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Estimation of Above Ground Biomass for Oil Palm Plantations Using Allometric Equations

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Abstract. Malaysia is the second largest world producer of palm oil (*Elaeis guineensis)* with current planted area of plantations around 4.69 million ha. Oil palm contributes of about 75 percent of total planted area as compared to other agricultural tree crops. Since the oil palm plantations play an important roles in the economic and sources of income to Malaysia, accurate and reliable information is needed for its management efforts and planning. In Malaysia, there is lack of data and information regarding the aboveground biomass (AGB) for oil palm plantation. Therefore, the need for current inventory on resource availability has leads this research into ground field survey using existing allometric equations. The objectives of this study are (1) to estimate the AGB of oil palm plantations using different allometric equations and (2) to determine the relationships of AGB with oil palm stand variables. This study was conducted in 60 oil palm plantations in Selangor, Malaysia. The AGB of oil palm measured in the field using Corley and Tinker's equation (2003) estimates an average of 40.77 tonnes per hectare while using Khalid's equation (1999) estimates an average of 47.19 tonnes per hectare.

Keywords: Above ground biomass, oil palm plantations, allometric equations

1. Introduction

The oil palm had already been tremendously studied in the aspect of botanical and cultivation due to its commercial importance and values. In Asia, Malaysia is known as the second world largest palm oil producer and exporter after Indonesia which contributes to about 47 percent of palm oil producing capacity. Nowadays, a large area of agricultural land had already been converted into oil palm plantation. In 2011, the total oil palm planted areas had been increased and expanded to 4.69 million ha [1] compared to 2006, when the area covered 4.17 million ha [2]. Oil palm contributes of about 75 percent of total planted area as compared to other agricultural tree crops.

Fall short of timber capacity from natural forest now have become the most current issues. The shortfall will need to be met by promoting the sustainable use of existing woody material. One alternative is to utilize oil palm tree crops as they provide raw materials for bio-composite products. In Malaysia, there is lack of data and information regarding the above ground biomass (AGB) for oil palm plantation management and planning which hold up the decision making [3]. The plantation manager use ground survey, interpreted the photographic data and plantation growth model to assess the oil palm plantations attributes [4]. Despite the importance roles of oil palm crops in providing palm oil products and other benefits that support basic human needs and economic development, little attention has been given to inventory of the crops. Therefore, the remedy to these problems is to conduct research in ground field survey using existing allometric equations.

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The objectives of this study are (1) to estimate the current AGB of oil palm plantations using different allometric equations and (2) to determine the relationships of AGB with oil palm stand variables.

2. Materials and Methods

2.1. Study site and field data collection

This research was conducted in 60 oil palm stands throughout the state of Selangor, Malaysia. The state of Selangor is on the West Coast in Peninsular Malaysia with a total of 796,084 km^2 land area. Selangor state has nine districts with average annual rainfall varies from 2,000 to 2,500 mm and high humidity all year around. Plantations of oil palm were sampled from various private oil palm agencies and also the government. The selected oil palm stands were ranging from 6 to 23 years old with different planting density of 136 to 148 stems per hectare.

The oil palm stands were classified into three age stages which are intermediate, productive and mature stages. The classification of oil palm age follows study done by [5] which they classify the oil palm age based on oil palm physical factors and characteristics. According to [5], the young age stage ranges from one to three years after planting and intermediate ranges from four to ten years after planting. The productive age stage ranges from 11 to 20 years of planting while mature age stage belongs to over years of planting. Therefore, for this study only three age stages were involved since the lowest age is six years of planting. For each stands, four to 14 circular plots (depending on the area and densities) were randomly located and mean for stand parameters were measured and used to represent the entire stand [6]. In all plots, the AGB were calculated from the measurements of diameter of breast height (DBH), height, height below frond, length and depth of petiole developed by [7] and [8].

2.2. Allometric functions

One of the studies done by [7], they had developed specific allometric equation for oil palm in Malaysia using harvesting and labor- intensive approach. From the result, they found out that the total fresh weight was significantly correlated with palm height (R=0.96, P<0.05). The established equation to calculate biomass is as follow;

$$\text{Above Ground Biomass} = 71.797*H - 7.0872 \quad (R = 0.91)$$

Where;

AGB = Dry weight (kg $palm^{-1}$)

H = Palm height in unit meter (m)

This allometric equation was used in further calculations to estimate AGB. On the other hand, [9] developed equation for AGB using destructive method. The equation used to calculate AGB is as follow; Trunk biomass is indicated as T_b. The trunk biomass was calculated using (1). The trunk density, ρ was calculated using (2). Frond biomass is indicated as F_b. Frond biomass was measured using (3). AGB is thus determined using (4).

$$T_b = \Pi * (r*z)^2 * h * 100 * \rho \quad (1)$$

$$\rho = (x*0.0076 + 0.083) / 1000 \quad (2)$$

$$F_b = 0.102*l*d + 0.21 \quad (3)$$

$$AGB = T_b + F_b \quad (4)$$

Where;

r = radius of the trunk (in cm) without frond bases

ρ = trunk density in kg/m^3 dependent on the age

x = years of the palm

z = ratio of diameter below frond bases, estimated to be 0.777

h = height of trunk (in m) to the base of the frond

l = length of the petiole (in cm)

d = depth of petiole (in cm)

3. Results and Discussions

A total of 60 stands of oil palm were sampled in this study. Table 1 shows the descriptive statistics of oil palm parameters for field data collections.

Table 1: Descriptive statistics of oil palm parameters

Variable	*No. of stands (n)*	*Min*	*Max*	*Mean*	*SD*
Age	60	6	23	13.75	5.10
DBH (cm)	60	52.40	85.90	74.25	7.39
Height (m)	60	5.00	20.70	11.11	3.42
Height below frond (m)	60	1.60	9.70	4.81	2.14
Length petiole (cm)	60	102.10	164.00	132.85	12.72
Depth petiole (cm)	60	3.00	4.60	3.61	0.44
Trunk biomass (tonnes/ha)	60	8.53	70.94	33.84	16.85
Frond biomass (tonnes/ha)	60	4.50	9.75	6.92	1.10
AGB using Corley (tonnes/ha)	60	14.71	79.98	40.77	17.55
AGB using Khalid (tonnes/ha)	60	15.95	102.23	47.19	21.17

3.1. Above Ground Biomass Using Allometric Equations

Figure 1 present two biomass estimates of oil palm stands using collected ground data measurement; (i) [7] equation and (ii) [8] equation. This figure shows that the AGB increase with the increases in age or years of planting until it decreases when it reach 20 years of planting. This is due to the abscission of the frond bases as the palm mature after 20 years of planting [9]. Reference [7] equation was used for subsequent data analysis. The average value of AGB calculated using allometric equation develop by [7] is 47.19 tonnes ha^{-1}, slightly higher when compared to the average value of AGB calculated using equation develop by [8] which is 40.77 tonnes ha^{-1}. The maximum value of AGB calculated using [7] equation is 102.23 tonnes ha^{-1} while the maximum value AGB calculated using [8] equation is 79.98 tonnes ha^{-1}.

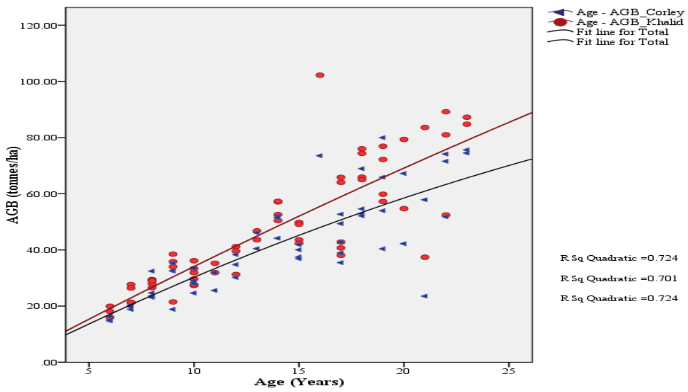


Fig. 1: Oil palm AGB estimates.

The mean AGB for this study is slightly lower compared to the mean value of AGB done by [9] which amounted about 52 tonnes ha^{-1} and this is agreeable with the result from this study. The other studies done by [10] estimated the mean of total AGB was 90 tonnes ha^{-1} while [8] found that the mean total of AGB was 85.26 tonnes ha^{-1} which also higher by 45% from this study. The higher value obtained by [10] and [9] might be due to the calculation that based on planting density of 136 palm per ha while the oil palm planting density for this study ranged from 136 to 148 palm per ha. According to [11], published values on the quantity of above ground biomass on oil palm plantations range from 50 tonnes ha^{-1} to over 100 tonnes ha^{-1} towards the end of the plantations economical live span after 20-25 years. Based on previous study done by [12], they have collected biomass data from 51 oil palm fields and estimates the averaged oil palm aboveground biomass of 60 +/- 20 tonnes biomass/ha for 25 years after planting which also agreeable with the result from this study.

3.2. Above Ground Biomass between Age Stages

A one-way between subjects Analysis of Variance (ANOVA) was conducted to compare the means between AGB in intermediate, productive and mature age stages. There is a significant difference in the means of AGB on the age ($p \le 0.05$) in all three age stages [$F(2, 57) = 38.558$, $p = 0$].

3.3. Multiple Comparison Test for AGB

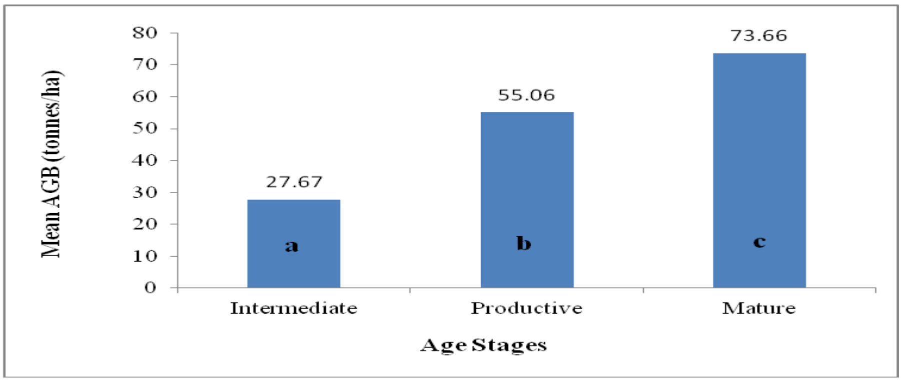
Multiple comparison tests (Tukey test) were designed to compare the means of AGB between intermediate, productive and mature age stages. From the analysis, the means of AGB indicated that the mean difference for the intermediate age stage ($p \leq 0.05$) is significantly different from productive [p = 0] and mature age stages [p = 0] as shown in Table 2. The mean different for the productive age stage at $p \leq 0.05$ level is significantly different from intermediate and mature age stage with significant value of 0 and 0.007 respectively. On the other hand, mature age stage shows a significantly different from intermediate and productive age stages with significant values of 0 and 0.007 respectively.

Table 2: Multiple Comparison Test of AGB

AgeStage (I)	AgeStages (J)	Mean Difference (I-J)	Std. Error	Sig.
Intermediate	Productive	-27.39421*	3.91486	0
	Mature	-45.98730*	6.09409	0
Productive	Intermediate	27.39421*	3.91486	0
	Mature	-18.59309*	5.87669	0.007
Mature	Intermediate	45.98730*	6.09409	0
	Productive	18.59309*	5.87669	0.007

*The means significant at 0.05 level

Figure 2 present the means of AGB at three different age stage. Intermediate age stage shows the mean of 27.67 tonnes/ha and productive age stage has the mean of 55.06 tonnes/ha. While the mature age stage shows the mean of AGB is 73.66 tonnes/ha.



*Means with the same letters are not significantly different ($p \leq 0.05$)

Fig. 2: Multiple Tukey test for AGB.

3.4. Correlation matrix of AGB with stand parameters

The DBH of oil palm for this study is inversely correlated to age of oil palm, indicating that as the age increases the DBH decreases. One of the studies done by [13] reported that the stem diameter decreased gradually with the age with the reduction of 18cm while [14] reported that the oil palm maintains a steady increase in trunk diameter throughout the nursery stage and the first years in the field. However, the stem virtually ceases its growth in width before the internodes begin to elongate which agreeable with the result from this study. This could be due to the fluctuations in nutrient uptake which cause changes in stem diameter [15]. Strong correlations were found between age, DBH, height, height below frond, depth of petiole and crown width versus AGB (r = 0.851, -0.612, 0.673, 0.996, 0.648 and 0.567) (Table 3).

Table 3: Correlation Matrix between Stand Attributes

	Age	DBH	Height	Height below frond	Length of petiole	Depth of petiole
DBH	**-.738****					
	0					
Height	**.637****	**-.331****				
	0	0.01				
Height below frond	**.858****	**-.610****	**.648****			
	0	0	0			
Length of petiole	-0.027	0.139	**.366****	0.129		
	0.837 ns	0.288 ns	0.004	0.327 ns		
Depth of petiole	**.663****	**-.330****	**.437****	**.672****	0.062	
	0	0.01	0	0	0.639 ns	
AGB	**.851****	**-.612****	**.673****	**.996****	0.135	**.648****
	0	0	0	0	0.305 ns	0

*. Correlation is significant at the 0.05 level (2-tailed)
**. Correlation is significant at the 0.01 level (2-tailed)
ns – No significant difference

4. Conclusions

The AGB from this study was estimated using non- destructive method of established allometric equations. The total AGB from this study amounted about 47.19 tonnes ha^{-1} using equation develop by [9] and 40.77 tonnes ha^{-1} using equation developed by [8]. Both equations produced a slightly different amount or almost similar total AGB. From this study, it can be concluded that there are strong correlations were found between age, DBH, height, height below frond, depth of petiole and crown width versus AGB (r = 0.851, -0.612, 0.673, 0.996, 0.648 and 0.567).

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