Tree Species Diversity and Conservation Status of Keniam Forest, Taman Negara, Pahang

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Abstract. This study was conducted to quantify the community structure with regards to tree species composition and species diversity of tree communities at Kuala Keniam. Five study plots of 25 m x 20 m each were established randomly covering a total area of 0.25 ha. In each plot, all trees with diameters at breast height of 5 cm and above were tagged, measured and identified. Voucher specimens were then taken for further verification purposes. The floristic composition of Kuala Keniam consists of 244 individuals represented by 142 species, 95 genera and 36 families. Euphorbiaceae was the most speciose family with 20 species and nine genera. Elateriospermum tapos (Euphorbiaceae) was recorded as the most dominant species with 16 trees. Kuala Keniam recorded Shannon-Weiner Diversity index of $H' = 3.01$ and Margalef’s Richness Index with $D_M = 22.78$. Low evenness index of $J' = 0.14$ portrayed the unequal distribution of the tree species in the forest. Total tree biomass was estimated at 955.02 t/ha, represented by 815.43 t/ha of above ground biomass and 139.59 t/ha of below ground biomass. Carbon stock was estimated at 448.86 t/ha, contributed by, 383.25 t/ha of above ground carbon and 65.61 t/ha of below ground carbon.

Keywords: biomass, ecology, species accumulation curve, tropical forest, SDG15

1. Introduction
The primary forests are said to be the most diverse, complex and productive terrestrial ecosystems in the world, harbouring many species as well as repositories for species that cannot persist in secondary and degraded forests [1]. Taman Negara is often referred to as the untouched jungle and among the oldest rainforests (130 million years old) in the world. The Park was established in 1939 and was previously known as King George V National Park [2]. It covers an area of 4,343 square kilometres of which 4,000 km is covered by forest [3] [4]. It is situated across three states of Pahang, Kelantan and Terengganu. Taman Negara Pahang comprises most of the forest as it makes 57% of the total area of the park followed by Kelantan (24%) and Terengganu (19%) [5].

Taman Negara forms the main region of tropical rainforests in Malaysia and the country’s current position as one of the mega diversity countries in the world is largely due to these rainforests.
The overall vegetation type in Taman Negara Pahang is lowland dipterocarp forests that characterized by numerous trees from Dipterocarpaceae family with Meranti (Shorea spp.) and Keruing (Dipterocarpus spp.) as the dominant species [7]. Other plant types in Pahang National Park range from humid lowland rainforests to montane oak-laurel and ericaceous forests at higher elevations. Mount Tahan at 2,187 m is the highest point in Peninsular Malaysia. Sungai Tahan and Sungai Tembeling are the headstream tributaries of Pahang National Park with the presence of riparian tree species such as Keruing neram (Dipterocarpus oblongifolius) and Kasai daun besar (Pometia pinnata) growing along the riverbanks. The rainforest comprised of tall evergreen trees that reach heights of 30 – 50 m such as Koompassia excelsa or locally known as Tualang [7].

Taman Negara Pahang is gazetted under full protection forest where no human intervention to the forest is allowed. This practice is in line with the proposed Sustainable Development Goals by United Nations in 2015, particularly SDG 15 “Life on Land” [8]. SDG 15 was established based on its mission statement of “Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and reverse land degradation and halt biodiversity loss”. Thus, this makes the present study significantly beneficial in contributing to SDG 15 as the study aims to quantify the community structure with regards to tree species composition and species diversity of tree communities at Kuala Keniam forest. Further, the quantitative information of tree species composition in Kuala Keniam forest can be integrated for the updates of current tree inventory for forest management in Pahang National Park.

2. Methods

2.1. Study area

This study was conducted in lowland forest of Kuala Keniam, Taman Negara Pahang, Malaysia which is located about 25 km north of Kuala Tahan (latitude 4° 31’ 07.17” N, longitude 102° 28’ 31.26” E) (Figure 1). It has a tropical climate with annual rainfall of about 2,260 mm and average monthly temperature ranges from 25-37°C with more than 80% humidity. Kuala Keniam is characterized by a lowland dipterocarp forest with an elevation ranging about 120 – 250 m above sea level. In 2007, Universiti Teknologi Mara (UiTM) has developed a research station (UiTM-PERHILITAN) for research activity in the area of biodiversity, ecology, sustainability and climate change. This site contains many tree species such as Perah (Elateriospermum tapos), Merbau (Intsia palembanica), Penarahan (Knema laurina), Kempas (Koompassia malaccensis) and Kelat (Syzygium spp.) [9].
2.2 Tree sampling

For the purpose of tree inventory, a total of five sampling plots measuring at 25 m x 20 m (0.25 ha) were randomly established at Kuala Keniam forest. In each plot, all trees with diameter at breast height (DBH) of 5 cm and above were tagged and measured its diameter. The specimens for all measured trees such as leaves and fruits were collected for the preparation of voucher specimens and for species identification. The morphological characteristics were also compared to herbarium specimens from Universiti Kebangsaan Malaysia and the nomenclature was obtained using keys described in Tree Flora of Malaya [10-13].

2.3 Data analysis

Data of all tree communities were tabulated and summarized to describe floristic composition of Kuala Keniam, Taman Negara Pahang. Species accumulation curve was constructed using Ecosim version 7 to represent the adequacy of the sampling effort in the study area [14]. The Sorensen index, also known as Sorensen’s similarity coefficient, mainly uses abundance (presence-absence data) for comparing the similarity between tree communities in all study areas. Several ecological indices such as Shannon-Weiner Diversity Index [15], Evenness Index [16] and Margalef’s Richness Index [17] were used to compute the species diversity and species richness of the study area by using Paleontological Statistic Software Package for Education and Data Analysis (PAST) Software version 2.17c [18]. Total biomass was estimated by summing up the estimated above ground biomass (AGB) and below ground biomass (BGB) using the allometric equations [19] [20]. Carbon stock was calculated by using carbon conversion factor 0.47 [21].

Figure 1. Map of Kuala Keniam located in Taman Negara Pahang
3. Results & Discussions

3.1 Floristic composition

A total of 244 trees with diameter at breast height (dbh) of 5 cm and above were encountered in 0.25 ha of Kuala Keniam forest, of which overall floristic composition comprised of 142 species, 95 genera and 36 families (Table 1). These findings are comparable with earlier studies conducted at this forest such as Nor Farika [22] recorded 419 trees consisted of 184 species, 104 genera and 43 families in 0.8 ha study area. Further, Mohd Nazip [7] reported a taxonomic composition of 448 trees, 198 species, 116 genera and 44 families in 0.20 ha study area whilst Nizam [23] recorded 251 trees, 150 species, 83 genera and 39 families in 0.18 ha study site. It is evident that this forest supported diverse composition of tree communities, reflecting the importance of primary forest as biodiversity hotspots.

Table 1. Total numbers of genera, species and individuals for all tree families in 0.25 ha at Kuala Keniam forest

| No | Family            | Genus | Species | No of Ind |
|----|-------------------|-------|---------|-----------|
| 1  | Anacardiaceae     | 5     | 5       | 5         |
| 2  | Annonaceae        | 11    | 14      | 19        |
| 3  | Apocynaceae       | 3     | 3       | 3         |
| 4  | Burseraceae       | 4     | 7       | 9         |
| 5  | Dichapetalaceae   | 1     | 1       | 1         |
| 6  | Dilleniaceae      | 1     | 2       | 2         |
| 7  | Dipterocarpaceae  | 5     | 7       | 11        |
| 8  | Ebenaceae         | 1     | 5       | 5         |
| 9  | Euphorbiaceae     | 9     | 20      | 66        |
| 10 | Flacourtiaeae     | 2     | 2       | 2         |
| 11 | Guttiferae        | 4     | 8       | 9         |
| 12 | Icacinaceae       | 1     | 1       | 4         |
| 13 | Ixonanthaceae     | 1     | 1       | 2         |
| 14 | Lauraceae         | 2     | 3       | 3         |
| 15 | Lecythidaceae     | 1     | 1       | 1         |
| 16 | Leguminosae       | 4     | 4       | 16        |
| 17 | Loganiaceae       | 1     | 1       | 1         |
| 18 | Melastomataceae   | 2     | 2       | 2         |
| 19 | Meliaceae         | 3     | 6       | 7         |
| 20 | Meliosmaceae      | 1     | 1       | 1         |
| 21 | Moraceae          | 2     | 2       | 2         |
| 22 | Myristicaceae     | 4     | 9       | 14        |
| 23 | Myrtaceae         | 1     | 6       | 8         |
| 24 | Opiliaceae        | 1     | 1       | 3         |
| 25 | Pandaceae         | 2     | 2       | 3         |
| 26 | Polygalaceae      | 1     | 3       | 3         |
| 27 | Rubiaceae         | 6     | 6       | 11        |
| 28 | Rutaceae          | 1     | 1       | 1         |
| 29 | Sapindaceae       | 4     | 4       | 8         |
| 30 | Sapotaceae        | 3     | 4       | 8         |
| 31 | Sterculiaceae     | 2     | 2       | 2         |
Euphorbiaceae was recorded as the most abundant family with 66 individual trees and represented by 20 species in nine genera. This result is similar to previous findings that indicated Euphorbiaceae as the most dominant family in Kuala Keniam National Park, Pahang such as 23.9% of the total individuals belong to this family [24]. Besides, Nor Farika et al. [25] also recorded Euphorbiaceae with largest number of tree species, represented by 27 species and 107 trees in Kuala Keniam forest. Several studies have also reported similar observation of which the Euphorbiaceae was the most speciose family in Perlis State Park [26] as well as in lowland dipterocarp forests in Peninsular Malaysia [27][28]. These findings are in accordance with Turner [29] who stated that Euphorbiaceae was the second largest vegetation family in Peninsular Malaysia, represented by 371 species and 71 genera in total.

The most abundant species in the study plots was *Elateriospermum tapos* (Euphorbiaceae) with 16 individuals followed by *Mallotus leucodermis* (Euphorbiaceae) with 9 individuals and *Koompassia malaccensis* (Leguminosae) and *Macaranga lowii* (Euphorbiaceae) with 8 individuals each, respectively. Similar observation was also reported by Mohd Nazip [24] that *E. tapos* was the mostly occurring species from the family of Euphorbiaceae in Kuala Keniam National Park, Pahang. He also reported other dominant trees from this family such as *Macaranga lowii* which was also found to be among dominant trees in the present study.

### 3.2 Similarity coefficient

Community similarity between the pair of plots were assessed using Sorensen’s similarity index [30]. This index refers to the abundance of data and effectively measure species that overlap between pairs of study plots to display variation of assemblages within and between study plots (Table 2). Comparison of Sorenson index values among the five plots data indicates that the species composition of KK1 had a high species similarity to KK2. KK1 was similar to some degree to KK3 and KK5.

| Plots   | KK1 | KK2 | KK3 | KK4 |
|---------|-----|-----|-----|-----|
| KK2     | 0.18|     |     |     |
| KK3     | 0.10| 0.16|     |     |
| KK4     | 0.07| 0.12| 0.08|     |
| KK5     | 0.10| 0.11| 0.05| 0.14|

### 3.3 Diversity indices

Table 3 shows the summary statistics for various indices of diversity, evenness and richness. Kuala Keniam forest recorded Shannon Weiner Diversity Index of 3.01 ($H'$ max = 4.96), which was relatively lower than those recorded in previous studies. For instance, in the same forest of Kuala Keniam, Mohd Nazip [24] recorded a higher $H'$ value at the ranges of 3.42 to 3.97. Further, Nor Farika et al. [22] also reported the lowland forest with higher $H'$ value of 4.84, than riparian forest of Pahang National Park with 3.38. This value indicates the present study of Kuala Keniam forest were less complex and less diverse in terms of tree species composition.
Tree species richness was determined by calculating the Margalef’s Richness Index ($D_{MG}$) where this index is mainly depended on species number and total number of individuals. It is apparent that the study area contained 244 trees from 142 species altogether, thus the study area exhibited richness index of 22.78. As a comparison, higher richness value was reported in same forest of Kuala Keniam with $D_{MG} = 32.27$, $S = 198$ [24] and $D_{MG} = 30.31$, $S = 184$ [22]. High number of species encountered at both study areas of Kuala Keniam contributed to the high richness index, as supported by the statement of [17]. The high tree species richness is a common scenario in tropical forest ecosystem and the number of tree species could always more than 100 species per hectare [31].

Other than species richness, species evenness also accounted as a measure of biodiversity to quantify the uniformity of the species distribution. Pielou Evenness Index ($J'$) is constrained between 0 and 1 [32]. As a result, low species evenness of 0.14 recorded in the present study representing the tree species in the study plots were not equally abundant. For instance, among 142 species recorded, *Elateriospermum tapos* dominated the study area with 66 individuals meanwhile the remaining 96 species (68% of total species number) represented by single individual. Thus, the uneven distribution of trees in the plots lead to the low evenness index obtained.

### Table 3. Shannon-Weiner Diversity Index ($H'$), Evenness ($E$) and Margalef’s Richness Index ($D_{MG}$) values from this study and previous findings in Kuala Keniam Forest

| References | Shannon Index ($H'$) | Evenness ($E$) | Margalef Index ($D_{MG}$) |
|------------|----------------------|----------------|--------------------------|
| This study (2021) | 3.02 | 0.14 | 22.78 |
| [25] (2018) | 4.84 | 0.89 | 30.31 |
| [24] (2012) | 3.42 | - | 32.27 |

#### 3.4 Species accumulation curve

Figure 2 shows species accumulation curve (SAC) for each study plot at Kuala Keniam forest. The graph plots the cumulative number of species recorded as a function of sampling effort during the process of data collection [33]. A well-defined plateau in the graph indicates the adequacy of sampling effort containing all species in the study area. However in this study, the graph indicates that the curve were rising and not reaching a plateau although the total number of individuals was combined. It was suggested that more species should be captured in larger study areas, owing to the characteristics of tropical forests with high species richness. Similar increasing pattern of SAC was recorded in other lowland forests such as Bukit Lagong Forest Reserve [34] and Sungai Lalang Forest Reserve [35]. This also revealed that tropical forests support high species richness, whereby the increase of the study area would result in an increase in the number of species.
Figure 2. Species accumulation curve (SAC) plotted for each five plots of Kuala Keniam forest

3.5 Stand structure

The diameter distribution of all individuals in the study area illustrated an inverse J-shaped distribution, with most trees in smaller DBH classes and few trees in large DBH classes (Figure 3). The diameters of all sampled trees in Kuala Keniam forest ranged from 5.0 cm to 121.4 cm of which 158 trees were represented by small DBH size class (5.0 – 14.9 cm) whilst only 7 individuals were recorded in the DBH size class (>75 cm). Similar patterns of stand structure were also observed in Malaysia forests such as in Sungai Lalang Forest Reserve in Selangor [35], Bukit Lagong Forest Reserve, Selangor [34] and Perlis State Park [26]. The forest stands with inverse J-shaped reflecting uneven aged stand structures that correspond to the condition of natural forest and regeneration of trees [36]. Further, Zhang et al. [37] reported that the forests have good recruitment patterns and as a main feature of matured forest in Peninsular Malaysia.

Figure 3. Stand structure of trees at different DBH classes in Kuala Keniam forest
3.6 Biomass estimation and carbon stocks

The total biomass of trees with DBH of 5 cm and above was estimated at 955.02 t/ha where above ground biomass (AGB) contributed 815.43 t/ha meanwhile below ground biomass (BGB) with 139.59 t/ha. High total biomass estimated from this study as the study site is considered as a primary forest with no occurrence of anthropogenic activities. Therefore, it is expected that the forest recorded high tree biomass, reflecting the forest productivity to the ecosystem. At the family level, Dipterocarpaceae recorded the highest total biomass of 249.64 t/ha (30.61%), followed by Leguminosae with 223.97 t/ha (27.47%) and Euphorbiaceae (96.13 t/ha; 11.79%) (Table 4). All in all, these three leading families make up 69.87% of the overall tree biomass in Kuala Keniam forest. Previous research demonstrated a similar result of Dipterocarpaceae as the highest biomass contributor (25% from total biomass) in Bukit Lagong Forest Reserve, Selangor [34]. This is possible because most dipterocarp trees are generally large and dominated the tropical forests thus contributing to the high biomass recorded. The estimation of forest biomass is significantly important for the environment as a critical aspect for studies of the carbon sequestration and its role in the global carbon cycle.

The estimation of carbon stocks in Kuala Keniam forest was recorded at 448.86 t/ha, which was represented by 383.25 t/ha of above ground carbon and 65.61 t/ha of below ground carbon. This value is recorded higher than hill dipterocarp forest of Pahang National Park with 289.52 t/ha [25]. The differences of estimated carbon storage among tropical forests might be due to some limiting factors such as species composition, soil fertility, disturbance history and successional stage [38]. For instance, hill dipterocarp forest consisted of 579 individuals and high number of big-sized trees in comparing to the present study with only 244 individuals. Based on 36 families encountered in the study site, Dipterocarpaceae attained the highest carbon stock with 117.33 t/ha, followed by Leguminosae and Euphorbiaceae with 105.27 t/ha and 45.18 t/ha each, respectively. Similarly, in hill dipterocarp forest of Pahang National Park Dipterocarpaceae contributed the most in carbon stock because of their trees have larger diameter and height as compared to other family [25].

Table 4. Total biomass and carbon stock of three leading families in Kuala Keniam

| No. | Family          | AGB (t/ha) | BGB (t/ha) | Total biomass (t/ha) | Percentage (%) |
|-----|----------------|------------|------------|----------------------|---------------|
| 1.  | Dipterocarpaceae | 210.22     | 39.43      | 249.64               | 30.61         |
| 2.  | Leguminosae     | 191.35     | 32.63      | 223.97               | 27.47         |
| 3.  | Euphorbiaceae   | 83.00      | 13.13      | 96.13                | 11.79         |

Table 4. Total biomass and carbon stock of three leading families in Kuala Keniam

| No. | Family          | AGB (t/ha) | BGB (t/ha) | Total carbon stock (t/ha) | Percentage (%) |
|-----|----------------|------------|------------|--------------------------|---------------|
| 1.  | Dipterocarpaceae | 98.80      | 18.53      | 117.33                   | 26.14         |
| 2.  | Leguminosae     | 89.93      | 15.33      | 105.27                   | 23.45         |
| 3.  | Euphorbiaceae   | 39.01      | 6.17       | 45.18                    | 10.07         |

3.7 Endemism and conservation status

Ng et al. [39] compiled a checklist of endemic trees for Peninsular Malaysia included a total of 2,830 tree species from 532 genera and 100 families, of which 746 species (24.6%) are endemics. From the total of 142 species in the present study, 13 species were identified as endemic species (Table 5). Therefore, the endemic species in this study plots represented 1.74% of endemic trees in Peninsular Malaysia. The finding for this study was comparatively lower because the present study covers a sampling size of 0.25 ha of Kuala Keniam forest. The occurrence of endemic species in the forest played a crucial role in structure and composition of tree communities, as well as reflecting the uniqueness of the forests.
Table 5. List of endemic tree species found in study plots of Kuala Keniam

| No. | Endemic species              | Total no of individuals | Distribution               |
|-----|------------------------------|-------------------------|----------------------------|
| 1.  | *Aporosa globifera*          | 1                       | Kd, Pn, Kl, Pk, Ph;        |
| 2.  | *Enicosanthum fuscum*        | 1                       | Pk, Ph.                    |
| 3.  | *Gordonia singaporiana*      | 2                       | Pn, Pk, Ph, NS, MI, Jh, Sp.|
| 4.  | *Hopea pubescens*            | 4                       | Kl, Ph                     |
| 5.  | *Palaquium maingayi*         | 2                       | Kd, Kl, Pk, Ph, Sl, NS, MI, Jh|
| 6.  | *Rothmannia malayana*        | 1                       | Kl and Ph                  |
| 7.  | *Ryparosa fasciculata*       | 1                       | MI and Ph                  |
| 8.  | *Schoutenia kunstleri*       | 1                       | Pn, Tg, Pk, Ph, Jh        |
| 9.  | *Syzygium anisosepalum*      | 1                       | Kd, Pn, Sl, NS, MI         |
| 10. | *Syzygium politum*           | 1                       | Kd, Pn, Pk, Sl, MI, Jh.   |
| 11. | *Vatica bella*               | 1                       | Pk and Ph                  |
| 12. | *Xylopia magna*              | 1                       | Kd, Kl, Tg, Pk, Ph, Sl, NS, MI, Sp |
| 13. | *Xylopia malayana*           | 1                       | Tg, Ph, Jh                 |

Species that are categorized as Critically Endangered (CR), Endangered (EN) and Vulnerable (VU) are collectively referred as threatened. All species in the study plots were compared with the IUCN list to evaluate the conservation status. Overall, six species were classified as vulnerable species and four species were classified as near threatened species include *Aglaia forbesii* (Meliaceae), *Cynometra malaccensis* (Fabaceae), *Enicosanthum fuscum* (Annonaceae), *Intsia palebanica* (Fabaceae) (Table 6). Three vulnerable species of Dipterocarpaceae in this study were *Anisoptera laevis*, *Dipterocarpus crinitus* and *Hopea pubescens*. According to Kettle [40], Dipterocarpaceae has the most significant percentage of threatened species due to its high economic value and dominating the international timber trade, especially in Southeast Asia. The largest number of threatened species in one family indicated that the family needs more attention in conservation. This also shows the importance of the investigation on the conservation status of the tree species for the forest management activities.

Table 6. The IUCN conservation status of tree species in Kuala Keniam

| Family            | Species           | IUCN status |
|-------------------|-------------------|-------------|
| Dipterocarpaceae  | *Anisoptera laevis* | VU          |
| Dipterocarpaceae  | *Dipterocarpus crinitus* | VU          |
| Dipterocarpaceae  | *Hopea pubescens*  | VU          |
| Sapotaceae        | *Palaquium maingayi* | VU          |
| Achariaceae       | *Ryparosa fasciculata* | VU          |
| Malvaceae         | *Schoutenia kunstleri* | VU          |
| Meliaceae         | *Aglaia forbesii*  | NT          |
| Fabaceae          | *Cynometra malaccensis* | NT          |
| Annonaceae        | *Enicosanthum fuscum* | NT          |
| Fabaceae          | *Intsia palebanica* | NT          |

Note: VU = Vulnerable, NT = Near threatened
4. Conclusion

This study shows that Kuala Keniam, Taman Negara Pahang is protected primary forest which comprises of diverse tree species composition. The quantification of ecological indices in this study described high species richness of the forest. Assessments on species composition and diversity of trees are important to provide information on the species richness that could presumably be useful for current tree inventory and understanding of forest ecological functions. In terms of stand structure of the forest, this study found that young trees with diameter less than 15 cm dominated the study site indicating that the forest has good regeneration potential. In addition, the significant amount of tree biomass as a measure of forest’s productivity depicted the importance of the forest as a carbon sink for terrestrial ecosystems. Further, this study site harbour endemic and vulnerable species that are categorized in IUCN Red List, indicating that the forest reserve requires more attention and additional consideration for the purpose of biodiversity conservation.

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