et al.*, 2009), the changes in biomass density can be used to estimate the carbon sequestration by plants and carbon release in the atmosphere.

This paper reports the results of a study carried out aimed at investigating the relationships between biomass (W) and diameter (D), height (HT), chlorophyll content index (CC), stomatal conductance (SC), photosynthesis rate (PN), transpiration rate (TRPT), leaf area index (LAI) and age (AG) of rubber trees.

## MATERIALS AND METHODS

This study was carried out at the RISDA Nursery and Landscape Sdn. Bhd. located at the north-east of Sungkai, Perak. A total of 650 healthy saplings of rubber trees were sampled. The saplings comprised of five stages of rubber tree growth i.e, 45 (one whorl), 90 (two whorls), 135 (three whorls), 180 (four whorls) and 225 (five whorls) days.

Measurements of stomatal conductance (SC), chlorophyll content index (CC), photosynthesis rate (PN) and transpiration rate (TRPT) were made on ten randomly selected matured and fully expanded leaves for each variable. PN, SC and TRPT were measured using TPS-2 Portable Photosynthesis System while CC index using a Minolta SPAD 502

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Plus chlorophyll meter. Heights were measured using a measurement tape and stem diameters were measured using a digital caliper. An LAI-2200 Plant Canopy Analyzer was used to estimate the leaf area index (LAI) of the rubber tree saplings.

After measurements, the rubber saplings were severed at the soil surface, cut and divided into three sections i.e, leaves, stems and roots. The fresh weights of the leaves, stems and roots were measured and samples were then oven-dried at 70°C for 48 hours or until constant weight to determine the total aboveground and belowground biomass.

Then, data analysis was carried out. The independent variables (X) consist of D, HT, CC, SC, PN, TRPT, LAI and AG. In this study, the dependent variable (Y) is W. Pearson's Correlation Coefficients (r) was run to determine relationship between two variables X and Y which is known as bivariate.

An ordinary least square (OLS) estimator was used to develop multiple linear regression models (Neter *et al.,* 1996). Data exploration and preliminary model fitting were carried out to get models that best fit the data. Logarithmic transformation ($\log_{10}$) were found to be the best transformations which produced models that meet the regression assumptions and at the same time showed high goodness of fit.

## RESULTS AND DISCUSSION

Pearson's Correlation Coefficient indicated that most of the independent variables involved in the study are significantly correlated ($p \leq 0.001$) with biomass. Results showed that W is linearly correlated with D, HT, LAI and AG, indicating that as D, HT, LAI and AG increase (r=0.90, 0.97, 0.91 and 0.95 respectively), biomass increase. In contrast, W is inversely correlated with TRPT, PN, and SC, indicating that when TRPT, PN, and SC decrease, W increase. The r value for TRPT, PN, and SC were -0.08, -0.14 and -0.26, respectively (Table 1).

Regression models for biomass are all highly significant (all $p \leq 0.001$). The models initially developed are shown in Eq. (1) and Eq. (2):

$$\log_{10} W = c + a \log_{10} D \quad (1)$$

$$\log_{10} W = c + a \log_{10} HT \quad (2)$$

where W is in g/tree, D is in mm, HT is in cm, c is the intercept, and a is the slope coefficient of the regression.

The values of the coefficients determination, ($R^2$) are presented in Table 2. For Eq. (1), the value $R^2$ is 0.81 which uses only D as a predictor variable.

However, tree biomass is affected by its height as well. Hence in Eq. (2), HT is incorporated as the predictor variable and the $R^2$ of the Eq. (2) is 0.94. By combining D and HT in Eq. (3), it becomes a multiple linear regression as follows:

$$\log_{10} W = c + a \log_{10} D + b \log_{10} HT \quad (3)$$

Since the r value between W versus D and W versus HT are high, the incorporation of both D and HT in Eq. (3) only increased $R^2$ slightly which is 0.94. The strong correlation between W and AG suggested that the latter is an important predictor variable for biomass estimation. It is therefore added in Eq. (4):

$$\log_{10} W = c + a \log_{10} D + b \log_{10} HT + c(AG) \quad (4)$$

where AG is age of rubber tree measured in days.

In order to choose the best prediction model for W, comparisons are carried out between the above seven models. The parameters compared are $R^2$, Milow C(p), $SE_E$ (Sum square error estimate) and the results are as presented in Table 2. The correlation Index Square ($I^2$) values for each model ranged between 0.77 and 0.95. Models 2 to 4 appeared to provide strong estimates of W indicated by high $I^2$ (0.94 to 0.95) and lower RMSE (0.09 to 0.10g/tree) in Table 3.

This study is comparable to a study from Shorrocks *et al.* (1965) which studied on the

**Table 1.** Pearson's Correlation Coefficients, n=429

| | Pearson's Correlation Coefficients, (n = 429) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Variables | $^aW$ | $^bD$ | $^cHT$ | $^dCC$ | $^eSC$ | $^fPN$ | $^gTRPT$ | LAI | AG |
| $^aW$ | 1 | | | | | | | | |
| $^bD$ | 0.90 | 1 | | | | | | | |
| $^cHT$ | 0.97 | 0.93 | 1 | | | | | | |
| $^dCC$ | 0.52 | 0.46 | 0.51 | 1 | | | | | |
| $^eSC$ | -0.26 | -0.27 | -0.27 | -0.11 | 1 | | | | |
| $^fPN$ | -0.14 | -0.15 | -0.14 | -0.07 | 0.11 | 1 | | | |
| $^gTRPT$ | -0.08 | -0.06 | -0.07 | -0.02 | 0.56 | 0.12 | 1 | | |
| LAI | 0.91 | 0.82 | 0.90 | 0.53 | -0.33 | -0.05 | -0.07 | 1 | |
| AG | 0.95 | 0.86 | 0.94 | 0.56 | -0.27 | -0.13 | -0.11 | 0.93 | 1 |

Note: $^{a\text{-}g}\log_{10}$

**Table 2.** Comparison of candidate models (n=429)

| Model Candidate and Predictor Variables | R-square | C(p) | $SE_E$ | No. Predictor Variables |
|---|---|---|---|---|
| 1. $\log_{10} W = c + a \log_{10} D$ | 0.81 | 1599.83 | 0.19 | 1 |
| 2. $\log_{10} W = c + a \log_{10} HT$ | 0.94 | 185.02 | 0.10 | 1 |
| 3. $\log_{10} W = c + a \log_{10} D + b \log_{10} HT$ | 0.94 | 186.79 | 0.10 | 2 |
| 4. $\log_{10} W = c + a \log_{10} D + b \log_{10} HT + c(AG)$ | 0.96 | 6.31 | 0.09 | 3 |

**Table 3.** Summary of regression model validation results for W, (n=221)

| Model No. | $p^a$ | $I^2$ | RMSE (g/tree) |
|---|---|---|---|
| 1 | 1 | 0.77 | 0.20 |
| 2 | 1 | 0.94 | 0.10 |
| 3 | 2 | 0.94 | 0.10 |
| 4 | 3 | 0.95 | 0.09 |

Note: a is number of predictor variables

relationship between diameter and aboveground dry biomass of rubber. They found the relationship of the linear function between diameter (log G) and dry biomass (logMd) as:

$$\log Md = 2.786 \log G - 2.5843$$

Another research which determined the relationship between girth and the above ground biomass of *Hevea brasiliensis* was conducted by Chaundhuri *et al.* (1995). A general equation was thus developed i.e,

$$g(W) = 2.278X^{2.200}$$

(where $X$ is the girth at 15 cm height from bud union).

Previous study by Vahedi *et al.* (2014) for mixed-specific regression equations with 45 sample trees using different input variables. The result showed that D is the most prominent explanatory variable for biomass prediction and simple equation ($1n\ Y = a + b\ 1n\ D$) can be used in the absence of height and wood density with ($R^2$adj = 0.92; $SE_E$ = 0.22). Another study by John (2010) was carried out on Radiata pine (*Pinus radiata* D. Don) which is an exotic plantation tree species grown in New Zealand. The results of the study indicated that the equation of

$$1n\ AGB = \beta_0 + \beta_1\ 1n\ D + \beta_2\ 1n\ D^2 + \beta_3\ 1n\ H + \beta_4\ 1n\ H^2$$

is the best equation that meets the entire requirement for 'best fit model'.

## CONCLUSIONS

In conclusion, Model 4 is the most suitable allometric equation for estimation of biomass since it meets the requirement of best fit model.

$$\log_{10} W = 0.18 + 0.007 \log_{10} D + 0.705 \log_{10} HT + 0.002 \log_{10} AG$$
$$(R^2=0.96)$$

Therefore, this allometric equation developed from this study contributes to biomass estimation and subsequently help to determine the carbon sequestration potential in rubber tree saplings.

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