Tree diversity, forest structure and species composition in a logged-over mixed dipterocarp forest, Bintulu, Sarawak, Malaysia

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ABSTRACT The Anap Muput Forest Management Unit (AMFMU) located in Bintulu, Sarawak, Malaysia is a production forest. It have undergone at least one or two cycle of selective logging where valuable timber species are depleting. Therefore the structure, composition and productivity of the re growth forests are quite different from the virgin stands. Measuring the diversity is one of the ways to access the soundness of ecological ecosystems. This study aim to collect information on tree diversity, forest structure and species composition. A total of 61 circular plots of 25-m radius were established covering a total area of 7.67 hectares. Trees with diameter at breast height (DBH) of 10 cm and above were recorded. Species composition, diversity, relative density (RD), relative basal area (RBA) and relative frequency (RF) and important value index (IVI) were calculated. A total of 5,871 trees comprised of 66 families, 208 genera and 827 species were recorded. Dipterocarpaceae was the most dominant family with 31.8% of trees. *Shorea* was the dominant genus, while *Macaranga hosei* of Euphorbiaceae with 193 trees is the most dominant species here. *Shorea collaris* was the highest record for Dipterocarpaceae with 176 stands. The highest IVI of trees in lowland dipterocarp forest was *Shorea macroptera* ssp. *baillonii* with the value of 84.73 though it only represented 1.8% of the total IVI of the area. At Shannon-Weiner diversity index (H') of 3.44, the diversity of logged-over lowland dipterocarp forest in the study area is considered highly diverse. The results of this study strengthen the importance to manage the forest sustainably as timber industry is important for the state's economy.

KEYWORDS: Biodiversity; Tree species; Diversity; Sample plots; Mixed Dipterocarp Forest

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INTRODUCTION

Tropical rainforests are well known for harbouring the world's most species-rich plant communities and are recognized as the richest ecosystems in the world in terms of structure and species diversity (LaFrankie *et al.,* 2006). Lowland dipterocarp forest is one type of tropical rainforest. The lowland dipterocarp forest in Southeast Asia has the most diverse ecosystems of the world (Asthon 2005; Hedl *et al.,* 2009), whose tree species richness exceeds 200 species per hectare (Newbery *et al*., 1992; Poulsen *et al*., 1996; Leigh *et al*., 2004; Small *et al*., 2004 and Condit *et al.,* 2005). Logging and forest conversion are major threats to biodiversity of the tropical rainforest (Curran *et al.,* 2004 and Sodhi *et al.,* 2004). Achard *et al.* (2002) and Sodhi *et al.* (2004) reported that the deforestation rate in Southeast Asia is highest among major tropical regions. Therefore, it is important to understand species composition, structure and dynamics of these valuable forests before they have vanished. Knowing the forest diversity are also important for timber production, habitats for wildlife and also protective functions such as safeguarding of soil fertility, supply of clean water for domestic and industrial use and prevention of damage by flooding and erosion to rivers.

Mixed Dipterocarp Forest (MDF) is the richest of Sarawak major forest type, the archetypal tropical rainforest. The MDF in Sarawak comprises both the lowland and hill dipterocarp forests (Ashton, 1995) and extends from sea level to 750 m. The MDF is a high forest, with a deep, dense

canopy, upper surface of which is usually very uneven. The canopy reaches a height of 35 to 55 m, with emergent trees occasionally exceeding 60m. The trees are mostly evergreen and their dense shade much reduces light intensity at the forest floor. The trees of the upper canopy usually have long, straight and cylindrical boles. Trees are dominant life form in the mixed dipterocarp forests with Dipterocarpaceae is the main family. Other life forms such as lianas, palms, herbs and epiphytes such as orchids and ferns, parasitic plants are particularly rich in species. Tropical botanists have gradually revealed the floristic diversity of MDF in Sarawak (Whitmore, 1972 and Ashton, 1988).

The Anap Muput Forest Management Unit (AMFMU) is a MDF comprising about 106,820 hectares, of which more than 90% has already been logged. It is a production forest and have undergone at least one cycle of selective logging where valuable timber species, especially those that were once dominant in MDF are depleting making the structure, composition and productivity of the second growth forests are quite different from the virgin stands. Measuring the diversity is one of the ways to access the soundness of ecological ecosystems. An assessment of flora biodiversity is an essential step towards the conservation of forest biodiversity. The objective of this study is to collect information about the forest vegetation which includes species composition, number of individual trees, tree height, and diameter at breast height (DBH) within timber concession area. Therefore, the most important species and families for trees are revealed. The information will enable foresters to make better decisions that ensure sustainable management of forest.

MATERIALS AND METHOD

Study Area

The study was conducted in a logged-over tropical rainforest located within the Anap Muput FMU (2º08-37'N, 112º37-59'E), in Bintulu, Sarawak, Malaysia (Figure 1). Bintulu is located in the northern part of Sarawak enjoying annual rainfall of averaging 4,237 mm and average temperature of about 26.8ºC. The natural vegetation in the study area is mainly mixed dipterocarp forest (Demies & Julia, 2008). Most of the commercial trees belong to Dipterocarpaceae family such as *Shorea* spp., *Dipterocarpus* spp. and *Vatica* spp, and there are other associates namely *Palaquium* spp. and *Gluta* spp. The logged-over areas are usually dominated by pioneer species, particularly by *Macaranga* spp. with *M. gigantea* and *M. hypoleuca* as the most common. Other non-dipterocarpaceae such as *Nauclea* spp., *Porterandia* spp., *Glochidion* spp. and *Gironniera* spp. are also found.

The Anap Muput FMU is managed by Zedtee Sdn. Bhd. under the Timber Licence of Shin Yang Trading Sdn. Bhd. The site is located in the Tatau District of Bintulu Division, Sarawak, Malaysia. A major part of the FMU is classified as Permanent Forest Estate under the Mukah Hills Protected Forest and Anap Protected Forest which were constituted on 1st September 1956 and 1st March 1958, respectively (Demies & Julia, 2008).

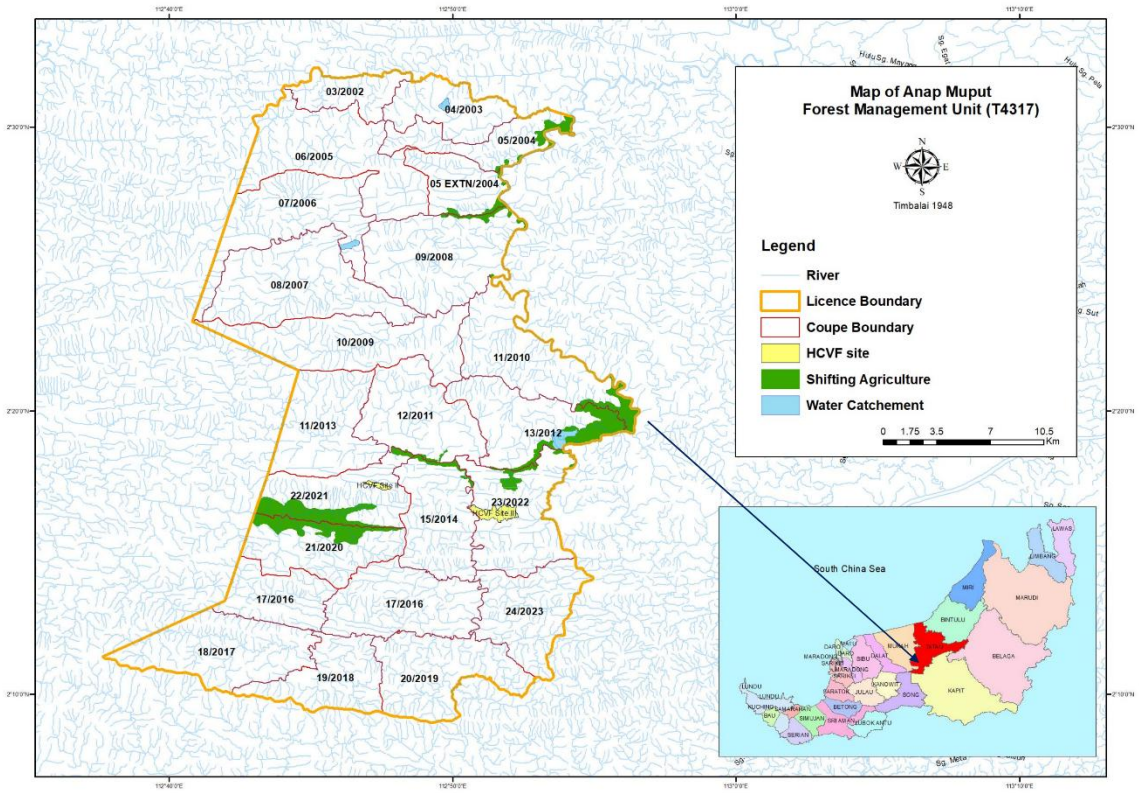

Figure 1. The map of Anap Muput Forest management Unit

Selection and Establishment of Sample Plots

A total of 61 circular plots of 20-m radius were established covering a total area of 7.67 hectares. Out of these, trees in 18 plots were enumerated in March 2012, 25 in September 2012 and 19 in April 2013. Circular plot was preferable because it is easy to implement in the field, and determination of trees inside the plot is less problematic than square plots (Langner *et al*., 2012).

The 61 plots were established randomly throughout the FMU. Local names, DBH and height of trees with at least 10 cm DBH were recorded (for the method, see Araujo *et al*., 1999; Brown 1997 and Foody & Cutler, 2003). Species or genera names were also verified from PROSEA (Soerianegara & Lemmens, 1993; Lemmens *et al*., 1995; Rantai & Chai, 2007 and Sosef *et al*., 1998). Trees were permanently marked with an aluminum tag nailed to the tree.

Data Analysis

Species composition and diversity were calculated based on the forest inventory data. Species composition refers to the number of different species in the study area. It can be represented in terms of relative density (RD), relative basal area (RBA) and relative frequency (RF). Important value index (IVI) was calculated to determine the species importance in the community. In order to determine the species abundance, several parameters were calculated which include the density, frequency and basal area of a particular area (Brower *et al*., 1989). Formula used to calculate RD, RBA, RF and IVI are as listed below.

$$RD = (\text{Number of individuals of a species/ total number of individuals of all species}) \times 100 \quad (1)$$

$$RBA = (\text{combined BA of a species/ total BA of all species}) \times 100 \quad (2)$$

$$RF = (\text{frequency of a species/ sum of all frequencies}) \times 100 \quad (3)$$

$$IVI = RD + RBA + RF \text{ (1-300 \%)} \quad (4)$$

In this study, basal area (BA) was calculated as:

$$BA = 0.00007854 \times DBH^2 \quad (5)$$

Species diversity was determined using Shannon-Weiner Diversity Index (H').

$$H' = -\Sigma\, p_i \ln p_i \quad (6)$$

where

H' = Shannon-Weiner Diversity Index

p_i = the proportion of individuals belonging to species in the all individuals

Species evenness (E) was determined using Shannon-Weiner values.

$$E = H'/\ln(S) \quad (7)$$

where

E = Evenness

H' = Shannon diversity index

S = The number of species at the study area

RESULTS AND DISCUSSIONS

Tree Composition

From the 7.67 ha sampled, a total of 5,871 trees were enumerated, comprising 66 families, 208 genera and 827 tree species (including subspecies) (Table 1). The tree composition is very much higher compare to Lubuk Kakap, West Kalimantan where Budiharta (2010) recorded 13 families, 27 genera and 48 species. The study site in Lubuk Kakap is a virgin forest, surrounded by logged over forests. The number of families, genera and species in AMFMU are also higher than those recorded at nearby Bukit Mina by Vilma *et al.* (2012) and at Bukit Jugam by Demies *et al.* (2010). Both Bukit Mina and Bukit Jugam are logged over forest.

The tree composition in Lambir Hills National Park, Sarawak recorded 81 families, 286 genera and 1173 species (Lee *et al.*, 2002). Lambir Hills National Park is an undisturbed forest and the number of tree composition is much similar to AMFMU.

Table 1: Comparison of tree density and the number of families, genera and species in three locations in Sarawak (≥ 10cm DBH)

	Anap Muput	Bukit Mina (Vilma *et al.*, 2012)	Bukit Jugam (Demies *et al.*, 2010)
No. of trees/ha	766	712	728
No. of families	66	53	41
No. of genera	208	156	86
No. of species	827	540	178

The most dominant family recorded in Anap Muput FMU was Dipterocarpaceae (31.8% of individual trees), followed by Euphorbiaceae (13.6%) as distant second, Myrtaceae (5.5%) and Myristicaceae (5.0%) (Table 2). The total Dipterocarp trees are less than one third of total trees in the

area. This contravene Tsai's finding that Dipterocarpaceae generally are the major floristic groups or dominated stands in mixed dipterocarp forest (Tsai, 2006).

Some plots of the study area were more disturbed and gaps were evident. Beckage *et al*. (2008) have emphasized that forest gaps play a significant role in determining patterns of forest regeneration by enhancing the regeneration of light-demanding or shade-intolerant tree species, thus increasing the range of pioneer tree species in the forest. Newman (1990) has reported that tree seedlings and saplings will remain dormant for many years, not growing at all until a tree falls or forest disturbance occurs, creating gaps in canopy. Therefore, forest gaps could contribute to high species richness. The reason of the higher number of trees per ha including the number of families, genera and species at Anap Muput is the area recently had been extensively logged compared to Bukit Mina and Bukit Jugam.

Among Dipterocarpaceae, *Shorea* was the most dominant genus with a total number of 1,423 (24.2%) trees, as well as the most diverse genus with 61 species. The other dominant genera were *Macaranga* (368 trees), *Syzygium* (233 trees), *Knema* (172 trees) and *Dipterocarpus* (168 trees). In terms of species, *Macaranga hosei* has the highest record with 193 trees while *Shorea collaris* is the highest record for Dipterocarpaceae with 176 trees.

The tree composition of rainforest in the tropics Australia recorded 208 species in 128 genera and 53 families (Bradford *et al*., 2014). This is very much lower compared to AMFMU.

Table 2: Diversity and tree density of the ten dominant families in Anap Muput

Families	No. of Genera	No. of Species	No. of Trees	% No. of Trees
Dipterocarpaceae	8	118	1,868	31.8
Euphorbiaceae	25	88	798	13.6
Myrtaceae	3	37	320	5.5
Myristicaceae	5	47	293	5.0
Flacourtiaceae	8	23	229	3.9
Burseraceae	3	29	157	2.7
Lauraceae	13	46	157	2.7
Sapotaceae	5	37	140	2.4
Rubiaceae	9	12	139	2.4
Anacardiaceae	10	22	13.7	2.3

Species Diversity

Shanon-Weiner diversity index (H') were categorized as high with an average H' of 3.44. and are comparable with other studies. Suratman *et al*. (2010) studied the lowland forest of Kuala Keniam and recorded a lower H' value ranging from 3.42 to 3.97 while Zani *et al*. (2013) reported the H' for lowland dipterocarp forest at Taman Negara Pahang at 4.84. The value of H' usually lies in between 1.5-3.5 (Magurran, 1988), although in exceptional cases the value can exceed 4.5. Therefore species diversity in the area can be considered high given the fact that the area has been logged-over, whereby the matured timber trees including the fruiting trees has been removed during harvesting.

Forest Structure

The importance value index (IVI) is an important parameter to determine the economic value of a forest, timber wise (Lajuni & Latiff, 2013). Timber species with the high IVI mean the forest stands can be classified as an economically valuable stand.

In this study, the IVI of Dipterocarpaceae (18.8%) was highest for the area, followed by that of Euphorbiaceae (12.6%) and Myristicaceae (8.3%) (Table 3). However, the IVI of timber species is not high enough to be classified as such.

Table 3: Ten dominant families based on percentage of Important Value Index (IVI) in Anap Muput

Family	IVI (%)
Dipterocarpaceae	18.8
Euphorbiaceae	12.6
Myristicaceae	8.3
Lauraceae	7.3
Burseraceae	6.2
Clusiaceae	6.1
Myrtaceae	6.0
Fagaceae	5.6
Anacardiaceae	4.7
Fabaceae	3.8

By species, *Shorea macroptera* ssp. *baillonii* of Dipterocarpaceae had the highest species IVI of 84.7. However it is only 1.8% of the total IVI of the area (Table 4). Five Dipterocarpaceae species were recorded in the top 10 of IVI with all three top positions occupied by the species from this family.

Table 4: Ten dominant species based on Important Value Index (IVI) in Anap Muput

Family Name	Scientific Name	IVI	IVI %
Dipterocarpaceae	*Shorea macroptera* ssp. *baillonii*	84.7	1.8
Dipterocarpaceae	*Shorea parvifolia* ssp. *parvifolia*	62.0	1.3
Dipterocarpaceae	*Vatica micrantha*	54.0	1.1
Actinidiaceae	*Saurauia glabra*	53.2	1.1
Euphorbiaceae	*Macaranga hosei*	52.3	1.1
Anacardiaceae	*Semecarpus glauca*	51.9	1.1
Euphorbiaceae	*Elateriospermum tapos*	51.0	1.1
Rubiaceae	*Pleiocarpidia capituligera*	48.3	1.0
Dipterocarpaceae	*Shorea collaris*	47.2	1.0
Dipterocarpaceae	*Shorea sagittata*	44.6	0.9

According to Curtis & Macintosh (1951), species with IVI of more than 10% and families with IVI more than 40% can be considered as dominant in a particular community. The above results show that there are no dominant species or families identified in the area.

CONCLUSION

A total of 5,871 trees comprised of 66 families, 208 genera and 827 species were recorded in the lowland dipterocarp forest of Anap Muput. However, the non-dipterocarp is more dominant than the dipterocarp. *Shorea* is the dominant genus while *Macaranga hosei* of Euphorbiaceae with 193 trees is the most dominant trees here. *Shorea collaris* is the highest record for Dipterocarpaceae with 176 stands. The highest IVI of trees in lowland dipterocarp forest of Anap Muput is *Shorea macroptera* ssp. *baillonii* with 84.73. However it was only 1.8% of the total IVI of the area. The lowland dipterocarp forest of Anap Muput has high H' which is 3.44, which mean a high taxa diversity.

Results of this study strengthen the importance to manage the forest sustainably as timber industry is important for the state's economy. Moreover, about half of Sarawak's population continues to live in the vicinity of forests and depend largely on forest resources for their livelihoods.

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