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Research Article

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Development of Allometric Equation for Estimating Aboveground Biomass in Ampang Forest Reserve, Malaysia

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Abstract

The accurate estimation of aboveground biomass is crucial for assessing the amount carbon sequestration in tropical forest. Although various allometric equations already developed across the region, few researchers have been agreed that the site-specific allometric equations are capable to improve the accuracy of aboveground biomass estimation. The intent of this study is to develop new site-specific allometric equation using stem diameter at breast height and tree height parameters. In total 96 trees with stem diameter at breast height more than 30 cm from 25 different species were measured from the Ampang Forest Reserve. The estimated total aboveground biomass for 96 trees using reference allometry was 383.714 while the estimated total aboveground biomass using new developed equation was 380.202 tonnes with only 0.9% different percentage. The results indicated a good coefficient of determination (R^2) value with 0.985. The results of this study also significantly improved the estimation accuracy as compared to the previous developed equations. The inclusion of the tree height in the developed equation is proven to be capable in estimating the accurate total aboveground biomass for this study area.

Keywords

Aboveground biomass; Carbon stock; Tropical forest; Allometric equation; Tree height

Introduction

Estimating aboveground biomass is a significant task in evaluating the amount of carbon sequestration in tropical forests [1]. The accurate estimation of carbon stock in tropical forest is crucial for Reducing Emissions from Deforestation and Degradation (REDD) program since deforestation and forest degradation in the tropics considered as a major cause of climate change [2].

In Malaysia, tropical forests cover about 59.5% of the total land area. Major types of tropical forests in Malaysia are lowland dipterocarp forest, hill dipterocarp forest, upper hill dipterocarp forest, peat-swamp forest, coastal forest and mangrove forest [3]. Each forest type has different tree species such as lowland dipterocarp forest consists of marketed species from a family of Dipterocarpaceae including Hopea, Neobalanocarpus, and Shorea. Based on Cao et al. [4], Shorea is the largest genus that consists of approximately 196 species in the Dipterocarpaceae family.

Tree information extracted from tree basic component such as tree height, stem diameter at breast height (DBH), crown diameter are important for forest management and planning purposes [5]. Secondary information such as aboveground biomass estimation and tree growth can be measured from tree biophysical component.

The accurate estimation of biomass in tropical forests is crucial for various applications particularly for estimating carbon sequestration and the timber exploitation [6]. The most accurate method for the estimation of biomass is through destructive sampling method. This method causes severe destruction to the forests and yet the non-destructive method through allometric relationship is increased in demand. Previous studies have shown extensively used of the DBH value in estimating the above ground forest biomass [6-15].

Based on Chave et al. [8], the basic allometric equation was solely used the stem DBH parameter. However, recently many researchers had improved the biomass estimation by including tree height and other tree components [14,16].

The estimated biomass for individual trees depends on allometric equations that are developed from a limited region or a broader combination of sites. Unfortunately, allometric equations consist of transfer error across all sites.

The study carried out by Kenzo et al. [12] supports the importance of site-specific equations for accurate estimation of aboveground biomass in tropical rainforests. They mentioned that the equation by Brown et al. [7] overestimated the aboveground biomass by 65% than actual value and an equation by Chave et al. [8] overestimated aboveground biomass by approximately 50%. The previous allometric have a limited ability for accurately estimating aboveground biomass in tropical rainforests in Southeast Asia [12].

Therefore, this study intent to present a new site-specific allometric equation for Ampang Forest Reserve using the DBH and tree height parameters in order to achieve a better estimation of aboveground biomass for the selected area.

Materials and Methods

Study site

The study area is located at 3° 9'53" North, 101°46'43" East in the Ampang Forest Reserve, Selangor. The annual mean rainfall is 2600 mm. The Ampang Forest Reserve consisted tree from the Dipterocarpaceae family with the dominant genera are *Shorea* (Meranti, Balau), *Myrtaceae* (Kelat), *Sapotaceae* (Nyatuh) and *Burseraceae* (kedondong).

Figure 1 shows the location of study area in the map of Selangor (a), subset of survey plot in Site A (b) and subset of survey plot in Site B (c).

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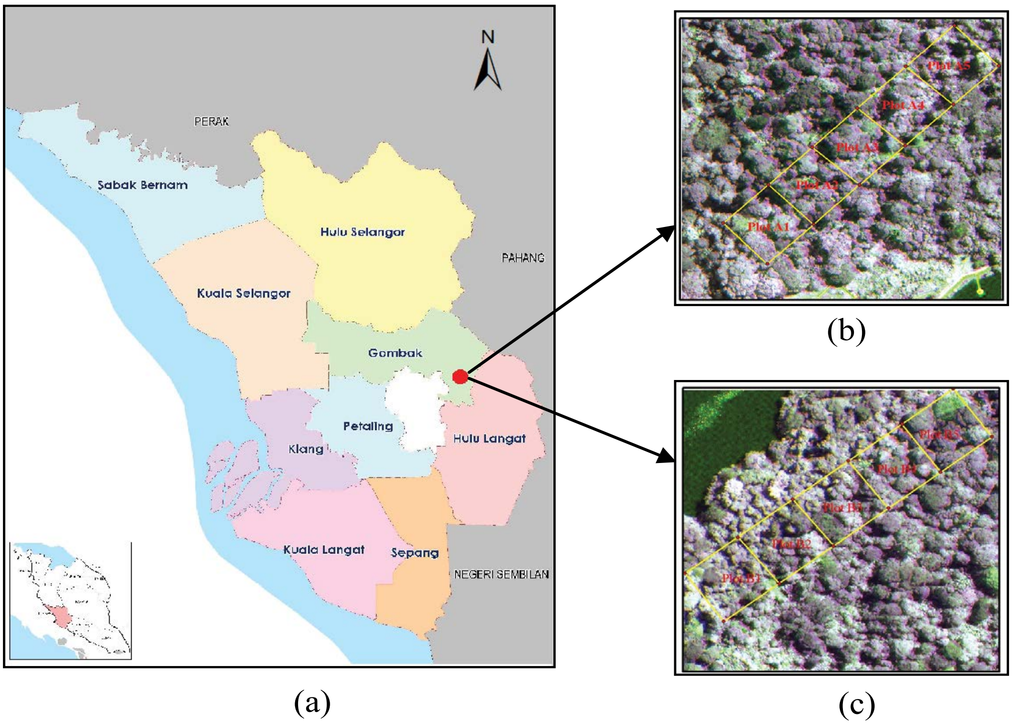

Figure 1: Location of Study Area in the Map of Selangor (a), plot in Site A (b) and plot in Site B (c).

Field sampling

Field data collection is carried out to identify the tree parameters and used to verify the derived allometric equation. In this study, the parameters that are obtained from the field measurement are tree position, stem diameter at breast height (DBH), total tree height and tree species. Altogether, 96 numbers of matured trees with DBH more than 30 cm from more than 25 species have been checked and identified in the Site A and B. The trees are measured in 10 plots with the size of the plot is 50×50 m each. The tree parameters are measured using the TruPluse laser and the measuring tape is used to measure the DBH.

According to FAO [17], the DBH is measured at 1.30 m above ground, but for trees with enlargement or buttresses, the diameter is measured at 30cm above the main enlargement. This study focuses on the trees with stem DBH more than 30cm due to the large contribution of this matured tree to aboveground biomass.

Analysis of previous developed Allometric equations

Various allometric equations have been developed for tropical forests. However, only a few allometric equations developed specifically for lowland Dipterocarp forests and suitable to be used for Malaysian tropical forest. So far, allometric equations for mixed species of tropical forests have been listed in Table 1 [6-12,15].

Khali et al. [18] stated that, common equations used for estimating tropical tree biomass in Malaysia were developed by Kato et al. [10]. Moreover, the equation of Chave and Hashimoto et al. [8,9] cannot be applied as it requires stand age and wood density which is not available. Only six (6) developed equations out of 9 were examined in this study.

In this study, a new site-specific allometric equation was derived for mixed species using the stem DBH and tree height (H) parameters. As no destructive sample of aboveground biomass was available at these sites, references on above ground biomass values are based on allometry equations developed by Kato et al. [10] as commonly practice in Malaysia.

Results and Discussion

Descriptive statistics

Table 2 summarizes the descriptive statistics of 96 mixed tree species from the field data collection. The measured DBH ranges between 30 cm to 121 cm with a mean of 54.072 cm. The tree height ranges between 11.600 m to 49.600 m with the mean of 28.217 m.

Analysis of aboveground biomass from previous allometry models

Before deriving a site-specific allometry model, the analyses of aboveground biomass (AGB) by using previous developed allometric equations are assessed. The Forest Research Institute of Malaysia (FRIM) is currently using the allometric equation which is formulated by Kato et al. [10] in practice.

Kato et al. [10] had carried out the destructive sampling in 1971 and 1973 in implementing the tree biomass and growth increment studies at Pasoh Forest.

Referring to Table 1, only six (6) developed allometric equations are examined in this study where equation developed from Kato et al. [10] as a reference allometry. The following Figure 2 shows the comparison of total aboveground biomass (TAGB) estimated from 6 selected equations using DBH value.

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Table 1: Existing Allometric Equation for Tropical Forests.

Site	Regression	References
Pasoh, Malaysia	$1/H = 1/(2.0 \times DBH) + 1/61$ $M_s = 0.0313 \times (DBH^2H)^{0.9733}$ $M_b = 0.136 \times M_s^{1.070}$ $1/M_L = 1/(0.124 M_s^{0.794}) + 1/125$ $Wt = M_s + M_b + M_L$	[10]
Kalimantan, Indonesia	$\ln(Wt) = 2.196 \times \ln(DBH) - 1.201$	[6]
Sumatra, Indonesia	$\ln(Wt) = 2.59 \times \ln(DBH) - 2.75$	[11]
India, Karnataka	$\ln(Wt) = 2.12 \times \ln(dbh) - 0.435$	[13]
World moist tropical	$\ln(Wt) = 2.53x \times \ln(DBH) - 2.13$	[7]
Kalimantan, Indonesia	$\ln(Wt) = 2.62 \times \ln(DBH) - 2.30$	[15]
Sarawak, Malaysia	$Wt = 0.0829 \times dbh^{2.43}$	[12]
Kalimantan, Indonesia	$\ln(Wt) = 2.44 \times \ln(DBH) - 2.51$	[9]
World moist tropical	$Wt = W_D \times \exp$ $(-1.562 + 0.148 \times \ln(DBH) + 0.207$ $\times (\ln(DBH))^2 - 0.0281 \times (\ln(DBH))^3)$	[8]

Table 2: Descriptive Statistics of Measured Trees.

	N	Minimum	Maximum	Mean	Standard Deviation
DBH	96	30.0	121.0	54.07	21.45
Tree Height	96	11.6	49.6	28.21	8.31

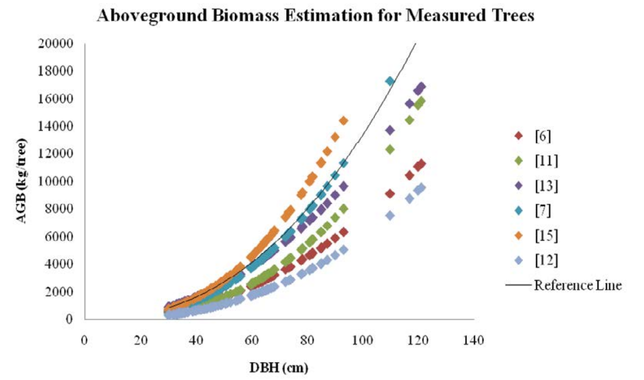

Figure 2: Scatter Plot of DBH (cm) and Aboveground Biomass AGB (kg/tree) of Mixed Species.

As seen in the Figure 2, several equations under-estimate and over-estimate the AGB from the reference line. Total aboveground biomass (TAGB) estimated from the reference allometric equation is 383.714 tonnes for 96 mixed species trees. The estimation below than the reference value indicates the underestimates and the higher values indicate the over estimates. Five (5) from six (6) examined equations have underestimated the TAGB where the equation by Yamakura et al. [15] underestimated the TAGB by more than 50%. The best result obtained from the equation by Brown et al. [7] estimated TAGB with only 4.69%.

The result reveals that the developed equations differed substantially from one site to the other site and strongly depends on the size and pattern of the sample. Hence, this study highly supports the importance of site-specific equations for accurate estimation of aboveground biomass in tropical rainforests as strongly recommended [12].

Development of allometric equation

As no destructive sampling is available at this site, the reference aboveground biomass values are estimated based on allometry equations developed by Kato et al. [10] as commonly practiced in Malaysia. The estimated parameters and coefficients of DBH and DBH^2H against the estimated TAGB from reference allometry are indicated in Table 3.

Results in Table 3 indicate that there are perfect coefficients of determination (R^2) for DBH using the power function model and the standard error was 0.015. The second row represents the estimated parameter and a coefficient for DBH2H with the value of R2 was 0.958 and the standard error was 0.173.

In relation to the given results, TAGB estimation is strongly correlated with DBH as compared to DBH^2H parameters due to the reference allometry is solely using the DBH parameter. Hence, the inclusion of tree height and DBH parameters also give strong correlation even though are not as perfect as the correlation given by DBH.

The development of new site-specific allometric equation is following the standard form of the allometric equation as shown in equation (1). Yi is biomass of a tree component i, X is the product of one or more dimensions, *a* gives the allometry coefficient and parameter *b* indicates the proportionality between cumulated parameters.

$$Yi = aX^b \qquad (1)$$

Therefore, the new allometric equation using DBH^2H parameters for this study area is deduced from the coefficient given in Table 3. Hence, the model for DBH^2H is presented in equation (2).

$$AGB = 0.229 \times (DBH^2H)^{0.844} \qquad (2)$$

The estimated TAGB for 96 trees using reference allometry was 383.714 while the proposed equation estimated TAGB was 380.202 tonnes. The different percentage given by the proposed equation was only 0.9% with strong correlation. In addition, the scatter plot in Figure 3 Table 3 shows that the AGB estimation increases with the increasing of DBH^2H values.

Conclusion

In this study, we developed a new site –specific equation for Ampang Forest Reserve using the DBH and tree height parameters.

Table 3: Parameter Estimates and Coefficients for Mixed Species.

Parameter	*a*	*b*	R^2	Std. Error
DBH	0.316 ± 0.005	2.314 ± 0.004	1.000	0.015
DBH^2H	0.229 ± 0.046	0.844 ± 0.018	0.958	0.173

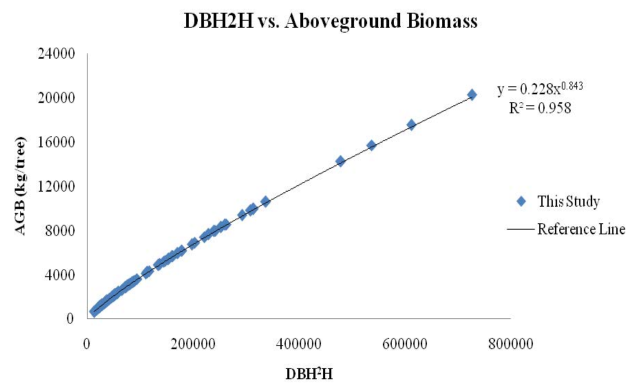

Figure 3: Scatter Plot of DBH^2H Against AGB.

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In total 96 trees with DBH more than 30 cm from 25 different species were measured from the study area. Power function regression model was used to identify the relationship between tree parameters against the aboveground biomass estimation where zero (0) indicates no correlation between parameters while one (1) shows a high correlated value. The result indicated a good R^2 value with the produced regression line was close to the reference allometry line. In conclusion, the results of this study have significantly improved the estimation of total aboveground biomass for this study area. The inclusion of the tree height in the developed equation is proven to be capable in estimating the accurate TAGB for this study area.

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References

1. Okuda T, Suzuki M, Numata S, Yoshida K, Nishimura S (2004) Estimation of aboveground biomass in logged and primary lowland rainforests using 3-D photogrammetric analysis. For Ecol Manage 203: 63-75.
2. Available from http://www.forestcarbonpartnership.org/fcp/Node/30
3. Available from http://www.wwf.org.my
4. Cao C-P, Gailing O, Siregar IZ, Siregar UJ, Finkeldey R (2009) Genetic variation in nine Shorea species (Dipterocarpaceae) in Indonesia revealed by AFLPs. Tree Genet Genomes 5: 407-420 .
5. Chang A, Eo Y, Kim Y, Kim Y (2013) Identification of individual tree crowns from LiDAR data using a circle fitting algorithm with local maxima and minima filtering. Remote Sens Lett 4: 37–41.
6. Basuki TM, van Laake PE, Skidmore a K & Hussin Y a (2009) Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. For Ecol Manage 257:
7. Brown S (1997) Estimating biomass and biomass change of tropical forests: a primer. FAO. Forestry Paper 134, Rome.
8. Chave J, Andalo C, Brown S, Cairns Ma, Chambers JQ, et al. (2005) Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99.
9. Hashimoto T, Tange T, Masumori M, Yagi H, Sasaki S, Kojima K (2004) Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan. Tropics 14:123-130.
10. Kato R, Tadaki Y, Ogawa H 1978) Plant biomass and growth increment studies in Pasoh Forest. Malayan Nature Journal 30: 211-224.
11. Ketterings QM, Coe R, Noordwijk MVan, Ambagau Y, Palm CA (2001) Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For Ecol Manage 146: 199-209.
12. Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, et al. (2009) Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak Malaysia. J For Res 365-372.
13. Rai SN, Proctor J (1986) Ecological studies on four rainforest in Karnataka India. J Ecol 74: 439-454.
14. Sumida A, Miyaura T, Torii H (2013) Relationships of tree height and diameter at breast height revisited: analyses of stem growth using 20-year data of an even-aged Chamaecyparis obtusa stand. Tree Physiology 33: 106-118.
15. Yamakura T, Hagihara A, Sukardjo S, Ogawa H (1986) Above ground biomass of tropical rain forest stands in Indonesian Borneo. Vegetatio 68: 71-82.
16. Alves LF, Santos FaM (2002) Tree allometry and crown shape of four tree species in Atlantic rain forest, south-east Brazil. Journal of Tropical Ecology 18: 245-260.
17. www.fao.org/docrep/008/ae578e/ae578e00.html
18. Khali AH, Ismail P, Rahman Abd, Che Hashim K, Grippin HA, et al. (2009) Ecological Characteristics of a Gonystylus bancanus-rich Area in Pekan Forest Reserve, Pahang, Malaysia. Tropical Life Sciences Research 20: 15-27.

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