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Estimation of Biomass and Carbon Content in Durian Plantations, Malaysia

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ABSTRACT. The *Durio zibethinus* is one of the main crops introduced in Pahang, Malaysia. It has been widely planted and has grown to be one of Malaysia's major plantations, offering important ecological, economic, and social benefits. In this study, 92 durian trees from eight plots were sampled among those aged between 3 months to 10 years planted on slightly acidic soil with a mean value of pH 6.1. The allometric biomass equation was used to estimate the aboveground biomass (AGB). It is the species-specific volume equation with a diameter at breast height (DBH) as the main variable that could accurately determine the biomass of the durian tree. The morphological variables such as DBH, height, canopy width and ecological variables including soil pH and also other variables as age and were also determined. The oldest durian tree, which is 10 years old, has the highest AGB and carbon content which are 670.97kg per tree and 335.485kg per tree respectively. The Spearman's rank correlation coefficient (ρ) was also used to determine the relationship between biomass and morphological variables and other variables. The results showed strongest positive correlation between biomass and DBH which is ρ =0.863 and the lowest is between biomass and canopy size, which is ρ =0.730. The relationship between biomass and height and canopy width showed moderate positive correlation which are ρ = 0.863 and 0.788 respectively. The durian tree also had the potential for carbon sequestration, especially among the older trees that store large amounts of biomass, which can mitigate the accumulation of carbon dioxide (CO_2).

Key words: Durian Plantations, Biomass, Malaysia, Estimation, Correlation

INTRODUCTION

Photosynthesis is the most important process for plant development and biomass production (Chen et al., 2018) because plants receive the sun's energy and transform CO_2 and water into nutrients, which are then stored in biomass (carbohydrates). Biomass is recognized as a key measure of vegetation's ecological and management activities. Plants that control the nutrient, water, and sun resources on a site are reflected in the plants that dominate the site in terms of biomass. Biomass is also a range of organic materials that can be used to produce energy, electricity and heat. When the vegetation died, CO_2 remains trapped inside the decay plants, the vegetation then buried layers become compressed in the soil and transformed into coal, oil or natural gas (biomass). When this biomass is burned, CO_2 and stored energy will be released as heat. Thus, with the presence of plantations in a large area, the Earth's carbon cycle

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will be efficient as the releasing of CO_2 as heat will be reabsorbed by the vegetation during the photosynthesis process. However, one of the current environmental issues is the increase in CO_2 in the atmosphere and its possible impact on climate. Anthropogenic activities such as deforestation, construction, development, the release of smoke from factories and vehicles, and open forest burning cause an increase in releasing of CO_2. Several satellite data sets and climate models show that forest biomass is declining due to a variety of variables, with anthropogenic activities greatly outnumbering natural disasters (Pandey, 2019). Thus, the estimation of biomass in a study area is required to increase the quantity of accessible energy for the next trophic level and make biomass a carbon-neutral energy source.

There are two ways to measure biomass which are via destructive sampling method and non-destructive sampling method. As for the destructive sampling method, previous foresters and researchers used the "Gold Standard" method for determining biomass density at a sample plot (Houghton et al., 2009). Gold standard research is a labour-intensive, destructive procedure that involves gathering all plant material inside the plot, drying it to a consistent weight, and then weighing it, this causes this technique to become more challenging when large trees and small areas are involved. The term gold standard sometimes is not the ideal test, but it is the best access that has standard and predictable findings. The process of measuring biomass up to the issuance of the Gold Standard method includes using a random sampling approach with sample points that can be permanent plots to measure tree biomass. The plot size is particularly crucial because whether big trees are included or excluded, or tiny plots will either overstate or underestimate average biomass density. Thus, it is impossible to achieve biomass density accuracies over multi-hectare zones in tropical forests using these destructive samples.

To obviate this problem, the foresters and ecologists have created indirect approaches, such as the allometric equation, which is a non-destructive sampling method for assessing biomass. Estimating the biomass of any tree species is necessary to comprehend the current state of the carbon cycle, to comprehend the role of species in changing land-use patterns, primary productivity, and to assess the effects of mechanisms used to reduce carbon emissions to combat climate change (Saha et al., 2021). This allometric equation is used in the most popular way to estimate tree biomass density from more readily observed parameters like DBH and height (Houghton et al., 2009). The correctness of the allometric model is determined by the variables chosen as well as the parameters' critical analysis (Saha et al., 2021). This makes the technique more efficient and saves time and energy because this approach eliminates the need for the plant components to be managed and weighed to obtain dry weight.

Durian is the edible fruit of numerous tree species belonging to the genus *Durio*. *Durio zibethinus* L. is the only species accessible in the international market while other species are only sold in their native habitats, which are Borneo and Sumatra. Durian is Southeast Asia's most well-known and popular tropical fruit. Millions of durian fans in the Southeast Asian area seek out and relish the "King of Fruits," as it is tenderly known because it has a distinct flavour and odour, resulting in great demand for it (Sawitri et al., 2019). Its popularity is growing in Hong Kong and mainland China. Fans of durian may also be found in Taiwan, the United States, Europe, and Canada. Most Malaysia's durian orchards are in Kedah, Penang, Pahang, Johor, and Sabah, and durians are exported and sold across the country. This estimation of biomass in durian plantations was held in an orchard located in Pahang. The types of durians grown in the orchard are Musang King, Black Thorn, and Kampung. Hence, this study aims to determine the AGB and

carbon content of durian plantations at different growth stages and to determine the relationship between AGB and morphological variables and soil pH of the durian plantations.

METHODOLOGY

Study site

This study was conducted on the durian plantation of Fresh Nursery Farm Consultant Sdn. Bhd., which is located at Jalan Ulu Teh, Kampung Baharu, 27000, Jerantut, Pahang (**Figure 1**). The owners of this durian plantation are Tn. Hj. Lokman Bin Isa and Tn. Abdul Rahman Bin Hassan. The plantations occupy an area of 1.5 hectares. The primary routes in the research areas are unpaved roads and slopes. In these orchards, there are two types of agriculture areas which are flat ground and hilltops. The orchard's management is overly concerned about the confinement and planting distances between durian trees that are ideal for effective development and production of tree yields. The durian trees in this orchard are generally of diverse ages, ranging from two months to 24 years old, but all the trees still look healthy and fresh due to proper care. Thus, the suitability of the soil in Jerantut for durian plantation makes this area a production area for D197 organic Musang King durian.

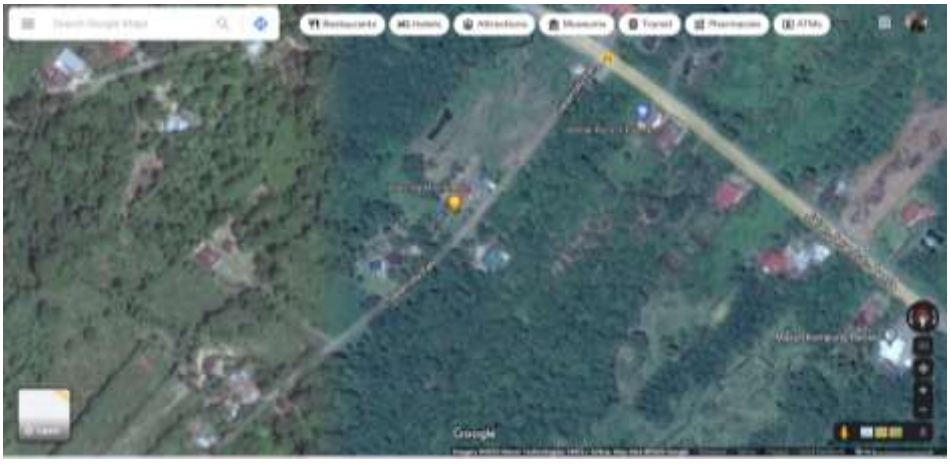

Figure 1. The study site of durian plantation
Source: Google (2022).

Data collections

The process of taking morphological measurements in durian fields begun with randomly dividing the orchard into circular plots that were 30 cm in diameter and stratified by the ages of the durian trees. The plant components involved in these morphological variables measurements of the durian tree are DBH, height and canopy size. The DBH stands for diameter at breast height (Do & Measure, 2011), 1.37 m above the ground's lowest point at the base of each tree (Morgenroth et al., 2020) was measured by utilizing diameter tape that have been calibrated or altered for diameter (Do & Measure, 2011).

Additionally, for young trees between the ages of three months and one year, the trunk is still small making it impossible to measure the diameter with a diameter tape because the reading is minimal. Therefore, the diameter of the small tree was measured using a digital calliper. Furthermore, the height of a tree, measured from its base to the tip of its highest branch, provides information about crop growth from a vertical perspective (Yue et al., 2017).

In each plot, plant height was measured using a Haga hypsometer. Haga is a medium-sized, lightweight device used to measure height. The height from the proper scale can be read when the observer are 15 m away from the tree, so to measure height using Haga, the measuring point must be 15 m from each plot's chosen tree such that the required point on the tree tip, could be seen from the standing position (Harkel et al., 2020).

When referring to the ecology of forests, the terms canopy structure refers to the organisation or spatial arrangement of a plant canopy in three-dimensional (3D) geometry, respectively. Canopy size is a key component of plant canopy structure, which influences crop functions like production and stress tolerance. Thus, it become an essential component of the structure of the canopy and is essential for plant photosynthesis, fruiting, and biomass accumulation (Jiang et al., 2018). The canopy width of each durian tree was measured with a measuring tape. The outermost leaf end of one canopy limb was used as the starting point for a measuring tape that extended to the opposing leaf end. For the stability measurement on both sides of the end leaves, the measurement tape was positioned in the centre, close to the trunk.

In addition, durian trees prefer deep, well-drained loamy soils that are at least 1.5 m deep (Kamil, 2019) due to their ability to retain water while draining fast and being rich in organic matter. Ideal pH levels are estimated to be between 5.5 and 6.8 (Kamil, 2019). Iron and zinc deficiencies are commonly observed at higher pH levels, while at lower pH levels, some nutrients may not be absorbed by the root system because of low cation exchange capacity (CEC) values. The soil pH was measured by using a GroLine Soil pH Meter brand HANNA instrument. Each of the two study plots, one soil sample was taken from a field using a shovel. The topsoil part was removed before being scooped up and put inside sampling bags. This procedure was repeated until the final plots. The soil was dug at the same depth in order to avoid pH discrepancies. Then, the soil samples were put inside the paper cup to measure the soil pH. Some distilled water was added to the paper cups as the soil inside should be damp but not saturated. Then, the soil pH meter was placed vertically onto the soil to give the reading time to develop and stabilize. Then, when the small hourglass on the soil pH meter's screen disappears from the screen, the measurement is then considered to be stable. The reading of soil pH was recorded, and the soil pH meter was removed from the paper cup and rinsed with distilled water.

Determination of biomass

There are two types of sampling methods related to biomass estimation which are the destructive sampling method and the non-destructive sampling method. Application of allometric equations, a non-destructive sampling approach for estimating forest AGB, was an essential step in climate change mitigation efforts. Forest biomass had been estimated by using the generalized allometric equations. This non-destructive sample approach used a manual procedure to determine the DBH, height, canopy size, and other factors. A random sample approach was used with all trees having an equal chance of being included in the research (Mills, 2021). As a result, trees with various DBH classes were chosen. The general allometric equation used is:

$$B = \exp[-2.134 + 2.53 \ln(D)] \quad \textbf{(Error! No text of specified style in document.}.1)$$

Description:
B is total AGB (kg per tree), and D is diameter at breast height (cm)

The total number of plots done were eight plots equipped with 92 durian trees. The mean (average) data set of biomass and other morphological variables were calculated by total up of all the numbers in the data set and then divided by the number of values in the set for each different tree age.

Data analysis

The relationship between total AGB and the morphological variables and soil pH of the durian plantations shall be estimated using Spearman's rank correlation coefficient. It is a measure of covariance of the two variables divided by the product of their standard deviation. In total, about 92 durian trees were observed within eight plots to measure the total AGB. The mean (average) of both data set of AGB and morphological variables are calculated by the sum of all the numbers in the data set and then divided by the number of values in the set. The absolute values of coefficients of correlation for the obtained allometric relationships between both variables are ranging on or between −1 and +1. If the absolute values of this correlation between two variables, ρ is close to ±1 ($\rho = \pm 1$) with all data points lying on the line, this shows a strong relationship between both variables of AGB and the measurements of morphological variables and soil pH in the economical way of studying the change in carbon stocks.

RESULTS AND DISCUSSION

The biomass of durian plantations in different growth stages

An observation of eight durian tree plots consisting of 92 durian trees within two orchards revealed that the age of the trees is spreading throughout all accessions, with an estimated, 90% of the durians' ages ranged between 0 to 5 years and 10% between 6 to 10 years (Table 1). In plantation ecosystems, age has the greatest impact on the amount and distribution of biomass. The AGB of each tree with various ages was estimated by a published allometric equation that relates measurements of DBH. Based on (Table 1), with increasing stand age, the proportion of biomass showed an increasing trend as the older the tree, the greater the biomass resulting in the higher carbon content stored inside the tree. These accumulated carbon content will increase the probability to reduce the climate change (Stecker, 2014). Having the oldest age in this selected study plot, which is 10 years old had the highest biomass value of 670.97 and carbon content value 335.485 kg per tree. This is because according to the study, an older tree absorbs carbon more effectively from the environment. In fact, trees accumulate over 70% of their carbon during the second half of their lives. The older trees absorb amount of energy from the sun and atmospheric CO_2 and convert it into carbon-based sugars to strengthen their tissues while they store carbon through photosynthesis (Kachur, 2017).

Age of durian trees from three months to four months old in this study, the tree biomass increased, and there was a slight decline in the six months to nine months (Table 1). However, the biomass increased from three years to eight years old and at 10 years old. These inconsistent relationships between AGB and morphological variables may be caused by climatic conditions, soil quality (Zhang et al., 2019), and mortality loss (Xu et al., 2011). Mortality loss

is a measurement of the frequency of death in a specific population, such as when the xylem tissues' water transport system deteriorates following drought (Rowland et al., 2015). The vulnerability of the xylem to drought relates water potential in xylem conduits to loss of hydraulic conductivity due to gas emboli occlusions by gas emboli. The water potential at which 50% loss of xylem conductivity occurs is a commonly used index of embolism resistance (Rowland et al., 2015).

Table 1 Biomass and carbon content of durian plantation at various ages.

Age (months and years)	AGB (kg per tree)	Carbon Content (kg per tree)
3 months	0.53	0.265
4 months	2.11	1.055
6 months	0.28	0.14
8 months	0.33	0.165
9 months	0.45	0.225
1 year	3.00	1.50
1.5 years	3.98	1.99
2 years	16.26	8.13
2.5 years	15.48	7.74
3 years	35.24	17.62
5 years	122.72	61.36
6 years	214.46	107.23
7 years	232.72	116.36
8 years	349.83	174.915
9 years	334.56	167.28
10 years	670.97	335.485

The relationship between biomass and morphological variables of the durian plantations.

The relationship between biomass and these morphological variables are strongly positive correlated as these ρ values are close to +1. The sample size, N for running Spearman's rho correlation is 92, which indicates that N = 92 (Table 2). The relationship between all these morphological variables is positive, which reveal that as one of the morphological variables increase, the other morphological variables also increase such as when biomass increase, DBH, height and canopy width also increase. Based on **Error! Reference source not found.**2, the Spearman's rho correlation coefficient between biomass and DBH shows strongest positive relationship which is 0.86 followed by relationship between biomass and height which is 0.79. Relationship between dry standing aboveground biomass (AB) and stand height (H) across 2,146 plant communities in three ecosystems: Canadian forests, Western US prairies and Central Germany managed grasslands were found to be strongly correlated (Proulx, 2021). Crown variable has been proven useful in estimating forest biomass using medium- (Phua & Saito 2003) and high-resolution (Palace et al. 2008; Phua et al. 2014) satellite imageries. Crown diameter has been used to estimate biomass under the scenario of small sample size of field data (Phua & Saito 2003). In this study, the relationship between biomass and canopy width also shows a positive correlation which is 0.75. The finding is parallel with a study by Alometri et al. (2016) mentioned that there was positive correlation between canopy size and AGB for oil palm plantations in Sabah. Pearson’s correlation analysis was performed between crown diameter (CD) and AGB was a nonlinear with R^2 ranging from 0.950 to 0.975.

Table 2 The relationship of biomass and morphological and ecological variables and Soil pH using Spearman's rank correlation coefficient, N = 92.

	Biomass	DBH	Height	Canopy size	Soil pH
Biomass	1.000	.86**	.79**	.75**	.73**
		.000	.000	.000	.000
DBH	.86**	1.000	.92**	.88**	.77**
	.000		.000	.000	.000
Height	.79**	.92**	1.000	.91**	.74**
	.000	.000		.000	.000
Canopy	.75**	.88**	.91**	1.000	.63**
	.000	.000	.000		.000
pH	.73**	.77**	.74**	.63**	1.000
	.000	.000	.000	.000	

CONCLUSION

In conclusion, the estimated total AGB and carbon content within eight plots is 2002.92 kg per tree and 1001.46kg per tree respectively. The Spearman's rho correlation coefficient was used to determine the relationship between biomass and the morphological factors and soil pH. All morphological variables and soil pH shows significant positive correlation with total AGB which shows when one variable increase, the other variable tends to increase. These findings will provide relevant data on biomass and carbon content in the durian plantations and will also serve as a scientific basis for sustainable measures to mitigate the atmospheric CO_2 concentrations.

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AUTHOR CONTRIBUTIONS

Writing original draft: Engku Azlin Rahayu Engku Ariff, Nurul Syafikah Darul'aludin,; Data curation: Ahmad Fitri Zohari,; Formal analysis: Mazlin Kusin Writing review & editing:; Project administration: Nik Hazlan Nik Hashim

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DATA AVAILABILITY

Not applicable.

COMPETING INTEREST

The authors declare that they have known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper

COMPLIANCE OF ETHICAL STANDARDS

Not applicable.

SUPPLEMENTARY MATERIAL

Not applicable.

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