Chapter 18

# Tree Species Diversity and Forest Stand Structure of Pahang National Park, Malaysia

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Additional information is available at the end of the chapter

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## 1. Introduction

Information on composition, diversity of tree species and species-rich communities is of primary importance in the planning and implementation of biodiversity conservation efforts. In addition, the diversity of trees is fundamental to the total tropical rainforest diversity as trees provide resources and habitat structure for almost other forest species (Cannon *et al*., 1998). According to Singh (2002), biodiversity is essential for human survival and economic well being and ecosystem function and stability. UNEP (2001) reported that habitat destruction, over exploitation, pollution and species introduction are identified as major causes of biodiversity loss. Hubbel *et al*. (1999) mentioned that disturbances created by these factors determine forest dynamics and tree diversity at the local and regional scales. These disturbances have been considered as an important factor structuring communities (Sumina, 1994).

In forest management operations, inventories on biodiversity are used to determine the nature and distribution of biodiversity region at the region being managed. Quantification of tree species diversity is an important aspect as it provides resources for many species (Cannon *et al*., 1998). Being a dominant life form, trees are easy to locate precisely and to count (Condit *et al*., 1996) and are also relatively better known, taxonomically (Gentry, 1992).

While Pahang National Park provides both fully-protected habitats and long-term maintenance of biological diversity, the structure and composition of its flora still remain rather insufficiently known. To protect forests from declining, it is essential to examine the current status of species diversity as it will provide guidance for the management of protected areas. Therefore, using Kuala Keniam forest as an example, a study was conducted to describe quantitatively stand structure of the forests of Kuala Keniam within Pahang National Park, and to determine the level of species composition, diversity and distribution in this area. Information from this quantitative inventory will provide a valuable reference for forest assessment and improve our knowledge in identification of ecologically useful species as well as species of special concern, thus identify conservation efforts for sustainability of forest biodiversity.

## 2. Materials and methods

### 2.1. Description of study area

The data for this study were collected from Kuala Keniam forest, Pahang National Park, Malaysia (latitude 4° 31′ 07.17″ N, longitude 102° 28′ 31.26″ E) which ranges about 120 – 200 m above sea level. Kuala Keniam is located at the protected lowland dipterocarp forests within the national park in the state of Pahang. The area is administered by the Department of Wildlife and National Park (DWNP) Malaysia in collaboration with the Universiti Teknologi MARA (UiTM) which operates a research station in the area.

The weather in Pahang National Park is characterized by permanent high temperatures ranging from 20°C at night and 35°C in the day with a high relative humidity (above 80%). Periods of sunshine in the morning are usually followed by heavy thunderstorms in the afternoon, sometimes accompanied by severe gusts of wind. The highest rainfall occurs in October to November with about 312 mm of rainfall. The lowest rainfall occurs in March with only about 50 mm of rain. Sedimentary rocks account for about 83% of National Park. The last formation of sedimentary rocks belongs to the Cretaceous-Jurassic era which exists in Kuala Keniam and its vicinity. The rocks are thick cross-bedded sandstone deposits with subordinate conglomerates and mudstones. The topography consists mainly of lowland, undulating and riverine areas and gently rolling hills with slopes of between 5° to 45°.

The overall vegetation type in Pahang National Pahang is lowland dipterocarp forests in which is characterized by high proportion of species in the family of Dipterocarpaceae with Meranti (*Shorea* spp.) and Keruing (*Dipterocarpus* spp.) as the dominant species. Lowland dipterocarp forest is one of the most rich-species communities in the world, with more than 200 species $ha^{-1}$ (Okuda *et al*., 2003). Other vegetation communities in Pahang National Park range from the humid rainforests of the lowland, to the montane oak and ericaceous forests in the higher elevation. The highest peak is Mount Tahan 2,187 m, which also the highest point in Peninsular Malaysia. Tahan River and Tembeling River are the headstream tributaries of Pahang National Pahang with the presence riparian tree species, i.e., Gapis (*Saraca multiflora*), Keruing neram (*Dipterocarpus oblongifolius*), Merbau (*Intsia palembanica*), Kasai daun bersar (*Pometia pinnata*) and Melembu (*Pterocambium javanicum),* along river banks. The rainforest consists of tall evergreen trees which attain heights between 30 – 50 m (i.e., Tualang - *Koompassia excelsa*).

### 2.2. Sampling design and data collection

A topographic map was used to locate the existing forest trails and baselines in the forest area. A total of five transect lines of 100 m in length and 20 m in width (abbreviated as T1, T2, T3, T4 and T5 thereafter) were established in east-west direction using a compass (Table 1, Figure 1).

Each transect line was gridded into five plots, each 20 m × 20 m in size, as workable units. These transect lines were perpendicular to the existing baseline in the forest area and constructed 5 m after the line. The topographic position, including the gradient was measured at each plot. The slope was measured using a clinometer. A tape measure was used to mark the transect lines at the intervals of 20 m. All trees with a diameter at breast height (DBH, 1.3 m above the ground) above 10 cm were measured, tagged and identified by species. The DBH was measured using a DBH tape. If field identification was not possible, the botanical specimens were taken to the herbarium section of the Forest Research Institute Malaysia (FRIM) for identification.

| Transect | No. of plots | Area ($m^2$) | Slope (°) | Topography |
|---|---|---|---|---|
| T1 | 5 | 20 × 20 | 5 – 35 | Steep lower slope with riverine areas |
| T2 | 5 | 20 × 20 | 3 – 20 | Gentle to mid-slope |
| T3 | 5 | 20 × 20 | 0 – 10 | Mainly flat and gentle slope |
| T4 | 5 | 20 × 20 | 3 – 30 | Mid-slope with riverine areas |
| T5 | 5 | 20 × 20 | 0 – 10 | Mainly flat and gentle slope |

**Table 1.** General features of sample plot within the five transect lines of the study area.

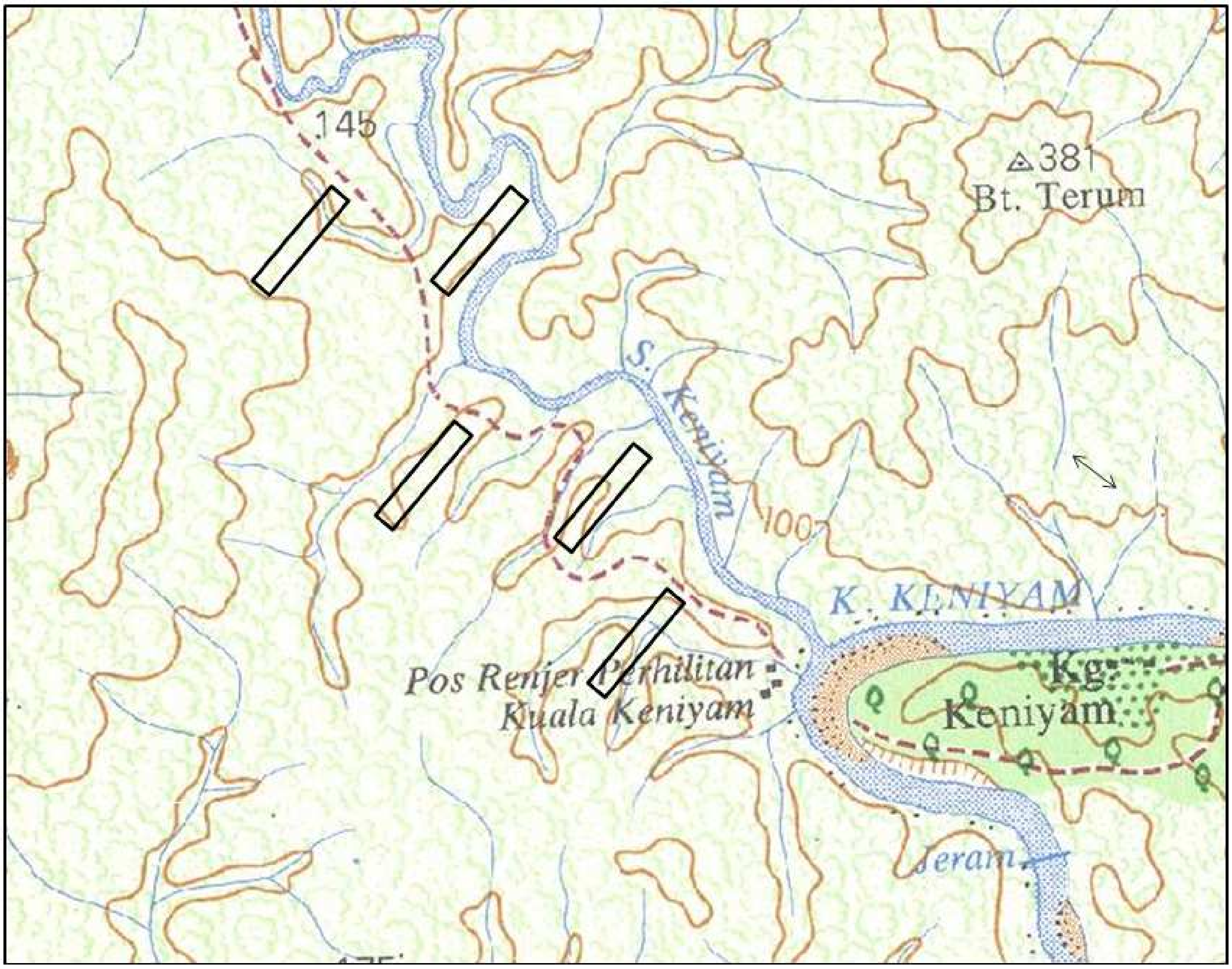


**Figure 1.** A map of the study area shows the location of five transect lines.

### 2.3. Data analysis

The means of basal area, genera, species and stem per hectare were calculated for each transect line. One-way analysis of variance (ANOVA) was used to test the differences between the means of these parameters using SAS system (SAS Institute, 2000). The relative dominance of species in each transect line was identified on the basis of relative basal area. The relative basal area of a species on transect lines was calculated as the basal area of a species divided by total basal area of the site and multiplied with 100. The dominant and co-dominant species of each site were identified based on this value. The species with the highest relative basal area was defined as dominant and that with the second highest relative basal area was defined as co-dominant.

In this study, the stand structure was described based on the distribution of species in the study sites and distribution of trees by diameter classes. Therefore, the tree data were grouped into 5 cm diameter classes e.g., the class boundaries were 10 – 14.9, 15 – 19.5 cm, etc. These gave a frequency of trees in each diameter class and were then used to draw bar char graphs.

### 2.4. Basal area

Basal area is a measure of tree density that defines the area of a given section of land that is occupied by the cross-section of tree. Basal area (*BA*) is calculated using the following equation that converts the DBH in cm to the basal area in m$^2$.

$$BA = \pi r^2$$

$$= 3.142 \times \left(\frac{\text{dbh}}{200}\right)^2$$

Where

*BA* = tree basal area (m2)
r = radius (cm)

### 2.5. Species diversity, richness and evenness indices

A variety of different diversity indices can be used as measures of some attributes of community structure because they are often seen as ecological indicators (Magurran, 1988). Diversity indices provide important information about rarity and commonness of species in a community. The indices can be used to compare diversity between habitat types (Kent and Coker, 1992). The comparison can be between different habitats or a comparison of one habitat over time. Different diversity, species richness, species evenness indices were calculated for each transect as well as pooled data for all transects.

a. Shannon-Weiner diversity index (*H′*) (Shannon and Weiner, 1949) is calculated using the following equation:

$$H' = \sum_{i=1}^{s} p_i \ln p_i$$

Where

$H'$= the Shannon-Wiener index
$p_i$= the proportion of individuals belonging to species $i$
ln=the natural log (i.e., 2.718)

b. The species richness (number of species per unit area) was calculated using Margalef index of species richness (Margalef, 1958) as follows:

$$\text{SR}=\frac{S-1}{\ln(N)}$$

Where

$SR$=the Margalef index of species richness
$S$ =the number of species
$N$ =the total number of individuals

c. The Whittaker's index of species evenness (Whittaker, 1972) was calculated using the following equation:

$$E_w = \frac{S}{\ln N_i - \ln N_s}$$

Where

$E_w$=the Whittaker's index of evenness
$N_i$=the abundance of most important species
$N_s$=the abundance of the least important species

d. $\alpha$-diversity was measured based on unified indices (exponential Shannon-Weiner index and Simpson's diversity) as follows:

$$N_1 = \exp^{H'}$$

Where

$N_1$=the number of equally common species
$H'$=the Shannon-Weiner index

e. Simpson's diversity ($D$) (Simpson, 1949) was calculated using the following equation:

$$D = 1 - \lambda$$

Where

D=the Simpson diversity

λ= the Simpson's concentration of dominance calculated as $\sum p_i^2$.

f. The Whittaker's index of β-diversity (Whittaker, 1972) was calculated as:

$$\beta w = \frac{S_c}{\bar{S}}$$

Where

$\beta_w$= the Whittaker's index of β-diversity
$S_c$=the total number of species
$\bar{S}$= the average number of species per sample

g. Bray-Curtis index ($C_N$) (Bray and Curtis, 1947), a similarity coefficient, is used to measure similarity between transect lines.

$$C_N = \frac{2jN}{(aN + bN)}$$

Where

$C_N$=the Bray-Curtis index
$aN$=individual numbers of plot A
$bN$=individual numbers of plot B
$jN$= the sum of less individual numbers of each species common in plots A and B

## 3. Results and discussion

### 3.1. Stand structure analysis of different sites

Information on the basal area, stem, species and genera densities are efficient expression for revealing forest stand structure and spatial distribution of trees present in the landscape. These four parameters are presented in Table 2. In this study, the means of basal area $ha^{-1}$, stem $ha^{-1}$, species $ha^{-1}$ and genera $ha^{-1}$ were measured in every plot (20 m × 20 m) and were averaged to provide an estimate for each transect line. From the analysis of variance, it was found that the difference in the means of these parameters among transects were not statistically significant at $P \leq 0.05$.

The mean of basal area obtained in the present study ranged from 17.2 $m^2$ $ha^{-1}$ (T4) to 34.3 $m^2$ $ha^{-1}$ (T3) (Table 2), which is lower compared to those recorded in other tropical rainforests. Examining the structure and composition of lowland tropical rainforests in north Borneo, Burgess (1961) recorded a basal area of 73.6 $m^2$ $ha^{-1}$ (≥ 10 cm DBH) over a small area (0.08 ha) at Gum Gum Sabah. In another study in an evergreen forest of Andaman Islands, basal area of 44.6 $m^2$ $ha^{-1}$ has been recorded in 4.5 ha sampled area (Padalia *et al.*, 2004). A much lower basal area of 29 $m^2$ $ha^{-1}$ and 5.6 $m^2$ $ha^{-1}$ have been recorded in logged over forest of Sungkai, Perak (Suratman *et al.*, 2007) and secondary forests of Sungai Sator, Kelantan (Suratman *et al.*, 2009), respectively. Both are secondary forests and were put under a selection system of timber extraction in the past, and are considered to be of poor species.

| Variables | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Mean basal area ($m^2$ $ha^{-1}$) | 25.2 (25.2) | 24.8 (13.3) | 34.3 (15.1) | 17.2 (16.0) | 33.3 (12.2) |
| Mean no. of stems $ha^{-1}$ | 510 (123.3) | 430 (105.2) | 505 (51.2) | 315 (219.8) | 480 (186.6) |
| Mean no. of species $ha^{-1}$ | 370 (105.2) | 370 (105.2) | 450 (30.6) | 280 (190.7) | 405 (125.5) |
| Mean no. of genera $ha^{-1}$ | 340 (72.0) | 340 (72.0) | 435 (51.8) | 250 (165.8) | 365 (109.8) |
| Total no. of species per individual | 0.50 | 0.69 | 0.63 | 0.79 | 0.64 |

**Note:** The values in parentheses are standard deviation. All means for the first four parameters above are not significantly different at **P** $\leq$ 0.05.

**Table 2.** The stand structure of Kuala Keniam forest.

The density and size distribution of trees contribute to the structural pattern characteristic of rainforests. In primary tropical rainforests, the density of trees varies within the limits and depends on many factors. The means number of species and stems per hectare on different transects varied from 280 (T4) – 450 (T3) and 315 (T4) – 510 (T1), respectively (Table 2), indicating a mixed nature of distribution of species and individuals in the forest at each transect, a characteristic of the tropical rainforests. The factors controlling tree density include the effects of natural and anthropogenic disturbance and soil condition (Richards, 1952). From the field observation, the reserve area of the primary forest in the study sites is generally homogenous, with no evidence of major disturbance, and appeared to be a representative example of the lowland forest of Kuala Keniam.

Information on the density-dependent status of species in the study site is important for conservation and management. Studies have classified the density of trees $ha^{-1}$ in tropical forests ranges from low values of 245 stems $ha^{-1}$ (Ashton, 1964; Campbell *et al.*, 1992; Richards, 1996) intermediate values of 420 – 617 stems $ha^{-1}$ (Campbell *et al.*, 1992) in Brazilian Amazon and high values of 639 – 713 stems $ha^{-1}$ in Central Amazon upland forests (Ferreira *et al.*, 1998). In the present study, the density of stems per hectare ranged from 315 – 510 stems $ha^{-1}$, reflecting spatial variability in the sampled sites. The range fell within intermediate category in the above studies. In the Neotropics, the maximum richness is found up to 300 stems $ha^{-1}$ (Gentry, 1988). A much lower result was reported for forests in Africa where the species richness is about 60 stems $ha^{-1}$ (Bernhard-reversat *et al.*, 1978).

Tree species composition in tropical areas varies greatly from one place to another mainly due to variation in biogeography, habitat and disturbance (Whitmore, 1998). In the tropical rainforests, the tree species per hectare ranges from about 20 to a maximum of 223 (Whitmore, 1984). Philips and Gentry (1994) reported a range of 56 – 282 species $ha^{-1}$ (>10 cm DBH) in mature tropical forests. In the present study, a range of 280 to 450 species $ha^{-1}$ has been recorded in the lowland rainforest of Kuala Keniam (Table 2). In the very rich rainforests, the number of species in rainforests could be as high as 400 species $ha^{-1}$ (Nwoboshi, 1982). When compared to some rainforests around the world, the lowland rainforest of Kuala Keniam could be considered to be species rich. Tropical rainforests in

South America harbour 200 – 300 species $ha^{-1}$ (Richards, 1996). In the tropical evergreen forest of Andaman Islands, India, Padalia *et al*. (2004) found that 58 tree species $ha^{-1}$ were recorded belong to 176 genera and 81 families.

The mean numbers of genera per hectare varied from 340 to 435 genera $ha^{-1}$. These values are much higher than that obtained by Sagar *et al*. (2003) at a dry tropical forest region of India (4 – 22 genera $ha^{-1}$). T4 had the highest total number of species per individual when compared to the other four sites of study. The difference could be due to genetic and site difference. A study on vegetation types in Yunnan, Chiangcheng *et al*. (2007) found that slope direction had influence on the tree diversity at different altitudes. The tree diversity on the sunny slope was lower than that on shady slope. The difference in terrain, gradient and slope direction causes the difference soil, water and microclimate which may cause of differences in species adaptability.

### 3.2. Dominant tree species

On the basis of relative basal area, the five sites differed in the combination of dominant and co-dominant species (Appendix). *Elateriospermum tapos* was dominant in T1 and co-dominant in T4. *Koompassia malaccensis* dominated at the T2 and co-dominated at the T3. *Xanthophyllum lelacarum* was dominant in T3 while *Shorea leprosula* was dominant in T4. *Dyera costulata* and *Dipterocarpus costulatus* were dominated and co-dominated at T5, respectively. Thus, the species exhibit local dominance. These data revealed that T1 represented *Elateriospermum-Intsia* community; T2, *Koompassia-Pentaspadon* community; T3, *Xanthophyllum-Koompassia* community; T4, *Shorea-Koompassia* community; and T5, *Dyera-Dipterocarpus* community. Two tree species, i.e., *Alphonsea elliptica* and *Syzygium* sp., are common on all transects.

### 3.3. Species diversity

The five transect lines yielded a total of 448 stems and 198 species of trees ≥ 10 cm DBH. These species represent 116 genera and 44 families (Appendix). The number of species and individual varied from 50 to 64 species and 63 to 102 individuals per transect of 100 m × 20 m size, respectively. Table 3 shows the summary statistics for various indices of diversity, richness and evenness. It is generally recognized that the area and environmental heterogeneity have strong effects on species diversity (Rosenzweig, 1995; Whitmore, 1998; Waide *et al*., 1999). The Shannon-Weiner index ($H'$) was used to compare species diversity between transects. The $H'$ for T1–T5 were 3.42, 3.91, 3.97, 3.84 and 3.91, respectively, indicating that among transects, T3 was the most complex in species diversity whereas T1 is the simplest community in terms of species composition. The Shannon-Weiner diversity index (range between 3.42 – 3.91) obtained for trees more than 10 cm DBH in this study was lower than those recorded in the tropical rainforests of Barroo Colorado Island, Panama [4.8](Knight, 1975) and Silent Valley, India [4.89](Singh *et al*., 1981). In a more recent study in Shenzen, China, Wang *et al*. (2006) recorded a lower range of Shannon-Weiner index (i.e., 1.92 – 3.10) for trees ≥ 2 cm DBH in a subtropical forest. However, a comparison of diversity indices obtained in the present study with the ones above is difficult due to vast differences in the area sampled, plot size, and the standard diameter class taken.

| Variables | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|
| Shannon-Weiner index (*H'*) | 3.42 | 3.91 | 3.97 | 3.84 | 3.91 |
| Margalef index of species richness (*SR*) | 10.81 | 13.02 | 13.65 | 11.83 | 13.15 |
| Whittaker index of evenness ($E_w$) | 16.04 | 36.66 | 35.72 | 44.60 | 31.35 |
| The number of equally common species ($N_1$) | 30.72 | 49.72 | 53.11 | 46.55 | 49.75 |
| Simpson's diversity (*D*) | 0.93 | 0.98 | 0.98 | 0.98 | 0.97 |
| Whittaker index of β-diversity ($\beta w$) | 3.51 | 3.88 | 3.56 | 4.46 | 3.77 |

**Table 3.** Pattern of tree species diversity in Kuala Keniam forest.

Similar patterns were found for species richness, which was computed using Margalef index of species richness (*SR*) and the number of equally common species ($N_1$). The *SR* ranged from 10.81 to 3.97 and the $N_1$ ranged from 30.72 to 53.11. Whittaker index of evenness ($E_w$) ranged from 16.04 to 44.60, the highest value was recorded at T4 and the lowest at T1. In the present study, Simpson's diversity (*D*) was not a very sensitive indicator of diversity as four of five sites (T2 – T5) had somewhat similar values. Whittaker index of β-diversity ($\beta w$) was used to compare habitat heterogeneity within a transect. The $\beta w$ value was the highest for T4 (4.46) and the lowest for T1 (3.51). Further analysis indicated that the number of species per individual had a direct positive influence on β-diversity (Figure 2). According to Condit *et al*. (1998), species richness is positively associated with species abundance. This relationship suggests that large population is less prone to extinction than small ones (Preston, 1962). Based on the relationship between abundance and diversity, habitats supporting larger numbers of individuals can support more populations and more species than habitat supporting small number of individuals.

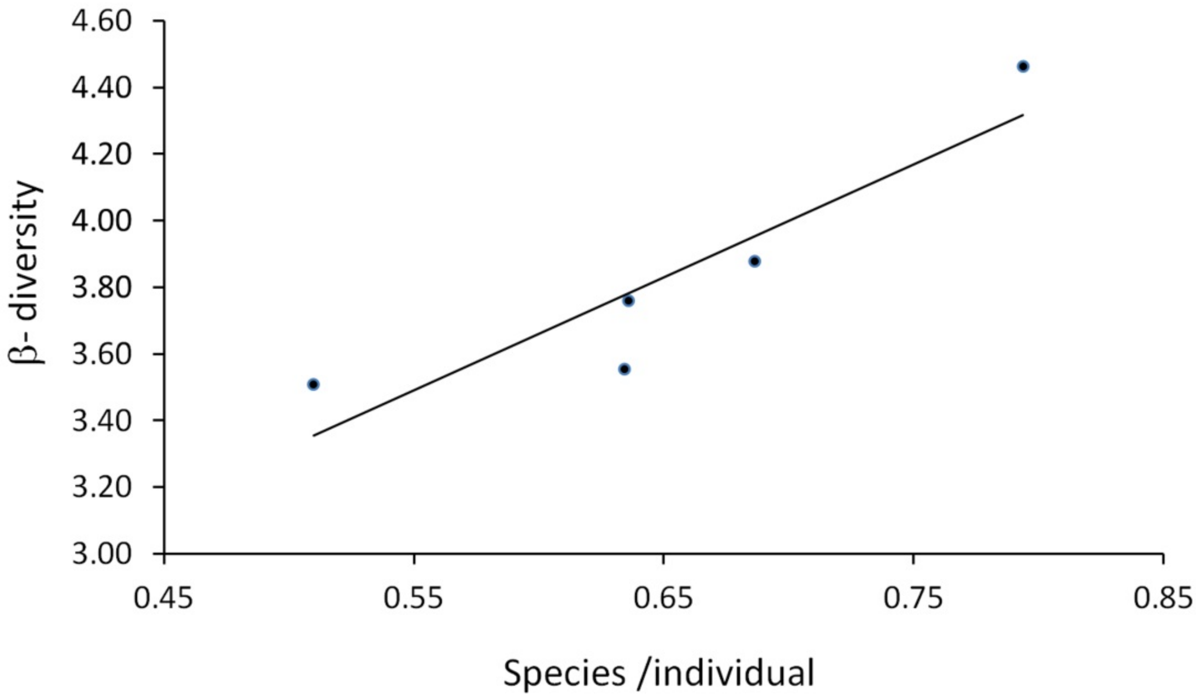


**Figure 2.** Relationship between β-diversity ($\beta_w$) and species/individual ($S_n$) according to $\beta_w = 1.624 + 3.393S_n$, $r^2$=83, p=0.03.

### 3.4. Similarity between transects

The similarity based on Bray-Curtis index ($C_N$) was calculated between the pair of transects, and abundance similarity matrix was constructed (Table 4). The Bray-Curtis similarity index was used because it is often a satisfactory coefficient for biological data on community structure (Clarke and Warwick, 1994). Comparison of $C_N$ values among the five transects data indicates that the species composition of T1 was fairly different from those of the other four sites. T3 had a high species similarity to T4 and T5, and T4 had a high species similarity to T5. T2 was similar to some degree to T4 and T5.

| Transect | T1 | T2 | T3 | T4 |
|---|---|---|---|---|
| T2 | 0.15 | | | |
| T3 | 0.14 | 0.19 | | |
| T4 | 0.13 | 0.13 | 0.27 | |
| T5 | 0.14 | 0.11 | 0.37 | 0.29 |

**Table 4.** Similarity coefficient among the five transects of Kuala Keniam forest.

### 3.5. Family-wise distribution

A total of 44 tree families were encountered in the forest of Kuala Keniam (Figure 3). The maximum number of tree species belongs to the family of Euphorbiaceae which accounts for 23.9% of the total individuals encountered in the study site. *Elateriospermum tapos* is the most widely occurring species from this family. Other trees from this family such as *Macaranga lowii, Mallotus leucodermis* and *Pimelodendron griffithianum* are among the important part of floristic composition in the study area. The other dominant families are Myristicaceae, Burseraceae, and Leguminosae which account for 8.3%, 5.4% and 4.5% of the total individual encountered in the study site, respectively. The fifth most dominant family is Myrtaceae with 4.2%. Earlier study also indicated that Euphorbiaceae was the dominant family in Sungkai forest with 27% of tree species belong to this family (Suratman *et al*., 2007). Two other studies conducted in India for tree species also support the fact that Euphorbiaceae is the dominant family in Bay Islands (Dagar and Singh, 1999) and Andaman Islands (Padalia *et al*., 2004). The dominant plant family in Neotropical lowland forests and Africa is Leguminosae (Gentry, 1988) and in Southeast Asia the dominants are Dipterocarpaceae (Richards, 1952; Whitmore, 1998).

### 3.6. Diameter class distribution

The stand structure of lowland rainforests of Kuala Keniam forest was studied based on the distribution of tree diameter class. The diameter distribution of trees is very variable and some forests have large numbers of trees of 40 – 60 cm DBH (Richards, 1952). In this study, the distribution of trees clearly displays the characteristic of De iocourt's factor procedure (inverse J distribution) where stems frequencies decrease with the increase in DBH (Figure 4). This generally indicates that stands are developing and regeneration in the forest is

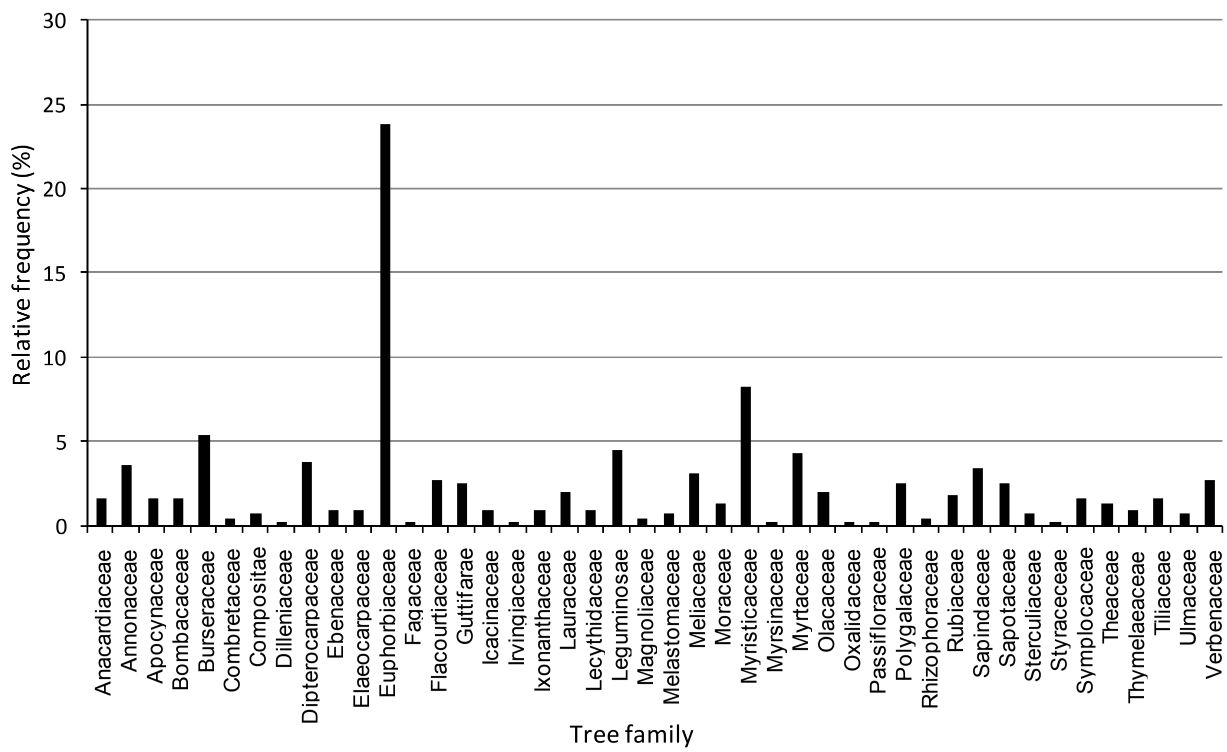


**Figure 3.** Family-wise distribution of tree species of Kuala Keniam forest.

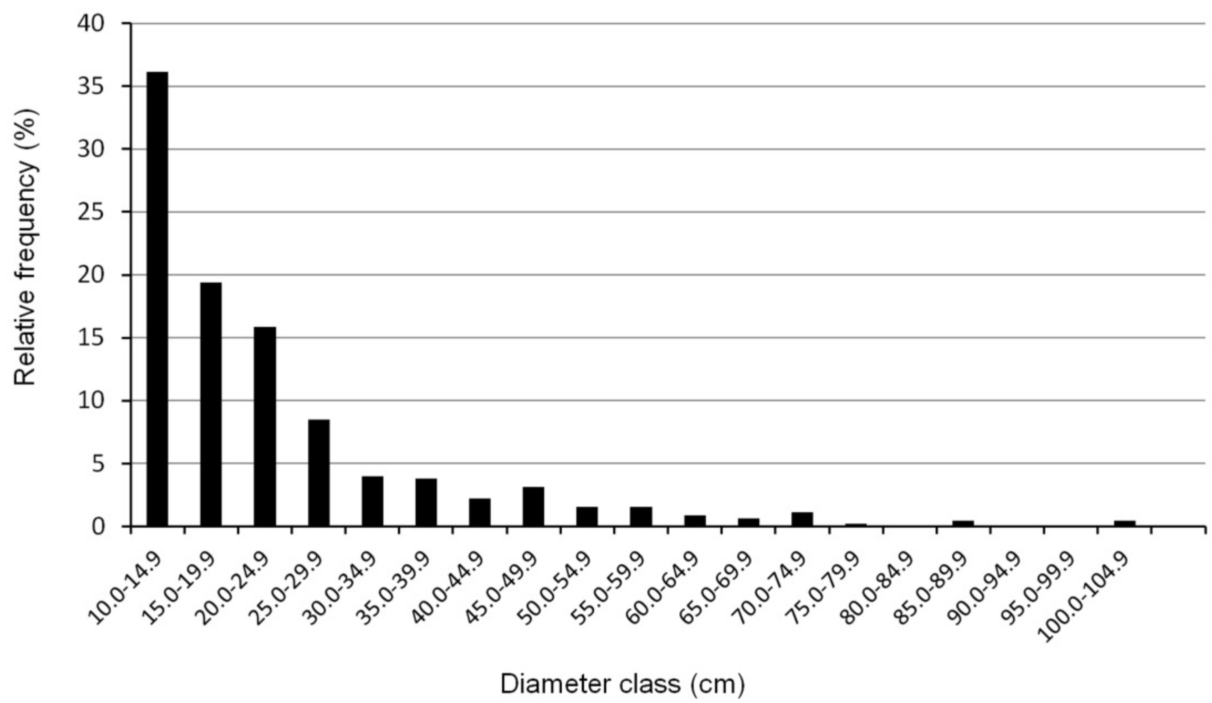


**Figure 4.** Diameter distribution of trees at Kuala Keniam forest.

present. Natural regeneration is dependent on the availability of mother trees, fruiting pattern and favourable conditions. As shown in the figure, the presence of growth of the forest is indicated by the movement of trees in various diameter classes. Higher number of stems for smaller diameter classes, with 36% of trees fell within the 10 – 14.9 cm, 19% fell within 15 – 19.9 cm, 16% fell within 20 – 24.9 cm, 9% fell within 25 – 29.9 cm and 4% fell within 30 – 34.9 cm. The histogram shows a less or an absent number of stems in diameter classes from 79.9 cm onwards. Under natural conditions, an old, big emergent tree may fall down and create gap. Forest regeneration via natural succession will take place if the area is not too far away from mature primary forest trees serving as source for the recalcitrant seeds.

## 4. Conclusion

The forests of Kuala Keniam are protected primary forests which comprises of natural vegetation and are dictated by a combination of biotic and abiotic factors like topography, altitude, geology, climatic etc. as well as historical conditions of geology and climate. The density and size distribution of trees contribute to the structural pattern characteristics of the forest. The study indicated that the forests of Kuala Keniam are characterized by a uniform distribution of individuals with mixed species composition, and the sites are represented by different combinations of the dominants and co-dominant species. The distribution of trees displays the characteristic of De iocourt's factor procedure (inverse J distribution) where stems frequencies decrease with the increase in DBH, indicating stable populations in which regeneration of forest in this area is present.

## Appendix

List of species, family and the relative basal area of Kuala Keniam forest

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Aglaia* sp. | Meliaceae | - | 2.65 | 0.23 | 0.37 | 0.17 |
| *Agrostistachys longifiolia* | Euphorbiaceae | - | 0.26 | - | - | - |
| *Aidia densiflora* | Rubiaceae | - | - | 0.21 | - | 0.24 |
| *Alphonsea elliptica* | Annonaceae | 2.37 | 0.55 | 1.48 | 5.91 | 1.41 |
| *Alphonsea jengkasii* | Annonaceae | - | - | - | - | 0.16 |
| *Alseodaphne intermedia* | Lauraceae | - | - | 0.84 | - | - |
| *Anisoptera laevis* | Dipterocarpaceae | - | - | 4.35 | - | - |
| *Antidesma coriaceum* | Euphorbiaceae | - | - | 0.47 | - | - |
| *Antisdesma* sp. | Euphorbiaceae | - | 0.28 | - | - | - |
| *Aporosa arborea* | Euphorbiaceae | 0.51 | - | - | - | - |
| *Aporosa aurea* | Euphorbiaceae | - | 0.28 | - | - | - |

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Aporosa falcifera* | Euphorbiaceae | - | - | - | 1.63 | 0.21 |
| *Aporosa globifera* | Euphorbiaceae | - | 0.25 | - | - | - |
| *Aporosa microstachya* | Euphorbiaceae | - | - | - | - | 0.22 |
| *Aporosa nigricans* | Euphorbiaceae | - | 0.29 | - | - | - |
| *Aporosa prainiana* | Euphorbiaceae | - | - | - | 0.24 | 0.12 |
| *Aporosa symplocoides* | Euphorbiaceae | - | - | - | - | 0.17 |
| *Archidendron ellipticum* | Leguminosae | - | - | 0.32 | - | - |
| *Ardisia* sp. | Myrsinaceae | - | 0.21 | - | - | - |
| *Aromadendron elegans* | Myristicaceae | - | 1.42 | - | - | - |
| *Artocarpus griffithii* | Moraceae | - | - | 0.48 | - | - |
| *Artocarpus lowii* | Moraceae | - | - | - | - | 0.73 |
| *Austrobuxus nitidus* | Euphorbiaceae | - | - | - | - | 5.10 |
| *Baccaurea brevipes* | Euphorbiaceae | - | - | - | 0.24 | - |
| *Baccaurea kunstleri* | Euphorbiaceae | - | - | - | 0.42 | - |
| *Baccaurea minor* | Euphorbiaceae | - | 0.72 | 2.77 | - | - |
| *Baccaurea reticulata* | Euphorbiaceae | - | - | - | 0.38 | 3.46 |
| *Barringtonia macrostachya* | Lecythidaceae | - | - | 0.28 | 0.37 | 0.20 |
| *Beilschmiedia lucidula* | Lauraceae | - | - | 0.99 | - | - |
| *Blumeodendron kurzii* | Euphorbiaceae | - | - | 0.82 | - | - |
| *Buchanania sessifolia* | Anacardiaceae | - | - | 0.79 | - | 0.28 |
| *Callicarpa maingayi* | Verbenaceae | - | - | - | - | 0.39 |
| *Callophyllum* sp. | Guttiferae | - | 0.40 | - | - | - |
| *Canarium littorale* | Burseraceae | 1.20 | - | 2.00 | - | - |
| *Carallia brachiata* | Rhizophoraceae | - | - | - | - | 0.75 |
| *Casearia clarkei* | Flacourtiaceae | - | - | 0.61 | 0.94 | 0.13 |
| *Casearia* sp.1 | Flacourtiaceae | - | 0.91 | - | - | - |
| *Cheilosa malayana* | Euphorbiaceae | - | 0.21 | - | 0.35 | - |
| *Chisocheton* sp. | Meliaceae | 0.25 | - | - | - | - |
| *Cinnamomum iners* | Lauraceae | - | 1.55 | - | - | - |
| *Croton levifolium* | Euphorbiaceae | - | - | - | - | 0.29 |
| *Cryptocarya densiflora* | Lauraceae | - | - | 0.61 | - | - |
| *Cryptocarya infectoria* | Lauraceae | - | - | - | - | 0.45 |
| *Cryptocarya kurzii* | Lauraceae | - | 0.63 | 0.50 | - | - |
| *Dacryodes costata* | Burseraceae | - | - | 0.24 | - | - |
| *Dacryodes rostrata* | Burseraceae | 0.59 | - | 0.13 | 0.31 | 4.79 |

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Dacryodes rugosa* | Burseraceae | 0.48 | - | 0.19 | 1.08 | 0.18 |
| *Dialium indum* L. var. *indum* | Leguminosae | 0.74 | - | - | - | - |
| *Dialium platysepalum* | Leguminosae | - | 0.82 | - | - | - |
| *Dillenia reticulata* | Dilleniaceae | - | 6.69 | - | - | - |
| *Diospyros buxifolia* | Ebenaceae | - | - | 0.18 | - | - |
| *Diospyros maingayi* | Ebenaceae | - | - | - | - | 1.87 |
| *Diospyros sumatrana* | Ebenaceae | - | - | - | - | 0.28 |
| *Diplospora malaccensis* | Rubiaceae | - | 0.28 | - | - | 0.57 |
| *Dipterocarpus costulatus* | Dipterocarpaceae | - | - | - | - | 12.63 |
| *Durio griffithii* | Bombacaceae | 0.28 | - | 1.67 | 0.33 | 0.68 |
| *Durio lowianus* | Bombacaceae | - | - | - | 5.03 | - |
| *Dyera costulata* | Apocynaceae | - | - | 0.84 | 2.97 | 13.38 |
| *Dysoxylum flavescens* | Meliaceae | - | - | 1.71 | - | - |
| *Dysoxylum* sp. | Meliaceae | 1.19 | - | - | - | - |
| *Dysoxylum* sp1. | Meliaceae | - | - | 2.91 | - | - |
| *Elaeocarpus nitidus* | Elaeocarpaceae | - | - | 0.30 | 1.13 | - |
| *Elaeocarpus palembanicus* | Elaeocarpaceae | - | - | - | - | 0.13 |
| *Elaeocarpus petiolatus* | Elaeocarpaceae | - | - | - | 0.68 | - |
| *Elateriospermum tapos* | Euphorbiaceae | 16.11 | - | 4.48 | 7.73 | 3.40 |
| *Erythrospermum candidum* | Flacourtiaceae | - | 0.34 | - | - | - |
| *Flacourtia rukam* | Flacourtiaceae | 0.33 | - | - | - | - |
| *Garcinia bancana* | Guttiferae | - | - | - | - | 3.96 |
| *Garcinia griffithii* | Guttiferae | - | - | - | 0.75 | 3.18 |
| *Garcinia nervosa* | Guttiferae | - | - | - | - | 1.79 |
| *Garcinia parvifolia* | Guttiferae | - | - | 1.03 | - | - |
| *Garcinia pyrifera* | Guttiferae | - | - | 0.40 | - | - |
| *Gironniera nervosa* | Ulmaceae | 0.26 | - | - | - | - |
| *Gironniera subaequalis* | Ulmaceae | - | - | 0.77 | - | - |
| *Gonocaryum gracile* | Icacinaceae | - | - | - | 0.27 | - |
| *Gonystylus maingayi* | Thymelaeaceae | - | 4.24 | 0.24 | 2.89 | - |
| *Gordonia penangensis* | Theaceae | - | 0.69 | 0.98 | - | 1.77 |
| *Guioa* sp. | Sapindaceae | - | - | - | - | - |
| *Homalium longifolium* | Flacourtiaceae | - | - | 1.95 | - | - |
| *Hopea sulcata* | Dipterocarpaceae | - | - | 0.84 | - | - |
| *Horsfieldia fulva* | Myristicaceae | | - | 1.12 | - | - |

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Horsfieldia sucosa* | Myristicaceae | 0.74 | - | - | - | - |
| *Horsfieldia tomentosa* | Myristicaceae | 0.19 | - | - | - | - |
| *Hosfieldia polyspherula var. sumatrana* | Myristicaceae | - | - | - | - | 0.57 |
| *Hunteria zeylanica* | Apocynaceae | - | - | 3.41 | - | - |
| *Hydnocarpus woodii* | Flacourtiaceae | 1.72 | - | - | - | - |
| *Intsia palembanica* | Leguminosae | 12.80 | - | - | - | - |
| *Irvingia malayana* | Irvingiaceae | - | - | - | 0.58 | - |
| *Ixonanthes icosandra* | Ixonanthaceae | - | 3.28 | 0.61 | - | 0.81 |
| *Kibatalia maingayi* | Apocynaceae | 0.31 | - | - | - | - |
| *Knema furfuracea* | Myristicaceae | - | - | - | 1.46 | 0.96 |
| *Knema hookeriana* | Myristicaceae | 1.70 | 0.27 | - | - | - |
| *Knema intermedia* | Myristicaceae | 1.62 | 0.60 | - | - | - |
| *Knema laurina* | Myristicaceae | 0.38 | - | - | - | - |
| *Knema patentinervia* | Myristicaceae | - | 1.53 | 1.35 | 2.51 | 0.30 |
| *Knema scortechinii* | Myristicaceae | 1.78 | 0.43 | - | - | - |
| *Knema stenophylla* | Myristicaceae | - | - | - | - | 0.57 |
| *Koompassia excelsa* | Leguminosae | - | 2.08 | - | 2.79 | - |
| *Koompassia malaccensis* | Leguminosae | 0.97 | 14.87 | 7.90 | - | - |
| *Lasianthus* sp. | Rubiaceae | - | - | - | 0.34 | - |
| *Lithocarpus curtisii* | Fagaceae | - | - | - | 3.48 | - |
| *Litsea machilifolia* | Lauraceae | - | - | - | 0.26 | - |
| *Macaranga hypoleuca* | Euphorbiaceae | - | - | - | 0.94 | 0.33 |
| *Macaranga lowii* | Euphorbiaceae | - | - | 1.06 | 0.78 | 2.57 |
| *Magnolia liliifera* | Magnoliaceae | - | - | 1.07 | - | - |
| *Mallotus leucodermis* | Euphorbiaceae | 6.22 | 1.05 | - | - | - |
| *Mallotus oblongifolius* | Euphorbiaceae | 0.24 | - | 0.24 | - | - |
| *Mallotus* sp. | Euphorbiaceae | 1.70 | - | - | - | - |
| *Mangifera griffithii* | Anacardiaceae | - | - | - | 1.33 | - |
| *Medusanthera gracilis* | Icacinaceae | - | - | 0.21 | - | 0.45 |
| *Meiogyne monosperma* | Annonaceae | - | 0.27 | - | - | - |
| *Memecylon minutiflorum* | Melastomaceae | - | 0.26 | - | - | - |
| *Memecylon pubescens* | Melastomaceae | - | 0.87 | - | - | - |
| *Mesua ferrea* | Guttiferae | - | - | 0.21 | - | - |
| *Mesua lepidota* | Guttiferae | 1.00 | - | - | - | - |

| **Species** | **Family** | **T1** | **T2** | **T3** | **T4** | **T5** |
|---|---|---|---|---|---|---|
| *Mesua racemosa* | Guttiferae | - | - | - | - | 0.47 |
| *Mezzettia elliptica* | Annonaceae | - | - | - | - | 2.54 |
| *Microcos antidesmifolia* | Tiliaceae | - | 0.72 | - | - | - |
| *Microcos fibrocarpa* | Tiliaceae | 0.17 | - | - | - | - |
| *Microcos laurifolia* | Tiliaceae | - | 1.26 | - | - | - |
| *Microcos tomentosa* | Tiliaceae | - | 0.16 | - | - | - |
| *Monocarpia marginalis* | Annonaceae | - | - | 0.35 | - | - |
| *Myristica gigantea* | Myristicaceae | - | - | - | - | 1.81 |
| *Nauclea officinalis* | Rubiaceae | - | - | - | 1.89 | - |
| *Neoscortechinia kingii* | Euphorbiaceae | - | - | 0.23 | - | - |
| *Nephelium costatum sub-species oppoides* | Sapindaceae | - | 0.41 | - | - | - |
| *Nephelium cuspidatum* | Sapindaceae | 4.77 | - | - | 1.05 | - |
| *Nephelium maingayi* | Sapindaceae | - | 0.16 | - | 1.62 | - |
| *Nothaphoebe umbelliflora* | Lauraceae | 0.90 | - | - | - | - |
| *Ochanostachys amentacea* | Olacaceae | 1.10 | - | 0.12 | - | 0.47 |
| *Palaquium clarkeanum* | Sapotaceae | - | - | - | 0.75 | - |
| *Palaquium gutta* | Sapotaceae | - | - | 2.01 | 4.02 | 1.22 |
| *Palaquium hexandrum* | Sapotaceae | - | - | 0.64 | - | - |
| *Palaquium hispidum* | Sapotaceae | - | 2.71 | - | - | - |
| *Palaquium maingayi* | Sapotaceae | - | - | 2.83 | - | - |
| *Palaquium microcarpum* | Sapotaceae | - | 0.57 | - | - | - |
| *Parartocarpus venenosus* | Moraceae | - | - | 0.39 | - | - |
| *Paratocarpus bracteatus* | Moraceae | - | - | - | 1.72 | - |
| *Paropsia vareciformis* | Passifloraceae | - | 0.23 | - | - | - |
| *Payena dasyphylla* | Sapotaceae | - | - | 0.94 | - | - |
| *Payena lanceolata var. lanceolata* | Sapotaceae | - | - | - | 5.07 | - |
| *Payena maingayi* | Sapotaceae | - | 1.88 | - | - | - |
| *Pellacalyx* saccardianus | Rhizophoraceae | - | - | - | 0.67 | - |
| *Pentace curtisii* | Tiliaceae | 0.17 | - | - | - | - |
| *Pentace strychnoidea* | Tiliaceae | - | - | - | - | 0.98 |
| *Pentaspadon velutinus* | Anacardiaceae | 7.40 | 7.76 | - | - | - |
| *Pimelodendron griffithianum* | Euphorbiaceae | 0.62 | - | 3.51 | 0.72 | 0.14 |
| *Planchonia grandis* | Lecythidaceae | - | - | - | 2.71 | - |
| *Polyalthia jenkensii* | Annonaceae | - | 0.56 | - | - | 0.13 |

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Polyalthia rumphii* | Annonaceae | - | 1.08 | - | - | - |
| *Pometia ridleyi* | Sapindaceae | 2.65 | - | - | - | - |
| *Pseudoclausena chrysogyne* | Meliaceae | - | 0.29 | - | - | - |
| *Pternandra echinata* | Melastomaceae | - | - | - | 0.38 | - |
| *Pterocymbium javanicum* | Sterculiaceae | 1.44 | - | - | - | - |
| *Ptychopyxis caput-medusae* | Euphorbiaceae | 3.29 | - | - | - | - |
| *Pyrenaria acuminata* | Theaceae | - | - | - | 0.75 | - |
| *Santiria griffithii* | Burseraceae | - | - | 0.18 | - | - |
| *Santiria laevigata* | Burseraceae | 1.03 | 0.96 | 10.47 | - | - |
| *Santiria* sp. | Burseraceae | 0.17 | - | - | - | - |
| *Santiria tomentosa* | Burseraceae | - | - | - | - | 1.64 |
| *Sapium baccatum* | Euphorbiaceae | - | 6.52 | - | - | - |
| *Saraca declinata* | Leguminosae | - | 0.46 | 0.25 | - | - |
| *Sarcotheca griffithii* | Oxalidaceae | - | - | - | - | 0.24 |
| *Scaphium linearicarpum* | Sterculiaceae | 1.13 | - | - | - | - |
| *Scaphium macropodum* | Sterculiaceae | - | - | - | - | 0.26 |
| *Schoutenia accrescens* | Tiliaceae | - | 0.20 | - | - | - |
| *Shorea leprosula* | Dipterocarpaceae | 5.18 | - | - | 12.67 | 6.73 |
| *Shorea multiflora* | Dipterocarpaceae | - | - | - | 3.26 | - |
| *Shorea ovalis* | Dipterocarpaceae | - | - | 0.28 | - | 6.19 |
| *Shorea parvifolia* | Dipterocarpaceae | 3.15 | - | 2.86 | - | 0.28 |
| *Species A* | Meliaceae | 0.73 | - | - | - | - |
| *Streblus elongatus* | Moraceae | 0.88 | - | - | - | - |
| *Strombosia ceylanica* | Olacaceae | - | - | - | - | 0.62 |
| *Strombosia javanica* | Olacaceae | - | 1.33 | - | - | - |
| *Strombosia* sp. | Olacaceae | - | - | - | 8.59 | - |
| *Styrax benzoin* | Styraceceae | - | 0.50 | - | - | - |
| *Symplocos fasciculata* | Symplocaceae | 2.37 | 1.75 | - | - | - |
| *Symplocos* sp. | Symplocaceae | - | - | - | 1.00 | - |
| *Syzygium chloranthus* | Myrtaceae | 0.63 | - | - | - | - |
| *Syzygium densiflora* | Myrtaceae | - | - | - | 0.25 | - |
| *Syzygium duthieanum* | Myrtaceae | 0.32 | - | - | - | - |
| *Syzygium griffithii* | Myrtaceae | - | - | 0.13 | 3.46 | 0.33 |
| *Syzygium lineatum* | Myrtaceae | 0.90 | - | - | - | - |
| *Syzygium protulata* | Myrtaceae | 0.69 | - | - | - | - |

| Species | Family | T1 | T2 | T3 | T4 | T5 |
|---|---|---|---|---|---|---|
| *Syzygium pustulatum* | Myrtaceae | - | - | 0.24 | - | - |
| *Syzygium* sp. | Myrtaceae | 0.79 | 1.38 | 9.23 | 0.92 | 1.32 |
| *Tarenna mollis* | Rubiaceae | 1.13 | - | - | - | - |
| *Teijsmanniodendron coriaceum* | Verbenaceae | - | - | 1.11 | - | 2.35 |
| *Terminalia citrina* | Combretaceae | - | 7.03 | - | - | - |
| *Timonius wallichianus* | Rubiaceae | 1.35 | - | - | - | - |
| *Vernonia arborea* | Compositae | - | 0.59 | - | - | 0.64 |
| *Vitex pinnata* | Verbenaceae | 1.35 | - | - | - | - |
| *Xanthophyllum griffithii* | Polygalaceae | - | - | 0.35 | - | 1.53 |
| *Xanthophyllum lelacarum* | Polygalaceae | - | - | 10.08 | - | - |
| *Xerospermum laevigatum* | Sapindaceae | - | 0.50 | - | - | - |
| *Xerospermum noronhianum* | Sapindaceae | - | 3.94 | - | - | - |
| *Xylopia magna* | Annonaceae | - | 7.76 | - | - | - |
| *Xylopia malayana* | Annonaceae | - | 0.16 | - | - | 0.43 |

**Table 5.** List of species, family and the relative basal area of Kuala Keniam forest.

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