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Community Structure, Diversity and Total Aboveground Biomass of Four Pioneer Species at Universiti Teknologi Malaysia Secondary Forest

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Abstract Forest compositions are different according to variation of biogeography, habitat and disturbances. Since trees provide resources and habitat to animals, the diversity of trees is a fundamental to tropical forest diversity. When diversity and forest composition at the equilibrium level it becomes large reservoir of aboveground biomass and carbon stock. At the same time forest aids in reducing amount of carbon in the atmosphere. Therefore, this study was conducted to determine the species composition, diversity and aboveground biomass of pioneer species at secondary forest. Four pioneer species were chosen because they were the dominant species in the forest. This study was conducted at Universiti Teknologi Malaysia's secondary forest. Fifty plots of 10 m x 10 m were established randomly with total sampling area 0.5 ha. All trees with ≥5 cm diameter at breast height (dbh) were tagged and measured. To identify species diversity among these four species, Shannon Weiner Index (1949) has been applied. Then, aboveground biomass of pioneer species were estimated using Kato's equation. Total of 256 trees of pioneer species were recorded from fifty plots survey. The dbh ranged between 5 until 77.7 cm and height between 3.2 until 11.5 meter was documented. A total of 1094 t/ha of aboveground biomass was recorded from four pioneer species. *Macaranga gigantea* becomes the major contribution of forest aboveground biomass since the number of diameter was greater which influenced the number of aboveground biomass which was 1063 t/ha.

Keywords Secondary forest, Pioneer species, Diversity, Aboveground Biomass

1. Introduction

Nowadays, tropical forest is in threatening stage where it faced massive human disturbances from illegal forest logged, deforestation and plantation. This situation happened due to high demand for land area for urban development due to increase in population in towns and cities. Tropical deforestation accounted almost 12% of anthropogenic CO_2 emissions in 2008 and keep increasing every year [1]. Large amount of green areas have been changed into non forest functions which lead to carbon increased in the atmosphere. Studies in forest ecology management found that trees act as carbon sink where they reduced amount of carbon in the environment as a benefit to the global climate change [2].

Although trees are well known in mitigating amount of carbon in the atmosphere from photosynthesis process, deforestation activities keeps increasing. Deforestation altered the primary forest into secondary forest and mostly located at urban areas especially in developing countries. In Malaysia, from 1990 to 2005 the forest cover has decreased to 1,486,000 ha annually and predicted to achieve 6.64% of total Malaysian forest area [3]. Primary rain forest in Kalimantan, Indonesia also faced the same situation where their primary forest lost through exploitation, large scale fires and conversion to agriculture. Naturally, forest will encountered with disturbance but with small scale such as tree fall because of tree diseases. In summary, forest in developing country including Malaysia faced with large scale of disturbance which is from human intervention for large scale developments [4].

Generally, formation of forest gap was due to human disruption that stimulates growth of secondary forest species. The bigger the gap the greater the solar radiation reaches to the forest floor. This process initiates the seed of pioneer species to grow since main attributes of pioneer species is tolerant to high temperature and poor nutrient condition [5]. Their seeds are also shade-intolerant where they required direct sunlight to germinate, and once they established at the secondary area it partially fill the forest gaps and create forest canopy [6]. Secondary forest also

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dominated by fast growing species, which are mostly pioneer species, compared to primary forest [7]. Secondary forest also higher in term of photosynthesis rate since much nitrogen accumulates after forest has been disturbed [8]. Pioneer species at secondary forest contained higher photosynthetic pigments therefore the photosynthesis rate much higher than primary forest [9]. In Table 1 below were lists of pioneer species that have been recorded from previous researchers which have been done at tropical area of secondary forest.

After primary forests were disturbed, it will enter a new phase of regeneration. Secondary forest replaced the primary forest which dominated with pioneer species filling the forest gap. This regeneration is important where it will determine future tropical forest structure, dynamics and composition [10]. Moreover, the heterogeneity of forest depends by gap dynamics in tropical forests especially light quality and intensity [9].

Table 1. List of Pioneer Species at Tropical Secondary Forest

Author and Year	Pioneer Species
Aryal, 2014 [11]	*Lonchocarpus xuul* Lundell *Lysiloma latisiliqua* (L.) Benth. *Croton arboreus* Millsp. *Bursera simaruba* (L.) Sarg. *Hampea trilobata* Standl. *Piscidia piscipula* (L.) Sarg. *Chysophyllum mexicanum Brandegee* ex Standl.
Ngo, 2013 [12]	*Ixonanthes reticulata* *Campnosperma auriculata*
Goldsmith, 2011 [13]	*Dillenia suffruticosa* *Adinandra dumosa* *Campnosperma auriculata* *Dicranopteris spp.* *Nepenthes gracilis*
Hashim, 2010 [14]	*Glochidion obscurum* Blume *Lagerstroemia speciosa* (l.) Pers. *Vitex pinnata* L.
Breugel, 2011 [15]	*Trichospermum mexicanum* *Trema micrantha* *Cecropia peltata* *Luehea speciosa* *Schizolobium parahyba* *Ochroma pyramidale* *Vernonia patens*

Understanding of floristic composition from the successional secondary forest after disturbances is important to identify the recovery process and planning for forest management. During forest succession, it changed the plant community over passage of time [16]. Therefore, this study investigates four pioneer species composition, diversity level and aboveground biomass in monitoring status of secondary forest. Carbon stock estimation was crucial to examine carbon reduction from the atmosphere. In completing this study the research question was what is the total amount of aboveground biomass accumulate at secondary forest.

2. Materials and Method

2.1. Study Site

The study area is located at Universiti Teknologi Malaysia (UTM) campus in Skudai. This university is situated at southern tip of Peninsular Malaysia. This university covered with 1145 hectares of land areas which consist of buildings for administration, hostels, faculty and staff residence. It also comprises plantation such as palm oil, rubber and fruit trees and lastly secondary forest which emerged after university development process. Among 22 public universities in Malaysia, UTM has the largest land areas relative to Universiti Putra Malaysia (UPM) Campus Bintulu only comprised with 715 hectares of land. UPM Bintulu also covered with secondary forest affected from campus development. Therefore, this secondary forest becomes the study area since few studies on pioneer species composition in educational institution campus. Mostly UTM campus is a undulating landform with level of height between 12 meters until 150 meters from sea level [17].

2.2. Plot Establishment and Data Collection

A total of fifty plots were established randomly at UTM secondary forest with dimension 10 m x 10 m which covered 0.5 hectare [18]. Each plot coordinates were marked using GPS and directed to North direction using a compass. Tree locations were also recorded including the diameter at breast height (dbh) at 1.3 meter from ground level as well as their height. Both parameters were taken using dbh tape and clinometer. In this study, four pioneer species have been chosen which are *Eurya acuminata, Macaranga gigantea, Macaranga heynei* and *Dillenia suffruticosa*. These four species were selected based on previous record from initial study and compliment with field observation at UTM secondary forest. Not all species that have been recorded in previous studies such as *Trema micrantha* and *Cecropia peltata* are grown at UTM secondary forest. This is because each pioneer species that survived depend on the succession process and usually there are fewer species emerged at secondary forest [4], [19].

2.3. Data Analysis

In identifying forest structure, it is important to measure the species composition and diversity which often seen as ecological indicators [20]. Species diversity considers both number of species in a defined sampling unit (species richness) and distribution of individuals among species (species evenness) to show relative abundance of the species [21]. Diversity indices provide important information regarding rarity and commonness of species in a community [22]. In this study, diversity index has been

use to understand rarity and commonness of the four pioneer species that grow in secondary forest. Shannon-Wiener diversity index has been selected in measuring diversity level of four pioneer species. This index has been chosen since several studies in estimating diversity level in one particular area were used [21], [23]. To identify the most dominant species among these four pioneer species at UTM secondary forest, important value index (IVi) was calculated [21]. The highest value of IVi showed that particular species was established well at this area. In calculating IVi, it was a summation of the percentage values of density, frequency and dominance. The total aboveground biomass was estimated using regression formula from Kato et al.(1978) which summation from weight of stems, branches and leaves [24]. The biomass values (kg) for stems (W_S), branches (W_B) and leaves (W_L) are calculate as follows:

$$W_s = 0.313\ (D^2H)^{0.9733}$$
$$W_B = 0.136\ W_s^{1.070}$$
$$1/W_L = 1/0.124W_S^{0.794}+1/125$$

3. Result and Discussion

3.1. Taxonomic Composition

A total of 256 trees with dbh of 5 cm and greater were recorded. It represented four species in three genera from three families (Table 2). *Macaranga gigantea* from family Euphorbiaceae recorded as the highest number of trees from the 50 plots, amounted to 0.5 ha. In Ayer Hitam Forest Reserve in Selangor, one of the compartments of plot study also documented *Macaranga* sp. as the main species emerged at the compartment. This was due to early successional stage [25]. Therefore, it suggests that UTM secondary forest still in early successional stage since it is dominated with *Macaranga gigantea* and *Macaranga heynei.*

Table 2. List of species and families of trees ≥5 cm dbh at UTM secondary Forest

Family	Species	Total number
Euphorbiaceae	*Macaranga gigantea*	75
Euphorbiaceae	*Macaranga heynei*	62
Pentaphylacaceae	*Eurya acuminata*	65
Dilleniaceae	*Dillenia suffruticosa*	54
Total		256

According to Figure 1, maximum dbh has been recorded was 77.7 cm from *Macaranga gigantea* and followed by *Dillenia suffruticosa* with 29.8 cm of diameter. While Figure 2 shows most of tree heights recorded at UTM secondary forest in range of 6 to 8 meter.

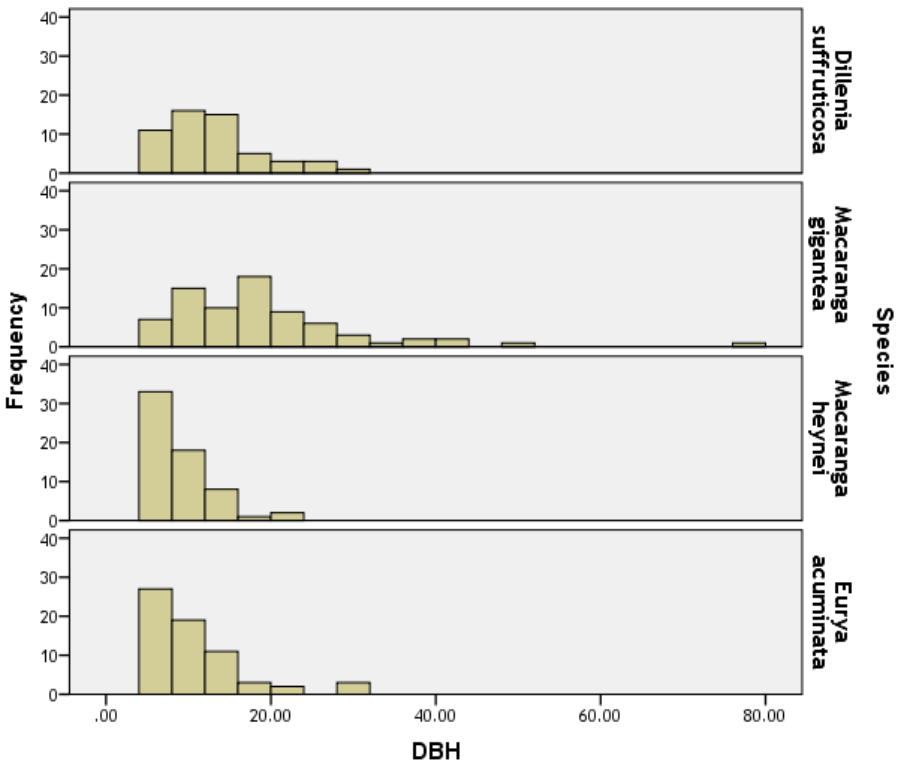

Figure 1. Histogram of diameter from four pioneer species

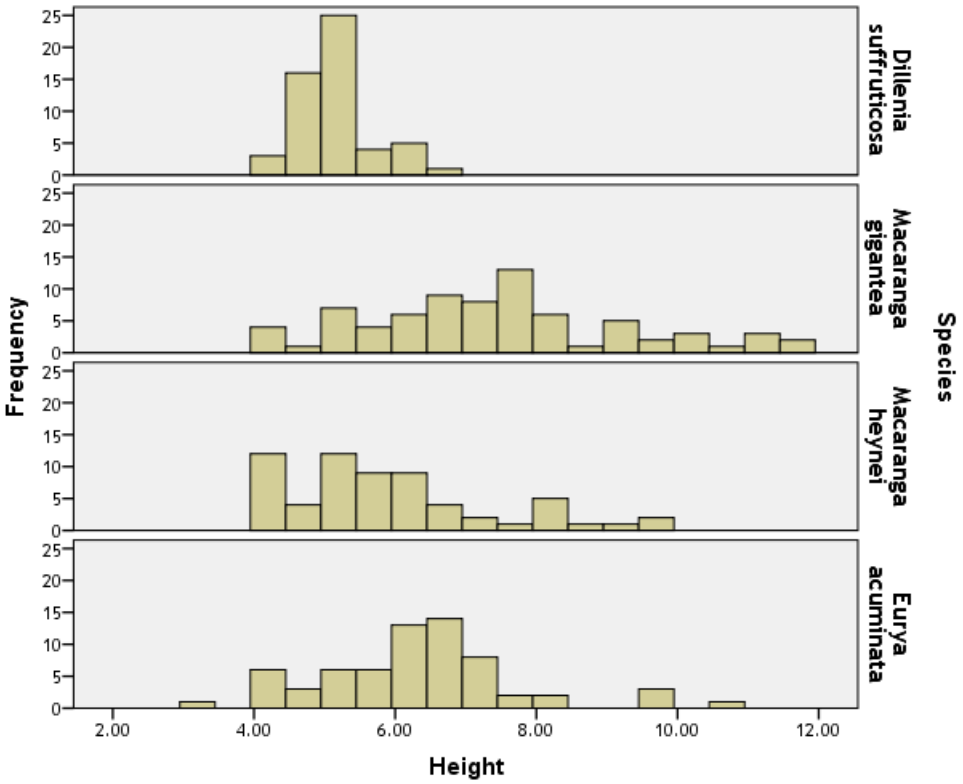

Figure 2. Histogram of height of four Pioneer Species

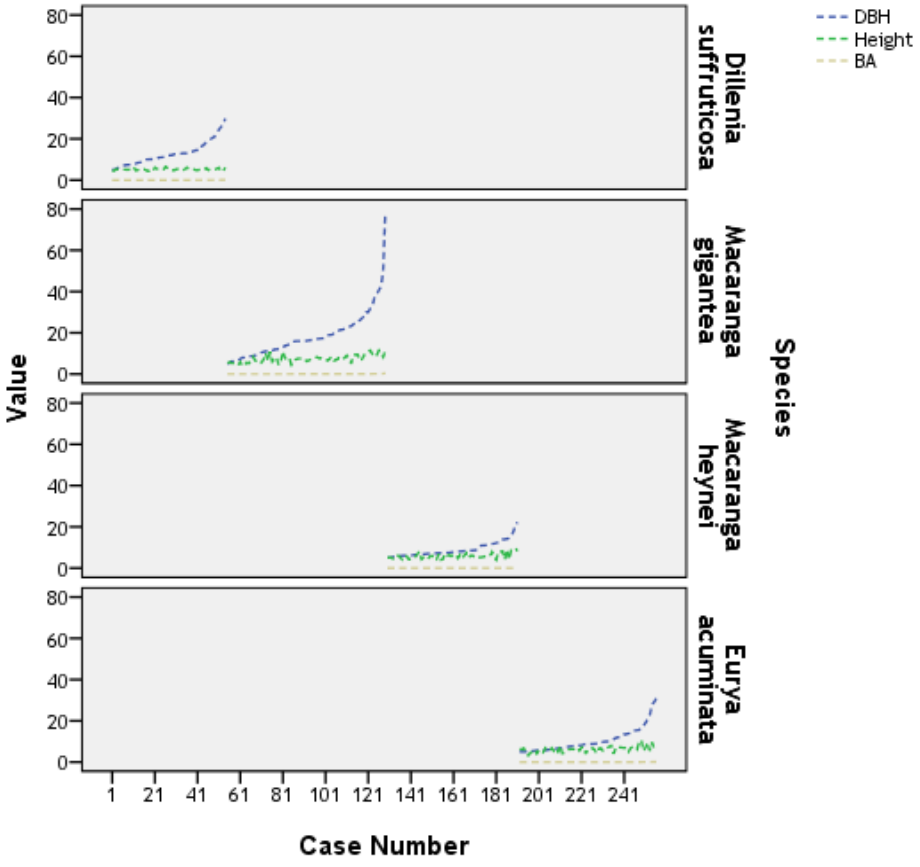

Figure 3. Distribution pattern of dbh, height and basal area

As shown in Figure 3, basal area (BA) presents the dbh and height increased parallel to basal area. However, total basal area at UTM secondary forest (9.674 m^2 ha^{-1}) was low compared to Danum secondary forest (27 m^2 ha^{-1}) [26]. This is due to most of the trees recorded mostly in juvenile stages with lower diameter. Basal area is an important indicator of succession because it modifies the local environment and as important filter for functional traits well adapted to local conditions [27].

3.2. Forest Structure

In the secondary forest, the dominant species within four pioneer species was *Macaranga gigantea* with IVi value 112.3 %. Table 3 described the important value index for each species in UTM secondary forest. Species with higher value of IVi indicates that a particular species dominated among the four pioneer species. Basal area of pioneer species at selectively logged forest at Sabah was higher compared to the unlogged forest. *Macaranga gigantea* also recorded at the Sabah secondary forest [28]. From their study, basal area of pioneer species at unlogged forest was lower since pioneer species only emerged at area with higher penetration of sunlight. Therefore, forest canopy influenced the regeneration of pioneer species at secondary forest where increasing forest canopy lead to formation species from primary forest. Moreover, less pioneer species available at primary forest since the dense canopy cover [29].

Table 3. Important Value Index (IVi) of Four Pioneer Species at UTM Secondary Forest

Species	IVi (%)
Macaranga gigantea	112.30
Macaranga heynei	58.77
Eurya acuminata	65.56
Dillenia suffruticosa	63.37

3.3. Species Diversity

Species diversity of four pioneer species with dbh ≥ 5 cm and above is presented in Table 4. Compared to other secondary forest in Singapore with diversity index was 1.17 [29], UTM secondary forest is higher in terms of diversity level but lower diversity when compared to secondary forest in Thailand which diversity index value is 2.078 [30]. Although, secondary forest diversity level was lower compared to primary forest at Krau Wildlife reserve in Pahang with value 5.19 [31]. Therefore, less tree species grow at secondary forest because of poor nutrient condition compared to primary forest.

Table 4. Diversity indices of four pioneer species (DBH ≥ 5 cm) in the study site

Diversity indices	UTM Secondary Forest
Shannon-Wiener diversity index (*H'*)	1.379

3.4. Aboveground Biomass

Total aboveground biomass of four pioneer species was recorded in Table 5. *Macaranga gigantea* has the highest total volume of aboveground biomass which is 1063.01 t/ha at UTM secondary forest since the total number of trees and dbh was greater which influence the total aboveground biomass. Most of *Macaranga heynei* in the plot study was in young stage of growth when diameters have been recorded were less than 30 cm. Primary forest contain large amount of aboveground biomass compared to the secondary forest since primary forest dominated with many large trees with greater diameter [32]. Therefore, secondary forest accumulated with lower number of aboveground biomass compared to the primary forest due to small diameters of trees. However, alteration of forest structure and species composition during forest succession typically result in substantial increases in aboveground biomass [33].

Table 5. Total Aboveground Biomass of four pioneer species

Species	Aboveground Biomass (t/ha)
Macaranga gigantea	1063.01
Macaranga heynei	8.74
Eurya acuminata	12.41
Dillenia suffruticosa	13.77

4. Conclusions

This study shows that four pioneer species contributes significantly in carbon stocking where it stored 1094 t/ha total of aboveground biomass. Although the total number 1094 t/ha is less compared to the primary forest but it is important to preserve secondary forest as a carbon stock reservoir that could substitute primary forest in the future. Therefore, pioneer species of secondary forest should be kept as tree stand to stock carbon such as *Macaranga gigantea*. This species is revealed as dominant pioneer species in UTM's secondary forest where it shows the highest value of *IVi*.

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