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The diameter increment of selected tree species in a secondary tropical forest in Sarawak, Malaysia

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Abstract. *Karyati, Ipor IB, Jusoh I, Wasli ME. 2017. The diameter increment of selected tree species in a secondary tropical forest in Sarawak, Malaysia. Biodiversitas 18: 304-311.* The diameter at breast height (DBH) increments of dominant tree species in a secondary forest can determine forest growth in the area. This study was conducted to investigate the DBH increments of the nine dominant tree species in a secondary tropical forest. A total number of 180 trees representing nine species, seven genera, and six families were selected for the assessment of DBH increments during two years of study. Those nine species, namely: *Acacia mangium* Willd. (2.33 cm year^{-1}), *Endospermum diadenum* (Miq.) Airy Shaw (1.05 cm year^{-1}), *Cratoxylum arborescens* Blume. (0.96 cm year^{-1}), *Vernonia arborea* Buch. Ham. (0.96 cm year^{-1}), and *Cratoxylum glaucum* Korth. (0.80 cm year^{-1}) had shown a high growth rate during the assessment, while the other four species such as *Macaranga gigantea* Mull. Arg., *Macaranga triloba* Mull. Arg., *Euodia glabra* (Bl.) Bl., and *Vitex pubescens* Vahl. had 0.53, 0.48, 0.37, and 0.30 cm year^{-1} in DBH increments, respectively. The average DBH increments for the entire selected species was 0.86 cm year^{-1} for periodic measurement and 0.75 cm year^{-1} for monthly measurement. This information is needed in order to understand the succession process in the secondary forests. It is important for the selection of the suitable species in a reforestation and a rehabilitation projects.

Keywords: Diameter increment, fast growing species, secondary forest, selected species

INTRODUCTION

A secondary forest is the type of vegetation resulted after a forest or woodland area have been disturbed or cleared for shifting cultivation prior to abandonment (Johnson and Miyanishi 2007; Keddy 2007). After field abandonment, the secondary forest develops naturally (Van Do et al. 2010). The secondary forests are reflected in their structure and extent of vegetative cover, as well as their composition in terms of dominant and secondary species (Mittelman 2001). Typical swidden fallow secondary forest vegetation includes many forest patches at different stages of succession. The structure of swidden fallow secondary forests changes rapidly at the young stages. The principal structural changes include increased canopy height and tree diameter, a stratification of the tree vegetation and a reduction in the number of stems per a considered area (Perera 2001). The patterns of stand development are based on tree physiology, soils, and micrometeorology. The rates of tree growth in tropical forests reflect the variation in life history strategies that contribute to the determination of species' distributional limits, set limits to timber harvesting and control the carbon balance of the stands (Baker et al. 2003). Uzoh and Oliver (2008) hypothesized that the increment of the trees was influenced by tree size and vigor effects, site effects, competitive effects and regional effect as well as relative competitive status to neighboring trees and the impact of land use management.

In addition, it is quite certain that the plant growth, development and its productivity depend on the internal factors (genetic or hereditary) and external factors (surrounding environmental). The environmental factors affecting the planting site encompass climate (meteorological variables), edaphic (soil), biotic (living or organisms), physiographic (elevation) and anthropogenic effects (Pancel 1993; Gopalaswamy 1994). Abazari and Talebi (2008) described the duration of development of a stand and transition from one stage to another varied among the forest communities. The growth characteristics and dynamic of the stands varied in different development stages. Lynch and Huebschmann (1992) clarified that large variances in diameter increment will tend to be associated with high covariance between increment and basal area at the end of growth period. In addition, the annual diameter increment was also influenced by planting space (Mawazin and Suhaendi (2012) and silvicultural treatments (Venturoli et al. 2015).

Seydack et al. (2011) pointed out that variation in stand-level growth was affected by species-inherent and resource factors as well as site-climate interactions. Rüger et al. (2016) stated the most important trait determining growth characteristics was wood density. In addition, intrinsic growth rates were related strongly to adult stature, while all traits contributed to light response. Hérault et al. (2011) added that the maximum absolute diameter growth rates increased with the increase of adult stature and leaf 13C and decreased with the increase wood density. The effect of growth-mediated ontogenic changes on the localization of water and carbohydrate storage within a tree is a result of sapwood and heartwood dynamics throughout tree ontogeny (Lehnebach et al. 2016).

There were few studies discussing on the diameter increment for different tree species in the tropical forest in Malaysia (Primack et al. 1985; Hassan et al. 2009; Mohammad and Suratman 2011). However, it is found out that there are still limited studies focusing on the diameter at breast height (DBH) increment of selected dominant species in secondary tropical forests, whereas the DBH increments of the major species represent the rates of tree growth on the site. The objective of this research was to determine the DBH increments of nine dominant tree species in a secondary forest. This study addresses the following questions: (i) What are the variations of the DBH increment according to species and DBH class as well as measurement period? (ii) What is the dominant tree species growth in terms of DBH increment? The information on DBH increment of the dominant species that characterized a secondary forest is very important and is needed very much. Because of a large number of species was found in the secondary forests, the selection of the representative species, which will be used to determine the vegetation growth in secondary forest, is crucial. The paper addresses basic understanding about the development during succession of secondary forest in general. The result is also necessary to consider species selection, especially for reforestation and rehabilitation projects in Malaysia and South East Asia.

MATERIALS AND METHODS

The study area

The study was carried out at a secondary forest of Universiti Malaysia Sarawak (Unimas) (01°28.111'N 110°26.234'E) in Kota Samarahan, Sarawak, East Malaysia (Figure 1). The forest area of Unimas campus covers about 245 ha of a total area 700 ha. The study site is situated approximately 30 km southeast, one hour drive, from Kuching the capital of Sarawak. The secondary forest is estimated about 30 years old (30 years after abandonment of shifting cultivation). The soils of Samarahan series include Bijat family and Gley soils based on the Sarawak Soil Classification Systems. Samarahan unit is covered by mainly secondary growth (shifting cultivation-wet rice) and generally between 0-20 feet above sea level (asl) (Andriesse 1972). Climate data were collected from the Meteorology Department of Malaysia (Sarawak Branch) at Kuching Airport Station, which is about 30 km from the study site. During the last 20 years, the study site receives average annual of 4,323.3 mm year^{-1} of rainfall, 247 rain days, 26.3°C of monthly temperature, and 85.3% of monthly relative humidity. Thus, it was categorized as very humid area with vegetation of tropical rain forest (Karyati 2013).

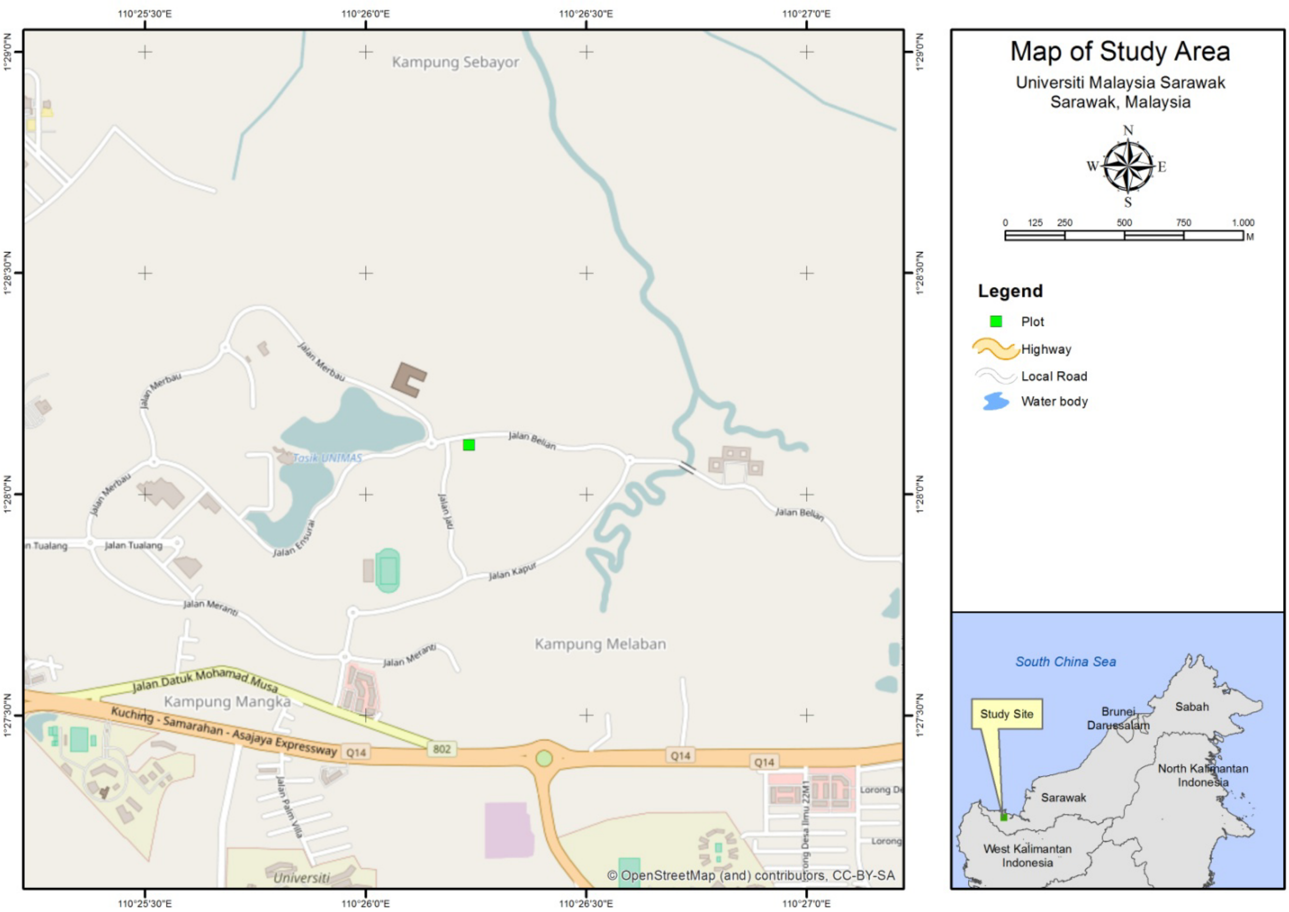

Figure 1. Map of the study area in Kota Samarahan, Sarawak, East Malaysia

Data collection and analysis

The initial survey of secondary forest was conducted in one hectare plot. All woody plants which have a diameter at breast height (DBH) of more than 2 cm within the plot were enumerated and identified. The numbers of recorded species were 52 species of 1332 individuals per hectare. To obtain the representative species of a secondary forest in the study site, the selection of tree species was based on consideration of the dominant species. The selected tree species (except *A. mangium*) included the dominant species in terms of stem numbers within the plot and Importance Value Index (IVi) in the study site. The DBH of selected trees at the beginning of assessment period represented the entire DBH distribution class as shown in Table 1. The 180 trees from nine species (20 trees for each species) were selected for DBH increment assessment in the field. These nine species were *Acacia mangium* Willd., *Cratoxylum arborescens* Blume, *Cratoxylum glaucum* Korth, *Endospermum diadenum* (Miq.) Airy Shaw, *Euodia glabra* (Bl.) Bl., *Macaranga gigantea* Mull. Arg., *Macaranga triloba* Mull. Arg., *Vernonia arborea* Buch. Ham., and *Vitex pubescens* Vahl. *A. mangium* trees was selected as a comparison, a represent of plantation trees and adjacent to secondary forest.

The DBH increment of 180 trees was measured for every 4 months using a DBH tape between December 2009 and December 2011 (6 times in total). The DBH of each tree was measured using a diameter tape at 1.3 m height from ground surface. For a smaller subset of 30 trees, the measurement of them in every month uses a dendrometer band (Series 5 Manual Band Dendrometer from AEC) for whole one year (July 2010-July 2011). With this in mind, three to four trees were selected to represent each species. The dendrometer band was attached slightly above the level of diameter tape. The initial reading of dendrometers of every selected tree was recorded and the following records were taken every month for the next 12 months. The assessment of DBH increment using dendrometer band had to be stopped because 14 of 30 of Series 5 Manual Band Dendrometer from AEC have gone since 20 July 2011. Meanwhile, the assessment of diameter tape was continued until December 2011. The DBH increment value of each tree was determined by subtracting its initial recorded DBH from its final recorded DBH. The DBH increment rate was DBH increment value divided by the number of years. Dendrometer bands measured changes in the circumference of the tree. For this assessment, the changes in tree diameter were calculated as the change in the circumference, and then divided by π. The analysis of variance (ANOVA) and the post hoc test (Tukey HSD) were used to compare the DBH increments among selected species. The statistical analysis was carried out using SPSS version 18 for Windows (SPSS Inc., 2012).

RESULTS AND DISCUSSION

The variations of DBH increment

Variations across species and DBH class

The DBH increments of the dominant species in secondary forest varied across species and class. There was significant difference between selected species as shown in Table 2. The variation of DBH increment was obtained through the tree between and within the selected species in a secondary forest being studied. Ogaya et al. (2003) reported that mean stem diameter increment showed a great variation depending on the species. The DBH increment rates of nine selected tree species were illustrated in Figure 2. While *A. mangium*, *C. arborescens*, and *C. glaucum* showed high DBH increment for all DBH classes, the DBH increments of *E. diadenum* were higher than those three trees with DBH > 5 cm. Meanwhile, the highest DBH increment of trees was *V. arborea* with 20-25 cm in DBH class. On the other hand, the other four species such as *E. glabra*, *M. gigantea*, *M. triloba*, and *V. pubescens* indicated low DBH increment during the 2-years measurement period. Their DBH increments were relatively constant for every DBH class. The figure illustrated the trees included to the higher DBH class tended to have higher DBH increment. The high diameter class showed the highest increment values (Marsoem 2013).

Variations across measurement period

During the assessment periods, the cumulative DBH increments differed among the tree species for both periodical (by diameter tape) and monthly (by dendrometer band) measurements as seen in Figures 3 and 4. In these two assessments, the five selected species of *A. mangium*, *C. arborescens*, *C. glaucum*, *E. diadenum*, and *V. arborea* had higher cumulative DBH increments. In this regards, during the assessment period, between six-time measurement, *A. mangium* had shown the highest of DBH increment among nine selected species. The highest average DBH increment of *A. mangium* (0.91 cm) and *E. diadenum* (0.48 cm) was in December 2010. Meanwhile, other two species of *C. arborescens* and *C. glaucum* had the highest average DBH increment of 0.41 cm in December 2011 and 0.34 cm in April 2010, respectively. On the other hand, low DBH increments were shown by *E. glabra*, *M. gigantea*, *M. triloba*, and *V. pubescens*. During the 2-year period, these four species only showed the relatively high DBH increment at the end of assessment (December 2011) (Figure 3).

Figure 4 indicated cumulative DBH increments of nine selected species were assessed by dendrometer band. The result showed a slight different average of DBH increment for each species every month. It was probably due to a few samples (only three to four trees) per species were recorded. The average of DBH increment varied from 0.14 to 0.16 cm month^{-1}, 0.02 to 0.11 cm month^{-1}, 0.02 to 0.13 cm month^{-1}, and 0.04 to 0.17 cm month^{-1} for *A. mangium*, *C. arborescens*, *C. glaucum*, and *E. diadenum*, respectively. The other three species, such as *E. glabra*, *M. gigantea*, and *M. triloba* showed the lowest record of average DBH increment at 0.01 cm month^{-1}, while *V. arborea* and *V. pubescens* pointed at 0.02 cm month^{-1} of the average DBH increment. At last, the highest DBH increments were recorded at 0.03, 0.06, 0.08, 0.10, and 0.11 cm month^{-1} for *E. glabra*, *M. gigantea*, *M. triloba*, *V. arborea*, and *V. pubescens*, respectively.

The average DBH increment of *A. mangium* and *E. glabra* was relatively constant (0.16 and 0.03 cm month^{-1}, respectively) at the first three months of the assessment period. The average DBH increment of *C. glaucum*, *E. diadenum*, and *V. arborea* had increased gradually since August to December 2010, though their diameter had growth very slowly until the end of the assessment (July 2011). On the other hand, the average DBH of *M. gigantea* and *M. triloba* had increased slightly during August to October 2010. In this regards, these two species reached the greatest increment in February 2011. It was revealed that the variation of DBH increment was also found on trees from similar species. This might due to the response of each species to the growth process, which is different among species as well as among trees of similar species. The internal and external factors had affected tree growth and development. The internal factors comprised genetic factor, plant growth process, internal growth property, and physiological process. On the other hand, the soil properties, climatic factors, and response plant to environment were included as external factors. It could be concluded that the variation of DBH increment was clearer on monthly measurement than that of periodical measurement. Miya et al. (2009) explained that variation on diameter growth of different sapling species in an uneven-aged mixed stand was influenced by individual growth conditions, but it was negatively related by the wood density (Keeling et al. 2008).

DBH increment of selected tree species

During 2-year assessment (December 2009–December 2011), the highest DBH increment was reached by *A. mangium* (2.33 cm year^{-1}), followed by *E. diadenum* (1.05 cm year^{-1}), *C. arborescens* (0.96 cm year^{-1}), *V. arborea* (0.96 cm year^{-1}), and *C. glaucum* (0.80 cm year^{-1}). On the other hand, *M. gigantea* (0.53 cm year^{-1}), *M. triloba* (0.48 cm year^{-1}), *E. glabra* (0.37 cm year^{-1}), and *V. pubescens* (0.30 cm year^{-1}) had low DBH increments (Table 3). Furthermore, the average of DBH increment for all selected tree species was 0.86 cm year^{-1}. In this regards, the DBH increments of *E. glabra* and *V. pubescens* showed significant difference to *E. diadenum* and *A. mangium*. Also, there was no significant difference of DBH increment between *C. arborescens*, *C. glaucum*, *M. gigantea*, *M. triloba*, and *V. arborea*.

The average of DBH increment of selected tree species which is recorded monthly by dendrometer band is also shown in Table 3. During 1-year measurement period (July 2010-July 2011), *A. mangium*, *E. diadenum*, *C. glaucum*, *C. arborescens* and *V. arborea* had an average of DBH increment of 1.85, 1.09, 0.92, 0.80, and 0.61 cm year^{-1}, respectively. While other four species namely *V. pubescens* (0.58 cm year^{-1}), *M. triloba* (0.40 cm year^{-1}), *M. gigantea* (0.36 cm year^{-1}), and *E. glabra* (0.26 cm year^{-1}) showed slower growths. Overall, the average DBH increment of all selected trees was recorded at 0.75 cm year^{-1} in this assessment.

Among the nine selected tree species, *A. mangium* showed the highest DBH increment. This species grew at open area which was adjacent to the study site. The species was the only planted trees, which then were compared to the others selected species of secondary forest. As light is abundantly available in any open areas, it is suggested that this factor may support the maximum growth of *A. mangium* trees. In this study, the tree samples of *A. mangium* include the young trees with DBH of less than 18 cm. DBH increment is greater in the young stands than in the old ones (Feldpausch et al. 2007). The average of DBH increment of *A. mangium* (2.33 cm year^{-1} of measurement periodically and 1.85 cm year^{-1} of measurement monthly) in this study was similar to the study conducted by Lim (1993). Lim (1993) concluded that DBH and height of *A. mangium* are considerably varied with age and site. The MAI (mean annual increment) for DBH ranged from 1.8 to 7.4 cm year^{-1}.

Table 1. The number of selected trees in terms of species and DBH class on DBH increment assessment in a secondary forest.

Species	Family	Size class (cm)				Total
		0.0-5.0	5.1-10.0	10.1-15.0	>15.1	
Acacia mangium Willd.	Fabaceae	9 (0)	8 (3)	2 (0)	1 (0)	20 (3)
Cratoxylum arborescens Blume.	Clusiaceae	2 (1)	14 (1)	4 (0)	0 (1)	20 (3)
Cratoxylum glaucum Korth.	Clusiaceae	6 (0)	14 (4)	0 (0)	0 (0)	20 (4)
Endospermum diadenum (Miq.) Airy Shaw	Euphorbiaceae	5 (0)	8 (1)	6 (2)	1 (0)	20 (3)
Euodia glabra (Bl.) Bl.	Rutaceae	4 (0)	10 (1)	5 (2)	1 (0)	20 (3)
Mcaranga gigantea Mull. Arg.	Euphorbiaceae	2 (0)	7 (3)	6 (1)	5 (0)	20 (4)
Macaranga triloba Mull. Arg.	Euphorbiaceae	2 (0)	11 (2)	3 (1)	4 (0)	20 (3)
Vernonia arborea Buch. Ham.	Asteraceae	0 (0)	5 (2)	6 (1)	9 (0)	20 (3)
Vitex pubescens Vahl.	Urticaceae	1 (0)	8 (2)	10 (2)	1 (0)	20 (4)
Total		31 (1)	85 (19)	42 (9)	22 (1)	180 (30)

Table 2. The analysis of variance for DBH increment of selected tree species in a secondary forest.

	Sum of squares	df	Mean square	F	Significance
Among species	60.723	8	7.590	17.090	.000
Within species	75.949	171	0.444		
Total	136.672	179			

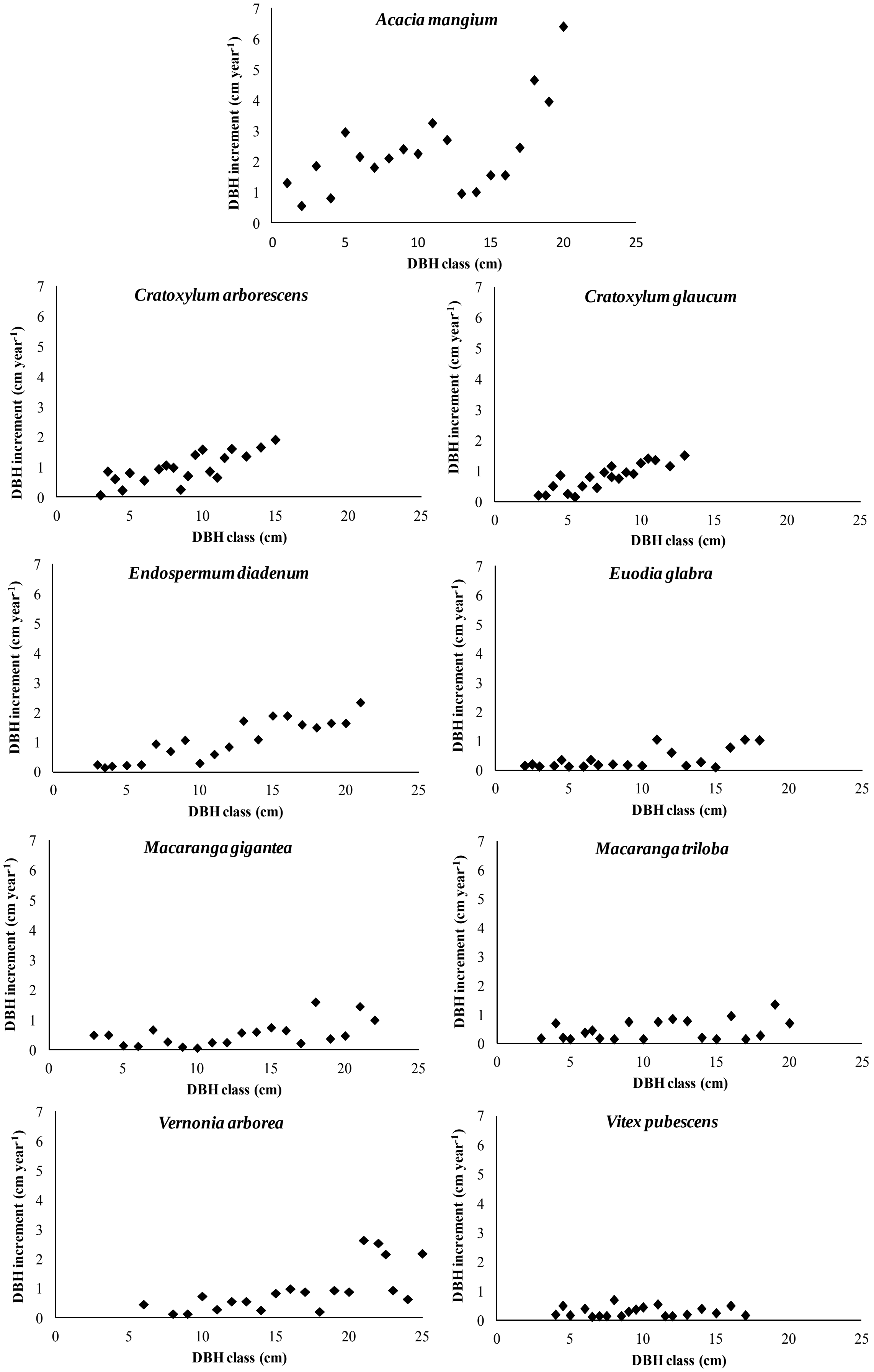

Figure 2. The DBH increment rates of nine selected species on measurement periods from December 2009 to December 2011

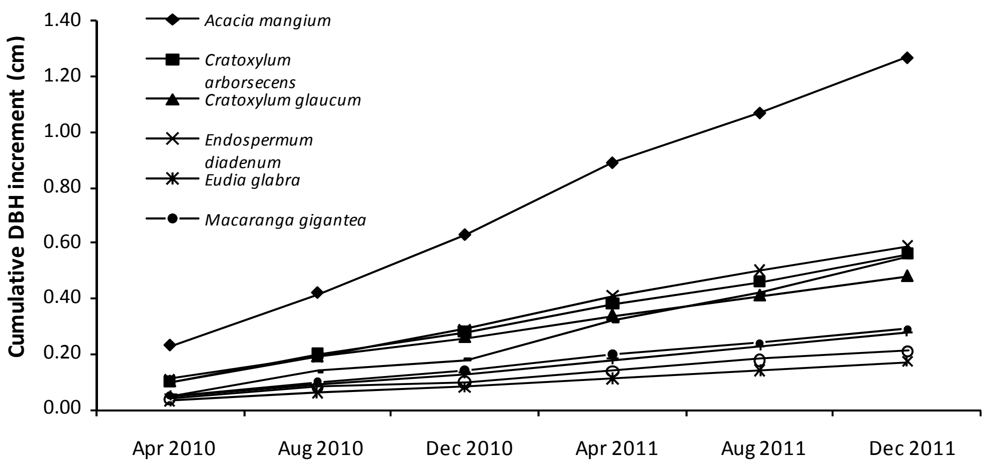

Figure 3. Cumulative DBH increments of nine selected species which were recorded periodically by diameter tape

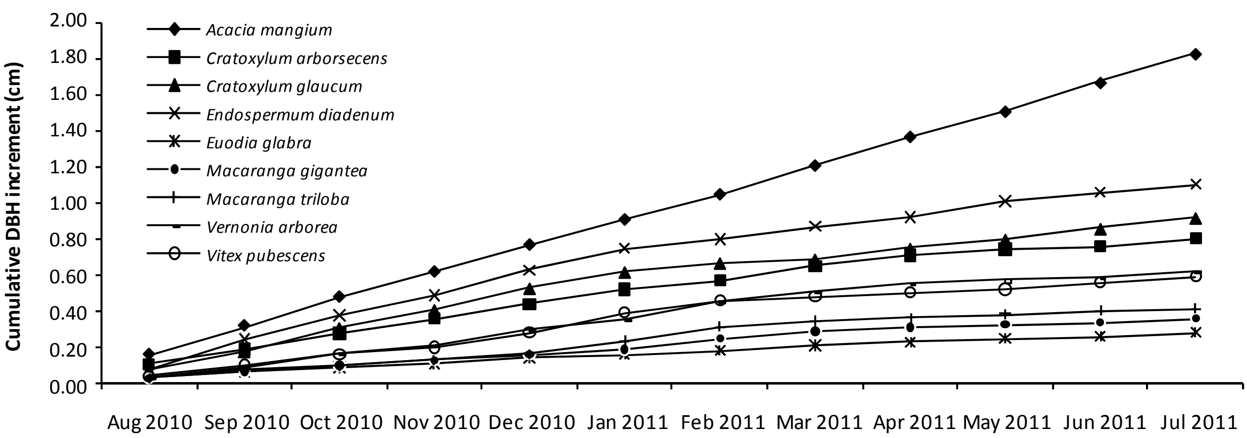

Figure 4. Cumulative DBH increments of nine selected species which were recorded monthly by dendrometer band

The average DBH increment of selected tree species (except *A. mangium*) varied from 0.30 to 1.05 cm year^{-1}. This result was higher compared to the diameter increment of ten selected tree species (ranged from 0.09 to o.57 cm year^{-1}) in Kuala Keniam, Taman Negara Pahang, Malaysia (Mohammad and Suratman 2011). In Hassan et al. (2009) study at secondary forest of Pasoh Forest Reserve Area, Negeri Sembilan, Malaysia, the diameter increments of *Azadirachta excelsa* and *Intsia palembanica* were 1.06 cm year^{-1} and 0.97 cm year^{-1}. Primack et al. (1985) used long-term forestry data from Sarawak and estimated mean annual diameter increments of between 0.4 and 3 mm year^{-1} in several *Artocarpus* and two *Ficus* species. The growth of *Artocarpus* saplings increased as fast as the adults. Additionally, the diameter growth is highly variable among species and size classes on a large number of tropical trees (Lang and Knight 1983; Ogaya et al. 2003).

To conclude, the result indicated that the variation of DBH increments of selected tree species in secondary forest, were affected by different species, DBH class, and measurement period during the assessment. The five species namely, *A. mangium* (2.33 cm year^{-1}), *E. diadenum* (1.05 cm year^{-1}), *C. arborescens* (0.96 cm year^{-1}), *V. arborea* (0.96 cm year^{-1}), and *C. glaucum* (0.80 cm year^{-1}) had high DBH increment during the assessment. While the other four species namely, *M. gigantea*, *M. triloba*, *E. glabra*, and *V. pubescens* showed low DBH increment. These four species had 0.53, 0.48, 0.37, and 0.30 cm year^{-1} in DBH increment. The tree growth of secondary forest reflects the development during secondary succession process as well as their floristic structure, composition, and diversity. The development and changes of floristic composition and diversity of plant during early stages of secondary succession process was mostly influenced by

Table 3. Average of DBH increment (± SD) and ranges (minimum-maximum) of selected tree species in a secondary forest

Species	n	i (cm year^{-1})$^{*)}$	SD	$i_{min.}$	$i_{max.}$	Ratio
Periodical measurement (by diameter tape)						
Acacia mangium Willd.	20	2.33^{c}	(±1.41)	0.55	6.40	11.64
Cratoxylum arborescens Blume.	20	0.96^{ab}	(±0.51)	0.06	1.90	29.23
Cratoxylum glaucum Korth.	20	0.80^{ab}	(±0.42)	0.15	1.50	10.00
Endospermum diadenum (Miq.) Airy Shaw	20	1.05^{b}	(±0.70)	0.15	2.35	15.67
Euodia glabra (Bl.) Bl.	20	0.37^{a}	(±0.34)	0.10	1.05	10.50
Macaranga gigantea Mull. Arg.	20	0.53^{ab}	(±0.42)	0.07	1.60	24.62
Macaranga triloba Mull. Arg.	20	0.48^{ab}	(±0.35)	0.15	1.35	9.00
Vernonia arborea Buch. Ham.	20	0.96^{ab}	(±0.79)	0.15	2.65	17.67
Vitex pubescens Vahl.	20	0.30^{a}	(±0.17)	0.13	0.70	5.60
All selected species	180	0.86	(±0.87)	0.06	6.40	106.67
Monthly measurement (by dendrometer band)						
Acacia mangium Willd.	3	1.85	(±0.09)	1.78	1.96	1.10
Cratoxylum arborescens Blume.	3	0.80	(±0.17)	0.60	0.92	1.53
Cratoxylum glaucum Korth.	4	0.92	(±0.08)	0.84	1.01	1.20
Endospermum diadenum (Miq.) Airy Shaw	3	1.09	(±0.13)	0.99	1.24	1.25
Euodia glabra (Bl.) Bl.	3	0.26	(±0.01)	0.25	0.28	1.12
Macaranga gigantea Mull. Arg.	4	0.36	(±0.22)	0.22	0.69	3.14
Macaranga triloba Mull. Arg.	3	0.40	(±0.10)	0.34	0.52	1.53
Vernonia arborea Buch. Ham.	3	0.61	(±0.20)	0.40	0.80	2.00
Vitex pubescens Vahl.	4	0.58	(±0.07)	0.48	0.64	1.33
All selected species	30	0.75	(±0.47)	0.22	1.96	8.91

Note: n, i, SD, i_{min}, and i_{max} are number of trees, average of DBH increment, standard deviation, minimum value of DBH increment, and maximum value of DBH increment. The ratio is calculated by dividing the maximum value by the minimum value. *)Different letters in the column indicate a significant difference at 5% level by Tukey HSD test among different selected species.

secondary succession process and fallow period in various ages of secondary forests after slash and burn process. The species composition at abandoned lands after burning begins to change after 20 years of abandonment. However, the late pioneer species and secondary species were common in this site (Karyati et al. 2013). The diameter increment of dominant tree species determine growth rate in the secondary forest. With the expansion of their area and the depletion of primary forests, secondary forests have become increasingly important for maintaining larger habitat for biodiversity conservation. The information on the sequence of change in community composition of secondary forests is needed to predict the succession of future forests. The findings can be considered to select the suitable species in rehabilitation and reforestation projects in Malaysia and South East Asia in general.

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