Pertanika J. Trop. Agric. Sci. 43 (3): 315 - 326 (2020)

TROPICAL AGRICULTURAL SCIENCE

Journal homepage: http://www.pertanika.upm.edu.my/

Tree Community Structure and Diversity of *Shorea lumutensis* (Balau Putih) Dominated Forest at Segari Melintang Forest Reserve, Perak

Nurul Hidayah Che Mat, Abdul Latiff, Ahmad Fitri Zohari, Nizam Mohd Said and Nur 'Aqilah Mustafa Bakray*

Department of Biological Sciences and Biotechnology, Faculty of Science and Technology, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor Darul Ehsan, Malaysia

ABSTRACT

Monodominant forests are often dominated by a single tree species at the canopy layer of the forest. At Segari Melintang Forest Reserve, Perak, where *Shorea lumutensis* dominates the forest, a study was conducted to understand the floristic composition and the soil properties that drove the abundance of *S. lumutensis* in the study area. To achieve the objectives, all trees with a diameter at breast height (DBH) of 5 cm and above and soil samples were collected within eight random subplots of 25 m × 50 m each. A total of 1,207 trees were enumerated, which comprised 117 species, 70 genera, and 35 families. The most speciose family and family with the highest density were Euphorbiaceae (12 species) and Dipterocarpaceae (201 individuals/ha), respectively. The total basal area for all trees in the study plots was 32.63 m^2/ha, with Dipterocarpaceae and *S. lumutensis* showing the highest basal area of 10.64 and 2.9 m^2/ha, respectively. For the diversity indices, the Shannon diversity index showed a value of 3.92, whilst the Shannon evenness index was 0.82. The redundancy analysis (RDA) ordination diagram showed that *S. lumutensis* is associated with magnesium (Mg) and calcium (Ca). The distribution pattern of tree communities is associated with the soil characteristics of the study site.

Keywords: Forest dynamic, *Shorea lumutensis*, tree association

ARTICLE INFO

Article history:
Received: 12 March 2020
Accepted: 13 July 2020
Published: 28 August 2020

E-mail addresses:
hidayah_cm@yahoo.com (Nurul Hidayah Che Mat)
pakteh48@yahoo.com (Abdul Latiff Mohamad)
ahmadfitri@ukm.edu.my (Ahmad Fitri Zohari)
m.n.said@ukm.edu.my (Mohd Nizam Mohd Said)
nuraqilah@ukm.edu.my (Nur Aqilah Mustafa Bakray)
* Corresponding author

INTRODUCTION

Shorea lumutensis is one of the hyper-endemic species from 160 species of the Dipterocarpaceae family found in Peninsular Malaysia. This species is known by the local community in Malaysia as

ISSN: 1511-3701
e-ISSN: 2231-8542

Balau Putih, *Balau Bukit*, and *Damar Laut*, and is easy to be identified based on the white color present underneath its leaves (Ashton, 1982; Smith & Kochummen, 1979; Symington, 1974; Turner, 1995). This species has a limited distribution (Lee et al., 2006) and only grows at altitudes of 300 to 500 m above sea level (a. s. l.) (Evans, 1995) with specific soil conditions and topography (Ashton, 1976, 1982; Plotkin et al., 2000; Rivers & Barstow, 2019; Whitmore, 1973).

Recently, *S. lumutensis* has been classified as one of the critically endangered species (Chua et al., 2010; International Union for Conservation of Nature [IUCN], 2012; Rivers & Barstow, 2019). Because of having recalcitrant seeds (Boshier, 2011; Dudash & Carr, 1998; Keller & Waller, 2002; Lee et al., 2006; Symington, 1974; Tompsett, 1992) and demanding conditions for growth. Ghollasimood et al. (2011) demonstrated that *S. lumutensis* was closely associated with two species of palms, *Eugeissona tristis* and *Calamus castaneus*. Abiotic and biotic factors are crucial in facilitating the distribution of tree species (Nik Norafida et al., 2018; Nizam et al., 2009); thus, an intensive study was conducted to assess the soil properties associated with *S. lumutensis*.

This study aimed to identify the ecological features of the forest dominated by *S. lumutensis* and the association of the tree community with soil factors. To achieve the main objectives, the ecological parameters, namely forest structure, species diversity, tree biomass, and soil characteristics, and their relationships between tree distribution and soil component at Segari Melintang Forest Reserve, Perak were determined. The Segari Melintang Forest Reserve has an area of approximately 4,566 ha and is classified as a coastal lowland dipterocarp forest. It is a unique forest because it is a combination of forests, beaches, and sea, and has been designated as a high conservation value forest (HCVF) by the Perak State Forestry Department. The effort to conserve this species should be followed by a broad understanding of the biodiversity around it (Mohd. Zaki et al., 2013).

MATERIALS AND METHODS

Study Site

Eight subplots of 50 × 25 m each were established at random in compartments 40 and 42 at Segari Melintang Forest Reserve, Perak located between altitude 100°33′30″T to 100°38′00″T and longitude 04°17′30″U to 04°26′00″U.

Experimental Design and Sampling

All trees with a diameter at breast height (DBH) of 5 cm and above were marked, measured, and identified based on the taxonomic textbook (Ashton, 1982; Corner, 1978; Ng, 1978, 1989; Symington, 1943; Whitmore, 1972, 1973). Three (3) soil cores at depths 0–20 cm were taken from each subplot, air-dried, and pooled before analysis. The soil's physical characteristics were determined accordingly, such as moisture content, organic matter (Avery & Bascomb, 1982), and particle size distribution (Abdulla, 1966). The soil's chemical characteristics such as pH (Avery & Bascomb, 1982; Metson, 1957), available macronutrient (phosphorus [P], potassium [K], and magnesium [Mg]) (Murphy & Riley, 1962), cation exchange capabilities [CEC] (McLean, 1965), and inorganic nitrogen (ammonium–N [NH_4–N] and nitrate–N [NO_3–N]) were determined using a spectrophotometer based on calorimetry principles.

Data Analysis

The basic community structure in the study plot was further explained by floristic composition, dominance, and abundance parameters calculated based on Brower et al. (1997). The total biomass estimation comprised aboveground (Kato et al., 1978) and belowground (Niiyama et al., 2010) biomass estimations. Species diversity and richness were determined by using the Shannon diversity index (Spellerberg & Fedor, 2003) and Margalef index (R′) (Brower et al., 1997), respectively. The relationships between tree communities and soil properties were analyzed using CANOCO program version 4.5 (Lepš & Šmilauer, 2003; ter Braak & Šmilauer, 1998) and the diagram was generated using CANODRAW 4.12. Before analysis, tree species in the data matrix having frequencies of one and two were omitted to improve the accuracy of the analysis, and soil data were $\log_{10}$ transformed. The significance of the degree of the relationship was assessed through the Monte Carlo permutation test based on 499 randomized tests at a significance of 0.05 (ter Braak, 1990).

RESULTS AND DISCUSSION

Floristic Composition and Species Diversity

In this study, 1,207 individuals were identified, which belong to 35 families of 70 genera and 117 species. The largest family and genus, represented by the greatest number of species, were the Euphorbiaceae (12 species) and *Syzygium* (10 species), respectively (Table 1). Table 2 shows *Gluta elegans*, *Canarium littorale*, *Dacryodes costata*, *Santiria rubiginosa*, *Shorea multiflora*, *Vatica maingayi*, and *Palaquium herveyi* were the species with the highest frequency at 100% and present in all eight subplots. *Shorea lumutensis* was only present in seven of the eight subplots. To determine the dominance of a family or species, the importance index (IVi) was calculated and the finding shows *Gluta elegans* (Anacardiaceae) (5.05%), *Drypetes kikir* (Euphorbiaceae) (4.24%), and *Shorea lumutensis* (Dipterocarpaceae) (4.04%) as the most dominant species in the study area. The total basal area of the 1,207 individuals was 32.63 m^2/ha with *S. lumutensis* (Dipterocarpaceae) as the largest-basal species of 2.9 m^2/ha. Two (2) individuals of *S. lumutensis* in the plots recorded the highest diameter of 90.1 cm and 80.2 cm, which contradicts Symington's (1943) finding where the diameter of this species rarely exceeds 50 cm. A similar finding was also reported in Sungai Pinang Forest Reserve and Lumut Forest Reserve, where the tree diameter recorded was over 100 cm (Lee et al., 2006). Shannon diversity index (H′) revealed a value of 3.92 and the maximum value of the Shannon index, H'_{max}, was 4.76. This indicates that the forest is highly diverse as the index value exceeds 3.5. Such a finding is commonly reported in tropical rainforests (Magurran, 1988). The well-known high species richness of the tropical rainforest is displayed in a rather small study area at the study site (Phillips et al., 1994). The Margalef richness index (R′) is used to assess species richness in a given area and, in this study, the R′ was 37.64. From biomass estimation, we can predict the productivity of the vegetation. In this study, the total biomass was 462.41 tonnes/ha, contributed by the aboveground biomass (AGB) of 397.36 tonnes/ha and belowground biomass (BGB) of 62.18 tonnes/ha. Dipterocarpaceae was the largest family, contributing 169.68 tonnes/ha (37.08%), followed by Sapotaceae and Anacardiaceae with 63.89 tonnes/ha (13.96%) and 41.07 tonnes/ha (8.88%), respectively. At the species level, *S. lumutensis* (Dipterocarpaceae) was the species with the highest biomass value of 51.99 tonnes/ha, followed by *Payena*

Table 1
Five leading families and genera based on the number of species in the Segari Melintang Forest Reserve, Perak

Family	No. Species	Genus	No. Species
Euphorbiaceae	12	*Syzygium*	10
Dipterocarpaceae	11	*Shorea*	5
Myrtaceae	11	*Diospyros*	5
Anacardiaceae	9	*Santiria*	4
Sapotaceae	8	*Gluta*	3

Table 2
Summary of abundance parameters of the five leading species in all subplot at Segari Melintang Forest Reserve, Perak

Species	No. Individual	BA (m^2/ha)	Frequency (%)	IV_i (%)
Gluta elegans	93	1.69	100	5.05
Drypetes kikir	94	0.96	88	4.24
Shorea lumutensis	15	2.90	88	4.04
Shorea multiflora	54	1.68	100	3.96
Canarium littorale	67	1.19	100	3.82

Table 3
Five leading families and genera based on the number of species in the Segari Melintang Forest Reserve, Perak

Family	Total Biomass (tonnes/ha)	Species	Total Biomass (tonnes/ha)
Dipterocarpaceae	169.68	*Shorea lumutensis*	51.99
Sapotaceae	63.89	*Payena lucida*	29.04
Anacardiaceae	41.07	*Shorea laevis*	24.30
Euphorbiaceae	31.43	*Shorea multiflora*	24.09
Burseraceae	28.11	*Shorea curtisii*	20.11

lucida (Sapotaceae) at 29.04 tonnes/ha and *Shorea laevis* (Dipterocarpaceae) at 24.30 tonnes/ha (Table 3). According to Zani et al. (2018), the estimation of biomass within three different forests, which are lowland dipterocarp forest, riparian forest, and hill dipterocarp forest, does not greatly differ with mean total tree biomass values of 415.11, 323.33, and 579.05 tonnes/ha, respectively.

Soil Properties

The soil texture at the study site was dominated by a sandy clay texture with high sand content, as summarized in Table 4. The soil was acidic with an average pH of 4.39 and low in organic matter content (1.03 ± 0.09%). This is a common feature of tropical soil, which is acidic due to a high amount of organic matter and cationic substances, which consist of H^+ and Al^{3+} (Neina, 2019; Othman & Shamshuddin, 1982). According to Longman and Jenik (1987) and Othman and Shamsuddin (1982), tropical soil has low organic matter because the rate of decomposition, temperature, and moisture is high in the tropics (Longman & Jenik, 1987; Othman & Shamsuddin, 1982). The mean values of available macronutrients such as phosphorus (P), magnesium (Mg), and potassium (K) were 2.92 ± 0.19, 7.60 ± 0.64, and 75.99 ± 7.93 µg/g, respectively. The contributors to these three macronutrients are from the decomposition of leaves, bark, and seedlings; animal bones and feces; and weathering process (Parzych & Trojanowski, 2006; Samuel & Werner, 1975). Available phosphorus (P) in the soil was the least as it easily dissolves and the bond with organic matter is weak (Khan et al., 2009). The P concentration is also closely related to pH, which decreases as the soil acidity increases (Barrow & Debnath, 2014; Penn & Camberto, 2019). The available K is categorized as high as it exceeded 10.63 µg/g (Landon, 1991). The available Mg content is also categorized as low and its content is inversely correlated with soil pH and organic matter, where low soil pH and organic matter decrease its content in the soil (Choudhury & Khanif,

Table 4
Summary of soil parameters in all subplots at Segari Melintang Forest Reserve, Perak

Soil parameter	Mean ± Standard error (s.e.)
pH	4.39 ± 0.04
Organic matter content (OM) (%)	1.03 ± 0.09
Available magnesium (Mg) (µg/g)	7.60 ± 0.64
Available phosphorus (P) (µg/g)	2.92 ± 0.19
Available potassium (K) (µg/g)	75.99 ± 7.93
Nitrate–N (NO_3–N) (µg/g)	2.91 ± 0.36
Ammonium–N (NH_4–N) (µg/g)	5.61 ± 0.15
Silt (%)	11.54 ± 1.75
Clay (%)	35.93 ± 1.77
Sand (%)	52.52 ± 2.16

2003; Nizam et al., 2006). Furthermore, the contents of ammonia–nitrogen (NH_4–N) and nitrate-nitrogen (NO_3–N) at the study site were 5.61 ± 0.15 and 2.91 ± 0.36 µg/g, respectively. This inorganic nitrogen was crucial for the production of chlorophyll and plant growth.

Relationship between Tree Communities and Soil Properties

Before analysis, the tree community data were tested using detrended correspondence analysis (DCA) to confirm that the data were unimodal and constrained linear ordination, with the length of the gradient of 1.696, which was greater than 4.0 SD (standard deviation). Hence, the use of Redundancy detrended analysis (RDA) is appropriate (ter Braak & Prentice, 1988; ter Braak & Šmilauer, 2002; Svenning et al., 2004). Based on the RDA, the correlation of species-environment is low at 1.000 with the first and second axis eigenvalues of 0.360 and 0.193 (Table 5). The results of the Monte Carlo permutation test also show no significant difference between the eigenvalues for the three ordinal axes (p = 1.000). This p-value explains that the distribution of tree species is independent and does not depend on soil characteristics.

The RDA diagram shows the relationship between the tree species and the soil properties, indicated by the direction and magnitude of the arrow that exits the center of the ordering (Figure 1) in which each number in the figure represents a different species as listed in Table 6. This analysis shows that although the study was only conducted in a single hectare area, a variation of soil conditions might have influenced the distribution and abundance of species between subplots. Species *Payena lucida* (63), *Gluta curtisii* (1), *Vatica cuspidata* (21), and *Stemonurus malaccensis* (44) show a close association with phosphorus (P) factor, while *Ixonanthes reticulata* (45) and *Botryophora geniculata* (30) with nitrate–N (NO_3–N) factor.

The species of interest, *S. lumutensis*, shows a close association with Ca^{2+} and Mg. *Kapur* trees (*Dryobalanops aromatica*) are highly associated with Mg and this is also supported by experiments in the glasshouse (Nik Norafida, 2018). The

Table 5
Summary of redundancy detrended analysis (RDA) on the vegetation and soil data in all subplots at Segari Melintang Forest Reserve, Perak

Axes	1	2	3	4	Total inertia
Eigenvalues	0.360	0.193	0.130	0.106	1.000
Species–environment correlations	1.000	1.000	1.000	1.000	
Cumulative percentage variance of species data	36.0	55.3	68.3	78.9	
Cumulative percentage variance of species-environment relation	36.0	55.3	68.3	78.9	
Sum of all eigenvalues					1.000
Sum of all canonical eigenvalues					1.000

species has also been found to be closely related to its distribution with *Drypetes kikir* (32), *Calophyllum canum* (38), *Canarium littorale* (9), and *Shorea laevis* (18). Most other species of Dipterocarpaceae such as *Dipterocarpus kerrii* (15), *Vatica cuspidata* (21), and *Dipterocarpus costatus* (14) show a close association with P. According to Sukri et al. (2012) stated that dipterocarp species in Borneo forests are closely associated with particular nutrients such as exchangeable and total calcium (Ca), magnesium (Mg) and potassium (K), total carbon (C), total nitrogen (N), total phosphorus (P). Overall, the distribution patterns of tree species in relation to the soil factors in this study illustrate that habitat variations influence the distribution of tree species communities in the study area. This statement is also supported by other studies conducted in various ecosystems (Nizam et al., 2012; Walthert & Meier, 2017).

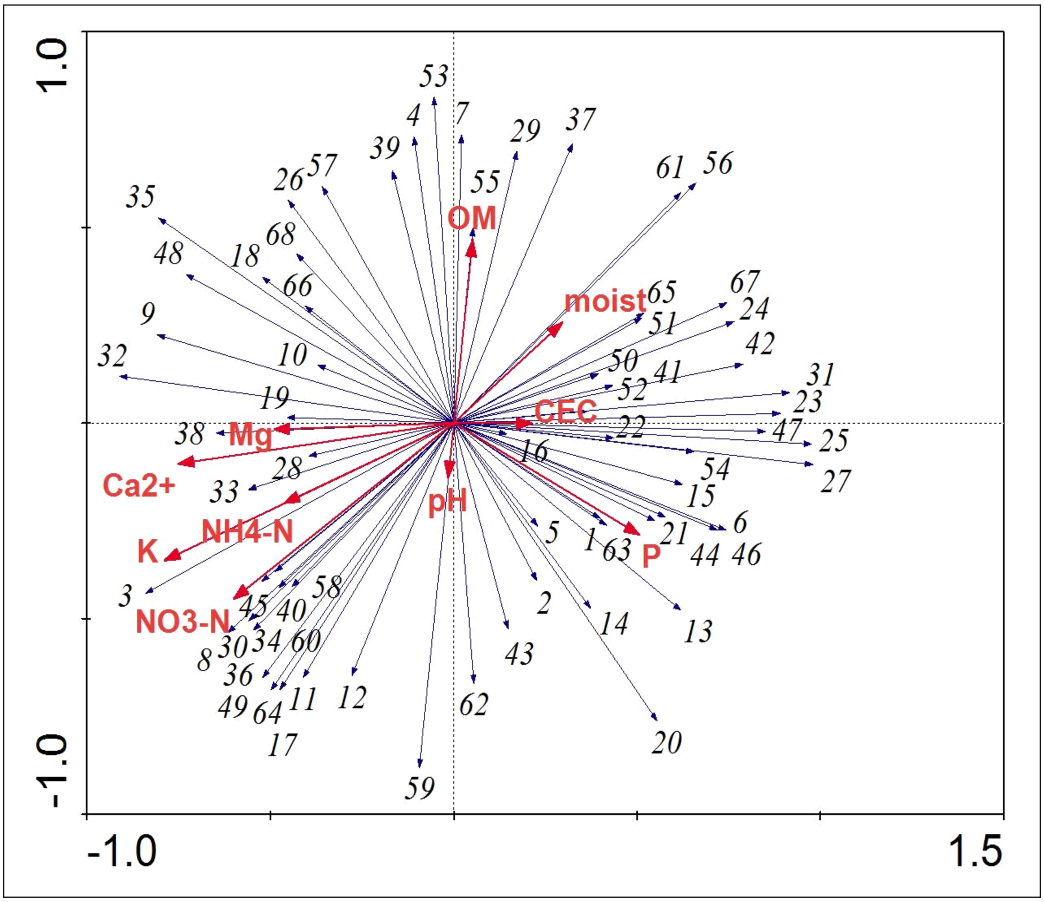

Figure 1. Redundancy detrended analysis (RDA) biplot of species and soil variables showing the species occurrence in relation to edaphic variables. The lengths and directions of vectors indicate the strengths and directions of gradients. *Note*. pH = soil pH; moist = soil moisture; Mg = available magnesium; P = available phosphorus; OM = organic matter content; CEC = total cation exchange capacity; K = available potassium; NH_4–N = ammonia–nitrogen; NO_3–N = nitrate–nitrogen. List of species as in Table 6.

Table 6
List of species number in ordination diagram of Figure 1

No.	Species	No.	Species
1	*Gluta curtisii*	35	*Mallotus lackeyi*
2	*Gluta elegans*	36	*Castanopsis* sp
3	*Gluta wallichii*	37	*Lithocarpus elegans*
4	*Mangifera quadrifida*	38	*Calophyllum canum*
5	*Melanochyla angustifolia*	39	*Calophyllum* sp.1
6	*Parishia insignis*	40	*Garcinia parvifolia*
7	*Swintonia floribunda*	41	*Garcinia urophylla*
8	*Mezzettia parviflora*	42	*Mesua kunstleri*
9	*Canarium littorale*	43	*Mesua racemosa*
10	*Dacryodes costata*	44	*Stemonurus malaccensis*
11	*Santiria apiculata*	45	*Ixonanthes reticulata*
12	*Santiria rubiginosa*	46	*Cinnamomum sintoc*
13	*Crypteronia griffithii*	47	*Barringtonia macrostachya*
14	*Dipterocarpus costatus*	48	*Lijndenia laurina*
15	*Dipterocarpus kerrii*	49	*Memecylon campanulatum*
16	*Shorea balanocarpoides*	50	*Artocarpus lanceifolius*
17	*Shorea curtisii*	51	*Horsfieldia brachiata*
18	*Shorea laevis*	52	*Knema communis*
19	*Shorea lumutensis*	53	*Syzygium* sp.1
20	*Shorea multiflora*	54	*Brackenridgea hookeri*
21	*Vatica cuspidata*	55	*Xanthophyllum monticolum*
22	*Vatica maingayi*	56	*Diplospora malaccensis*
23	*Diospyros buxifolia*	57	*Porterandia anisophyllea*
24	*Diospyros maingayi*	58	*Xerospermum laevigatum*
25	*Elaeocarpus floribundus*	59	*Madhuca laurifolia*
26	*Elaeocarpus pedunculatus*	60	*Madhuca* sp.1
27	*Agrostistachys gaudichaudii*	61	*Madhuca* sp.2
28	*Baccaurea maingayi*	62	*Palaquium herveyi*
29	*Baccaurea minor*	63	*Payena lucida*
30	*Botryophora geniculata*	64	*Payena* sp.1
31	*Cleistanthus lanuginosus*	65	*Eurycoma longifolia*
32	*Drypetes kikir*	66	*Gordonia multinervis*
33	*Drypetes pendula*	67	*Pentace curtisii*
34	*Endospermum diadenum*	68	*Gironniera parvifolia*

CONCLUSION

The flora composition and soil nutrient data obtained can serve as supporting evidence for conservation purposes, specifically for *S. lumutensis* and its habitat in general. Further study in greenhouses should be conducted to increase the information accuracy relating to plant-soil relationships.

ACKNOWLEDGMENT

This study was supported by the UKM Research Grant [GIP2018006].

REFERENCES

Abdulla, H. H. (1966). *A study of the development of podzol profiles in Dovey forest* (Unpublished Doctoral thesis), University of Wales, United Kingdom.

Ashton, P. S. (1976). Mixed dipterocarp forest and its variation with habitat in the Malayan lowlands: A re-evaluation at Pasoh. *Malayan Forester*, *39*, 56-72.

Ashton, P. S. (1982). Dipterocarpaceae. In C. G. G. J. van Steenis (Ed.), *Flora Malesiana I* (Vol. 9, No. 2, pp. 237-552). Leiden, Netherlands: Martinus Nijhoff Publishers.

Avery B. W., & Bascomb C. L. (1982). *Soil survey laboratory methods*: *Technical monograph No. 6*. Harpenden, United Kingdom: Soil Survey of Great Britain.

Barrow, N. J., & Debnath, A. (2014). Effect of phosphate status on the sorption and desorption properties of some soils of northern India. *Plant and Soil*, *378*(1-2), 383–395.

Boshier, D. (2011). Shorea lumutensis*: Genetic variation and conservation*. Retrieved January 22, 2020, from http://forest-genetic-resources-training-guide.bioversityinternational.org/module-1-species-conservation-strategies/case-study-13-shorea-lumutensis/

Brower, J. E., Zar, J. H., & von Ende, C. N. (1997). *Field and laboratory methods for general ecology* (4th ed.). Boston, USA: McGraw-Hill.

Choudhury, A. T. M. A., & Khanif, Y. M. (2003). Magnesium adsorption behavior of three Malaysian rice soils. *Pakistan Journal of Biological Sciences*, *6*(15), 1376-1379.

Chua, L. S. L., Suhaida, M., Hamidah, M., & Saw, L. G. (2010). *Malaysia plant red list: Peninsular Malaysian Dipterocarpaceae*. Kepong, Malaysia: Forest Research Institute Malaysia.

Corner, E. J. H. (1978). *The freshwater swamp: Forest of south Johore and Singapore*. Singapore: Botanic Gardens Parks and Recreation Department.

Dudash, M. R., & Carr, D. E. (1998). Genetics underlying inbreeding depression in *Mimulus* with contrasting mating systems. *Nature*, *393*(6686), 682-684.

Evans, J. (1995). *Hutan perladangan di kawasan tropika* [Plantation forests in the tropics]. Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka.

Ghollasimood, S., Hanum, I. F., Nazre, M., Kamziah, A. K., & Awang Noor, A. G. (2011). Vascular plant composition and diversity of a coastal hill forest in Perak, Malaysia. *Pertanika Journal of Agricultural Science*, *3*(3), 111-126.

International Union for Conservation of Nature. (2012). *IUCN red list of threatened species*. Retrieved July 22, 2012, from http://www.redlist.org

Kato, R., Tadaki, Y., & Ogawa, H. (1978). Plant biomass and growth increment studies in Pasoh forest. *Malayan Nature Journal*, *30*, 211-224.

Keller, L. F., & Waller, D. M. (2002). Inbreeding effects in wild populations. *Trends in Ecology and Evolution*, *17*(5), 230-241.

Khan, A. A., Jilani, G., Akhtar, M. S., Naqvi, S. M. S., & Rasheed, M. (2009). Phosphorus solubilising bacteria: Occurrence, mechanism and their role in crop production. *Journal of Agricultural Biological Science*, *1*(1), 48-58.

Landon, J. R. (1991). *Booker tropical soil manual: A handbook for soil survey and agricultural land evaluation in the tropics and subtropics*. Harlow, England: Longman Scientific and Technical.

Lee, S. L., Ng, K. K., Saw, L. G., Lee, C. T., Norwati, M., Tani, N., … Koskela, J. (2006). Linking the gaps between conservation research and conservation management of rare dipterocarps: A case study on *Shorea lumutensis*. *Biological Conservation*, *131*(1), 72-92.

Lepš, J., & Šmilauer, P. (2003). *Multivariate analysis of ecological data using CANOCO*. Cambridge, United Kingdom: Cambridge University Press.

Longman, K. A., & Jenik, J. (1987). *Tropical forest and its environment* (2nd ed.). Harlow, England: Longman Scientific Technical.

Magurran, A. E. (1988). *Ecology diversity and its measurement*. London, United Kingdom: Chapman and Hall.

McLean, E. O. (1965). Aluminium. In C. A. Black (Ed.), *Methods of soil analysis: Part 2* (pp. 978-998). Madison, USA: American Society of Agronomy.

Metson, A. J. (1957). Methods of chemical analysis for soil survey samples. *Soil Science*, *83*(3), 245.

Mohd. Zaki, H., Nazre, M., Ismail Adnan, A. M., Mohamad Azani, A., Latifah, Z. A., Siti Eryani, S., & Priyono, S. (2013). Species diversity, dominance and management of *Shorea lumutensis* - Stand at Pangkor Island, Perak, Malaysia. *Pertanika Journal of Tropical Agricultural Science*, *36*(S), 19-30.

Murphy, J., & Riley, J. P. (1962). A modified single solution method for the determination of phosphate in natural waters. *Analytica Chemica Acta*, *27*, 31-36.

Neina, D. (2019). *The role of soil pH in plant nutrition and soil remediation*. Retrieved January 22, 2020, from http://ugspace.ug.edu.gh/bitstream/handle/123456789/34201/5794869.pdf?sequence=1&isAllowed=y

Ng, F. S. P. (1978). *Tree flora of Malaya* (Vol. 3). Kuala Lumpur, Malaysia: Longman.

Ng, F. S. P. (1989). *Tree flora of Malaya* (Vol. 4). Kuala Lumpur, Malaysia: Longman.

Niiyama, K., Kajimoto, T., Matsuura, Y., Yamashita, T., Matsuo, N., Yashiro, Y., … Noor, N. S. (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*(3), 271-284.

Nik Norafida, N. A. (2018). *Ecological characteristics of tree communities and its relationships with soil factors in kapur dominated forests of Peninsular Malaysia* (Unpublished Doctoral thesis), Universiti Kebangsaan Malaysia, Malaysia.

Nik Norafida, N. A., Nizam, M. S., Wan Juliana, W. A., & Faezah, P. (2018). Edaphic relationships among tree species in the kapur (*Dryobalanops aromatica* Gaertn. f.) forests of Peninsular Malaysia. *Advances in Environmental Biology*, *12*(2), 11-16.

Nizam, M. S., Norziana, J., Sahibin, A. R., & Latiff, A. (2006). Edaphic relationship among tree species in the National Park at Merapoh, Pahang, Malaysia. *Jurnal Biosains*, *17*(2), 37-53.

Nizam, M. S., Rohani, S., & Wan Juliana, W. A. (2012). Floristic variation of tree communities in two distinct habitats within a forest park in Pahang, Peninsular Malaysia. *Sains Malaysiana*, *41*(1), 1-10.

Nizam, M. S., Ismail, P., Latiff, A., Shamsudin, I., & Faridah-Hanum, I. (2009). Diversity of tree communities and its relationships with soil properties in a peat swamp forest in Pahang, Peninsular Malaysia. *Ecology Environment and Conservation*, *15*(2), 3017-318.

Othman, Y., & Shamshuddin, J. (1982). *Sains tanih* [Soil science]. Kuala Lumpur, Malaysia: Dewan Bahasa dan Pustaka.

Parzych, A., & Trojanowski, J. (2006). *Precipitation and duff fall as natural sources of nitrogen and phosphorus for forest soils in the Slowiński National Park*. Retrieved January 22, 2020, from https://pdfs.semanticscholar.org/a0da/16ebf71cdd4c75f84c4a5f35da47508f7457.pdf

Penn, C. J., & Camberto, J. J. (2019). A critical review on soil chemical processes that control how soil pH affects phosphorus availability to plants. *Agriculture*, *9*(6), 120–138.

Phillips, O. L., Hall, P., Gentry, A. H., Sawyer, S. A., & Vasquez, R. (1994). Dynamics and species richness of tropical rainforests. *Proceedings of the National Academy of Sciences of the USA*, *91*(7), 2805-2809.

Plotkin, J. B., Potts, M., Leslie, N., Manokaran, N., LaFrankie, J., & Ashton, P. S. (2000). Species-area curves, spatial aggregation, and habitat specialization in tropical forests. *Journal of Theoretical Biology*, *207*(1), 81-99.

Rivers, M. C., & Barstow, M. (2019). *The IUCN red list of threatened species 2019:* Shorea lumutensis. Retrieved January 22, 2020, from https://www.iucnredlist.org/search?query=Shorea%20lumutensis&searchType=species

Samuel, L. T., & Werner, L. N. (1975). *Soil fertility and fertilizers*. New York, NY: Macmillan Publishing Co. Inc.

Smith, J. W., & Kochummen, K. M. (1979). *Pocket check list of timber trees*. (3rd ed., No. 17). Kepong, Malaysia: Forest Research Institute.

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.

Sukri, R. S., Wahab, R., Salim, K. A., & Burslem, D. F. R. P. (2012). Habitat associations and community structure of dipterocarps in response to environment and soil conditions in Brunei Darussalam, Northwest Borneo. *Biotropica*, *44*(5), 595-605.

Svenning, J. C., Kinner, D. A., Stallard, R. F., Engelbrecht, B. M. J. & Wright, S. J. (2004). Ecological determinism in plant community structure across a tropical forest landscape. *Ecology*, *85*(9), 2526–2538.

Symington, C. F. (1943). *Malayan forest records No. 16: Forester's manual of dipterocarps*. Kepong, Malaysia: Forest Research Institute.

Symington, C. F. (1974). *Malayan forest records No. 16: Forester's manual of dipterocarps* (2nd ed.). Kuala Lumpur, Malaysia: Penerbit Universiti Malaya.

ter Braak, C. J. F. (1990). *Update notes: CANOCO reference manual and user's guide to Canoco for Window: Software for canonical community ordination* (version 4). Ithaca, USA: Microcomputer Power.

ter Braak, C. J. F., & Prentice, I. C. (1988). A theory of gradient analysis. In *Advances in ecological research* (Vol. 18, pp. 271-317). Cambridge, USA: Academic Press.

ter Braak, C. J. F., & Šmilauer, P. (1998). *CANOCO reference manual and user's guide to Canoco for Windows: Software for canonical community ordination* (version 4). Ithaca, USA: Microcomputer Power.

ter Braak, C. J. F., & Šmilauer, P. (2002). *CANOCO reference manual and CanoDraw for Windows user's guide: Software for canonical community ordination* (version 4.5). Ithaca, USA: Microcomputer Power.

Tompsett, P. B. (1992). A review of the literature on storage of dipterocarp seeds. *Seed Science and Technology*, *20*(2), 251-267.

Turner, I. M. (1995). *A catalogue of the vascular plants of Malaya* (Vol. 1). Singapore: National Parks Board.

Walthert, L., & Meier, E. S. (2017). Tree species distribution in temperate forests is more influenced by soil than by climate. *Ecology and Evolution*, *7*(22), 9473-9484.

Whitmore, T. C. (1972). *Tree flora of Malaya: A manual for foresters* (Vol. 1). Kuala Lumpur, Malaysia: Longman.

Whitmore, T. C. (1973). Frequency and habitat of tree species in the rain forest of Ulu Kelantan. *Gardens Bulletin of Singapore*, *26*(2), 195-210.

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* [Adobe Digital Editions version]. doi: 10.5772/intechopen.69940