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FIELD ASSESSMENT OF ABOVE GROUND BIOMASS (AGB) OF MANGROVE STAND IN MERBOK, MALAYSIA

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ABSTRACT

Mangroves are considered as unique and important ecosystems that occupy an intertidal zone of protected shorelines. The halophytic plants present in mangroves provide support not only for social economic needs but also for ecological roles which include carbon sinks. Above ground biomass (AGB) of mangroves was estimated in mangrove stands in Merbok, Kedah. Field data collection was conducted from January 2013 to May 2013. A total of 25 sites measuring 100 m x 100 m were surveyed in the study area. Within randomly selected plots, diameter at breast height (DBH), tree height and crown width were measured. Mangrove trees were identified at the species level. Published allometric functions were used to compute the AGB of mangroves. *Rhizophoraapiculata* was found to be the most abundant species followed by *Bruguieraparviflora, Bruguieragymnorrhiza* and *Avicennia marina*. An overall mean for AGB in study area was estimated to be 176 Mg/ha. From the analysis of variance (ANOVA), it was found that there is a significant different in the means of all mangrove variables measured between four mangrove species ($p < 0.0001$). Positive relationships were found between DBH, height and crown width and AGB with r values of 0.88, 0.43 and 0.81 respectively. The subsequent analysis will involve a study of relationships between mangrove stand attributes with spectral radiance recorded from remote sensing.

Key words: Above Ground Biomass, Mangrove, Allometric Function, Diameter at Breast Height (DBH)

INTRODUCTION

Mangrove is considered as dominant ecosystem that can be recognized by its habitat that grow in intertidal zone along tropical and subtropical coastlines, river estuaries or tidal marshes inundated by sea at high tide. The unique characteristics and adaptations of this halophytic plant make mangroves a suitable ecosystem that can tolerate harsh coastal environment (Kathiresan and Bingham, 2001). The total extent of mangrove area in tropical and sub-tropical is estimated around 15.2 million ha, with the Southeast Asia holds about 33% of world total mangrove area (Spalding *et al.,* 2010). Mangroves provide numerous benefits such as ecological values to the environment (Alongi, 2002; Barbier, 2007) and socio-economic support to human (Hossain, 2009).

While mangroves offer numerous benefits, this ecosystem has been degraded at an alarming rate. According to William (2005), the total percentage covered by mangrove area throughout the tropical and subtropical coastlines was 75% and recently decreased to less than 50%. The climate change scenario coupled with anthropogenic activities such as deforestations (Spalding *et al.,* 2010) has made mangrove becoming plant in peril and contributing to the source of carbon. The increasing carbon from anthropogenic activities in the atmosphere accelerates the global warming phenomenon.

One of the critically important services that are being offered by mangroves is the ability to store carbon. According to Kauffman *et al.* (2011); Kaufman and Cole, 2010), AGB for riverine and fringe mangroves is estimated at > 500 Mg/ha and for dwarf mangrove of about 8 Mg/ha. The strategic location of mangroves in the coastal area, where the rapid exchange of sediment, organic materials and gases take place between the land and sea provide

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opportunity for carbon sequestration potential in mangroves. Furthermore, the dead materials from the mangrove trees that fall in to the ecosystem does not completely composed but sink as decomposed organic matter and this is important for carbon sink (Suratman, 2008).

Recently, the global warming scenario creates interest in understanding the carbon storage of mangroves species. Despite accounted for only 2.4% of tropical forests (Chmura *et al*., 2003; Spalding *et al*., 1997), the capacity of this halophytic plant to store carbon are four times greater than most other tropical forests around the world (Daniel *et al.,* 2011). Since mangroves have important roles in global carbon budget and mitigating climate change, accurate and reliable information is needed for estimating their biomass. Furthermore, the estimation of mangrove biomass provides understanding for the forest ecosystem characteristic hence contributes to sustainable forests management practice. The objectives of this study are 1) to study the variation in mangrove variables, i.e., diameter at breast height (DBH), height, crown width, basal area (BA) and above ground biomass (AGB) between *Rhizophoraapiculata, Bruguieraparviflora, Bruguieragymnorrhiza* and *Avicennia marina* in Merbok Mangrove Forests. 2) To study the relationships between DBH, height, crown width versus AGB for mangroves in the study area.

Considering the fact that biomass represents the role of trees as key indicator of carbon source and sink, information from this study is expected to provide baseline information and an understanding on the role of mangroves in sequestrating carbon in the atmosphere. Field data presented in this paper will be used for the development for carbon sequestration model by combining data from this current study with the remote sensing data.

MATERIALS AND METHODS

Study Area

The study sites were located at the Merbok Mangrove Forests (MMR), Kedah, Malaysia (Fig. 1). MMR is one of the mangrove reserves located in the north-western of Peninsular Malaysia which is the fourth biggest mangrove area in the Peninsular after Perak, Johor and Selangor. The forest is located in the north of Penang Island where its main river flows to the Straits of Malacca. It is located at 5º 41' 36"N and 100º 25' 22" E coordinate. This area occupies an approximately 4,085 ha of fringed mangroves and has been and gazetted since 1951. Merbok main stream stretches up to 35 km long and seawater can inundate up to 30 km with the depth varying from 13-15 m. The estuary receives supply of fresh water from several small streams that are connected to the main river. MMR is managed by the Department of Forestry of Sungai Petani district, Kedah.The management of MMR involves 30 years rotation of harvesting and replanting of *R. apiculata* for timber production.

Field data collection was conducted from January 2013 to May 2013. A total of 25 mangrove stands were located in the study area. In each stand, seven sampling plots of 25m × 25m were randomly selected. All individual mangrove trees withDBH

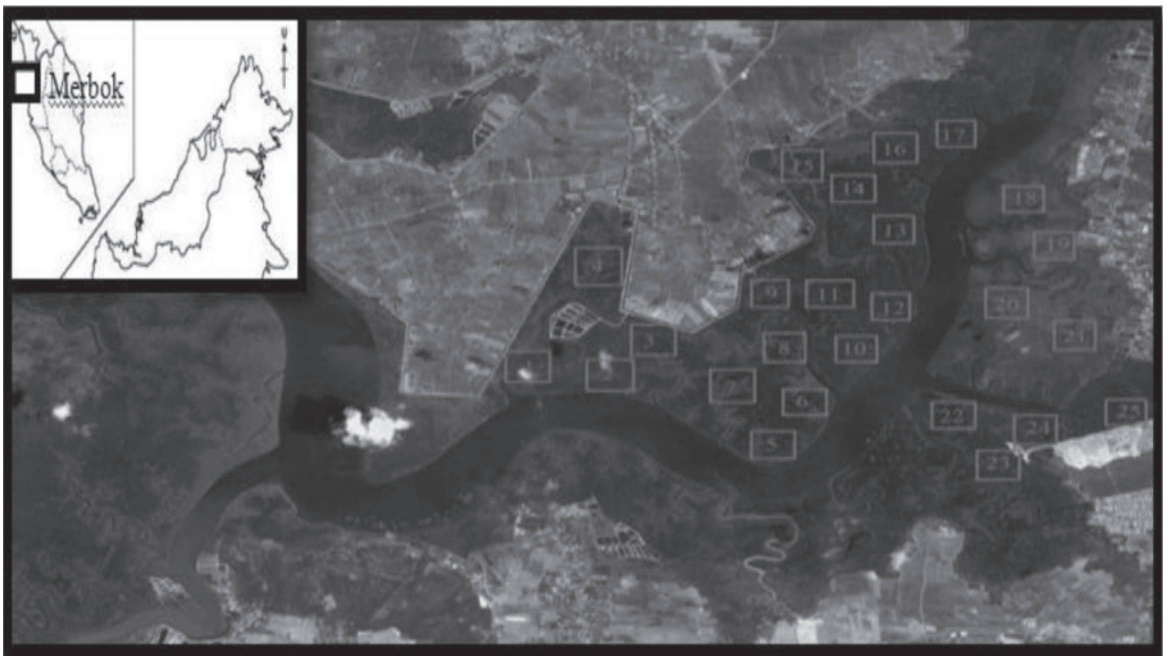

Fig. 1. Satellite image from Google earth showing the study area and location of field plots.

above 5 cm were measured using a DBH tape. The mangrove trees in the plots were identified at the species level. Four species *R. apiculata, B. parviflora,B. gymnorrhiza*and *A. marina* are present in the study area. For *R. apiculata,* the DBH was measured at 30 cm above the highest prop root. The tree height was measured using Hypsometer (Opti-Logicmodel 400 LH, US).The crown width was measured using a measuring tape, where the average length of longest spread from edge to edge across the crown and the longest spread perpendicular to the first section was taken. A Global Positioning System (GPS) receiver was used to locate and record the coordinates or positions of each field stand.

Data Analysis

AGB was computed using published allometric functions. The allometric functions were selected based on specific-species allometric equations that have been derived from previous studies within the sampling region. The allometric equation is a method to estimate the whole or partial weight of tree from a linear regression that relates biomass or productivity (dependent variable) to non-destructive growth parameter (independent variable). Table 1 show the allometric equations used in this study.

Analysis of variance (ANOVA) was performed to analyse any significant differences among mangrove stand variables. Following significant difference, a multiple comparison test procedure was performed (i.e., Duncan multiple range test) to study differences among the means. The relationships between mangrove stand attributes (e.g., DBH, height and crown width) and AGB were studied using Pearson's correlation coefficient (r) and scatter plots. A Statistical Analysis Software (SAS) version 9.3 was used to perform the analyses.

RESULTS AND DISCUSSION

Mangrove Species in the Study Area

Four species from three genera and two families of mangroves were identified in 25 stands of the study area (Table 2). From the table, *R. apiculata* was found to be the most abundant with an average of 444 trees/ha, followed by *B. parviflora* with 50 trees/ha, *B. g*ymnorrhiza with 22 trees/ha and *A. marina* with 10 trees/ha.

Analysis of Mangrove Variables for Each Species

Result from the ANOVA shows that there is a significant difference in the means of all mangrove variables (i.e., DBH, height, crown width, BA and AGB) among the four mangrove species ($p \leq 0.0001$). The analysis of multiple comparison test (Table 3) indicated that the means of DBH, height, crown width, BA and AGB for *R. apiculata* are significantly greater than the other three mangrove species ($p \leq 0.05$). However there is no significant difference in the means of DBH, crown width, BA and AGB between *B. parviflora, B. gymnorrhiza, A. marina*. Meanwhile the mean height of *A. marina* is significantly lower than the rest of the species ($p \leq 0.05$ level).

Table 1. Allometric equation for estimating AGB of mangroves

Species	Allometric equation	N	R^2	DMAX (cm)	Sources
Rhizophoraapiculata	$AGB = 0.1709D^{2.516}$	20	0.98	30.0	Putz and Chan, (1986)
Bruguieragymnorrhiza	$AGB = 0.186DBH^{2.31}$	17	0.99	25.0	Clough and Scott, (1989)
Bruguieraparviflora	$AGB = 0.168DBH^{2.42}$	16	0.99	25.0	Clough and Scott, (1989)
Avicennia marina	$AGB = 0.1848D^{2.3524}$	47	0.98	35.2	Dharmawan and Siregar, (2008)

AGB= above ground biomass, D= diameter at breast height (cm), N= sample size of trees to develop equation, R^2= coefficient of determination, DMAX= maximum diameter of sample trees (cm).

Table 2. Mangrove species observed in the study area of MMR

No	Species	Family	(N)	Density (Trees/ha)	AGB (Mg/ha)
1	*Rhizophoraapiculata*	Rhizophoraceae	4860	444	172.77
2	*Bruguieraparviflora*	Rhizophoraceae	309	50	1.69
3	*Bruguieragymnorrhiza*	Rhizophoraceae	19	22	1.33
4	*Avicennia marina*	Avicenniaceae	9	10	0.53

Table 3. Summary of the means of mangrove variables for each species in the study area

Species	DBH (cm)	Height (m)	Crown width (m)	BA (m^2/ha)	AGB (Mg/ha)
Rhizophoraapiculata	19.47a	14.63a	5.27a	0.034a	0.88a
Bruguieraparviflora	13.95b	11.60b	4.42b	0.017b	0.27b
Bruguieragymnorrhiza	10.37b	11.58b	5.43b	0.094b	0.12b
Avicennia marina	10.37b	6.83c	4.45b	0.009b	0.04b

Note: Means with same letter are not significantly different ($p \leq 0.05$)

Relationships between DBH, Height and Crown Width versus AGB

Scatter plot of DBH, height and crown width versus AGB for 25 stands in the study area are shown in Fig. 2, 3 and 4. In terms of correlation, there are linear positive relationships between DBH, height and crown width and AGB. The relationship between DBH versus AGB shows a strong correlation (r=0.88, p-value=0.0001). However, a moderate but significant relationship was recorded for the height versus AGB (r=0.42, p=0.0332). The relationship for crown width and AGB shows a positive and significant correlation (r=0.80, p-value=0.0001).

Table 2 depicts that *R. apiculata* isthe most abundant species compared to *B. parviflora, B. gymnorrhiza*and *A. marina* in the MMR. The abundance of this species might be due to the planting system that was implemented after timber harvesting. Approximately 24 ha of *R. apiculata*were replanted in 2002 (Ahmad and Muhammad, 2005) in which 4 out of 25 stands are included in the study area. Ong *et al.* (2004) stated that mangroves in Asia Pacific region are largely dominated by *R. apiculata* forests, and often grow almost like a pure stands.

R. apiculata also recorded the highest amount of AGB with an average of 176.2 Mg/ha in all sample stands. The high AGB recorded might be due to the geographic location of the study area that is in low latitude region. A study conducted in Matang, Malaysia was found that AGB in mangrove forests is dominated by *R. Apiculata* (i.e., 460 Mg/ha (Putz and Chan, 1986). Meanwhile, AGB in Halmahera, Indonesia mangrove forests was 300 Mg/ha (Komiyama *et al*., 1988). In high latitude areas, primary forests mostly have an AGB around 100 Mg/ha and the lowest AGB was recorded in *R. mangle* mangrove forests in Florida, USA with only 7.6 Mg/ha (Mackey, 1993). This is an agreement with Komiyama *et al*. (2008) who found out that low latitudes area have greater AGB as compared to the temperate area.

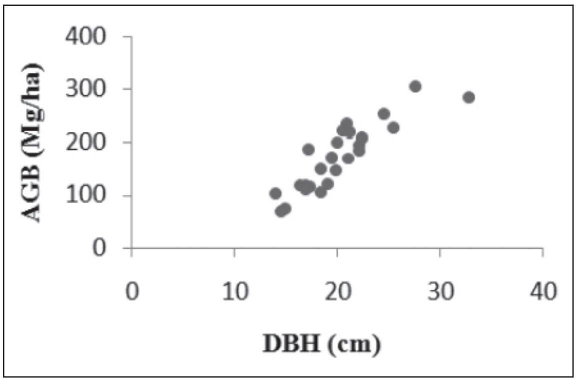

Fig. 2. Scatter plot between DBH and AGB (n=25).

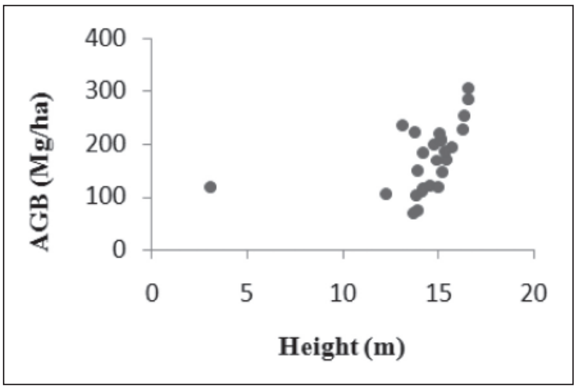

Fig. 3. Scatter plot between height and AGB (n=25).

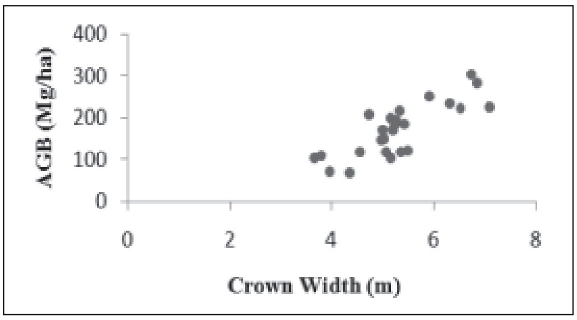

Fig. 4. Scatter plot between crown width and AGB (n=25).

The higher AGB for *R. apiculata* species could be due to the location of the species was found to be more on the landward area compare to the other species that mostly found in the seaward area. This is consistent with a study from Komiyama *et al.* (2008) who stated that higher AGB was found in stands that are more inland and low AGB found in the stands that are near to the sea. The reasons for the low AGB near the seaward relates to sea water salinity where the tree growth is stunted resulting in small value of DBH and less high tree (Komiyama *et al.,* 2008).

Previous study conducted by Norhayati and Latiff (2001) in Langkawi, Malaysia, found that *R. apiculata*produced higher AGB compared to mixed mangrove species (i.e., *R. mucronata*, *B. parviflora, B. gymnorrhiza, Ceriopstangal, Xylocarpusgranatum)*. Pellengrini *et al.* (2009) stated that DBH between 15.5-26 cm with height between 11.8-22.7 m in high structural forests tend to have greater value of AGB. A moderate structural forest with DBH class between 4.5-14.8 cm and height between 4.5-14.8 m has low value of AGB.

During the sampling, it was noticed that mangrove species in MMR that is closer to the seaward area (*B. parviflora, B. gymnorrhiza*and *A. marina*) have more tendency to be struck by lightning, which may reduce the number of individual trees with large size of DBH, height and crown width. More trees with smaller size of DBH, height and crown width were observed as part of regeneration process (Kautz *et al.,* 2011). Hence this may have contributed to the lower AGB.

From an analysis of 25 stands, there is a strong correlation (r=0.88) between DBH and AGB. This has been reported in many studies, i.e., (Komiyama *et al.,* 2008; Smith and Whelan, 2006), that DBH was an excellent predictor to estimate AGB of mangroves. The correlations between AGB and height show a moderate relationship (r=0.42). Even though height is considered as good predictor in estimating AGB, high density of trees and dense canopy layer in the mangroves area make it difficult to measure each individual species (Smith and Whelan, 2006).

Relationship between crown width and AGB shows that there is a strong correlation which suggests that crown width has the potential to be a predictor variable for estimating AGB. This is an agreement with Ross *et al.* (2011) who found that an introduction of crown width improved the prediction of biomass for *A. germinans, L. racemosa and R. mangle* in Southern Biscayne Bay, USA.

CONCLUSIONS

The results from the study showed that there are significant differences in the means of DBH, height, crown width, BA and AGB between *R. apiculata*, *B. parviflora and B. gymnorrhiza* and *A. marina* in the study area. In addition, there are positive relationships between DBH, height and crown width and AGB in the study area. Hence the findings from this study may contribute toward providing baseline data for carbon modelling which is useful in the climate change agenda.

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