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Research Article

An Inventory of Flora in Urban Forests of Universiti Malaysia Sabah Campus, Sabah, Malaysia

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Abstract
Species diversity is one of the most important measures for estimating the sustainability of forest communities. This study aims to compare plant diversity between two secondary forest sites namely the UMS Hill and ODEC in Universiti Malaysia Sabah (UMS) and to update the list of flora in UMS forests. A plot of 50 m x 50 m (0.25 ha) was set up at each forest site. Temperature, light intensity and relative humidity were measured in both study plots with HOBO data loggers. A total of 5,301 individuals, 84 species and 48 families were recorded in both plots. The family Zingiberaceae was represented by a single species *Alpinia aquatica* which dominated other families and species by having the highest abundance, contributing to 19.79% of the total density while the family Rubiaceae was the most speciose in both plots. There was no significant difference between plant species diversity in UMS Hill (*H*'= 3.355, Hill's number=29) and ODEC (*H*'= 3.290, Hill's number=27) (t=1.827; p = 0.0677). Species in UMS Hill (*E* = 0.792) was distributed more evenly compared to ODEC (*E* = 0.785). Measured climate parameters have slight variation in both plots which is attributed to microhabitat influence within each study plot. Similar environmental conditions in both study plots contribute to relatively similar plant diversity and composition in the study plots. The study added 26 species as new records to the existing flora checklist thus giving a total of 302 plant species for the UMS forest.

Keywords: Species diversity, biodiversity, secondary forest, tropical, conservation

Introduction
The lowland evergreen tropical rainforest is the most fertile forest, diverse in species and has a large and complex structure (Whitmore, 1991). Undisturbed forest or primary forest is the most biologically diverse type of forest, relatively unaffected by human activities, and still exists in its original condition (Butler, 1994). Meanwhile, secondary forest is a rainforest that has been disturbed in some ways, naturally or unnaturally. Generally, secondary forest is

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characterized (depending on its level of degradation) by less developed canopy structure, smaller trees and less diversity (Butler, 1994). Chokkalingam & de Jong (2001) stated that secondary forest relates to successional forests which develop after clearing of the original forest, and secondary succession is complete when they develop again into climax communities or primary forests.

Plant diversity can be affected by many factors, indirectly by elevation as environmental condition changes along elevational gradient (Korner, 2007; Brown, 2001; Malik, 2008), soil fertility (Takyu et al., 2002; Kumar et al., 2010), geological substrate (Aiba et al., 2002), disturbance (Denslow, 1995; Cayuela et al., 2006) and climate (Hidore & Oliver, 1993). Elevation gradients create varied climate, along with resultant soil differentiation and promote the diversification of plant species (Brown, 2001). Changes in climate could be expected to alter the regeneration success, growth and mortality rate of tree species (Malik, 2008). Climate may also affect the distribution of individual species and community (Hidore & Oliver, 1993). Changes in forest structure due to disturbance alter the environment within the forest, subsequently the diversity and composition of the forest also changes. According to Whitmore (1991), the forest can be replaced by a less fertile forest with medium sized trees and fewer species when environmental conditions become deficient.

Plants may be a renewable resource, but plant diversity is not. Anthropogenic activities such as deforestation, logging activities, and slash-and-burn clearing of forests for agriculture and infrastructure development pose a major threat to plant diversity. As a result, primary tropical rainforests are replaced with a secondary forest and open woodland patches or grassland (Whitmore, 1991). The loss of plant species is often accompanied with the loss of insects and animals. With the expansion of secondary forests in place of virgin forests in tropical countries, managing these forests has never been more relevant for the conservation of forest biodiversity. Regenerated forests or secondary forests are valued for their roles as refuge for flora and fauna, thus preventing extinction (Chazdon et al., 2009; Dent & Wright, 2009) and for their contribution to carbon pool recovery (Martin et al., 2013). The Universiti Malaysia Sabah (UMS) Hill and Out-Door Development Center (ODEC) forests are patches of secondary forests which form part of the extensive vegetation cover in UMS campus. For the past 23 years after the establishment of the campus, these patches of forest have been slowly recovering and a few notable species of fauna have been observed in UMS Hill forest. These patches of secondary forests attract animals by providing habitat and food sources.

The study aims to determine the composition and diversity of flora in the secondary forests on UMS Hill and ODEC. The only study on the flora of UMS Hill forest was conducted along the trail leading up to the peak of the hill that resulted in a plant checklist (Sugawara et al., 2009). No flora surveys were ever conducted in other forest areas in UMS campus. The UMS forests are an important source of biodiversity in the urban area and may act as refuge for flora as well as fauna, thus mitigating the effects of species loss such as local extinction. The enhancement of quality of the forests is deemed necessary and thus findings from this study may contribute to effective rehabilitation process of the forests. The presence or absence of dominant and rare species in a forest provide valuable information about the quality of the forest, for instance, dominance of climax tree species suggest that the forest has recovered and reached a stable climax forest community. On the other hand, dominance of secondary forest species implies the forest is still regenerating or recovering from past disturbances. Ecological restoration such as rehabilitation activities can accelerate the recovery process of the forest.

Materials and Methods

Study Site

UMS is located in Kota Kinabalu, Sabah with a total area of 4.04 km^2, facing the South China Sea at Sepanggar Bay. Prior to infrastructure development of the UMS campus in 1995, the landscape of the area was overlaid with a mosaic of human settlements, agricultural land and some vegetation cover. Since the establishment of the campus and operation of the university in its new campus in 2000, the undeveloped part of the land has regenerated resulting in the spread of vegetation cover to bare lands, some areas dominated by stands of *Acacia* species. This area is located northwest of the campus, and is a place covering approximately 1.2 km^2 (120 ha), and which has patches of vegetation (Sugawara et al., 2009). Other small forest patches isolated from the 1.2 km^2 area also exist within the campus. Within the context of our study, only the 1.2 km^2 is referred to as UMS forest. UMS forest is an extensive area with diverse landscape from fragmented secondary forest to open canopy areas which are primarily covered with bushes and grasses. The vegetation is reminiscent of typical lowland forest and mangrove forest in several areas extending seaward. The topography is flat undulating to hilly with steep slopes in some areas. The highest peak is UMS Hill peak at 190 m asl. The UMS forest experiences a typical equatorial climate, with constant temperature and considerable amount of rain and high humidity. The average annual rainfall is 2,700 mm and the average annual temperature is 28 °C.

This survey was carried out in selected forest areas in UMS forest, the first site was the forest in UMS Hill (hereafter called the UMS Hill) (06° 02’ 15.59” N; 116° 06’ 55.26” E) and the second site was in ODEC (hereafter called the ODEC) (06° 02’ 42.0” N; 116° 06’ 46.0” E) (Figure 1). UMS Hill site at 114 m asl is dominated by a secondary forest with hills, ridges and secondary ridges shaping its terrain. The ODEC site is located in a flat coastal area with an elevation of 29 m asl. The vegetation of the ODEC site consists of secondary forest and bushes.

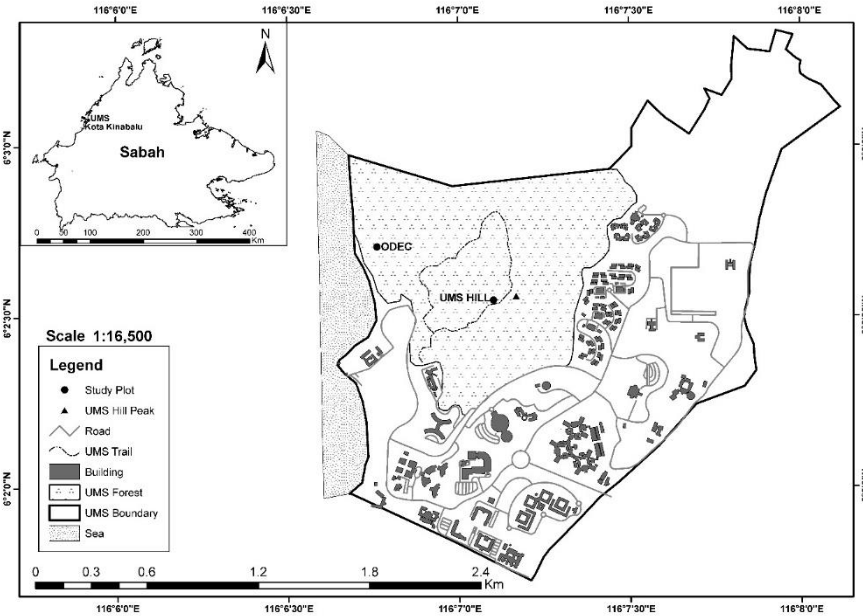

Figure 1. Location of the UMS forest and study plots in UMS campus

Data collection

To determine plant species diversity and composition, a plot of 50 m x 50 m was each set up at UMS Hill and ODEC. The plot was divided into 10 subplots, each measuring 10 m x 25 m. All vascular plants (trees, shrubs, herbs, grasses, ferns and palms) within the subplots were counted, recorded and identified. All plants with a minimum height of 3 m and ≥10 cm DBH were considered as trees. This included treelets with less than 10 cm DBH but reaching the height of 3 m. Plants with hard stem, less than 3 m height and ≤ 10 cm DBH were categorized as shrubs. Herbs included small forest floor plants with tender stem whereas grasses, ferns and palms were characteristically grouped based on their own distinctive features.

Voucher of fertile specimens were made in duplicates and deposited in Borneensis Herbarium (BORH) at the Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah. Fertile specimens included plants bearing either flowers or fruit or both were collected while mature fern with fronds bearing spores were prioritized for collection. Identification of plants is based on the Tree Flora of Sabah and Sarawak Volume 1 – 7 (Soepadmo & Wong, 1995; Soepadmo et al., 1996; Soepadmo & Saw, 2000; Soepadmo et al., 2002; Soepadmo et al., 2004; Soepadmo et al., 2007; Soepadmo et al., 2011) and Buku Panduan Hutan Bukit UMS (Sugawara et al., 2009). Additionally, identification of plants was performed by comparing voucher specimens in the BORH and SAN herbariums (Forest Research Centre, Sandakan).

HOBO Pendant Temperature/Light Data Logger (UA-002-64) and HOBO Pro v2 Logger (U23-002) were used to detect and record the data of temperature and light intensity for five months (November 2011 - March 2012), and relative humidity for four months (November 2011 - February 2012) in the two plots. The devices were set up high above the ground (>1.5 m) and secured with durable string on tree branches or tree trunks. Five data loggers (three U23-002 and two UA-002-64) were set up in each study plot. The data loggers were distributed at an interval of approximately 10 – 20 m apart along a transect line from north to south in the middle of each plot.

Data Analysis

To compare plant species diversity and composition, Shannon-Weiner Diversity Index, Sorensen's Similarity Index and Pielou's Evenness Index were determined for the two plots. Hutcheson's t-test for significance on Shannon-Wiener Indices (Hutcheson, 1970) was performed to test the difference between plant species diversity of the two plots. The Shannon Diversity Index was converted to effective number of species (also referred to as Hill's number) (Jost, 2006) to determine the magnitude of the difference between study sites in relation to plant species diversity.

Shannnon-Wiener Index:

$$H' = -\Sigma\, Pi \ln(pi)$$

$$Pi = \frac{ni}{N}$$

n_i= individual number of i species

N=total number of all individuals

Hutcheson t-test:

$$t = \frac{H_a - H_b}{\sqrt{s_{H_a}^2 + s_{H_b}^2}}$$

Ha = Shannon Index for sample a
Hb = Shannon Index for sample b
S = variance

Variance of the Shannon diversity is computed using the formula below:

$$s_H^2 = \frac{\sum p.(\ln p)^2 - \left(\sum p.\ln p\right)^2}{N} + \frac{S-1}{2N^2}$$

S = species richness
N = total number of individuals
p = proportion that each species makes towards the total

Sorenson's Similarity Index (Ss):

$$Ss = \frac{2a}{2a + b + c}$$

a= number of species common to both samples
b= number of species in sample 1
c= number of species in sample 2

Pielou's Evenness Index (*E*):

$$E = \frac{H'}{\ln S}$$

H'= the number derived from the Shannon Diversity Index
S = maximum value of *H'*

Results and Discussion

Forest micro-climate

No obvious variation of temperature, light intensity and relative humidity was observed in both study plots (Figure 2). The average monthly temperature from November 2011 to March 2012 in the study plots was similar (25ºC - 27ºC), a typical temperature for equatorial tropical forests (Hess, 2014; Peterson et al., 2015). The temperature was high in November 2011 and decreased in December

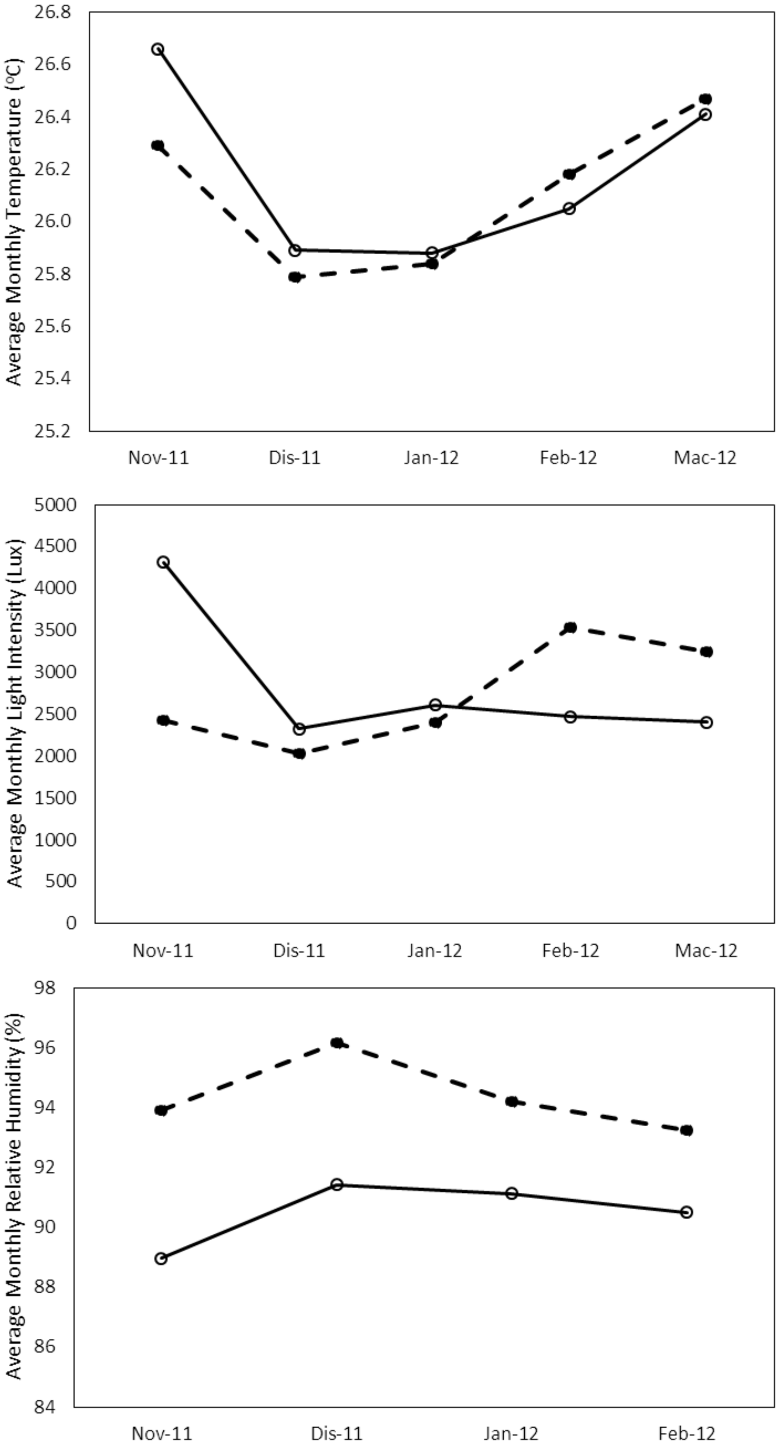

Figure 2. Fluctuation of temperature, light intensity and relative humidity in UMS Hill and ODEC (UMS Hill; ODEC)

2011 and January 2012 with the onset of the rainy season. The temperature started to rise in February and March 2012 because it was the beginning of the dry season. The study plots recorded the lowest light intensity in December 2011. The relative humidity was always interrelated with light intensity. There was a strong negative correlation between relative humidity and light intensity at each study plot (r = -0.943 for UMS Hill and r = -0.801 for ODEC). Both study plots recorded the highest relative humidity in December which coincided with the peak of the rainy season. During this time, the high rainfall coupled with proximity of the plots to the sea created a more humid air environment than usual. The average relative humidity was higher in ODEC as compared to UMS Hill and this was probably due to its location. ODEC was located nearer to the sea and received stronger sea breeze especially during the monsoon season and the air humidity around the coastal region was higher compared to other regions.

Species diversity and composition

A total of 5,301 individuals, 84 species and 48 families were enumerated from the plots. A majority of plant species recorded were classified as trees (including treelets) with 57 species, followed by shrubs with 11 species, herbs with six species, lianas with five species, grasses and ferns each with two species, and palm with one species (Figure 3).

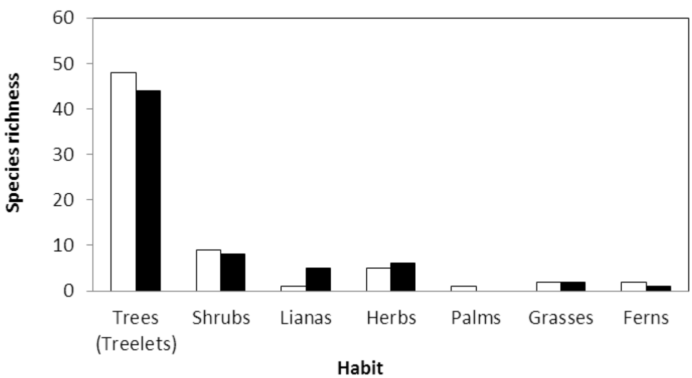

Figure 3. Comparison of plant types between study plots (□ UMS Hill; ■ ODEC)

Zingiberaceae was the most dominant family in term of density (19.79%), followed by Cyperaceae (16.32%), Myrtaceae (6.47%) and Poaceae (5.28%). Myristicaceae, Rhamnaceae (both 0.06%) and Taccaceae (0.04%) were rare. The most abundant species was a member of the Zingiberaceae family, *Alpinia aquatica*, which was the only ginger species recorded. *Alpinia aquatica* can adapt to a wide range of ecological conditions. An open area can be overgrown by this species in a relatively short period of time (Gobilik & Limbawang, 2010). Other abundant species were *Scleria sumatrensis, Carex* sp., *Syzygium leucoxylon, Acroceras* sp. and *Lygodium circinnatum*. In terms of species richness, many plant families enumerated in the study sites were less speciose with less than ten species (Figure 4). A majority of the plant families consisted of only a single species. Shannon-Weiner's diversity index for UMS Hill (H'= 3.355) was not significantly different from ODEC (H'= 3.289), indicating that the secondary forest in UMS Hill was apparently similar to the ODEC forest (t=1.827, *p*=0.0677). The actual numbers of species for UMS Hill and ODEC were 68 and 66 respectively. The effective number of species (Hill's number), which relates to equally abundant species, varied by only two species between the plots (29 species in UMS Hill versus 27 species in ODEC) (Table 1). In addition, Pielou's evenness index was similar for the two plots (*E*=0.795 for UMS Hill versus *E*=0.785 for ODEC). The species rank abundance curve also showed a similar pattern (Figure 5). UMS Hill and ODEC were moderately even in terms of species abundance. Some forest floor species such as *A. aquatica* and *S. sumatrensis* were common species that dominated both plots by having high abundance, whilst *Hypserpa nitida,* a woody climbing vine, was considered rare in UMS Hill plot, the only species that has two individuals. In ODEC plot, *Timonius villamilii*, *Fagraea cuspidata*, *Ficus septica* and *Tacca borneensis* have the lowest abundance with two individuals.

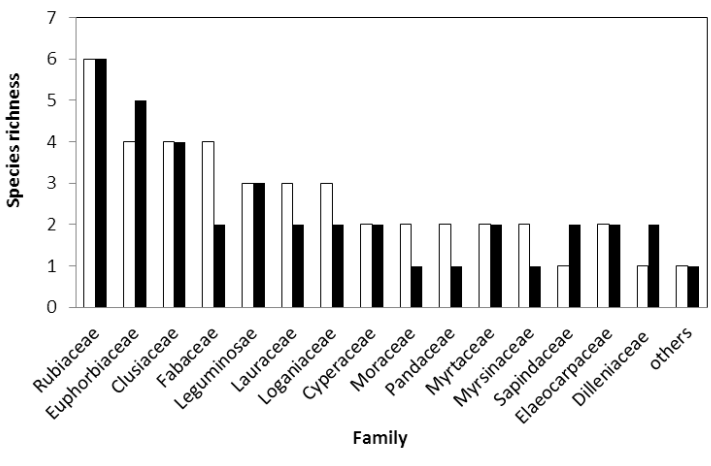

Figure 4. Species richness of enumerated plant family in UMS Hill and ODEC (□ UMS Hill; ■ ODEC)

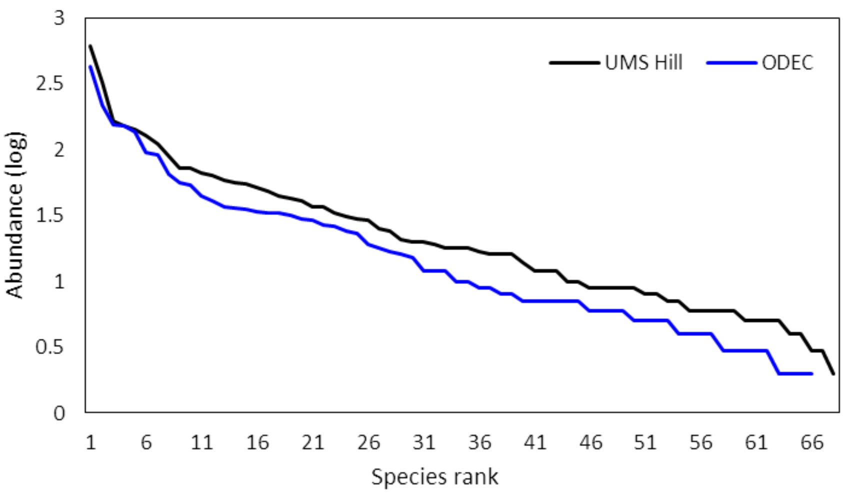

Figure 5. Species rank abundance curve of UMS Hill and ODEC

The calculated Sorenson similarity index showed that 74.5% of the total species recorded were common in both plots. From the total of 84 species identified, 50 species were found in both plots. Forests in both plots have similar environmental conditions such as climate, with little difference in elevation. The other 25.5% of species only occupied either one of the plots. Eighteen species were only observed in UMS Hill whereas 16 species only occurred in ODEC. Nevertheless, these species may be encountered in either plots if the magnitude of sampling effort is increased such as increasing the plot size to capture more plant species. Many of the tree species encountered in both plots are considered as constituents of secondary or disturbed forests. Previous studies have shown that the composition of species in a secondary forest is influenced by many factors, such as previous type of land-use, the degree and different type of forest degradation across the landscapes (Chazdon, 2003) as well as the level of forest succession, i.e. regeneration since disturbed, and previous vegetation (Brearley et al., 2004). Kessler et al. (2005) enumerated trees in 0.02 ha of a five year old secondary forest in Central Sulawesi and found

Table 1. Measures of plant species diversity of forest community in UMS Hill and ODEC

Elements of diversity	UMS Hill	ODEC
Species richness	68	66
Hill's Number	29	27
Number of family	40	44
Total number of individual	3,063	2,238
Shannon Diversity Index, *H'*	3.355	3.290
Pielou's Evenness Index, *E*	0.795	0.785

6 to 17 tree species. In contrast, Brearley et al. (2004) recorded an average of 55 tree species in six plots of 0.25 ha in a 55 year old secondary forest in West Kalimantan. Our study recorded an average of 67 species (66 species in ODEC and 68 in UMS Hill) in two plots of 0.25 ha, of which an average of 46 species were trees. A higher species richness was the result of including all vascular plant types except epiphytes in our survey. In addition, the UMS forest, inclusive of the study plots, has been regenerating and has been re-colonized for the past 23 years since the campus was developed. During that time, remnants of forest patches within the UMS forest may have already existed, and provided a source of plant propagules for regeneration in the open and disturbed areas. Monitoring of the forest is therefore crucial to determine the extent of natural and assisted forest succession. Thus, increasing the number and size of plots is deemed necessary in order to capture the actual species diversity and composition at different successional stages.

Species indicators of forest disturbance such as *Mallotus* and *Macaranga* (Slik et al., 2003) were absent in both plots which was in contrast to findings by Sugawara et al. (2009) that recorded *Mallotus paniculatus* and *Macaranga tanarius* in their survey. Their survey was conducted along forest trails which were in an open area and received abundant sunlight, a condition suitable for the growth of these species. On the other hand, our study plots were established in areas with dense canopy and no forest edges, thus it is likely that *M. paniculatus* and *M. tanarius* have been replaced by other plant species during the forest succession period. In a 55 year old secondary forest in Central Kalimantan, Indonesia, Brearley et al. (2004) recorded higher dominance by the tree species *Pternandra coerulescens* (Melastomaceae), a species regarded as a pre-disturbance remnant. Although not in abundance, the species occurred in both of our study plots suggesting the existing individuals were regenerated species or remnants of prior vegetation. Both plots were dominated by a tree species, *Syzygium leucoxylon* (Myrtaceae), which is a common tree species in coastal forests and along estuaries (Soepadmo et al., 2011), and can also be found in peat swamp forests (Siregar & Sambas, 2000).

Several species recorded in the plots were non-native such as *Hevea brasiliensis*, *Acacia auriculiformis* and *Acacia mangium* which were introduced for agricultural purposes in the past. Land use history such as human settlement, disturbance and cultivation may pose a significant effect on the pattern of plant diversity in the UMS forests. The rubber tree could be the remnant of cultivated crops which existed in the area. *A. auriculiformis* and *A. mangium* appeared abundant in forest patches within the campus area but not in the study plots.

Acacia species comprised only 2% of the total abundance enumerated from the plots. The species are non-native species that have become naturalized through intentional and unintentional introduction. Aguiar et al. (2013) reported that individuals of *Acacia* species growing underneath the forest canopy have greater potential to grow to adult phase compared to individuals growing outside of the canopy cover as the existing native trees can create a conducive micro-environment for *A. mangium*. However, lush ground vegetation overgrown with seedlings and sapling may hinder the invasion of *A. mangium* due to competition for light (Osunkoya et al., 2005). Both plots are dominated by dense undergrowth such as *Alpinia aquatica* and grass species that may out compete seedlings of *A. mangium*, thus individuals of the species were seldom encountered in the study plots.

The differences in plant species composition between the UMS Hill and ODEC plots may be influenced by the microclimatic condition within the forests. The interaction of temperature and light with humidity creates favourable condition for certain types of plants. The air humidity decreases as temperature or light increases in the environment as heat causes evaporation of the air. Forests in both study sites contain higher richness of small trees with less canopy structures. Due to lack of a full canopy, more light reaches the forest floor and support vigorous ground vegetation (Whitmore, 1991). UMS Hill plot has higher light intensity as compared to ODEC plot, this is due to the existence of open canopy and less canopy structures in the forest, allowing more sunlight to reach the forest floor. Higher diversity of plant species and abundance in tropical forests may be attributed to higher light intensity (Subramanyam & Sambamurty, 2006; Cavusoglu & Kabar, 2007). Additionally, the features of landscape in an area may act together with the within-site variations that could affect species occurrence and abundance (Johnson et al., 2000; Moran et al., 2000; Zarin et al., 2005), thus influencing the composition and abundance of species in the plots.

In a previous floristic survey along the trail to UMS Hill peak, a total of 276 plant species were recorded in UMS Hill (Sugawara et al., 2009). The current study has added 26 plant species (Table 2) to the existing list, giving a total checklist of 302 plant species in the UMS forest. A larger area (0.5 ha) was covered in this study, thus increasing the potential of discovering new records of plant species in the area.

Table 2. A list of new records of plant species found in UMS Hill and ODEC

Family	Species
Annonaceae	*Desmos teysmannii* *Polyathia angustissima* *Uvaria curtisii*
Aquifoliaceae	*Ilex cymosa*
Clusiaceae	*Calopyhllum obliquinervium* *Garcinia caudiculata* *Garcinia microphylla* *Garcinia penangiana*
Cyperaceae	*Scleria sumatrensis*
Euphorbiaceae	*Breynia racemosa*
Elaecarpaceae	*Elaeocarpus nitidus*
Fabaceae	*Airyantha borneensis* *Spatholobus gyrocarpus*
Lauraceae	*Litsea cylindocarpa* *Neolitsea cassia*
Menispermaceae	*Hypserpa nitida*
Myrsinaceae	*Ardisia macrocalyx* *Rapanea borneensis*
Oleaceae	*Chionantus pluriflorus*
Pandaceae	*Galearia stenophylla* *Microdesmis casearifolia*
Rubiaceae	*Aidia borneensis* *Metadina trichotoma* *Oxyceros longiflorus*
Rutaceae	*Clausena excavata*
Sapotaceae	*Palaquium gutta*
Total = 15 Families	**Total = 26 Species**

Conclusion

Species diversity is similar for UMS Hill and ODEC plots but species composition and abundance are different between the plots. Similar geographic location, elevation, land use history and climate could be the contributing factors that influence plant diversity in the plots. The present survey contributes a total of 26 new records of plant species to the current checklist by Sugawara et al. (2009), thus giving a total of 302 plant species found in the UMS forest. The new update of plant species checklist and plant specimens collected during the present study can be used as a reference or guideline for a future study in the UMS forest. To know the exact richness and composition of plant species, expansion of plot size and increasing the number of plots is necessary. Understanding the structural and floristic vegetation are important for proper management of forest rehabilitation process in the UMS forest. The UMS forest is still in the regenerating phase and faster recovery can be facilitated through a specific rehabilitation programme. In future, any rehabilitation programme of

UMS forests should consider matching habitat suitability with native species that are of ecological match to the forest type in UMS.

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