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THE INFLUENCE OF PHYSICAL AND CHEMICAL PROPERTIES OF SOIL ON COMMUNITY STRUCTURE OF TREE SPECIES IN BUKIT LAGONG FOREST RESERVE, SELANGOR

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Abstract: Bukit Lagong Forest Reserve is a hill dipterocarp forest known for its quarrying and timber production, which led to the lack of tree species composition. A study was conducted to determine the relationship between tree communities and edaphic factors. Tree communities and soil sampling were carried out in 14 study plots within 0.7 ha. Trees with a diameter at breast height of 5 cm and above were recorded. The tree communities comprised 25 families, 47 genera and 53 species. Dipterocarpaceae was the most speciose family, with six species. Density wise, the Lauraceae recorded the highest density at 107 individuals per hat species level, *Syzygium* sp. showed the highest density of 87 individuals per ha. Total basal area (BA) was 36.02 m^2 ha^{-1} in which Dipterocarpaceae contributed the highest value of 8.02 m^2 ha^{-1} *Endospermum diadenum* showed the highest basal area of 4.51 m^2 ha^{-1} at the species level. Dipterocarpaceae and *Syzygium* sp. were the most important family and species with an Important Value Index of 13.11% and 8.79%, respectively. The Shannon-Weiner diversity index (H'), Evenness Index (E) and Margalef Index (D_{MG}) recorded a moderate value of H' value of 3.41 (H_{max} = 3.97), E = 0.57 and D_{MG} of 8.52. The total biomass recorded was 525.20 t/ha in which 455.24 t/ha was contributed by aboveground biomass and 69.96 t/ha from belowground biomass. Sandy loam texture was dominant in 64.29% of the area t Organic matter content ranged from 3.53% to 5.71%, with a pH value of 4.69 ± 0.35. Soil pH, cation exchange capacity (CEC) and available nutrients are associated with several tree species as shown by the ordination diagram from Redundancy Analysis (RDA). Overall, the forest is composed of diverse tree communities and moderate species richness, which justifies the conservation of this forest.

Keywords: Edaphic variation, forest structure, redundancy analysis, tropical forest, sustainability.

Abbreviations: [Magnesium (Mg), Potassium (K), Nitrogen (N), Phosphorus (P), Cation exchange capacity (CEC), Organic matter (OM)].

Introduction

Tree species composition in a forest varies greatly from one place to another, mainly due to the influence of edaphic factors (Ferreyra *et al.,* 1998; Webb & Peart, 2000; Palmiotto *et al.,* 2004;). Edaphic factors refer to physical, chemical and biological properties of soil that result from a biologic phenomenon, geologic phenomenon or human activities. Six main components in edaphic factors are texture, structure, depth, organic matter, pH and ion availability. These factors are of great importance since plants are obtaining their nutrients (Rahayu *et al.,* 2012) and water from the soil (Rajakaruna & Boyd, 2018).

Soil texture is important for plant growth as it influences the ability of the soil to provide nutrients for the plant's roots. According to Eswaran *et al.* (2003), soils are grouped into textural classes based on their sand, silt and clay content. There are 12 textures: sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, sandy clay, clay loam, silty clay loam, silty clay and clay. In terms of structure, the three-dimensional arrangement of soil particles is important for water penetration into deeper soil layers. The depth of soil is associated with the type of plant species that can be grown on that soil. Also, deeper soil provides more nutrients for the plant than shallow soil (Rajakaruna & Boyd, 2018).

Organic matter (OM) refers to plant and animal materials that are in the process of decomposing. The content of organic matter in the soil will reflect the amount of Cation exchange capacity (CEC) in the soil, as the organic matter has a higher amount of CEC (Rajakaruna & Boyd, 2018). The soil pH is a measure of hydrogen ion concentration in the soil. Most soils in the tropical rainforest in Peninsular Malaysia are acidic, with a pH range between 3 and 5 (Shamshuddin *et al.,* 2011). The availability of ions in the soil can be divided into two, which are exchangeable acid cations (H^+, Al^{3+}) and exchangeable base cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+). The soil capacity for retaining ion nutrients in a form available to plants is important for the forest (Pritchett & Fisher, 1987).

Many studies have been conducted to determine the relationship between trees and edaphic factors, such as at Taman Merapoh Pahang, which reported *Macaranga lowii* and *Kayea ferrea* as closely related to P availability, and K availability is closely associated with *Garcinia pyrifera* (Nizam *et al.,* 2006). At the watershed forest of Tasik Chini, Pahang, *Artocarpus scortechinii, Dipterocarpus costatus, Streblus elongatus* and *Syzygium griffithii* were influenced by OM, *and Buchanania sessifolia* was strongly related to soil pH (Khairil *et al.,* 2014).

Previous researched on biogeography and ecosystem dynamics have focused on studies on tree species community and diversity in a different type of forest (Ahmad Fitri *et al.,* 2019; Faezah *et al.,* 2013 and Ismail *et al.,* 2009). However, with respect to establishing the relationships between all vegetation types and soil, little information is available (Khairil *et al.,* 2014; Nizam *et al.,* 2012). In this context, there is a large knowledge gap regarding the relationship between attributes of plant communities and soil characteristics in forest habitats that are also water catchment areas (Er *et al.,* 2011) and also gazetted as a Highly Environmentally Sensitive Area (Rawang Forestry Department, 2000). To date, there is no detailed study on tree species composition and soil factors at Bukit Lagong Forest Reserve. This study aimed to verify whether soil features (physical and chemical) determine the structure of vegetation and the diversity of species in Bukit Lagong Forest Reserve.

The following questions were addressed: (i) Is there a high diversity of tree species? (ii) Do soil traits influence the forest structure and plant diversity? This paper gives insight into the study of tree species distribution and its relationship to edaphic factors in Bukit Lagong Forest Reserve. Due to the increase of anthropogenic activities, forests and other natural vegetation of Peninsular Malaysia are being diminished at an unusual rate (Kiew *et al.,* 2010) Hence, this paper is important as it expands knowledge on the forest ecosystem and hopes to generate further action by the authorities for conserving and protecting forest ecosystems.

Materials and Methods

Study Area

Bukit Lagong Forest Reserve, Selangor is located between 3°15'N and 10°119'E with an elevation of 368 metres (Er, 2010). This forest reserve is to the south of Dusun Wam and close to Bukit Nolang (Mapcarta, 2019 and approximately 20 km from the city of Kuala Lumpur (Er *et al.,* 2011). The total area of Bukit Lagong Forest Reserve is 3624.1 hectares and it is gazetted as a forest reserve of Highly Environmentally Sensitive Area (Rawang Forestry Department, 2000). The annual rainfall is around 2000 mm to 2900 mm while the daily range of temperature is between 27°C to 32°C. Bukit Lagong Forest Reserve is a hill dipterocarp forest with light reddish loam and shallow soil, with underlying rock and granite (EngHai & Yahya, 1996). In this forest reserve, there are sources of the Buloh, Jinjang, Kuang and Keroh Rivers, which provide clean water supplies for local communities, protect slopes, prevent landslides and important for indigenous people in Kampong Orang Asli Ulu Keledek and Kampong Orang Asli Bukit Lagong, which belong to the Temuan tribe (Er, 2010) (Figure 1).

Tree Sampling and Data Collection

In this study area, 14 plots of 25 m x 20 m were set up totalling 0.7 hectares. The detailed coordinates and elevations for all plots in the study area are shown in Table 1. All trees with a diameter of 5 cm and above were measured, identified and recorded. All specimens (includes fruits and flowers if any) of each measured tree were collected for preparation of voucher specimens and species identification. Identification of plant specimens was done after drying (Forman & Bridson, 1992) with the aid of an experienced plant taxonomist and forest ranger. Keys in Tree Flora of Malaya (Whitmore, 1972, 1973; Ng, 1978, 1989) and Malaysian Plant Red List, Peninsular Malaysia Dipterocarpaceae (Chua *et al.,* 2010) were used for nomenclature after comparing the morphological characteristics with the herbarium specimens.

Soil Sampling and Analysis

Soil samples from 14 established plots were collected and taken as one composite sample in three replicates in each plot. The samples were taken using soil corer from 0 - 20 cm depth for analyses of physical and chemical properties. The samples were immediately transferred to polythene bags and double-sealed. The samples were then air-dried at room temperature; root fragments and unwanted materials were removed (Gautheyrou *et al.,* 2001), after which samples were lightly ground and passed through a 2 mm mesh sieve prior to analysis.

The distribution of soil particles was determined by using pipetting and dry sieving (Abdulla, 1996) and soil texture is certified by plotting the sand, silt and clay content in the triangle of texture. Organic matter content was examined by the loss-on-ignition method (Avery

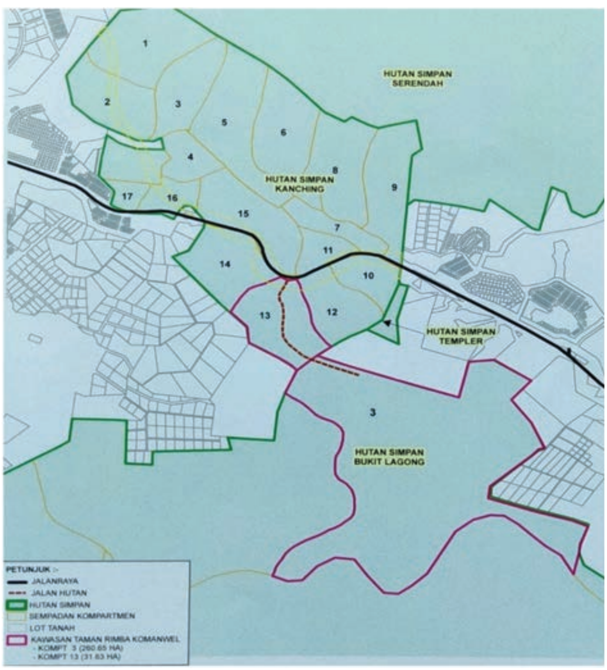

Figure 1: Study area of Bukit Lagong Forest Reserve, Selangor

Table 1: Topography and coordinates for 14 plots at Bukit Lagong Forest Reserve

Plot	Altitude (m)	Latitude	Longitude
1	168	03°16.1907' N	101°37.2041' E
2	185	03°17.2811' N	101°37.2041' E
3	188	03°17.2593' N	101°37.2651' E
4	228	03°17.1844' N	101°37.2806' E
5	202	03°17.1124' N	101°37.2718' E
6	226	03°17.0496' N	101°37.209' E
7	234	03°16.9813' N	101°37.1905' E
8	223	03°16.9978' N	101°37.1188' E
9	272	03°16.9649' N	101°37.0658' E
10	282	03°16.9173' N	101°37.0117' E
11	299	03°16.8321' N	101°37.0412' E
12	340	03°16.8346' N	101°37.1027' E
13	294	03°16.7316' N	101°37.1089' E
14	331	03°16.6493' N	101°37.0456' E

& Bascomb, 1982) while soil pH analysis was determined by using a pH meter in soil with the water ratio of 1:2:5 using Metson method (Metson, 1956) as mentioned by Natasha *et al.* (2020). Exchangeable of acid cation was done by titration to extract the soil with 1 M potassium chloride (KCL). Exchangeable basic cation was determined by soil extraction in 1 M ammonium acetate and the extract was determined by flame atomic absorption spectrophotometer (FAAS) (Shamshuddin, 1981). The cation exchange capacity (CEC) was obtained by summation of acid and base cations (Rowell, 1994). Available macronutrients and micronutrients in the soil were extracted using 1 M ammonium acetate-acetic acid and were run under an ultraviolet (UV) spectrophotometer and atomic absorption spectrophotometer (AAS) (Nurfarfazliza *et al.,* 2012). Availability of total nitrogen in the soil was determined by using the Kjeldahl method (Kjeldahl, 1883).

Data Analysis

All trees enumerated were tabulated and summarized into a floristic composition and quantitative data were analysed to quantify forest structure, species diversity and tree biomass. Forest structure was determined by calculating the density, frequency and basal area based on the formula below;

$$\text{Density (d), (individual per ha)} = \frac{\text{Total number of species A}}{\text{Total area}} \quad (1)$$

$$\text{Frequency (f), (\%)} = \frac{\text{Number of subplots that species A present}}{\text{Total subplots}} \quad (2)$$

$$\text{Basal area (BA), (m}^2\text{)} = (\text{DBH})^2 \times 0.00007875 \quad (3)$$

Importance value index (IV_i) was calculated by summing up the value of relative density (R_d), relative frequency (R_f) and relative dominance (R_D) and the total sum later divided by three to determine species importance (Curtis & Macintosh, 1951) as follows:
Importance Value (IV_i) = ($R_d + R_f + R_D$) / 3

$$\text{Relative density } (R_d) = \frac{\text{Density of species A}}{\text{Total density of all species}} \times 100 \quad (4)$$

$$\text{Relative frequency } (R_f) = \frac{\text{Frequency of species A}}{\text{Total subplots}} \times 100 \quad (5)$$

$$\text{Relative dominance } (R_D) = \frac{\text{Basal area of species A}}{\text{Total basal area of all species}} \times 100 \quad (6)$$

Species diversity and species richness in the study area was determined by using the Shannon-Weiner Diversity Index (H'), Shannon Evenness Index (E') and Margalef Richness Index (R') (Clifford & Stephenson, 1975; Spellerberg & Fedor, 2003). All diversity parameters were obtained using the software Paleontological Statistic Software Package for Education and Data Analysis (PAST) Software version 2.17c (Hammer, 2012). The formula to determine the species diversity and species richness are as follows;

a) Shannon-Weiner Diversity Index (H')

$$H' = \sum_{i-1}^{s} \quad P_i \; In \; P_i \quad (7)$$

Where,
S = number of species
pi = proportion of i-th individual number (n_i/N)

b) Shannon Evenness Index (E')

$$E = H'/ \text{ In S} \quad (8)$$

Where,
H' = Shannon- Weiner Diversity Index
S = Total number of species
The equation for the maximum value of Shannon- Weiner Index, H'_{max}
H'_{max} = In S

c) Margalef Richness Index (D_{MG})

$$(D_{MG}) = S\text{-}1/(\text{In N}) \quad (9)$$

Where,
S = Total number of species
N = Total number of individual

The estimation of tree biomass was determined by adding the above ground biomass (AGB) (Kato *et al.,* 1978) and below ground biomass (BGB) (Niiyama *et al.,* 2010). Biomass regression equation by Kato *et al.* (1978) as below:

$$\text{Tree height (h)} = \frac{122 \times DBH}{2DBH+61, \text{ unit } cm^2} \quad (10)$$

$$W_S \text{ (Weight of stem)} = 0.313\ (DBH^2h)^{0.9733}\ \text{(kg)} \quad (11)$$

$$W_b \text{ (Weight of branch)} = 0.136\ (W_S)^{1.070}\ \text{(kg)} \quad (12)$$

$$W_l \text{ (Weight of leaves)} = \frac{1.25 \times 0.124\ (W_S)^{0.794}\ /}{0.124 \times (W_S)^{0.794} + 125}\ \text{(kg)} \quad (13)$$

$$\text{Above Ground Biomass (AGB)} = \frac{W_S + W_b + W_l\ /\ \text{Total area of plots}}{1000 \text{ in t/ha}} \quad (14)$$

The equation for below ground biomass was based on Niiyama *et al.* (2010)

$$\text{Below Ground Biomass (BGB)} = 0.0262 \times DBH^{2.497}\ \text{t/ha} \quad (15)$$

From the above ground and below ground biomass, the total amount of biomass of the study plot was calculated.

Total Biomass (t/ha) = AGB + BGB

The distribution pattern of tree species composition with the measured edaphic variables was analysed by multivariate techniques that are available in CANOCO for windows 5.0 (Lepš & Šmilauer, 2014). Preliminary analysis of the data indicated that ordination methods based on linear responses were appropriate (Lepš & Šmilauer, 2005). Therefore, the ordination method used were principal component analysis (PCA) and redundancy analysis (RDA) to illustrate the influence of edaphic factors on tree species (Lepš & Šmilauer, 2005). Species compositional variation was obtained by using the Monte-Carlo permutation test based on 499 random trials at a 0.05 significance level (ter Braak, 1990). Lastly, illustrated diagram of the relationship between tree communities and soil factors was performed by RDA using CANOCO 5.

Results and Discussion

Floristic Composition

A total of 448 trees with a diameter at breast height (DBH) of 5 cm and above were enumerated in all 14 plots (0.07 ha each) at Bukit Lagong Forest Reserve. Table 2 showed the detailed floristic composition in Bukit Lagong Forest Reserve which comprised 25 families, 47 genera and 53 species. The most speciose family was Dipterocarpaceae, represented by six species and one genus from 42 trees, followed by Fabaceae with five species. Genera wise, Fabaceae recorded the highest number of five genera, followed by Anacardiaceae and Euphorbiaceae with four genera.

The floristic composition at Bukit Lagong Forest Reserve was compared to other previous studies from various forest habitats (Table 3). Based on the comparison, it is apparent that even though in similar habitat types, the floristic composition distribution varied distinctly, reflecting the uniqueness of each forest habitat that could harbour different types of forest species. Besides, the variation of tree communities in different habitat types indicates the heterogeneity of the forest ecosystems and could be due to differences in environmental factors of the different study area.

The species-rich composition of family Dipterocarpaceae in the study sites is in line with other studies in Kota Damansara Forest Reserve (Hannani, 2020) which recorded a total of nine species in a 0.5 ha plot, and in three forest reserves in Kelantan, Bukit Bakar, Gunung Basor and Gunung Stong Tengah, recorded a total of 31 species and seven genera (Norashikin *et al.,* 2015). The comparative high species count of Dipterocarpaceae was also reported by Suhaili (2005) in a 2 ha study plot of Virgin Jungle Reserves in Lesong Forest Reserve, where 23 species were recorded. In addition, Ashton, (1982) made a similar finding that Dipterocarpaceae is one of the largest family in

Table 2: Total numbers of genera, species and individuals for all trees families in the study plot (0.7 ha) at the Bukit Lagong Forest Reserve, Selangor

No.	Family	Genus	Species	Number of Individuals
1	Anacardiaceae	4	4	10
2	Annonaceae	2	2	20
3	**Arecaceae**	**2**	**2**	**8**
4	Burseraceae	2	2	10
5	**Clusiaceae**	**3**	**3**	**15**
6	Dilleniaceae	1	1	2
7	Dipterocarpaceae	1	6	42
8	Euphorbiaceae	4	4	59
9	Fabaceae	5	5	18
10	Fagaceae	2	2	15
11	Lauraceae	2	3	75
12	Malvaceae	3	3	33
13	Melastomaceae	2	2	12
14	Meliaceae	1	1	9
15	Moraceae	2	2	13
16	Myristicaceae	1	1	5
17	Myrtaceae	1	1	60
18	Olacaceae	2	2	11
19	Poaceae	1	1	4
20	Polygalaceae	1	1	7
21	Rhizophoraceae	1	1	8
22	Rubiaceae	1	1	4
23	Sapotaceae	1	1	3
24	Ulmaceae	1	1	4
25	Verbenaceae	1	1	1
	Total	47	53	448

Table 3: Comparisons of tree species number at Bukit Lagong Forest Reserve with the previous study

Study	Location	Type of Forest	Number of Family	Number of Genus	Number of Species
Present study	Bukit Lagong Forest Reserve (0.7 ha)	Hill dipterocarp	26	47	53
(Lajuni & Latiff, 2013)	Bangi Permanent Forest Reserve (1.0 ha)	Lowland dipterocarp	43	113	171
(Nizam *et al.*, 2012)	Kenong Forest Park (0.2 ha)	Lowland dipterocarp	54	161	322
(Sasse *et al.*, 2010)	Sungai Lalang Forest Reserve (1.0 ha)	Lowland and hill dipterocarp	29	59	92

Peninsular Malaysia, represented by 17 genera and 500 species.

Species Accumulation Curve

The relationship between the number of species and number of individuals was determined by constructing the species accumulation curve. Figure 2 shows that the study area of 0.7 ha in Bukit Lagong Forest Reserve was almost the optimum size to capture the species richness of the area, whereby a plateau is nearly reached at the top of the graph; nevertheless, no clear asymptote was obtained, as the number of species was still increasing when the survey area was enlarged.

The increasing pattern in the curve shows that more species will be found as the study area is enlarged. This is because tropical forests support high species richness, whereby a larger study area would cause an increase in the number of species, even just one species would be added. Hence, the tropical rainforest accumulation curve is in asymptote format on any scale compared to the temperate forest (Condit *et al.,* 1996). The curve in this study is not reaching asymptote and this indicates that the sampling effort was insufficient to account for all species present in the study area (Seaby & Henderson, 2007). A similar curve was shown in many studies, such as in Sungai Pinang Forest Reserve (Ghollasimood, 2011) and Sungai Menyala Forest Reserve (Abdul Razak *et al.,* 2019).

Species Diversity and Species Richness

Species diversity consists of the measurement of two distinct components: the number of species in a locality (species richness) and the degree to which relative abundance of species are similar (evenness or unevenness) (Hurlbert, 1971; Magurran & McGill, 2011). The Shannon-Weiner diversity (H') index of tree community at Bukit Lagong Forest Reserve, Selangor, indicated a moderate H' value of 3.41 and H'max of 3.97. The H' value must exceed 5 for the forest to be classified as high diversity (Eswani *et al.,* 2010). According to Spellerberg and Fedor, (2003), the high value of the Shannon Diversity Index (H') indicates the species-rich ecosystem and a low value will have a low species diversity. The Evenness Index in this study was 0.57, showing that the evenness in the study site was low compared with other studies and reflects that all tree species in the present study were not equally abundant in the forest. This scenario was reflected by the tree species of *Syzygium* sp. from the family of

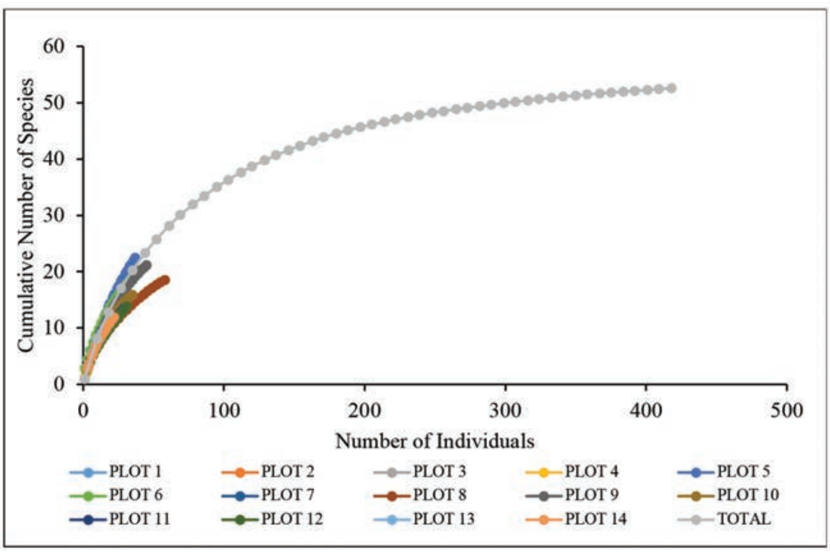

Figure 2: Species accumulation curve plotted for 14 plots of Bukit Lagong Forest Reserve

Myrtaceae which dominated the study area with 60 individuals from six species (11.32% of total species) were represented by a single individual. Besides, the species richness index determined in Bukit Lagong Forest Reserve is essentially a measure of the number of species in a defined sampling unit (Magurran, 2004). Species richness (Margalef Index) of Bukit Lagong Forest Reserve showed lower value of DMG = 8.52 compared with other studies. The higher value was recorded in other studies due to the sample size, such as the number of individuals in determining the value of the Margalef Index (Magurran, 1988). The Shannon Diversity Index (H'), H' max, Evenness (E) and Margalef Index (D_{MG}) value from this study was compared with another similar habitat in Peninsular Malaysia as tabulated in Table 4.

Forest Structure

The forest structure of trees in the study plots of Bukit Lagong Forest Reserve was described by the distribution of tree diameter class in seven categories, from the smallest of 5.0 - 14.9 cm, to the largest of 68.0 cm (Table 5). This tree diameter measurement was a standard method used by ecologists in determining DBH of trees, such as Ghollasimood (2011) and Faezah *et al.* (2013). All 448 trees that were observed in the study plots had diameters in the range of 5.0 cm to 68.0 cm, with an average diameter of 23.45 cm. The first DBH class of 5.0 - 14.9 cm had 114 individuals, which came from 24 species, 15 genera and 16 families. The second DBH class (15.0 – 24.9 cm) had 138 individuals, composed of 33 tree species, 20 genera and 21 families, and the last DBH class (65.0 – 74.0 cm) had one individual. It is apparent that the number of individuals, species, genera and families decreases as the size of the diameter class increases.

The diameter class distribution of the forest in each study site was strongly size-dependent and showed a reversed J-shaped curve (Figure 3). The inverse J-shaped curve of the DBH distribution in the study sites is typical of tropical forests, and was observed in three forest reserves in Selangor (Hannani, 2020), Sungai Lalang Forest Reserve (Natasha, 2020) and Gunung Tebu Forest Reserve (Ahmad Fitri *et al.,* 2019). Those findings indicated that the forest stands in the study sites had good recruitment patterns, with rich sampling bank (Zhang & Ni, 2012) and it is also the main feature of matured forest in Peninsular Malaysia (Manokaran *et al.,* 1990).

Table 4: Shannon Diversity Index (H'), H' max and Evenness (E) values from this study and other similar habitats in Peninsular Malaysia

Study	Location	Shannon Diversity Index (H')	H' max	Evenness (E)	Margalef Index (D_{MG})
Present	Bukit Lagong Forest Reserve	3.41	3.97	0.57	8.52
(Natasha, 2020)	Sungai Lalang Forest Reserve	3.64	4.41	0.83	12.79
(Hannani, 2020)	Bukit Tarek Forest Reserve	3.39	3.83	0.50	10.53
	Ulu Gombak Forest Reserve	3.50	3.95	0.64	10.26
	Kota Damansara Forest Reserve	3.43	4.08	0.67	8.45
(Ahmad Fitri *et al.,* 2019)	Gunung Tebu Forest Reserve	5.16	5.53	0.93	38.32

Table 5: Number of families, genera and species of trees ≥ 5 cm by different DBH classes in the 0.7 ha study plots at Bukit Lagong Forest Reserve, Selangor

DBH Classes Number	DBH Classes	Number Individuals	Number Species	Number Genera	Number Family
I	5.0-14.9	114	24	15	16
II	15.0-24.9	138	33	20	21
III	25.0-34.9	96	28	21	17
IV	35.0-44.9	72	25	19	16
V	45.0-54.9	21	13	11	9
VI	55.0-64.9	6	5	5	4
VII	65.0-74.9	1	1	1	1

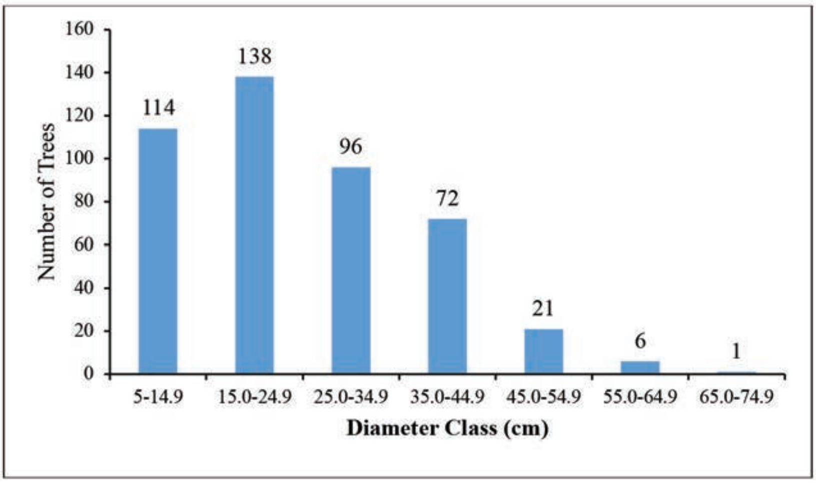

Figure 3: Stand structure based on Diameter Breast Height (DBH) class at Bukit Lagong Forest Reserve, Selangor

Artocarpus elasticus (Moraceae) was the tree species that had the largest DBH with a diameter of 68 cm, followed by *Shorea maxwelliana* (Dipterocarpaceae) and *Neolamarckia cadamba* (Dipterocarpaceae) with diameters of 62 cm and 60 cm, respectively (Table 6). The largest tree DBH size recorded in the forest was influenced by ecological factor such as climate, biotic and physiographic factors (Kumar, 2021). The low number of trees with DBH > 68 cm is common; this was also observed by Haugaasen & Peres (2006), where they reported a very small number of large trees in flooded and unflooded forests of central Amazonia, Brazil, of which only 23 (0.43%) emergent trees in the entire sample reached diameters ≥ 100 cm and only 11 stems touched the diameter ≥ 120 cm. These results showed the common scenario in an uneven-aged forest, in which large trees generally occur at low densities in forests, but they can account for more than 40% of the biomass of stands (Brown & Lugo, 1992; Brown *et al.,* 1992).

Abundance Parameters and Species Importance

The density of trees in Bukit Lagong Forest Reserve was 640 individuals per ha. Lauraceae contributed the highest density with 107 individuals per ha (16.72%). Myrtaceae had the second-highest density with 86 individuals per ha (13.44%), followed by Euphorbiaceae with 84 individuals per ha (13.13%). Species-wise,

Table 6: Five largest trees in 0.7 ha of study plots at Bukit Lagong Forest Reserve, Selangor

Family	Species	DBH (cm)
Moraceae	*Artocarpus elasticus*	68
Dipterocarpaceae	*Shorea maxwelliana*	62
Rubiaceae	*Neolamarckia cadamba*	60
Dipterocarpaceae	*Shorea maxwelliana*	58
Dipterocarpaceae	*Shorea leprosula*	58

Syzygium sp. (Myrtaceae) had the highest density with 86 individuals per ha (13.44%) followed by *Cinnamomum* sp. (Lauraceae) with 79 individuals per ha (12.34%) and *Endospermum diadenum* (Euphorbiaceae) with 47 individuals per ha (7.34%) (Table 7). Forest ecosystems could support different densities of tree families and species, reflecting different characteristics of ecosystems where factors such as soil type, fire and specific interactions influence the value of tree density (Atanasso *et al.,* 2019).

Further, the frequency of tree species on 14 plots in Bukit Lagong Forest Reserve was dominated by the family of Dipterocarpaceae and Euphorbiaceae, which shared the same highest frequency of 93%, since both of them were observed in 13 out of 14 plots in the study area. The family with the second highest frequency was Lauraceae, with 86%, followed by Myrtaceae and Annonaceae, each with a frequency of 79%. At species level, *Endospermum diadenum* was the species with the highest frequency ar 93%. *Syzygium* sp. was the second highest with a value of 79%, followed by *Polyalthia* sp. and *Shorea leprosula* each with a frequency of 71% (Table 7). The family and species with the highest frequency indicates a widespread distribution of the trees in the study plots. Hubbell (1979) and Masaki *et al.* (1992) stated that the distribution of tree communities in a forest ecosystem is influenced by ecological characteristics, such as topography, soil properties and gap effects in the habitat.

The total tree basal area in Bukit Lagong Forest Reserve was 36.02 m^2 ha^{-1}. According to Sharma (2004), basal area is not influenced by the number of individuals, instead, a smaller number of individual may represent a high value of basal area if the diameter at breast height (DBH) is larger. Dipterocarpaceae dominated the study area with a value of 8.02 m^2 ha^{-1} (22.3%) as expected, since most of the large trees with DBH greater than 55 cm are diptercorp trees. Euphorbiaceae had the second highest with a value of 5.98 m^2 ha^{-1} (16.6%) followed by Malvaceae with a basal area value of 3.24 m^2 ha^{-1} (9%). Species-wise, *Endospermum diadenum* (Euphorbiaceae) contributed the highest basal area with a value of 4.51 m^2 ha^{-1} (12.5%) followed by *Shorea leprosula* (Dipeterocarpace) and *Syzygium* sp. (Myrtaceae) with a value of 3.94 m^2 ha^{-1} (10.9%) and 2.85 m^2 ha^{-1} (7.91%), respectively (Table 7).

In contrast with other studies, Ahmad Fitri *et al.* (2019) found the total basal area at Gunung Tebu Forest Reserve was 56.20 m^2 ha^{-1} at Bukit Panchor State Park, the total basal area recorded was 40.90 m^2 ha^{-1}. The value of basal area recorded at both study sites was contributed by the family of Dipterocarpaceae, which indicates that individuals from this family are mostly larger compared to other trees hence. The differences in the value of basal area may be attributed to altitude, species composition, age of trees, degree of disturbances and also the successional stage of the stand (Naidu & Kumar, 2016).

Based on the calculated Importance Value Index (IV_i), Dipterocarpaceae recorded the highest IV_i value of 13.11%, followed by Euphorbiaceae and Lauraceae with an IV_i value of 12.49% and 10.16%, respectively. At species level, *Syzygium* sp. had the highest IV_i value of 8.79%. *Endospermum diadenum* represented the second-highest with 8.62%, followed by *Cinnamomum* sp. with an IV_i value of 7.47%

and *Shorea leprosula* with an IVi value of 6.52% (Table 7). The results show that none of the family and species in the study plots are considered as absolutely dominant. Curtis and Macintosh (1951) state that only the family with IV_i of more than 40% and species with more than 10% could be considered as having absolute dominance.

Biomass

Total tree biomass in Bukit Lagong Forest Reserve was estimated at 525.20 t/ha, which was contributed by the above ground biomass and below ground biomass of 455.24 t/ha (86.68%) 69.96 t/ha (13.32%), respectively. At family level, Dipterocarpaceae contributed the highest total biomass of 129.78 t/ha (24.71%) followed by Euphorbiaceae and Malvaceae with biomass value of 88.12 t/ha (16.78%) and 46.68 t/ha (8.89%), respectively (Table 8). Domination of Dipterocarpaceae at the family level was a common finding as this family is usually represented by larger trees compared with others (Kochummen *et al.,* 1990; Norazlinda *et al.,* 2016). Species-wise, *Endospermum diadenum* (Euphorbiaceae) recorded the highest value with 68.41 t/ha (13.03%). The second leading species was *Shorea leprosula* (Dipterocarpaceae) with a recorded value of 64.75 t/ha (12.33%) and the third leading species was *Syzygium* sp. with a value of 36.21 t/ha (6.90%) (Table 8).

For comparison, Ahmad Fitri *et al.* (2019) estimated a total tree biomass of 715.45 t/ha at Gunung Tebu Forest Reserve, of which a total of 608.89% t/ha was contributed by above ground biomass, and 106.56 t/ha was contributed by below ground biomass. Meanwhile, at two forest subtypes in Pekan Forest Reserve, the total biomass recorded at Kempas-Ramin-Durian subtypes and Durian Nyatoh subtypes were

Table 7: Summary of tree density, frequency, basal area (BA) and Importance Value (IV_i) of five leading families and species at Bukit Lagong Forest Reserve, Selangor

	Family	Value	Species	Value
Density (individual per ha)	Lauraceae	107	*Syzygium* sp.	86
	Myrtaceae	86	*Cinnamomum* sp.	79
	Euphorbiaceae	84	*Endospermum diadenum*	47
	Dipterocarpaceae	60	*Scaphium macropodum*	43
	Malvaceae	47	*Shorea leprosula*	26
Frequency (%)	Euphorbiaceae	93	*Endospermum diadenum*	93
	Dipterocarpaceae	93	*Syzygium* sp.	79
	Lauraceae	86	*Polyalthia* sp.	71
	Myrtaceae	79	*Shorea leprosula*	71
	Annonaceae	79	*Cinnamomum* sp.	64
Basal area, BA (m^2 ha^{-1})	Dipterocarpaceae	8.02	*Endospermum diadenum*	4.51
	Euphorbiaceae	5.98	*Shorea leprosula*	3.94
	Malvaceae	3.24	*Syzygium* sp.	2.85
	Myrtaceae	2.85	*Scaphium macropodum*	2.59
	Lauraceae	2.39	*Cinnamomum* sp.	2.15
IVi (%)	Dipterocarpaceae	13.11	*Syzygium* sp.	8.79
	Euphorbiaceae	12.49	*Endospermum diadenum*	8.62
	Lauraceae	10.16	*Cinnamomum* sp.	7.47
	Myrtaceae	9.27	*Shorea leprosula*	6.52
	Malvaceae	7.23	*Scaphium macropodum*	5.86

Table 8: Summary of total biomass for five leading family and species in the 14 plots (0.7 ha) at Bukit Lagong Forest Reserve, Selangor

	AGB (t/ha)	BGB (t/ha)	Total Biomass (t/ha)	Percentage (%)
Family				
Dipterocarpaceae	112.29	17.49	129.78	24.71
Euphorbiaceae	76.44	11.67	88.12	16.78
Malvaceae	40.52	6.15	46.68	8.89
Myrtaceae	31.47	4.74	36.21	6.89
Lauraceae	25.10	3.80	28.90	5.50
Species				
Endospermum diadenum	59.32	9.08	68.41	13.03
Shorea leprosula	56.01	8.74	64.75	12.33
Syzygium sp.	31.47	4.74	36.21	6.90
Scaphium macropodum	31.33	4.72	36.06	6.87
Artocarpus elasticus	23.28	3.73	27.01	5.14

Table 9: List of endemic species found in study plots at Bukit Lagong Forest Reserve, Selangor

Species	Family	Distribution	Number of Individuals
Dillenia reticulata	Dilleniaceae	Kl, Pk, Ph, Sl, NS, Ml, Jh.	2
Eugeissona tristis	Arecaceae	Ps, Kd, Kl, Tg, Pn, Pk, Ph, Sl, NS, Ml, Jh	2
Palaquium maingayi	Sapotaceae	Kd, Kl, Pk, Ph, Sl, NS, Ml, Jh	3

Note: Kl = Kelantan, Pk = Perak, Ph = Pahang, Sl = Selangor, NS = Negeri Sembilan, Ml = Melaka, Jh = Johor, Ps = Perlis, Kd = Kedah, Tg = Terengganu, Pn = Penang

399.21 t/ha and 328.14 t/ha, respectively (Ismail *et al.,* 2009). These previous reports indicated different forest habitats support different productivities and structures of forest stands, which reflected the variety of tree biomass in these forests. In addition, Norashikin *et al.* (2017) stated that tree biomass is also influenced by tree density, biogenic (carbon emission by living organism) and anthropogenic activities.

Species Status

Endemic Status

From the total of 53 species in Bukit Lagong Forest Reserve, three species were identified as endemic (Table 9). Ng *et al.* (1990) stated that there are 2830 tree species found in Peninsular Malaysia and the number of endemic trees is 746 species, or 26.4% of the total number of tree species. Therefore, the endemic species in Bukit Lagong Forest Reserve, Selangor represented 0.4% of endemic trees in Peninsular Malaysia. The occurrence of endemic species in forests play a crucial role in the structure and composition of tree communities, as well as reflecting the uniqueness of the forests (Bryan, 2002).

Conservation Status

The tree species at Bukit Lagong Forest Reserve were categorized according to International Union for Conservation of Nature (IUCN) Red List of Threatened Species version 2020 - 3 (www.iucnredlist.org). The species were classified under nine categories; Extinct (E), Extinct in the Wild (EW), Critically Endangered (CR), Endangered (EN), Vulnerable (VU), Near Threatened (NT), Least Concern (LC), Data Deficient (DD) and Not Evaluated (NE). Species that are CR, EN, and VU are, collectively referred to as threatened. Twenty-two species out of 53 in the study site were listed in the Red List of Threatened Species (Table 10).

All species classified as endangered and critically endangered were from Dipterocarpaceae, which were *Shorea bracteolata*, *Shorea maxwelliana* and *Dipterocarpus cornutus.* Dipterocarpaceae has the most significant of threatened species because it is the main source of timber in Southeast Asian countries (Richter & Gottwald, 1996). Besides, anthropogenic activities, such as deforestation and logging, as well as natural interferences, have led to the loss of dipterocarps species in the forest. A study by Natasha, (2020) also reported that Dipterocarpaceae as the most threatened family at Sungai Lalang Forest Reserve, which recorded four species from the family of Dipterocarpaceace: *Anisoptera costata, Neobalanocarpus heimii, Shorea bracteolata* and *Shorea parviflora*.

Soil Properties

Physical Properties of Soil

Soils are grouped into textural classes based on their sand, silt and clay content. There are 12 textures, namely; sand, loamy sand, sandy

Table 10: The IUCN Conservation status of 22 tree species in the 14 plots (0.7 ha) at Bukit Lagong Forest Reserve, Selangor

Family	Species	IUCN Status
Arecaceae	***Orania sylvicola***	**Near Threatened**
Burseraceae	*Santiria laevigata*	Least Concern
Burseraceae	*Dacryodes rugosa*	Least Concern
Clusiaceae	***Cratoxylum arborescens***	**Least Concern**
Dilliniaceae	*Dillenia reticulata*	Least Concern
Dipterocarpaceae	*Dipterocarpus cornutus*	Critically Endangered
Dipterocarpaceae	*Shorea bracteolata*	Endangered
Dipterocarpaceae	*Shorea maxwelliana*	Endangered
Dipterocarpaceae	*Shorea ovalis*	Least Concern
Dipterocarpaceae	*Shorea leprosula*	Near Threatened
Dipterocarpaceae	*Dryobalanops aromatica*	Vulnerable
Euphorbiaceae	*Sapium baccatum*	Least Concern
Euphorbiaceae	*Endospermum diadenum*	Least Concern
Fabaceae	*Pometia pinnata*	Least Concern
Fabaceae	***Koompassia malaccensis***	**Conservation Dependent**
Lauraceae	*Cinnamomum javanicum*	Least Concern
Malvaceae	*Scaphium macropodum*	Least Concern
Moraceae	*Artocarpus elasticus*	Least Concern
Myristicaceae	*Myristica cinnamomea*	Least Concern
Olacaceae	*Ochanostachys amentacea*	Data Deficient
Sapotaceae	*Palaquium maingayi*	Vulnerable
Ulmaceae	*Gironniera subaequalis*	Least Concern

loam, loam, silt loam, silt, sandy clay loam, sandy clay, clay loam, silty clay loam, silty clay and clay (Eswaran *et al.,* 2003). The analyses of particle size in 14 study plots in Bukit Lagong Forest Reserve showed that the soils were dominated by sandy loam texture, which was observed in nine plots (64.29%) of the total. As a comparison with other studies, Nizam *et al.* (2006) reported clay dominated soil texture in Merapoh National Park, Pahang. At Endau-Rompin State Park, the soil texture was mainly sandy loam clay, and Bukit Bauk Forest Reserve soil texture was dominated by loam (Nizam *et al.,* 2013).

The organic matter (OM) content of the soil in Bukit Lagong Forest Reserve ranged from 3.53% to 5.71%, with a mean value of 4.24 ± 0.29%. The amount of OM in the soil at Bukit Lagong Forest Reserve was considered low when compared with a study by Nizam *et al.* (2006) at National Park in Merapoh, Pahang, which recorded a value of OM of 5.83 ± 0.30% while at upper hill dipterocarp forest of Temengor Forest Reserve mean OM content recorded was 10.06 ± 1.30% (Ahmad Fitri, 2013). A low OM content in the soil was due to climate factors in the tropical rain forest, as a high rate of decomposition of organic residue is influenced by the hot and wet climate in the forest (Longman & Jeník, 1974). Those results indicate that the soils of dryland forests in Peninsular Malaysia display low organic matter content, due to the high decomposition rate of the organic matter. Overall, Organic Matter (OM) content is important in sustaining soil structure as they hold individual mineral particles that are essential for shaping the distribution and diversity of tree species in the forest.

Chemical Properties of Soil

A summary of the soil chemical properties in the 14 plots of Bukit Lagong Forest Reserve is given in Table 11.

The mean soil pH of Bukit Lagong Forest Reserve was 4.69 ± 0.35 which indicates that the soil of the study area was acidic. This corresponds with the statement from Shamshuddin *et al.* (2011) who mentioned that most soils in the tropical rain forest in Peninsular Malaysia were acidic with a pH range between 3 to 5. The high acidity of the soil in wet tropical regions was a common scenario as it has resulted in the soil becoming leached and weathered due to the leaching of base cations such as Na^+, K^+, Ca^{2+} and Mg^{2+}, then, being replaced by H^+ and Al^{3+}

Table 11: Summary of soil variables in 14 plots at Bukit Lagong Forest Reserve, Selangor

Soil Parameters	**Bukit Lagong Forest Reserve**
pH	4.69 ± 0.35
Cation exchange capacity, CEC (meq/100g)	
Ca^{2+}	3.18 ± 0.27
Mg^{2+}	1.21 ± 0.14
Na^+	1.70 ± 0.02
K^+	0.94 ± 0.10
H^+	0.15 ± 0.04
Al^{3+}	0.23 ± 0.07
CEC	7.40 ± 0.35
Nutrient availability (µg/g)	
Phosphorus (P)	7.50 ± 1.47
Total Nitrogen (N)	0.30 ± 0.02
Magnesium (Mg)	136.80 ± 13.93
Potassium (K)	605.06 ± 7.40

ions which were produced from the process of H_2O hydrolysis (Lal & Greenland, 1979). Besides, the amount of organic matter (OM) in the soil also contributes to the acidity of the soil due to the releasing of H^+ ions from humus colloids (humus acids), which were formed by the partial decomposition of soil Organic Matter (OM) when water is mixed with the soil (Nizam *et al.,* 2006).

Cation exchange capacity (CEC) is a measure of the soil's ability to hold positively charged ions. According to Hazelton & Murphy (2007), this soil property is important as it may influence the soil structure stability, nutrient availability, soil pH and the soil reactions to fertilizers and other ameliorants. Generally, the following cations are involved in describing CEC, i.e. exchangeable acid cations (H^+, Al^{3+}) and exchangeable bases cations (Ca^{2+}, Mg^{2+}, Na^+ and K^+). The CEC in the 14 plots of Bukit Lagong Forest Reserve showed a mean value of 7.40 ± 0.35 meg/100g. The mean value of CEC is influenced by the percent of clay content, soil pH, and organic matter (Ohta *et al.,* 1993). As a comparison, in various forest habitats in Chini Watershed Forest, Khairil *et al.* (2011) reported that CEC value at riverine areas was the highest (9.01 ± 1.72 meq/100g), followed by seasonal flood (8.34 ± 2.08meq/100g) and inland (7.94 ± 1.45 meq/100g). The CEC value at three forest reserves in Selangor recorded a value of 4.17 ± 0.30, 7.19 ± 0.62 and 15.44 ± 0.44 meq/100g in Kota Damansara Forest Reserve, Ulu Gombak Forest Reserve and Bukit Tarek Forest Reserve respectively (Hannani, 2020). A study by Nizam *et al.* (2013) in Endau-Rompin State Park and Bukit Bauk Forest Reserve recorded a mean value of 0.273 ± 0.01 meg/100g and 0.294 ± 0.006 meg/100g, respectively, which were lower than the mean value of CEC at Bukit Lagong Forest Reserve. The highest CEC value was attributed to the high organic matter content (Barnes *et al.,* 1998).

The concentration of available macronutrients phosphorus (P), total nitrogen (N), potassium (K) and magnesium (Mg) was determined in this study, as plants need them to grow and survive. The mean value of P content in Bukit Lagong Forest Reserve was 7.50 ± 1.47 µg/g, which is lower than what Nizam *et al.* (2006) found in National Park at Merapoh, Pahang (9.85 ± 0.95 µg/g). Low P concentration was also recorded in three forest reserves in Selangor: 1.77 ± 0.14 µg/g in Bukit Tarek Forest Reserve, 2.15 ± 0.11 µg/g in Kota Damansara Forest Reserve and 5.00 ± 2.15 µg/g in Ulu Gombak Forest Reserve (Hannani, 2020). The concentration of P in soil was controlled by the factors such as soil pH (Friesen *et al.,* 1980), organic matter content in soil (Othman & Shamshuddin, 1982) and depth of soil (Allbrook, 1973; Ismail, 2009).

Other than phosphorus, nitrogen is also one of the limiting macronutrients for plants. Most plants absorb nitrogen from the soil in the form of the inorganic nitrate ion (NO_3-N) and ammonium ion (NH_4-N). The total nitrogen recorded in Bukit Lagong Forest Reserve was 0.30 ± 0.02 µg/g. Runge (1983) stated that soil pH will influence the concentration of nitrogen elements. Compared with other studies, a high value of total nitrogen was recorded in National Park at Merapoh, Pahang with a mean value of 27.61 ± 2.45 µg/g (Nizam *et al.,* 2006). However, in Sungai Lalang Forest Reserve, Natasha (2020) recorded a low mean value of total nitrogen of 0.12 ± 0.02 µg/g. Hannani's (2020) study in three forest reserve in Selangor recorded a mean value of total nitrogen of 0.44 ± 0.07 µg/g in Kota Damansara Forest Reserve, 0.30 ± 0.03 µg/g in Ulu Gombak Forest Reserve and 0.24 ± 0.04 µg/g in Bukit Tarek Forest Reserve.

The mean value of K in Bukit Lagong Forest Reserve was 605.06 ± 7.40 µg/g, which was higher than the study by Natasha (2020) in Sungai Lalang Forest Reserve, which recorded a K content of 267.46 ± 20.28 µg/g. Low K content was also recorded in three forest types in Chini Watershed Forest: 153.93 ± 31.55 µg/g (inland forest), 108.69 ± 18.48 µg/g (seasonal flood forest) and 175.88 ± 27.95 µg/g (riverine forest) (Khairil *et al.,* 2011). Variation of K in the soil is influenced by the supply of nutrients, soil properties, plant population and moisture availability (Gasim *et al.,* 2011).

Lastly, Mg is essential for plant photosynthesis, as it is the only mineral that is a constituent of the chlorophyll molecule and it is usually ample in most forest soil (Pritchett & Fisher, 1987). The mean value of Mg in Bukit Lagong Forest Reserve was 136.80 ± 13.93 µg/g, which was higher than the mean of available Mg in Sungai Lalang Forest Reserve, which is 28.70 ± 1.24 µg/g (Natasha, 2020). Low Mg availability was also recorded at National Park at Merapoh, Pahang, which is 12.39 ± 0.28 µg/g (Nizam *et al.,* 2006). Mg content in three forest reserves in Selangor were 21.20 ± 1.14 µg/g in Kota Damansara Forest Reserve, 148.19 ± 26.66 µg/g in Ulu Gombak Forest Reserve and 5.88 ± 1.61 µg/g Bukit Tarek Forest Reserve (Hannani, 2020).

Relationship of Tree Communities with Soil Properties

The RDA of the tree communities and soil properties shows that the eigen values (a measurement of the strength of an axis or the amount of variation along an axis) for axis 1 and axis 2 were 0.4888 and 0.1380 respectively. The cumulative explained variations were 48.88% and 62.67% for axis 1 and axis 2 respectively (Table 12). The sum of explanatory variable account was 88%, which showed that the tree species are highly related to the soil characteristics in the study area.

The relationship between study plots and soil variables was indicated by the direction and length of arrows that radiated from the centre of the ordination diagram (Figure 4). The soil characteristic vectors with long arrows were more correlated and more important in influencing the community variation than short arrows. The location of sample plots near the arrow of the soil factors represents the environmental characteristics of the plots. The plots that were clumped together were relatively similar floristically; while the separated plots indicate dissimilarity in terms of floristic composition between the plots.

BL 5 was strongly associated with soil pH, BL 4 and 11 by P, BL 13 by Ca^{2+} and BL 4 and 2 by inorganic nitrogen (inorganic-N). As a comparison, a study by Khairil *et al.* (2014) in Chini watershed forest indicated that the study area was strongly influenced by P, OM, K and soil pH. In the National Park of Merapoh, Pahang, the area was strongly associated by P and soil pH (Nizam *et al.,* 2006). A study by Khairil *et al.* (2020) in Chemerong Recreational Forest indicated that the study area was highly influenced by P, Mg and soil pH. The previous findings showed the significant role of edaphic factors in controlling the tree species distribution, thus contributing to floristic variation patterns in all forest habitats (Figure 4).

However, four plots, BL 6, BL 7, BL 8 and BL 10, showed a weak association with soil characteristics in Bukit Lagong Forest Reserve and most of the plots did not show a clear relationship with the soil characteristics vectors. This shows that other environmental factors such as altitude, topography, soil water content and forest gap should be taken into consideration in determining the influences that shaping a pattern in tree species diversity and composition in the plot of the study area (Baldeck *et al.,* 2013; John *et al.,* 2007; Khairil *et al.,* 2015, 2014) (Figure 4).

Table 12: Summary of the RDA on tree communities and soil properties at Bukit Lagong Forest Reserve, Selangor

Axes	1	2	3	4
Eigenvalues	0.4888	0.1380	0.0715	0.0486
Explained variation (cumulative)	48.88	62.67	69.82	74.68
Pseudo-canonical correlation (supplementary)	0.9546	0.9995	0.9366	0.9506
Explained fitted variation (cumulative)	55.57	71.26	79.39	84.91

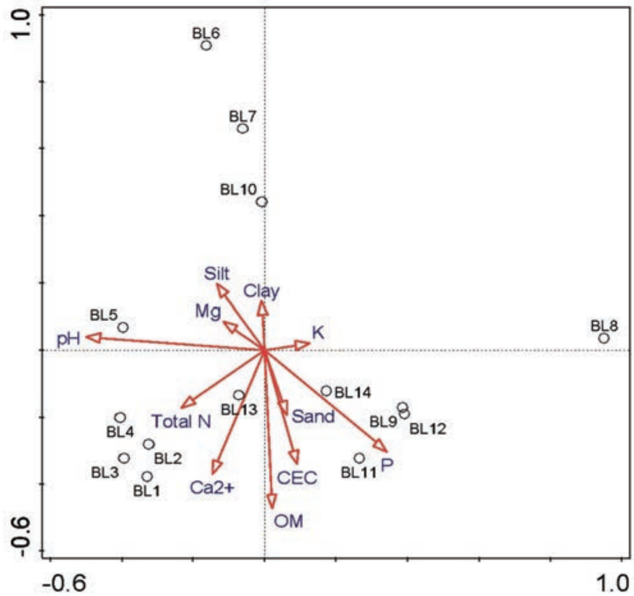

Figure 4: RDA ordination diagram showing the location of study plots and the soil characteristics at Bukit Lagong Forest Reserve, Selangor

Note: pH=soil pH; Ca^{2+}=calcium; Mg=magnesium; Na= sodium; K=potassium; CEC=cation exchange capacity; Total N= total inorganic nitrogen; soil texture=silt, clay, sandy

The tree species preference with the soil characteristics as portrayed in Figure 5. *Vitex sp.* (51) was influenced by soil pH and *Palaquium maingayi* (31) had a strong association with CEC. Further, *Memecylon* sp. (26) was strongly associated with OM, and *Ochanostachys*

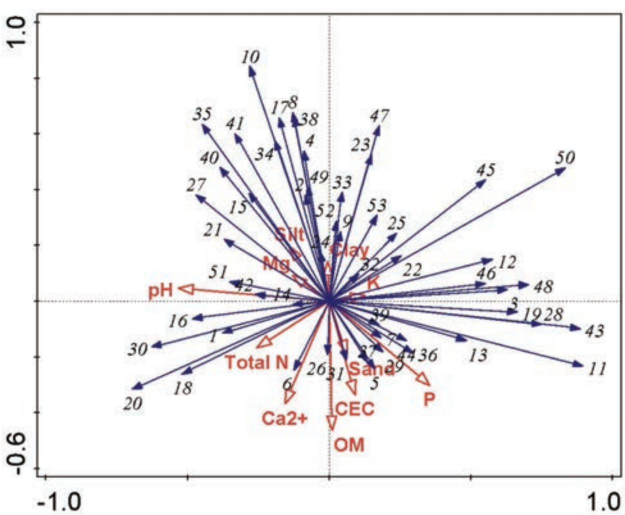

Figure 5: RDA ordination diagram showing the preference of tree species and the soil characteristics at Bukit Lagong Forest Reserve, Selangor

Note: pH=soil pH; Ca^{2+}=calcium; Mg=magnesium; Na= sodium; K=potassium; CEC=cation exchange capacity; Total N= total inorganic nitrogen; soil texture=silt, clay, sandy

Table 13: List of species number in ordination diagram of Figure 5

No.	Species	No	Species
1	*Actinodaphne* sp.	28	*Neolamarckia cadamba*
2	*Aglaia* sp.	29	*Ochanostachys amentacea*
3	*Albizia splendens*	30	*Orania sylvicola*
4	*Artocarpus elasticus*	31	*Palaquium maingayi*
5	*Bouea* sp.	32	*Pellacalyx axillaris*
6	*Callerya atropurpurea*	33	*Pentaspadon velutinus*
7	*Calophyllum rubiginosum*	34	*Polyalthia* sp.
8	*Campnosperma auriculatum*	35	*Pometia pinnata*
9	*Castanopsis* sp.	36	*Porterandia anisophyllea*
10	*Cinnamomum javanicum*	37	*Pternandra* sp.
11	*Cinnamomum* sp.	38	*Pterocymbium javanicum*
12	*Cratoxylum arborescens*	39	*Pterospermum* sp.
13	*Dacryodes rugosa*	40	*Santiria laevigata*
14	*Dillenia reticulata*	41	*Sapium baccatum*
15	*Dipterocarpus cornutus*	42	*Saraca* sp.
16	*Dryobalanops aromatica*	43	*Scaphium macropodum*
17	*Endospermum diadenum*	44	*Shorea bracteolata*
18	*Eugeissona tristis*	45	*Shorea leprosula*
19	*Garcinia* sp.	46	*Shorea maxwelliana*
20	*Gigantochloa scortechinii*	47	*Shorea ovalis*
21	*Gironniera subaequalis*	48	*Streblus elongatus*
22	*Koompassia malaccensis*	49	*Strombosia javanica*
23	*Lithocarpus* sp.	50	*Syzygium* sp.
24	*Macaranga* sp.	51	*Vitex* sp.
25	*Melanochyla fulvinervis*	52	*Xanthophyllum* sp.
26	*Memecylon* sp.	53	*Xylopia ferruginea*
27	*Myristica cinnamomea*		

amentacea (29) and *Porterandia anisophyllea* (36) were associated with P. *Callerya atropurpurea* (6) was strongly associated with calcium Ca^{2+}.

In comparison with other studies, several species were reported to have a strong association with soil characteristics at Chemerong Recreational Forest, such as *Barringtonia scortechinii* and *Shorea macrantha,* which were strongly associated with nitrate (NO_3) and CEC. *Monocarpia marginalis* and *Palaquium rostratum* displayed a strong correlation with P and soil pH (Khairil *et al.,* 2020). Moreover, tree species of *Scaphium linearicarpum* were strongly associated with N availability and *Shorea parvifolia* has a positive correlation with P availability in Sungai Lalang Forest Reserve (Natasha, 2020).

However, some tree species, such as *Cinnamomum javanicum* (10), *Cinnamomum* sp. (11) and *Syzygium* sp. (50) showed a weak association with the soil factors, where they are farther away from all soil gradients (Figure 5). This is not surprising as, in the study by John *et al.* (2007) and (Swaine, 1996), only some species were reported to have specific correlations with soil characteristics. Besides, Baldeck *et al.* (2013); Itoh *et al.* (1995); John *et al.* (2007) and Whitmore (1990) stated that soil, sunlight, topography and altitude are among the important factors influencing the distribution of several tropical plants species.

Conclusion

The hill dipterocarp forest of Bukit Lagong Forest Reserve, Selangor shows moderate species richness and diversity. An increasing pattern in the species accumulation curve shows that more species will be found with the increase of the study area. The distribution of trees with DBH of 5 cm and above displays the J inverse distribution, which indicates that trees are developing and regeneration are present in the forest. The high importance value index (IVi) showed by several important species reflect the forest as home to the most ecologically important species. The highest total tree biomass shows that the forest has high productivity and has a capability for carbon sink and energy supply. Endemic and threatened species found in the forest need to be protected with effective measures. The soil analyses demonstrate the dominance of sandy loam texture, acidic soil and with different concentrations of available nutrients. By knowing the nature and properties of soils in forest ecosystem, it is useful for proper management of environment and utilization of resources. The relationship between tree species and edaphic factors reflect the importance of conservation measures in this forest to ensure the sustainability of the forest because the tree species in particular are closely related to the physical and chemical properties of the soil in shaping the community structure of tree species in forest ecosystems.

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