Forest Structure and Tree Species Composition at Kuala Langat South Peat Swamp Forest, Selangor, Malaysia

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ABSTRACT

Kuala Langat South Forest Reserve (KLSFR) was the main highlight when Selangor State Agriculture Corporation proposed to acquire the whole of KLSFR (about 6,908 ha) for the establishment of oil palm plantations. Many parties expressed their concern and opposed the plan as it would lead to the destruction of the forest and its biodiversity. As such, this study was aimed to determine the forest structure and tree species composition to conserve and sustainably manage the forest. Seven plots of 40 m x 20 m covering 0.56 ha were established randomly in KLSFR. All trees with 5 cm diameter breast height (DBH) and above were tagged, measured and identified. Voucher specimens were then taken for further verification purposes. The floristic composition of KLSFR consists of 335 individuals represented by 47 tree species from 21 families. Annonaceae, Guttiferaceae and Myristicaceae were the most speciose families with five species recorded for each family. *Goniothalamus malayanus* and *Koompassia malaccensis* were considered to have absolute dominance at the study site with Important Value index of 14.73 % and 14.19 %, respectively. KLSFR recorded low Shannon-Weiner Diversity index of H' = 2.85 (H'max = 3.81) and Margalef's Richness Index with D_{MG} = 7.91. Evenness (E) index of 0.75 portrayed that the tree species are almost equally abundant in the study area. Total trees biomass was estimated at 406.90 t/ha, represented by 349.61 t/ha of above ground biomass (AGB) and 57.29 t/ha of below ground biomass (BGB). The study indicated that KLSFR has uniform distribution of individuals with mixed species composition of trees. Tree distribution showed the pattern of De iocourt's factor procedure (inverse J distribution) where number of tree decreases with the increase in diameter, representing the natural regeneration of the forest.

INTRODUCTION

Peatlands are ecosystems characterized by the accumulation of partially decayed organic matter (peat) formed from plant debris under waterlogged conditions [1]. Peat swamp forests (PSF) are found adjacent to the shoreline and extends inland along the lower reach of the major river systems. PSF are reported to be the carbon sink for the world [2]. The total forest cover of Peninsular Malaysia is approximately 5.76 million ha where 4.34 million ha (83.41 %) are gazetted as Permanent Reserved Forests (PRF). PRF consist of dryland forests (4.34 million ha), wetland forests (0.34 million ha) and plantation forests (0.11 million ha).

The total forested area in Selangor was 250,210 ha, of which 82,890 ha or 33 % are peat swamp forests, located in Kuala Langat and Sabak Bernam [3]. Further peat swamp forests of covering an area of 1,265 ha in North Kuala Langat [4] and 6,908 ha in South Kuala Langat [5], respectively. Both forests are the most important PSF in the southern part of Selangor. A virgin jungle reserve (VJR) was also established in Compartment 26 of the Kuala Langat South Forest Reserve of approximately 174 ha. Many important tree species were found in VJR such as geronggang (*Cratoxylum arborescens*), kempas (*Koompassia malaccensis*), meranti bunga (*Shorea teysmanniana*) and bintangor (*Calophyllum* spp.) [5].

However, this forest has faced many issues of illegal encroachments such as land-use, rapid development and forest fires which contribute to forest degradation [6]. The reserve which was originally at the size of 12,141 ha had since been subjected to de-gazettement and reduced to 6,908 ha (57 % of the original). Areas excised from the reserve have been developed for agriculture (mainly oil palm plantations) and for the Kuala Lumpur International Airport (KLIA). Other than that, due to its proximity to agricultural areas, this forest was also constantly being threatened by forest fires. Farmers living around the forest have slashed, burned and cleared the land to plant vegetable crops, contributing to frequent forest fires and haze related problems [7].

Consequently, these activities not only lead to the rapid loss of forest biodiversity but also may have a major impact on the environment such as climate change and hydrology malfunctions. In 2014, Forest Research Institute Malaysia (FRIM) prepared the report on blueprint for KLSFR for the Forestry Department of Selangor through ASEAN Peatland Forest Projects. The report provides the estimation of forest stocking and aboveground carbon for peat swamp forests within KLSFR [7]. Trees as the dominant plant life form, contributing to the most aboveground carbon and total biomass in the forest. Thus, the present study is conducted to quantify the forest structure and tree species composition in KLSFR. The quantitative information of tree species composition in the study is essential for the updates of current tree inventory in KLSFR for forest management purposes.

EXPERIMENTAL

Study Area

The study area was located at Kuala Langat South Forest Reserve (KLSFR) within the district of Kuala Langat, Selangor (2° 48' 39.01" N 101° 37' 28.19" E). The study covered 0.56 ha from a total area of 6,908 ha in KLSFR, focusing on compartment 26 (Virgin Jungle Reserve) (Figure 1). The forest is surrounded by the towns of Banting, Sepang, Sungai Pelek and Tanjong Sepat. There are numerous Orang Asli settlements in and around the forest. Historically on 13 March 1927 and 13 March 1940, KLSFR was gazetted as a forest reserve under the provisions of the Federated Malay States Forest Enactment 1918 [6]. The forest area was originally larger than its current state but was subjected to several de-gazettement and eventually decreased to 6,908 ha and remains to be listed as a "production forest" that allows commercial harvesting [8].

Figure 1: The location of study area in compartment 26 of Kuala Langat South Forest Reserve, Selangor (Source: Forestry Department of Selangor)

Tree Sampling

Seven sampling plots of 40 m x 20 m each were established randomly at the study area, making the total area of 0.56 hectare. 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 the trees measured (i.e leaves and fruit) were collected for the preparation of voucher specimens and for species identification with the help of expert plant taxonomists from Selangor Forestry Department. The morphological characteristics were also compared to herbarium specimens and the nomenclature was obtained using keys described in Tree Flora of Malaya [9-12].

Data Analysis

Data of all tree species were tabulated and summarized to describe the floristic composition of the tree communities. Abundance parameters such as density, frequency, basal area were calculated to describe the forest structure. The importance value index (IVi) of species and family were determined based on the sum of relative frequency, relative basal area and relative density [13]. Species accumulation curve was constructed using Ecosim version 7 to represent the adequacy of the sampling effort in all study areas [14]. Total biomass estimation was calculated by the equations of Kato *et al.* [15] and Niiyama *et al.* [16] as follows:

$$\text{Weight of stem}, W_S = 0.313 \, (DBH^2 h)^{0.9733} \, (kg)$$

$$\text{Weight of branch}, W_B = 0.136 \, (W_S)^{1.070} \, (kg)$$

$$\text{Weight of leaves}, WL = \frac{125 \times 0.24 \, (W_S)^{0.794}}{0.124 \, (W_S)^{0.794} + 125} \, (kg)$$

$$\text{Tree height}, h = \frac{122 \times DBH}{2 \, DBH + 61}$$

$$\text{Above ground biomass (AGB)} = ((W_S + W_B + W_L) \times 0.001/0.56) \, t/ha \, [15]$$

$$\text{Below ground biomass (BGB)} = 0.0262 \times DBH^{2.497} \, t/ha \, [16]$$

$$\text{Total biomass (t/ha)} = AGB + BGB$$

The data were also used to compute the ecological indices as follows:

Shannon Weiner Diversity Index equation [17]

$$H' = -\sum (p_i)(\ln p_i)$$

Where, p_i is the proportion of the individuals found in i^{th} species

Evenness Index equation [18]

$$E = H'/\ln S$$

Where, H' = Shannon-Weiner Diversity Index
S = Total number of species

Margalef Index equation [19]

$$D_{MG} = (S-1)/\ln N$$

Where, S = total number of species
N = total number of individuals

RESULTS AND DISCUSSION

Floristic composition

A total of 335 trees with a diameter at breast height (DBH) of 5 cm and above were recorded in 0.56 ha sampling plots of Kuala Langat South Forest Reserve, Selangor. Identification of all specimens revealed that the 335 trees recorded consist of 47 species, 33 genera from 21 families. The highest number of individuals recorded were from Annonaceae family with 105 individuals, Myrtaceae with 56 individuals and Chrysobalanaceae family with 42 individuals (Table 1).

Annonaceae, Guttiferaceae and Myristicaceae were the most speciose family in the study site with 5 species in total (0.11%). This finding is in line with the previous study conducted in Ayer Hitam Forest Reserve, Selangor where Myristicaceae and Guttiferaceae among the largest families recorded with 20 and 15 species altogether [20].

Table 1: Total numbers of genera, species and individuals for all tree families in 0.56 ha at the Kuala Langat South Forest Reserve

No.	Family	Species	Genera	No. of Ind.
1	Anacardiaceae	1	1	1
2	Annonaceae	5	3	105
3	Apocynaceae	1	1	1
4	Burseraceae	4	3	9
5	Celastraceae	1	1	1
6	Chrysobalanaceae	1	1	42
7	Dipterocarpaceae	2	2	6
8	Ebenaceae	1	1	18
9	Elaeocarpaceae	1	1	2
10	Euphorbiaceae	3	3	16
11	Fabaceae	3	2	14
12	Guttiferaceae	5	2	10
13	Hypericaceae	1	1	2
14	Lauraceae	3	1	11
15	Moraceae	1	1	2
16	Myristicaceae	5	3	14
17	Myrtaceae	3	1	56
18	Rhizophoraceae	1	1	1
19	Sapotaceae	3	2	17
20	Simaroubaceae	1	1	3
21	Thymelaceae	1	1	4
	Total	47	33	335

In addition, it is interesting to note that some of the families in the present study represented by a single species and single individuals such as Anacardiaceae (*Campnospermum coriaceum*), Apocynaceae (*Alstonia angustiloba*), Celastraceae (*Lophopetalum multinervium*) and Rhizophoraceae (*Carallia brachiata*). The result of this research is in accordance with the findings

of [21] who stated that although there are usually several tree species in the tropical rainforest ecosystem, some may have only one representative per hectare. Similar observations have also reported singleton families in Pulau Perhentian Besar, Terengganu (nine families) [22], Bukit Lagong Forest Reserve, Selangor (eight families) [23], and Gunung Stong Tengah, Kelantan (11 families) [24]. The occurrence of single species with few individuals in tree communities contributed to low species dominance and high species diversity within the site.

As a comparison with other studies in forest habitats of Peninsular Malaysia, Bukit Bakar Forest Reserve, Kelantan [24] revealed a taxonomic composition of 147 individuals from 50 species, 44 genera and 25 families. Meanwhile enumeration of trees at Bukit Lagong Forest Reserve, Selangor showed a total of 448 individuals from 53 species, 47 genera and 26 families [23]. Further, Sungai Lalang Forest Reserve, Selangor [25] reported a total of 562 trees comprising of 82 species, 67 genera and 34 families in 0.7 ha study site. It is evident that the variation of tree communities in different habitat types reflects the heterogeneity of each forest ecosystem with various types of tree species.

Species Diversity

KLSFR recorded Shannon-Weiner Diversity Index of 2.85 (H' max = 3.81), which was comparatively lower than other tropical forests (Table 2). This value indicated that KLSFR is a forest with low species diversity which is correlated with the status of KLSFR as a secondary forest due to anthropogenic pressures that caused the forest to be less diverse than the primary forest. Shannon Evenness Index of 0.75 recorded in KLSFR, representing the species are almost equally abundant. Low species richness was reported in KLSFR, represented by Margalef Index of 7.91. This index was correlated with species abundance, for instance, Sungai Lalang Forest Reserve exhibited high Margalef Richness Index which was attributed to 562 trees of 82 species [25], as compared to the present study of KLSFR with 335 trees and 47 species.

Table 2: Shannon-Weiner Diversity Index (H'), H'max, Evenness (E) and Margalef's Richness (D_{MG}) values from this study and other forest types in Peninsular Malaysia

Location	Shannon Index (H')	H' max	Evenness (E)	Margalef Index (D_{MG})
Pekan Peat Swamp Forest, Pahang [26]	3.61	4.12	0.85	18.64
Bukit Lagong Forest Reserve, Selangor [23]	3.41	3.97	0.57	19.25
Sungai Lalang Forest Reserve, Selangor [25]	3.64	4.41	0.83	29.46
Kuala Langat South Forest Reserve, Selangor	2.85	3.81	0.75	7.91

Species Accumulation Curve

Species accumulation curve plots the cumulative number of species recorded as a function of sampling effort that illustrate the increase in the total number of species encountered during the process of data collection [27]. A plateau in this graph indicates the adequacy of sampling effort to capture a maximum number of species in the study area [14] [28]. Although the curve has almost reached a plateau (Figure 2), no clear asymptote is obtained, as the number of species was still on the increase along with the increase study area. Other studies in lowland forests such as Perlis State Park [31] and Bukit Lagong Forest Reserve [23] also showed no asymptote where the species number continues to increase. Further, Condit *et al*. [14] found the tree species richness continued to accumulate up to and beyond 50 ha in inventory plots of Pasoh Forest Reserve, indicating the tropical forests support high species richness, whereby the increase of the study area would cause an increase in a number of species.
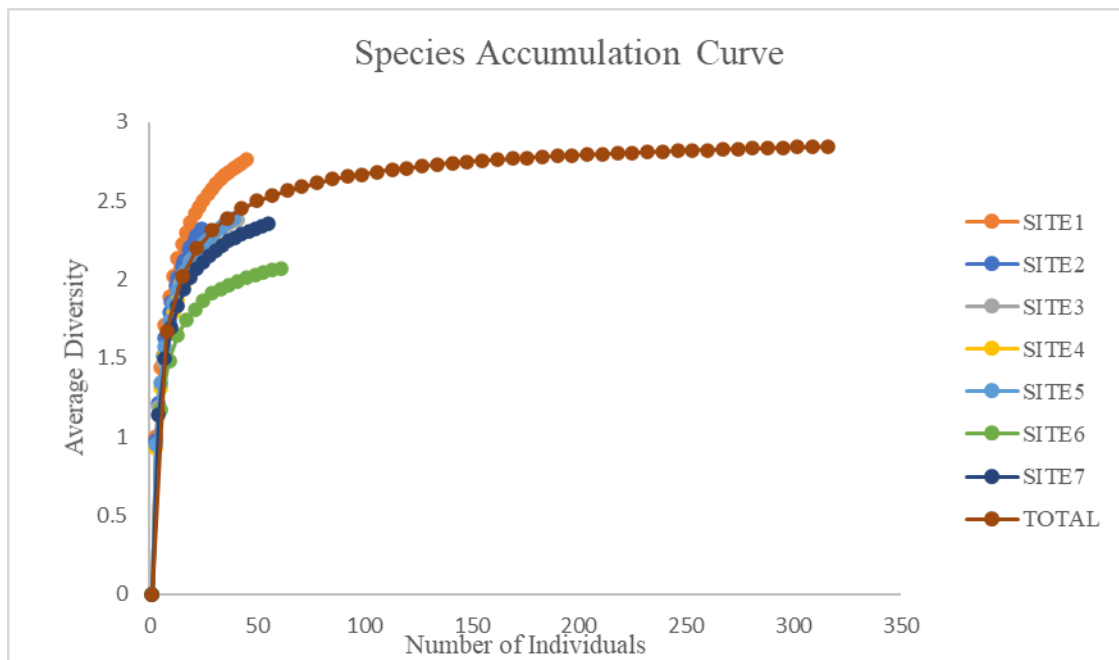

Figure 2: Species accumulation curve (SAC) plotted for each seven plots of KLSFR

Stand Structure

Stand structure described as the distribution of trees by diameter class within a stand or forest area [30]. The diameters of all trees sampled in KLSFR ranged from 5.0 cm to 91.5 cm of which 50.7 % of the trees (170 trees) were represented by trees with DBH size of 5.0 cm to 14.9 cm whilst large trees (DBH>55 cm) dominated the least with a total of 12 individuals at the study site. Similar distribution pattern of small DBH classes dominated the forest stand were also showed in Sungai Lalang Forest Reserve, Selangor [25], Belum Temenggor Forest Reserve, Perak [31] and Perlis State Park [29]. These findings indicated that the forest has new tree regenerations as small trees are active to give good support for the future of the forest. Figure 3 clearly shows the characteristic of De iocourt's factor procedure (inverse J-shaped) where stem frequencies decrease with the increase in DBH, indicating trees with small diameter were predominant the study area [32-35]. The pattern indicates that the forest stands in the study sites have good recruitment pattern and as the main feature of matured forest in Peninsular Malaysia [22].
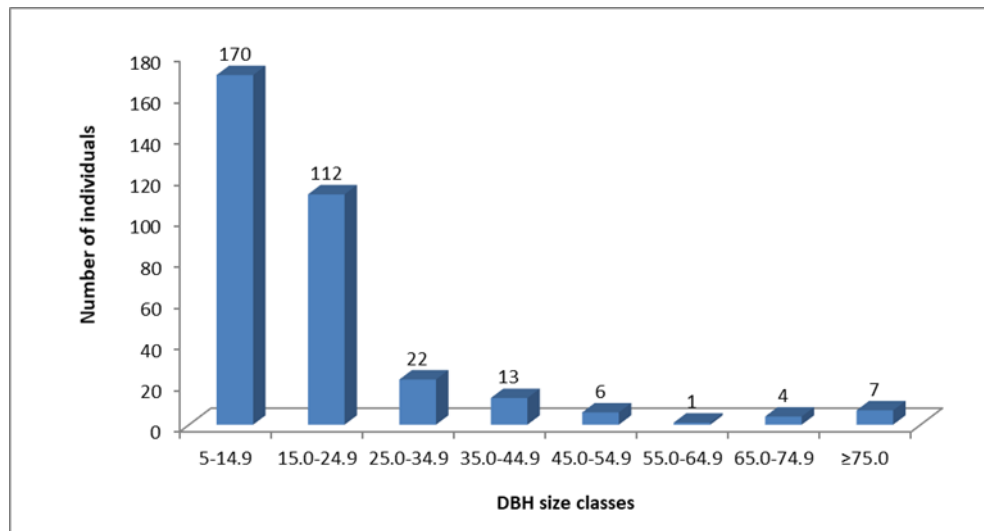

Figure 3: Stand structure of trees at different DBH classes in all study plots at the Kuala Langat South Forest Reserve, Selangor

Abundance and Species Importance

The density of all trees in the study area was 598 trees/ha. Annonaceae contributed the highest density with 188 trees/ha, representing 31.4 % of total tree density in KLSFR (Table 3). Species-

wise, *Goniothalamus malayanus* from Annonaceae family recorded the highest in tree density with 150 trees/ha (25 %). Further, the present study showed a total tree basal area (BA) of 53.08 m^2/ha. Fabaceae and *Koompasia malaccensis* represented the highest BA in the study area with 9.12 m^2/ha and 9.02 m^2/ha, respectively. Species dominance encountered in the study area was determined using Important Value index (IVi) which represented by the sum of relative density, relative dominance or basal area and relative frequency. Based on the calculated IVi, *Goniothalamus malayanus* (Annonaceae) dominated the highest IVi of 14.73 %, followed by *Koompassia malaccensis* (Fabaceae) and *Parastemon urophyllus* (Chrysobalanaceae) with IVi of 14.19 % and 8.40 %, respectively. *G. malayanus* trees recorded the highest IVi which might be attributed to their high tree density of 150 trees/ha in the forest reserve. Meanwhile, *K. malaccensis* are mostly large trees in the study area thus representing large basal area of 9.02 m^2/ha (16 %) of the total basal area of the forest. Similarly, in other studies where *Koompassia malaccensis* had large tree diameter which led to the highest IVi (25.86 %) in Gunung Leuser National Park, Sumatra, Indonesia [36] and among the most important species in Pekan Forest Reserve, Pahang [37]. The highest family importance value index (FIVi) was observed for Annonaceae (18.79 %) followed by Fabaceae with FIVi of 15.01 % and Myrtaceae with FIVi of 10.15 %. Curtis and Macintosh [13] suggested that the species with more than 10 % IVi and family with more than 40 % can be considered as having absolute dominance in the community. Overall, *Goniothalamus malayanus* and *Koompasia malaccensis* were absolute dominant species in KLSFR, while none of the families showed an absolute dominance due to their low FIVi. It can be deduced that the families were only relatively dominant than other families in KLSFR.

Table 3: Summary of tree density, basal area and Importance Value index (IVi) of five leading families and species at KLSFR, Selangor

	Family		Species	
Density (trees/ha)	Annonaceae	188	*Goniothalamus malayanus*	150
	Myrtaceae	100	*Syzygium* sp.	79
	Chrysobalanaceae	75	*Parastemon urophyllus*	75
	Ebenaceae	32	*Diospyros maingayi*	34
	Sapotaceae	30	*Polyalthia* sp.	32
Basal area (m^2/ha)	Fabaceae	9.12	*Koompasia malaccensis*	9.02
	Annonaceae	4.56	*Goniothalamus malayanus*	3.52
	Chrysobalanaceae	1.82	*Parastemon urophyllus*	1.82
	Myrtaceae	1.56	*Syzygium* sp.	1.17
	Euphorbiaceae	1.42	*Blumeodendron tokbrai*	1.15
IVi (%)	Annonaceae	18.79	*Goniothalamus malayanus*	14.73
	Fabaceae	15.10	*Koompasia malaccensis*	14.19
	Myrtaceae	10.15	*Parastemon urophyllus*	8.40
	Chrysobalanaceae	9.08	*Syzygium* sp.	7.51
	Euphorbiaceae	6.00	*Diospyros maingayi*	4.68

Biomass Estimation

Total biomass of trees in the KSLFR was estimated at 406.90 t/ha. From this amount, a total of 349.61 t/ha was represented by the above-ground biomass (AGB) and 57.29 t/ha by below-ground biomass (BGB). Based on 21 families enumerated in 0.56 ha study plots of KLSFR, Fabaceae showed the highest total biomass of 177.92 t/ha, contributed by 151.5 t/ha of AGB and 26.42 t/ha of BGB. This family alone represented 43.7 % of the total biomass estimation, because of the abundance of large trees encountered in KLSFR. Trailing behind was Annonaceae with biomass of 55.25 t/ha and followed by Anacardiaceae (23.20 t/ha) with 13.6 % and 5.7 % of the total biomass estimation respectively (Table 4).

In term of species, *Koompasia malaccensis* (Fabaceae) attained the highest tree biomass with 176.74 t/ha or 43.4 % of the total biomass. This was followed by *Goniothalamus malayanus* (Annonaceae) and *Campnospermum coriaceum* (Anacardiaceae) with 43.04 t/ha (10.6 %) and 23.20 t/ha (5.7 %) of total tree biomass, respectively. According to Zani [39], tree biomass is related to the tree diameter. This can be seen in the present study where *K. malaccensis* recorded the highest biomass because of seven large trees as compared to *G. malayanus* with 84 small trees. Similarly, other forests also postulated that large trees dominated primarily to the total biomass in Pahang National Park [38], Ulu Gombak Forest Reserve, Selangor [39], Jengka Forest Reserve, Pahang [40] and Hulu Langat Forest Reserve, Selangor [41].

Table 4: Total biomass of five leading families and species in 0.56 ha plot of KLSFR

No.	Family	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Percentage (%)
1.	Fabaceae	151.50	26.42	177.92	43.7
2.	Annonaceae	47.96	7.29	55.25	13.6
3.	Anacardiaceae	19.66	3.54	23.20	5.7
4.	Chrysobalanaceae	18.12	2.74	20.86	5.1
5.	Euphorbiaceae	16.80	2.53	19.33	4.8

No.	Species	AGB (t/ha)	BGB (t/ha)	Total biomass (t/ha)	Percentage (%)
1.	*Koompasia malaccensis*	150.47	24.27	176.74	43.4
2.	*Goniothalamus malayanus*	37.35	5.70	43.04	10.6
3.	*Campnospermum coriaceum*	19.66	3.55	23.20	5.7
4.	*Parastemon urophyllus*	18.12	2.74	20.86	5.1
5.	*Blumeodendron tokbrai*	14.06	2.12	16.18	4.0

CONCLUSION

This study shows that Kuala Langat South Forest Reserve appeared to have low species diversity, but it is apparent that the evenness is high which means that most trees are equally abundant in the study sites. The stand structure of tree communities in the study sites was dominated by small trees <15 cm DBH with a reverse J-shaped pattern, reflecting a high regeneration potential of the forest. The dominant tree species in this study were *Goniothalamus malayanus* and *Koompasia malaccensis*. Meanwhile, none of the families showed absolute dominance and did not strongly influence the community. Based on the value calculated for total biomass, it can be noted that the ecological services function of the KLSFR as a carbon sink for the terrestrial ecosystems. It is therefore recommended to have larger sampling area in a future study for more reliable result and to investigate forest fire prevention for the KLSFR in order to monitor the carbon emission to the atmosphere by the degraded forest. As for respective stakeholder, it is highly recommended to explore the potential of the site for ecotourism due to its close proximity to Kuala Lumpur International Airport (KLIA) and Kuala Lumpur.

ACKNOWLEDGMENTS

CONFLICT OF INTEREST STATEMENT

The authors agree that this research was conducted in the absence of any self-benefits, commercial or financial conflicts and declare absence of conflicting interests with the funders.

REFERENCES

[1]   Andriesse, J.P. (1988). Nature and Management of Tropical Peat Soils. Food and Agriculture Organization of the United Nations Soils Bulletin no.59. FAO.

[2]   Kiyoshi, F., Masafumi, M., Shigeo, K. & Herwint, S. (2019). Habitat evolution of a peat swamp forest and belowground carbon sequestration during the Holocene among the

coastal lowland in Central Sumatra, Indonesia. Progress in Earth and Planetary Science, *6*(1), 1-13.

[3]   FDPM (Forestry Department Peninsular Malaysia). (2018). Annual report 2018. 192 pp.

[4]   GEC (Global Environment Centre). (2010). Rapid assessment of Kuala Langat South Peat Swamp Forest in Selangor. Report prepared by Global Environment Centre (GEC).

[5]   Razani, U. & Jalil, M.D.S. (1997). Status of peat swamp forests in Selangor. Palle, H. et al. (eds.). Proceedings of the Workshop on Sustainable Management of Peat Swamp Forest. Forestry Department Peninsular Malaysia. 15-21pp.

[6]   Shlisky, A., J. Waugh, P. Gonzalez, M. Gonzalez & M. Manta. (2007). Fire ecosystems and people threats, and strategies for global biodiversity conservation. GFI Technical Report 2007-2 The Nature Conservancy. Arlington, VA. 21pp.

[7]   Forestry Department Peninsular Malaysia & Forest Research Institute Malaysia (2014). Report on Blueprint for Kuala Langat South Forest Reserve (KLSFR), Selangor (pp. 1-44, Rep.).

[8]   GEC (2014). Integrated Management Plan for North Selangor Peat Swamp Forest 2014-2023 for Selangor State Forestry Department, Petaling Jaya: Global Environment Centre.

[9]   Ng FSP (ed.) (1978), *Tree Flora of Malaya*. A manual for foresters, Vol. 3. Longman Malaysia Sdn. Bhd. Kuala Lumpur, 339 pp.

[10]   Ng FSP (ed.) (1989), *Tree Flora of Malaya*. A manual for foresters, Vol. 4. Longman Malaysia Sdn. Bhd: Kuala Lumpur, 549 pp.

[11]   Whitmore TC (ed.) (1972), *Tree Flora of Malaya.* Vol. 1, Malayan Forest Records No. 26. Longman Malaysia Sdn. Bhd: Kuala Lumpur, 471 pp.

[12]   Whitmore TC (ed.) (1973), *Tree Flora of Malaya*. Vol. 2, Malayan Forest Records No. 26. Longman Malaysia Sdn. Bhd: Kuala Lumpur, 444 pp.

[13]   Curtis, J.R. & Macintosh, R. P. (1951). An upland continuum in the prairie forest – forest border region of Wisconsin. *Ecology, 32*, 476-496.

[14]   Condit, R., Hubbell, S. P., LaFrankie, J. V., Sukumar, R., Manokaran, N., Foster, R. B. & Ashton, P.S. (1996). Species-area and species-individual relationship for tropical trees. A comparison of three 50-ha plots. *Journal of Ecology, 84*, 549-562.

[15]   Kato, R., Tadaki, Y. & Ogawa, F. (1978). Plant biomass and growth increment studies in Pasoh Forest. *Malayan Nature Journal, 30*(2), 211-224.

[16]   Niiyama, K., Kajimoto, T., Matsuura, Y., Yamashita, T., Matsuo, N., Yashiro, Y., Azizi, R., Abd Rahman, K. & Nur Supardi, N. (2010). Estimation of root biomass based on excavation of individual root systems in a primary dipterocarp forest in Pasoh Forest Reserve, Peninsular Malaysia. *Journal of Tropical Ecology, 26*, 271-284.

[17]   Spellerberg, I.F. & Fedor, P.J. (2003). A tribute to Claude Shannon (1916–2001) and a plea for more rigorous use of species richness, species diversity and the 'Shannon-Wiener' index. *Global Ecology and Biogeography, 12*(3), 177–179.

[18]   Pielou, E. C. (1966). The measurement of diversity in different types of biological collections. *Journal of Theoretical Biology, 13*, 131–144.

[19]   Magurran, A.E. (1988). *Ecological Diversity and its Measurement*. (1st ed.). Princeton NJ, Bangor. 81-99 pp.

[20] Nurul Shida, S., Faridah Hanum, I., Wan Razali, W.M. & Kamziah, A.K. (2014). Community structure of trees in Ayer Hitam Forest Reserve, Puchong, Selangor, Malaysia. *Malaysian Forester, 77*, 73-86.

[21] Oguntala, A. B (1981). Dynamics of tree population in Gambari Forest Reserve. *Nigeria Journal of Forestry, 11*(1), 181-187.

[22] Faezah, P., Mohd Nizam, M.S., Asmida, I., Norrizah, J.S., Khairul, A.R., Hasya, H.R. & Siti S. K., (2018). Tree diversity, stand structure and community composition in an island forest of Pulau Perhentian Besar, Terengganu. International Journal of Engineering & Technology, *7* (4.14), 31-35

[23] Zawani, N. (2020). Edaphic influences on Tree Species composition, biomass distribution and community structure of Bukit Lagong Forest Reserve, Selangor. MSc thesis. Universiti Teknologi MARA. (unpublished).

[24] Norashikin, F., Azizi, S. & Latiff, A. (2015). Floristic composition of logged hill dipterocarp forests in three permanent reserved forests in Kelantan, Malaysia. *Malayan Nature Journal, 67*(1), 71-80.

[25] Natasha, H. (2020). Community structure, diversity and edaphic relationship of tree communities in Sungai Lalang Forest Reserve, Selangor. MSc thesis. Universiti Teknologi MARA. (unpublished)

[26] Hamzah, K. A., Ismail, P., Kassim, A. R., Hassan, C. H., Akeng, G., & Said, N. M. (2009). Ecological Characteristics of a Gonystylus bancanus-rich Area in Pekan Forest Reserve, Pahang, Malaysia. *Tropical life sciences research, 20*(2), 15–27.

[27] Newton, A. C. (2007). *Forest ecology and conservation: A handbook of techniques.* New York: Oxford University Press.

[28] Gotelli, N. J. & Entsminger, G. L. (2003). EcoSim: Null Models Software for Ecology, Version 7. Burlington: Acquired Intelligence Inc. and Kesey-Bear. http://homepages.together.net/';gentsmin/ecosim.htm.

[29] Radhiah, Z. (2015). Ecological Characteristics of Vegetation Communities in a Semi-Deciduous Forest at Perlis State Park, Perlis, Peninsular Malaysia. Thesis. PhD. Universiti Kebangsaan Malaysia. (unpublished).

[30] Husch, B., Beers, T. W. & Kershaw Jr., J. A. (2003). *Forest Mensuration*. 4th ed. USA: John Wiley &Sons.

[31] Ahmad Fitri, Z. (2013). Community structure, species diversity and relationship of tree communities with soil factors in upper hill dipterocarp forest of Perak State, Peninsular Malaysia. M.Sc. Thesis. Universiti Kebangsaan Malaysia, Bangi. (unpublished).

[32] Abdurachman, Saridan, A & Lanniari, I. (2009). Potency, Diameter Increament of aqualaria ma-laccensis LMAK at Natural Forest Production Labanan, Berau District, West Borneo Province. *Journal of Forest Research and Natural Conservation, 6* (1), 1–11.

[33] Putra, A.T. (2015). Analysis Stand Potency Result of Forest Inventory at KPHP Model West Berau. *Journal Agrifor, 14* (2),147–160.

[34]   Juperi, Shaodah & Zakaria, Rahmad & Mansor, Asyraf. (2012). The Distribution of Anacardiaceae in Teluk Bahang Forest Reserve, Pulau Pinang, *Tropical Life Sciences Research, 23*, 35-44.

[35]   Natasha, H., Nurul Aqilah, M.B. & Faezah, P. (2020). Floristic variation of tree communities and their association with soil properties in Pulau Jerejak, Penang, Peninsular Malaysia, *Science Letters, 14*(1), 34-48.

[36]   Arida, S., Deni, E., Henti, H.R., Kusumadewi, S.Y., Adi, N.H……& Sri A. L. B. (2020). Vegetation structure and floristic composition of tree species in the habitat of Scaphium macropodum in Gunung Leuser National Park, Sumatra, Indonesia. *Biodiversitas, 21*(7), 3025-3033.

[37]   Ismail, P., Nizam, M.S., Faridah Hanum, I., Khali Aziz., Shamsudin, I., &…. A. Latiff. (2009). Community structure, diversity and biomass of trees in two different subtypes of Pekan Forest Reserve, Pahang, Malaysia, *The Malaysian Forester, 72* (1), 117-133.

[38]   Zani, N. F., Suratman, M. N., Yaacob, A., & Asari, N. (2018). Biomass and carbon stocks estimation of lowland dipterocarp, riparian and hill dipterocarp forests in Pahang National Park, Malaysia. In M. N. Suratman (Ed.), National Parks - Management and Conservation (pp. 123–140). IntechOpen.

[39]   Hasya Hannani, R. (2020). Community structure, endemism and edaphic influences of tree communities in forest reserves of Selangor. MSc Thesis. Universiti Teknologi MARA. (unpublished).

[40]   Kusin M. (2013). Struktur komuniti pokok, taburan dan hubungan dengan faktor tanah dalam hutan pusingan kedua di Jengka, Pahang. MSc Thesis. Universiti Kebangsaan Malaysia. (unpublished).

[41]   Ahmad Fitri, Z., Mohd Puat D., Raffae A., Tengku Mohd. & A. Latiff. (2020). Tree community structure and diversity in two forest reserves of Selangor, Peninsular Malaysia, *The Malaysian Forester*, 83(1), 84-102.