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# Aboveground Biomass Production of *Rhizophora apiculata* Blume in Sarawak Mangrove Forest

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**Abstract: Problem statement:** Mangrove forests are found in tropical and subtropical coastal tidal regions. *Rhizophora apiculata* Blume is one of the most important species in mangrove forest. It is also one of the commercial mangrove timber species in Asia-Pacific region which dominates large areas of mangrove in this region. In order to understand forest ecosystem characteristics and to establish the proper management system, a precise estimation of biomass is necessary. The objective of this study is to quantify the aboveground biomass production and stem volume of *R. apiculata* in Awat-Awat mangrove forest, Sarawak. **Approach:** Seven representative trees were used in this study for sampling from February 2011 to March 2011. Allometric relationships were examined using either independent variable Diameter (D) or combination of quadratic of D and Height ($D^2H$). **Results:** The best fit of allometric equations were developed from the combination of quadratic of D and H (y = 0.055×0.948, $R^2$ = 0.98) which is more recommended to estimate biomass and stem volume of *R. apiculata* in Awat-Awat mangrove forest, Sarawak. Total aboveground biomass and stem volume of *R. apiculata* were 116.79 t $h^{-1}$ and 65.55 $m^3$ $h^{-1}$, respectively. **Conclusion:** Aboveground biomass and stem volume is closely related with tree diameter and height which indicates that aboveground biomass and stem volume will increase with increasing diameter and height of *R. apiculata*.

**Key words:** Aboveground biomass, allometric equation, *Rhizophora apiculata*, mangrove forest, commercial mangrove, timber species, expensive since, forest ecosystem, aboveground biomass

## INTRODUCTION

Mangroves are coastal forests that affects by tides, soil texture and marine salinity. This forest is found in tropical and subtropical coastal tidal regions. As a component of wetlands, mangroves has also been recognized as one of the most productive ecosystem which grow on sheltered shores and estuaries in the tropics and sub-tropical area (Gandaseca *et al*., 2011). Mangroves are very well adapted to grow in sea and brackish water. They have roots that typically grow in anaerobic sediment and receive oxygen through aerating tissue which communicates to the air through lenticels on the aerial roots and trunks (Lai *et al*., 1993).

The species *R. apiculata* Blume is one of the most important species in mangrove forest. It is also one of the commercial mangrove timber species in the Asia-Pacific region which is dominate large areas of mangrove in the region and often grows as pure stand (Ong *et al*., 2004). Mangrove forests in Malaysia, especially in Sarawak is about 175,153 ha which are found along the coastline (Bennet and Reynold, 1993). The values of mangroves consist of both monetary and non-monetary such as forest industry, fisheries industry, wildlife conservation, tourism and environment protection (Bennet and Reynold, 1993; Lai *et al*., 1993).

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Studies found that quantification of tree biomass can be very difficult and expensive since it involves tree felling, unearthing root systems, weighing and drying samples. Such activities are very expensive for any other purpose than research (Specht and West, 2003). Therefore, attention has been paid to develop techniques to estimate tree biomass from easily measured tree characteristics known as 'allometry'. Allometry is a powerful tool for estimating biomass production from easily measured tree characteristic such as stem diameter and height that are quantifiable in the field (Komiyama *et al*., 2005). Common allometric equations have been reported for aboveground biomass (Brown *et al*., 1989; Brown, 1997; Ketterings *et al*., 2001) and also for mangroves biomass (Komiyama *et al*., 2002; Ong *et al*., 2004; Nguyen and Ninomiya, 2007) elsewhere.

The estimation of aboveground biomass of mangrove is not only provides increasingly valuable means for making comparisons among ecosystems but could also use to evaluate the productivity pattern, nutrient cycle and energy flow (Kusmana *et al*., 1992). Furthermore, in order to understand the forest ecosystem characteristics, the measurement of tree biomass is important. The main objective of this study is to assess the biomass production of *R. apiculata* in Awat-Awat mangrove forest, Sarawak, Malaysia.

## MATERIALS AND METHODS

**Study site:** This study site is situated in Awat-Awat mangrove forest, Lawas Sarawak, Malaysia Fig. 1 and all of *R. apiculata* are 15 years old. Forest inventory and sampling were done from February 2011 to March 2011. Within sample plot (100×50 m), all tree heights and diameters were measured. The Diameter (D) of trees was measured using diameter tape at 30 cm above the highest prop-roots while tree Height (H) was measured using hypsometer (Komiyama *et al*., 2005). To estimate the aboveground tree biomass in this forest, seven tree samples were selected for sampling (2 small, 3 medium and 2 big size trees). In order to choose the representative trees for sampling, D and H data for all trees inside tree plot was sorted from the lowest to the highest value then divided into three classes namely small (0-12 cm), medium (12-24 cm) and big (24-36 cm). The mean values of each class were selected for calculation.

All selected trees were harvested and each sample tree was divided into several components named (1) stem, (2) branch and twig and (3) leaf.


Fig. 1: Location of study area showing Awat-Awat mangrove forest in Lawas, Sarawak, Malaysia

After each tree sample was completely felled, its main stem were separated into each component as 0-2, 2-4, 4-6 m log to the top. All tree components were weighted to acquire the total fresh weight. About±10 cm disc stem sample was taken from each part together with plant sample such as branches and leaves and brought to the laboratory. The sample was oven dried for two days. Total dry weight of those plant parts (stem, branch and leaf) were estimated as dry/fresh weight ratios (Brown, 1997). Allometric relationships were examined using independent variable D or combination of quadratic of D and H. The relationship between independent variable and components biomass and stem volume was described by a power function, $Yi = aD^b$ or $Yi = a (D^2H)^b$, where a and b are regression constant, D is tree diameter (cm), H is total height (m) and Yi is the dry biomass (kg) of a tree component i.e., stem, branch and leaf (Heryati *et al*., 2011). To choose the most appropriate biomass prediction of *R. apiculata*, both methods for stand biomass prediction were compared. The aboveground biomass was determined summing of the biomass of stem, branch and leaf. The total aboveground biomass of *R. apiculata* was calculated from the summation of tree biomass found from sampling plot. All data for biomass and stem volume were converted into hectares.

## RESULTS

The percent of aboveground biomass of *R. apiculata* was found 62.55% for stem, 31.89% for branch and 5.57% for leaf in the Awat-Awat mangrove forest. Biomass production of stem was higher than the leaf and branch biomass of *R. apiculata* Table 1.

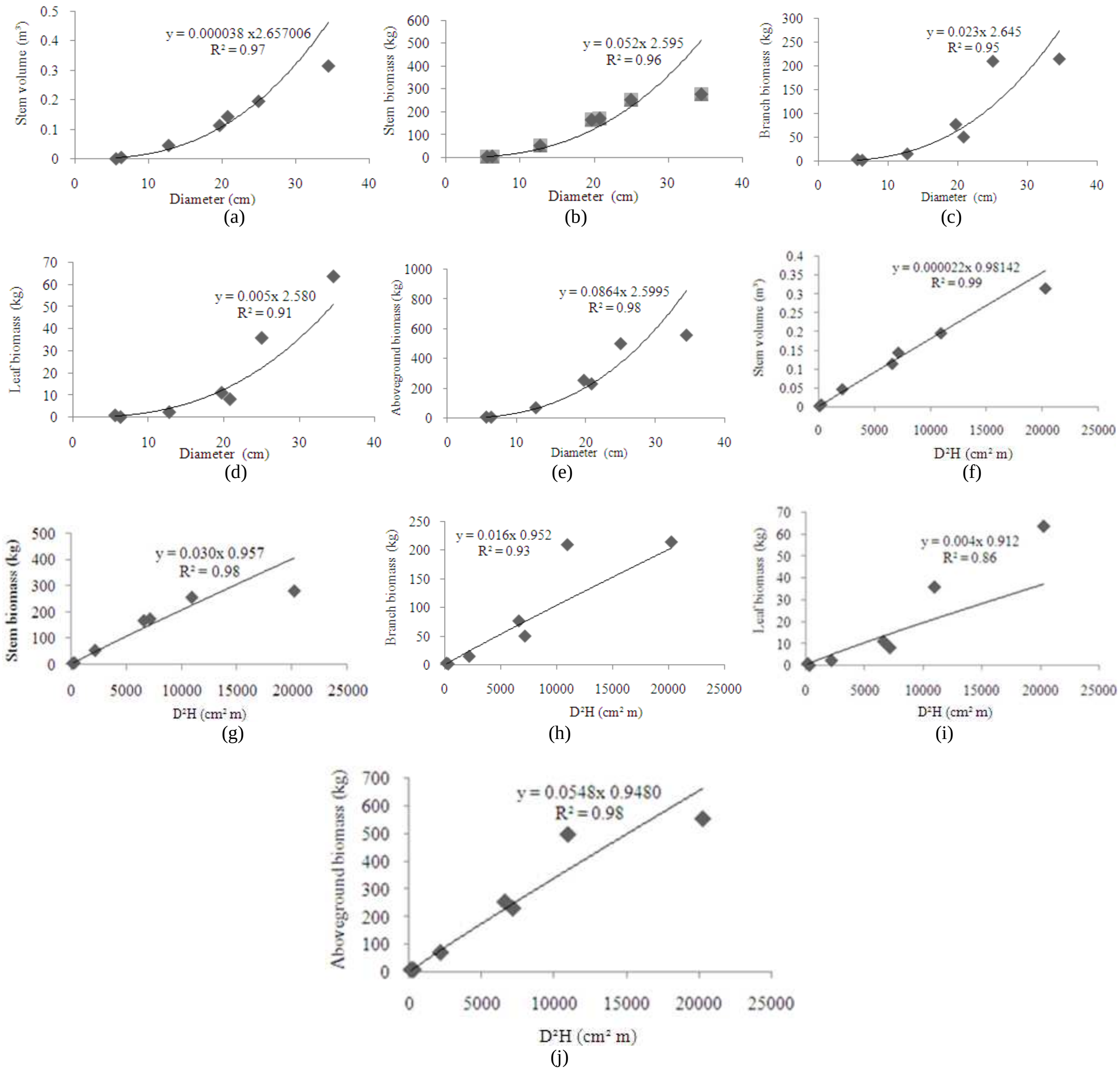


Fig. 2: Graphic relationship between (A) Diameter and stem volume; (B) Diameter and stem biomass; (C) Diameter and branch biomass; (D) Diameter and leaf biomass; (E) Diameter and aboveground biomass; (F) Combination of square of D and Height ($D^2H$) and stem volume; (G) $D^2H$ and stem biomass; (H) $D^2H$ and branch biomass; (I) $D^2H$ and leaf biomass and (J) $D^2H$ and aboveground biomass of *R. apiculata*

Table 1: Stem volume and biomass for different classes of diameter of *R. apiculata* in Awat-Awat mangrove forest, Lawas, Sarawak, Malaysia

| | | Mean ± SE | | | Biomass (t $h^{-1}$) | | | |
|---|---|---|---|---|---|---|---|---|
| Tree class (cm) | Stand density (trees $h^{-1}$) | Diameter (D) (cm) | Height (H) (m) | Stem volume ($m^3$ $h^{-1}$) | Stem (a) | Branches (b) | Leaves (c) | Above ground (a+b+c) |
| Small (0-12) | 364 | 7.95±0.1730 | 8.10±0.115 | 3.940 | 4.67 | 2.41 | 0.47 | 7.54 |
| Medium (12-24) | 376 | 16.65±0.254 | 14.43±0.227 | 30.71 | 34.62 | 17.70 | 3.14 | 55.45 |
| Big (24-36) | 100 | 29.81±0.679 | 18.37±0.265 | 30.90 | 33.76 | 17.14 | 2.89 | 53.80 |
| Total | 840 | 14.45±0.375 | 12.16±0.217 | 65.55 | 73.05 | 37.24 | 6.50 | 116.79 |

Table 2: Comparison of standing biomass in aboveground components of different mangrove species at different places

| Location | Species | Stand characteristics | Aboveground biomass (t $h^{-1}$) | Sources |
|---|---|---|---|---|
| Thailand | *Rhizophora apiculata* | Mean height 11.00 m | 159.0 | Christensen (1978) |
| Matang mangrove, Malaysia (4º50´ N, 100º36´ E) | *R. apiculata* | DBH ranged from 1.11-24.51 cm | 185.30 | Gong and Ong (1990) |
| Satun, Thailand (6º40´N, 100°01´E) | *Ceriops tagal* | Mean DBH 4.20 cm, mean height 4-6 m, density 10010 stem $h^{-1}$ | 92.24 | Komiyama *et al*. (2000) |
| Pulau langkawi, Malaysia (6º22´N, 99º48´E) | *Bruguiera parviflora*<br>*R. mucronata*<br>*B. gymnorrhiza*<br>*B. parviflora*<br>*C. tagal*<br>*Xylocarpus granatum* | Mean DBH 12.15 cm, mean height 13.09 m, density 849 stem $h^{-1}$ | 115.56 | Norhayati and Latiff (2001) |
| Kuala selangor, Malaysia (3º19´N, 101º14´E) | *B. parviflora* | Mean DBH, mean height and density of saplings and trees were 2.37 cm, 3.92 m and 565 saplings $ha^{-1}$; 9.84 cm, 10.27 m and 2030 trees $h^{-1}$, respectively | 144.47 | Hossain *et al*. (2008) |
| Okinawa, Japan (26º11´N, 127º40´E) | *Kandelia obovata* | Mean D at 10% of Height 5.41 cm, mean height 3.61 m, density 15475 tree $h^{-1}$ | 80.5 | Khan *et al*. (2009) |
| Lawas, Malaysia (4º56´N, 115º14´E) | *R. apiculata* | Mean DBH 14.45 cm, mean height 12.16, density 840 stem $h^{-1}$ | 116.79 | Present study |

Regression coefficients using tree diameter (D) were found 0.97, 0.96, 0.95, 0.91 and 0.98 with stem volume, stem biomass, branch biomass, leaf biomass and aboveground biomass, respectively Fig. 2. The regression models using combination of quadratic of D and H with stem volume, stem biomass, branch biomass, leaf biomass and aboveground biomass were 0.99, 0.99, 0.93, 0.86 and 0.98, respectively. Comparatively, these r-squares values were higher than those were found for D and tree components and almost of the r-square values were closed to 1. Therefore, quadratic of D and H was used to estimate the aboveground biomass of *R. apiculata*.

The average diameter of *R. apiculata* was 14.45±0.375 cm with the average height of 12.16±0.217 m in the sample plot of Awat-Awat mangrove forest. Medium class (12-24 cm diameter) trees was the dominate species of *R. apiculata* in this forest plot with the density of 376 trees $h^{-1}$ while the lower (100 trees $h^{-1}$) was found for big class (24-36 diameters) of trees. Stem volume was found higher for big class (30.90 $m^3$ $h^{-1}$) of mangrove followed by medium class (30.71 $m^3$ $h^{-1}$) and small class (3.94 $m^3$ $h^{-1}$). The estimated total aboveground biomass was found higher (55.45 ton $h^{-1}$) for medium class trees followed by big class (53.80 t $h^{-1}$) and small class (7.54 t $h^{-1}$) of mangroves in this mangrove forest.

## DISCUSSION

Biomass studies of mangroves have been done in many places of the world with many species i.e., *Avicennia marina*, *Bruguiera gymnorrhiza*, *Ceriops tagal*, *Kandelia obovata*, *Rhizophora mucronata* and *R. apiculata*. In present study, *R. apiculata* shows comparatively higher aboveground biomass than mixed mangroves (*R. apiculata*, *R. mucronata*, *B. gymnorrhiza*, *B. parviflora*, *C. tagal*, *Xylocarpus granatum*) in Langkawi Island, Malaysia (Norhayati and Latiff, 2001), *C. tagal* in Satun, Thailand (Komiyama *et al*., 2000) and *K. obovata* in Okinawa, Japan (Khan *et al*., 2009). Moreover, the biomass value of *R. apiculata* was comparable with the values recorded elsewhere Table 2. Studies revealed that the variation in above ground biomass depends on species but also on ecological circumstances and geographical location (Komiyama *et al*., 2008). Furthermore, Komiyama *et al*. (2008) noted that total aboveground biomass of *Rhizopora* sp. in the Pacific and Australia region ranges from 40.7-460 t $h^{-1}$. Norhayati and Latiff (2001) also reported 115.56 t $ha^{-1}$ of biomass for mixed mangrove (*R. apiculata*, *R. mucronata*, *B. gymnorrhiza*, *B. parviflora*, *C. tagal*, *X. granatum*) forests in Langkawi Island, Malaysia. In this present study, the level of aboveground biomass *R. apiculata* was lower compared to those reported by Christensen (1978); Gong and Ong (1990); Hossain *et al*. (2008) and Norhayati and Latiff (2001) globally (Table 2).

Table 3: Comparison of biomass proportion in different components of mangrove forest species at different places

| Location | Species | Total Above ground components (%) | Root (%) | Stem (%) | Branch (%) | Leaves (%) | Reproductive components (%) | Sources |
|---|---|---|---|---|---|---|---|---|
| Matang, Malaysia (4º50´N, 100º36´E) | *R. apiculata* | 75.50 | 24.50 | 55.00 | 12.00 | 8.50 | - | Gong and Ong (1990) |
| Satun, Thailand (6º40´N, 100º01´E) | *Ceriops tagal* | 50.20 | 49.80 | 29.68 | 13.13 | 7.39 | - | Komiyama *et al*. (2000) |
| Pulau langkawi, Malaysia (6º22´N, 99º48´E) | *B. parviflora* | | - | 90.00 | 9.10 | 0.90 | - | Norhayati and Latiff (2001) |
| Kuala selangor, Malaysia (3º19´N, 101º14´E) | *B. parviflora* | 88.82 | 11.18 | 58.26 | 23.20 | 6.80 | 0.57 | Hossain *et al*. (2008) |
| Okinawa, Japan (26º11´N, 127º40´E) | *K. obovata* | 52.88 | 47.20 | 30.30 | 18.90 | 3.68 | - | Khan *et al*. (2009) |
| Lawas, Malaysia (4º56´N, 115º14´E) | *R. apiculata* | | - | 57.30 | 35.09 | 7.61 | - | Present study |

The proportions of biomass in this present study are unlikely among all components of *R. apiculata*. *R. apiculata* shows comparatively higher percentage of stem biomass (62.55%) compared to branch (31.89%) and leaf (5.57%). However, Heryati *et al*. (2011) mentioned that the amount of the stem biomass is closely related to the production of trees obtained through photosynthesis which is generally stored in the trunk. Similarly, Hossain *et al*. (2008) reported the same proportions of biomass stem>branch>leaf>reproductive components for *B. parviflora* in Kuala Selangor, Malaysia Table 3. All biomass proportion values found for *R. apiculata* in this present study are comparable with other studies elsewhere Table 3. The variation in biomass may be related to the ecology, species, plant density, growing season, plant age and global positioning of mangrove forests.

## CONCLUSION

The combination of quadratic of D and H is recommended as variables for stem volume and biomass quantification of *R. apiculata* in Awat-Awat mangrove forest, Lawas, Sarawak. In addition the aboveground biomass and stem volume is related with tree diameter and height which indicates that aboveground biomass and stem volume will increase if diameter and height also increase. Total Aboveground Biomass in Awat-Awat mangrove forest Lawas is 116.79 t $h^{-1}$.

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