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EDAPHIC INFLUENCES ON TREE SPECIES COMPOSITION AND COMMUNITY STRUCTURE IN A SECONDARY-LOWLAND DIPTEROCARP FOREST OF KOTA DAMANSARA FOREST RESERVE, SELANGOR

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ABSTRACT

This research was conducted to determine tree species composition and its relationship with edaphic factors at Kota Damansara Forest Reserve (KDFR), Selangor. Ten study plots of 25 m × 20 m each were established randomly covering a total area of 0.5 ha. In each plot, all trees with diameters at breast height (DBH) of 5 cm and above were tagged and measured whilst topsoil samples at 10 cm depths were taken for their physical and chemical properties. A total of 205 trees from 46 species and 22 families were recorded in KDFR. As for species diversity, the forest showed a Shannon-Weiner Diversity Index (H') of 3.43 and an evenness value of 0.89 which portrays the uniformity of tree species distribution in the study site. The soil analysis in this study demonstrated that KDFR was dominated by sandy clay texture with organic matter content ranging from 3.94% to 14.24% and acidic soil pH of 3.86. Redundancy analysis indicated that *Cinnamomum iners, Cratoxylum arborescens, Myristica cinnamomea,* and *Syzygium grandis* were closely related to soil chemical properties such as nutrients of Ca, P, K. Data and information from this study are crucial as a guideline for future ecological research in tropical forest areas.

Key words: Community structure, diameter breast height, dipterocarp forest, ecology, edaphic factors

INTRODUCTION

Kota Damansara Forest Reserve (KDFR) is a remnant logged-over secondary forest of the non-operational Sungai Buloh Forest Reserve, Selangor. From the 1960s to the 1990s, the forest reserve was degazetted a few times and subsequent development reduced the size of the reserve from 6,590 ha to 321.7 ha (Shaharuddin *et al*., 2002). KDFR has been under serious pressure from the government for land conversion into housing estates (Vaz & Lim, 2012). These anthropogenic activities have resulted in declining forest cover and affected the ecological functions of the forest. The forests in Malaysia have high species diversity with an estimated 15,000 plant species, and trees contribute largely to the vegetation communities (Ng *et al*., 1990; Saw, 2010). For instance, a total of 3084 trees (≥ 5 cm DBH) from 204 genera, 419 species, and 65 families were enumerated in an upper hill dipterocarp forest at Temengor Forest Reserve, Perak (Ahmad Fitri *et al*., 2017) meanwhile in Sungai Udang Forest Reserve, Malacca there were 1668 individual trees (≥ 5 cm DBH) consisted of 85 species belonging to 79 genera and 38 families (Sarah *et al*., 2020). Dipterocarp trees dominate both forest habitats and can comprise up to 50% of the total trees in the storey (Saw, 2010). Other than dipterocarps, common large trees that can be found in lowland forests are *Dyera costulata* (Apocynaceae), *Gluta* spp. (Anacardiaceae), *Heritiera* spp. (Malvaceae), *Intsia palembanica* (Leguminosae), *Koompassia malaccensis* (Leguminosae), *Palaquium* spp. (Sapotaceae) and *Sindora* spp. (Leguminosae).

Forest reserves in Selangor cover an area of 250,210 ha which is about 31.5% of the total land areas in Selangor (FDPM, 2017). National Forestry Act (1984) has established Permanent Reserved Forest and classified them into two functional categories namely Production Forest and Protection Forest. Kota Damansara Forest Reserve was gazetted as protection permanent reserved forests whereby they were managed based on Sustainable Forest Management (SFM) principles and practices. This practice is in line with the proposed Sustainable Development Goals by United Nations in 2015, particularly SDG

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15 "Life on Land". SDG 15 was established based on its mission statement of "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification and reverse land degradation and halt biodiversity loss".

The variations of floristic composition have been correlated with habitat variables and this correlation has created certain trends in the distribution and abundance of organisms. The abundance of tree species is primarily due to their favorable environmental condition where the same dominant species would be found under similar environmental conditions while different dominants are likely to be present at sites with varying environmental conditions (Asanok & Marod, 2016). Climate and edaphic factors are among the important environmental factors and drivers for the distribution of tree species (Walthert & Meier, 2017). Edaphic factors refer to the abiotic factors concerning the physical and chemical properties of soil. These factors include soil texture, soil pH, organic matter content, cation exchange capacity, and nutrient availability. It is, therefore, necessary to fully understand the tree species composition and distribution pattern in response to edaphic aspects to carry out a comprehensive management and conservation action plan to ensure the forest's sustainability for future generations. Thus, this study aimed to determine the associations between tree species composition and edaphic factors especially the physical and chemical properties of soil in a secondary-lowland dipterocarp forest in Kota Damansara Forest Reserve Selangor.

MATERIALS AND METHODS

Methodology

Study plots and tree sampling

KDFR is a secondary lowland dipterocarp forest located in the Petaling district of Selangor, Malaysia (Figure 1). It was part of a non-operational Sungai Buloh FR covering 3,900 acres of protected primary forest. This forest is surrounded by Kota Damansara residential areas and bordered by the New Klang Valley Expressway (NKVE). In February 2010, the state government and Selangor Forestry Department declared the remaining 320 ha of forest area as Kota Damansara Community Forest Reserve for education, recreation, and research in biodiversity conservation, public amenity, and eco-tourism activities (Shaffie, 2002).

The fieldwork was conducted for five days from 22 February 2019 to 26 February 2019. Ten sampling plots of 25 m × 20 m each were randomly established, making a total area of 0.5 hectares. At plot establishment, all trees above the diameter at breast height (DBH) of 5 cm were measured at 1.3 m above ground level (Husch *et al*., 2003; Luoma *et al*., 2017). All specimens were collected for the preparation of voucher specimens for further species identification. Then, the preservation of specimens in 70% alcohol was done to avoid any possible damage to the morphological characteristics of the specimens. In the laboratory, the specimens were transferred to dry newspapers for the pressing methods as referred to by Bridson and Forman (1992). The identification of specimens was conducted with the assistance of experienced plant taxonomists from the Silviculture Department of Selangor Forestry accordingly to the keys described in Tree Flora of Malaya (Ng *et al*., 1990; Whitmore, 1998).

Soil sampling and analysis

At each sampling plot, three top-soil samples at a depth of 10 cm were taken randomly using an auger. Root fragments, leaves, and small stones from the soil were removed and sieved through a 2 mm mesh sieve. The soil samples were further analyzed for their physical and chemical properties. The textural composition of the soil samples was determined using the pipette method together with dry sieving (Medugu *et al*., 2017). Then the ratio of sand, silt, and clay content in a soil sample was used to determine the texture by referring to the USDA soil textural classification. Organic matter was determined by the loss-on-ignition technique, soil ignition in a furnace for 16 hr at 400 °C (Avery & Bascomb, 1982; Salehi *et al*., 2011). Soil pH was measured using a pH meter with a soil-to-water ratio of 1.0:2.5 (Metson, 1956; Kabała et al., 2016). Soils were extracted with 1 M potassium chloride (KCl) for exchangeable acid cations, which later be determined by titration. As for exchangeable basic cations, the soil samples were extracted using 1 M ammonium acetate and determined by Inductively Couple Plasma-Mass Spectrometry (ICP-MS) (Mclean, 1965). Then, the summation of acidic and basic cations of soil samples yields the cation exchange capacity of the soil. Whilst for determining the nutrient availability in the soil (i.e magnesium, phosphorus, & potassium), soil samples were extracted with 1 M ammonium acetate-acetic acid. The extract was run under ICP-MS for the determination of available magnesium and available potassium, whilst available phosphorus was determined using an ultraviolet (UV) spectrophotometer. The phosphorus concentration of the sample solution was obtained according to the standard curve that plotted the absorbance readings versus the phosphorus concentration. Meanwhile, total nitrogen content in soil was performed using the Kjedahl method which includes processes of digestion, distillation, and titration (Benton & Warner, 2008).

Data analysis

Data of all tree communities were tabulated and summarized to describe the floristic composition

Fig. 1. Google map of Kota Damansara Forest Reserve in Petaling Jaya, Selangor.

of Kota Damansara Forest Reserve, Selangor. Ecological indices of the Shannon-Weiner Diversity Index (Spellerberg & Fedor, 2003), Evenness Index (Pielou, 1966), and Margalef's Richness Index (Magurran, 1988) were used to compute the species diversity and species richness of the study area using Paleontological Statistic Software Package for Education and Data Analysis (PAST) Software version 2.17c (Hammer *et al*., 2001). Total tree biomass was estimated by summing up above-ground biomass (AGB) (Kato *et al*., 1978) and below-ground biomass (BGB) (Niiyama *et al*., 2010), respectively. As for determining the soil-vegetation relationships, ordination methods were conducted in the software CANOCO version 5.0. Preliminary analysis of detrended correspondence analysis (DCA) indicated the appropriateness of redundancy analysis (RDA) to be used in this study (Ter Braak & Smilauer, 2015).

RESULTS AND DISCUSSION

Taxonomic composition

A total of 205 trees were enumerated in 10 plots of Kota Damansara Forest Reserve, Selangor. Identification of all trees recorded 46 tree species from 35 genera and 22 families (Table 1). Euphorbiaceae and Olacaceae recorded the highest number of individuals with 27 individuals. Dipterocarpaceae was the most speciose family with nine species recorded in the forest whilst the best-represented genera were *Shorea* trees. This is in line with the fact that dipterocarp trees dominated most forests in Malaysia and hence it was referred for the classification of forest types based on their elevation such as lowland dipterocarp forest and hill dipterocarp forest (Manokaran & Kochummen, 1987). In addition to this, Saw and Sam (2000) reported dipterocarp trees dominated over 50% of the total trees in the forest stands and provide the habitat structure for other life forms in the complex rainforests.

A similar observation was also reported by Norashikin and Sarah Aziz (2015) where Dipterocarpaceae dominated three study sites namely Bukit Bakar, Gunung Basor, and Gunung Stong Tengah in Kelantan which included 31 species and seven genera altogether. Nik Norafida *et al*. (2013) recorded the domination of dipterocarp tree in all study areas; *Dryobalanops aromatica* at Lesong Forest Reserve, Pahang with 266 individuals, Bukit Bauk Forest Reserve, Terengganu with 216 individuals of D. *aromatica* and Gunung Belumut Forest Reserve, Johor with 110 individuals of *D. aromatica.* Other than being the dominant family, Dipterocarpaceae is also economically important because most of the valuable timbers were from this family (Whitmore, 1984).

In comparison with other studies in Malaysia forests where Norashikin and Sarah Aziz (2015) reported a taxonomic composition of 147 trees from 50 species, 44 genera, and 25 families in Bukit Bakar Forest Reserve, Kelantan while Gunung Basor Forest Reserve, Kelantan enumerated 202 trees comprised of 94 species, 65 genera, and 29 families. Further, Natasha *et al*. (2020) reported a total of 562 trees from 82 species, 47 genera, and 26 families in Sungai Lalang Forest Reserve, Selangor. It is noted that the tree species composition varies from site to site but primarily due to the variation in biogeography, habitat, and disturbances (Mohd Nazip, 2012). Thus, these factors contributed to the heterogeneity of the forest ecosystems with different tree species recorded in the study areas.

Species diversity

KDFR has a high Shannon-Weiner Diversity index of H'= 3.43 and a high Pielou's Evenness value of J'= 0.89. Generally, the value of the Shannon-Weiner Diversity Index is usually found to be between 1.5 to 3.5, and rarely surpasses 4.5 (Gaines *et al*., 1999). Besides, Pielou's Evenness Index (J') was used to obtain the evenness index where the J' is constrained between 0 and 1, representing a situation in which all species are equally distributed. Both indices indicate that KDFR is a tropical forest with high species diversity and needs to be conserved for future generations. However, the value is considered lower than in other tropical forests such as in Gunung Basor Forest Reserve with H' = 4.46 (Norashikin & Sarah Aziz, 2015) and Bukit Panchor State Park with H' = 4.69 (Norazlinda *et al*., 2016). It can be related to anthropogenic activities that occurred in the present study which affected its species diversity.

KDFR recorded low richness with a Margalef Index of 8.45. According to Magurran (1988), this index depends on the sample sizes such as the number of trees and species of the study area. For instance, high species richness of Margalef Index (D_{MG} = 23.91) was recorded at Bukit Panchor State Park (Norazlinda *et al*., 2016) as compared to Gunung Basor Forest Reserve (Norashikin & Sarah Aziz, 2015) with 17.52. This is possible because Bukit Panchor State Park had a higher number of individuals with 488 trees belonging to 149 species whilst Gunung Basor Forest Reserve had only 202 trees and 94 species. This can also clearly be seen by the lower value of the Margalef Index obtained for the present study with 8.45 which was represented by 205 trees consisting of 46 tree species. Further, KDFR also recorded a lower tree density of 410 trees per hectare as compared to Bukit Panchor State Park (976 trees/ha).

Biomass estimation

Tree biomass is the dry weight of plant material, which is a product of photosynthesis reflecting the carbon sequestration by the tree. It is often considered a parameter in the determination of forest productivity and is typically expressed in tonne per hectare or t/ha (Lajuni & Latiff, 2013; Zani *et al*., 2018). The total biomass of trees in KDFR was estimated at 531.8 t/ha, contributed by 458.68 t/ha of above-ground biomass (AGB) and 73.12 t/ha of below-ground biomass (BGB). Family-wise, Dipterocarpaceae represented the highest with 97.39 t/ha or 18.31% of total biomass in the study area. Euphorbiaceae and Olacaceae were the next leading families of total biomass with 80.51 t/ha (15.14%) and 62.34 t/ha (11.72%), respectively. According to Corlett and Primack (2011), Dipterocarpaceae dominates many of the large trees thus contributing the most to total biomass in tropical forests. For instance, Bukit Panchor Recreational Forest, Pulau Pinang recorded that more than half, or 57.26% of the total biomass was represented by the Dipterocarpaceae (Norazlinda *et al*., 2016). In addition, Nik Norafida *et al*., (2013) also noted Dipterocarpaceae family recorded the highest biomass at all plots in Bukit Bauk Forest Reserve Terengganu, Lesong Forest Reserve, Pahang, and Gunung Belumut Recreational Forest, Johor with values of 439.11 t/ha, 443.39 t/ha and 384.44 t/ha, each respectively.

At the species level, *Ochanostachys amentacea* (Olacaceae) indicated the highest tree biomass in KDFR of 56.55 t/ha or 10.63% of the total biomass. This was followed by *Endospermum diadenum* (Euphorbiaceae) and *Intsia palembanica* (Fabaceae) with 45.64 t/ha (8.58%) and 39.95 t/ha (7.51%) of total tree biomass, respectively. Although *I. palembanica* had only 3 individuals in the study area, this species recorded the third highest biomass due to the large size of trees. As a comparison, previous studies showed trees with large diameter classes achieved higher biomass in the study area. For instance, in Bukit Panchor Recreational Forest, Pulau Pinang where the leading total biomass was *Shorea leprosula* with the biggest DBH of 101 cm in the study plots (Norazlinda *et al*., 2016). In addition, Zani *et al*. (2018) reported a similar result of higher biomass value in Pahang National Parks, represented by trees with a diameter class >70 cm.

Soil physical and chemical properties

The soil textural composition in KDFR plots was predominated by sandy clay in six plots (60%), followed by sandy clay loam (three plots; 30%) and clay (one plot; 10%). Amlin *et al*. (2014) reported that soil with high sand content is cohesive and has a high risk for top-soil erosion and thus decreasing overall nutrients in the forest soil. In the present study, these sandy soils also have moderate clay content making the soil to be less resistance to erosion as compared to soil with low clay content. Understanding the forest soil and its relationship with the distribution of plant communities is of great importance to conserve and manage forest ecosystems. The soil–vegetation relationship in a logged-over secondary forest is important from the conservation biology point of view because it defines habitat preference, and plant structure and diversity supported on each soil type and habitat formations; i.e. richest habitats in both plant and soil nutrients could sustain greater animal diversity and be preferable to conservation, whereas poorest habitats in both plant and soil nutrient could

Table 1. Total numbers of genera, species, and individuals for all tree families in 0.5 ha at Kota Damansara Forest Reserve, Selangor

No.	Family	Genera	Species	No. of Ind.
1	Anacardiaceae	1	1	1
2	Annonaceae	1	1	1
3	Apocynaceae	1	1	6
4	Dilleniaceae	1	1	1
5	Dipterocarpaceae	2	9	23
6	Euphorbiaceae	4	4	27
7	Fagaceae	1	1	1
8	Guttiferae	2	2	3
9	Lauraceae	1	2	5
10	Leguminosae	4	4	8
11	Meliaceae	1	1	4
12	Moraceae	2	3	24
13	Myristicaceae	2	2	21
14	Myrtaceae	1	2	20
15	Olacaceae	2	2	27
16	Polygalaceae	1	1	7
17	Rhizophoraceae	1	1	5
18	Rubiaceae	1	1	1
19	Sapotaceae	1	1	1
20	Sterculiaceae	2	3	14
21	Thymelaeceae	2	2	3
22	Ulmaceae	1	1	2
	Total	35	46	205

be preferable for cases of restoration.

The percentage of organic matter in KDFR ranged from 3.94% to 14.24% with a mean of 7.35 ± 0.87%. This mean value was in the moderate range of 4% to 10% as suggested by Landon (1991). It was noted that various factors influence the organic matter content in soil including soil texture, soil organisms, and vegetation (Nath, 2014). For instance, in the study area, the highest organic matter content was observed in plot 10 with 14.24% and the lowest value in plot 4 with 3.94% and this might be attributed to their type of soil texture. Soils in plot 10 have a high percentage of clay, exhibiting higher organic matter because of the strong bonds of the surface of clay particles and organic matter that can slow the decomposition process. In comparison to other forest reserves, low organic matter content with the range of 3.55% to 5.71% was recorded at Bukit Lagong Forest Reserve (Zawani *et al*., 2020), 4.69 ± 0.25% at Kluang Forest Reserve, Johor, and 4.70 ± 0.45% at Lesong Forest Reserve, Pahang (Nik Norafida *et al*., 2018). Low organic matter content in the soil of tropical rainforests is related to the lower percentage of silt and clay in the soil; because the absence of silt and clay generally increases decomposition rates and decreases OM for a particular set of environment interactions (Raghad *et al*., 2015). The rate of decomposition is determined by three major factors of soil organisms, the physical environment (high rainfall & humidity) and the quality of the organic matter. Hence, the rapid rate of decomposition in the tropics was influenced by the humid tropical climate with high rainfall and temperature thus reducing the amount of organic matter.

The summary of soil parameters in the study plots of Kota Damansara Forest Reserve, Selangor is presented in Table 2. Soil pH showed a low mean value of 3.86 ± 0.02, indicating that the forest soils were predominantly acidic. This result agrees with the statement by Nik Norafida *et al*. (2018) that most tropical rainforest soils have acidic pH values in the range of 3.5 to 5.5. Tropical regions have soil weathering and high amounts of rainfall which contribute to the leaching process of base cations (Na^+, K^+, Ca^{2+} & Mg^{2+}) and replaced by acid cations (Al^{3+} & H^+ ions) thereby increasing the concentrations of H^+ in soil (Zawani *et al*., 2020). Furthermore, most bacteria and actinomycetes function well at intermediate to high pH values (Nik Norafida *et al*., 2018), where they increase the rate of decomposition of organic material hence causing the soil to be acidic. Metabolic activities of soil microorganisms as they release carbon dioxide (product of the respiration process) would then react with soil moisture and produce weak acid that can contribute to the high accumulation of H^+ ions in the soil (Natasha *et al*., 2020).

Cation exchange capacity (CEC) is a measure of the soil's capability to hold positively charged ions. The main ions associated with CEC in soils are the exchangeable calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium (Na^+), and potassium (K^+) which are generally referred to as base cations and acid cations of aluminum (Al^{3+}) and hydrogen (H^+). CEC in KDFR was 4.17 ± 0.30 meq/100g, which is considered low by Landon (1991). The low content of organic matter and clay minerals in the study area conduces to the low CEC values because of weak electrostatic forces that can adsorb and hold cations (Tomasic *et al*., 2013) (Ohta *et al*., 1993). A previous study reported low CEC values in Kapur-dominated forests where 7.25 meq/100 g was recorded for Bukit Bauk Forest Reserve, whilst 5.29 meq/100 g and 5.92 meq/100 g were recorded in Lesong Forest Reserve, Pahang, and Kluang Forest Reserve, Johor, respectively (Nik Norafida *et al*., 2018). Cation exchange capacity also indicated the potential of soils to hold plant nutrients mostly in cation forms and make them readily available for plants to absorb. However, low CEC values in soil cause limited capability of nutrients supply to the plants. This is possibly due to the leaching process where the base cations are reduced, and acid cations replace the exchangeable cation sites in soils (Finlay *et al*., 2020).

The nutrition of the plants depends on the availability and uptake of macro and micronutrients contained in the soil. Essential elements such as nitrogen (N), phosphorus (P), and potassium (K) are categorized as primary macronutrients as they are needed in larger quantities. Hence, the availability of these elements was determined in this study. The mean value of total nitrogen at the study plots of Kota Damansara Forest Reserve was 0.44 ± 0.07 µg/g. However, this is considered low because tropical forests have high precipitation leads to high leaching or nutrient loss from the soil (Vitousek & Sanford, 1986). Similarly, in other forest locations such as Bukit Lagong Forest Reserve where Zawani *et al*. (2020) recorded a low mean value of total nitrogen with 0.30 ± 0.002 µg/g whilst Sungai Lalang Forest Reserve recorded 0.12 ± 0.02 µg/g for the mean total nitrogen (Natasha *et al*., 2020).

The available phosphorus in most native soils is low, ranging from 0.001 µg/g to 1 µg/g (Weil & Nyle, 2017). Low availability of phosphorus compounds in soils because they are mostly unavailable for plant uptake, due to their insolubility and phosphorus loss from leaching (Raulino & Fortes, 2020). For instance, low available phosphorus concentrations were demonstrated in various tropical forests such as Lesong Forest Reserve (5.49 ± 0.15 µg/g) and Kluang Forest Reserve (8.64 ± 0.38 µg/g) (Nik Norafida *et al*., 2018). Low availability of phosphorus in forest soils can be avoided by conducting annual soil testing to monitor soil phosphorus levels and the efficient use of organic fertilizer that can significantly improve the phosphorus availability in soil for tree growth.

The mean value of available potassium (K) was recorded low in KDFR with 21.20 ± 1.14 µg/g respectively. According to Tening and Omueti (2000), potassium availability in soils depends on many factors such as weathering of minerals and decomposition of plant litter. Minerals like micas (clay fraction) and feldspars (sand & silt) contain most of the potassium and over long periods, the weathering of these minerals releases potassium into

Table 2. Mean (± SE) of soil chemical data in all study plots at Kota Damansara Forest Reserve, Selangor

Parameter	Mean ± SE
Soil pH	3.86 ± 0.02
Exchangeable cations (meq/100 g)	
Ca^{2+}	0.18 ± 0.02
Mg^{2+}	0.14 ± 0.01
Na^+	0.39 ± 0.05
K^+	0.19 ± 0.01
Al^{3+}	2.38 ± 0.20
H^+	0.89 ± 0.07
CEC	4.17 ± 0.30
Soil nutrients (µg/g)	
Available P	2.15 ± 0.11
Available K	21.20 ± 1.14
Total N	0.44 ± 0.07

the available pool. Besides, the decomposition of plant litter from the tree species can release potassium thus increasing the concentrations of available potassium in tropical forest soils. For instance, the mean concentrations of potassium were varied due to the ecological characteristics of each forest habitat such as Bukit Bauk Forest Reserve and Kluang Forest Reserve with 86.36 ± 7.96 µg/g and 101.57 ± 10.60 µg/g each, respectively (Nik Norafida *et al*., 2018).

Soil-vegetation relationships

Figure 2 illustrates the result of the ordination diagram of RDA on study plots at Kota Damansara Forest Reserve with 11 soil variables. The nature of the relationships is shown in the ordination diagram by vectors with lengths proportional to their importance and directions showing their correlation with each axis. The study plots that were placed near the arrow vector represented the favorable environmental characteristics of the plots (Ter Braak, 2015). The points that are close together correspond to plots that are similar in species composition, and points that far apart correspond to plots that are dissimilar in species composition (Ter Braak, 2015). For instance, points that are closed together such as plot 1 and plot 7 due to the high community similarity of trees between plots. On the other hand, plots 3 and 9 were located further away from the rest of the other plots in KDFR because they contained highly different species compared to others.

About the pattern of the ordination diagram, it is apparent that most study plots were clumped on the lower part of the diagram which correlated with soil variables of cation exchange capacity (CEC), clay texture, and total nitrogen (N). Tree communities in plot 2 were strongly associated with cation exchange capacity (CEC); tree communities in plot 4 were highly correlated to Ca^{2+}. These findings are congruent with Nik Norafida *et al*. (2018) who reported soil chemical properties (CEC, Ca^{2+}) exerted a strong influence on the distribution of tree species besides its vital role in determining soil fertility and nutrient retention capacity (Khairil *et al*., 2011). Further, plot 10 showed a positive correlation with organic matter content (OM) whilst plots 1 and 7 were influenced by total nitrogen (N). However, plots 3 and 9 showed a weak association with the soil factors as they are located farther away from all soil gradients. Thus, this indicated that other factors not evaluated in this study were also significant in influencing the distribution of tree communities in the study plots.

The RDA biplot of species and soil variables is presented in Figure 3. Several species showed higher affinity to soil variables with the preference of nutrients availability such as *Cratoxylum arborescens* (9) and *Syzygium grandis* (45) to available phosphorus while *Cinnamomum iners* (7) and *Endospermum diadenum* (15) to available potassium (K). Meanwhile, *Shorea bracteolate* (35) was strongly influenced by organic matter content whilst *Myristica cinnamomea* (25)

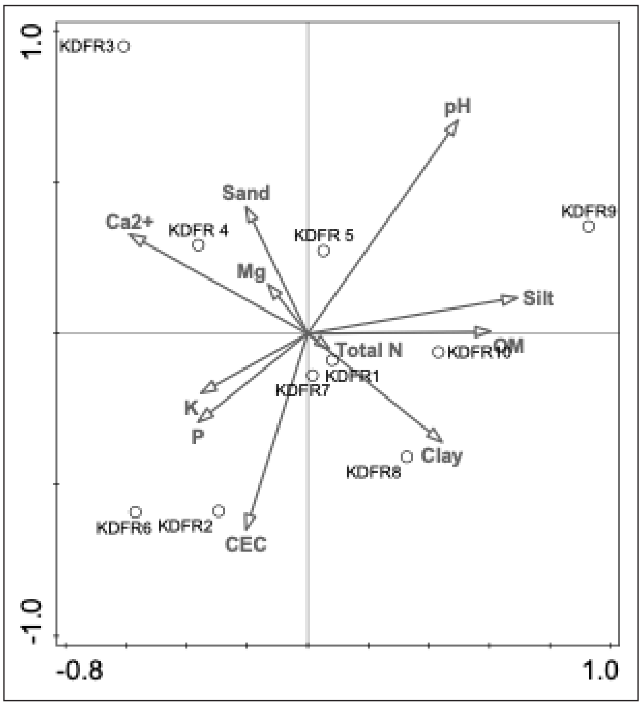

Fig. 2. Redundancy analysis (RDA) ordination plot showing the approximate location of sample plots (KDFR1 – KDFR10) and locations, lengths, and directions of soil variables. Note: pH = soil pH; Mg = available Mg; P = available phosphorus; K = available potassium; CEC = cation exchange capacity; Ca^{2+} = ion calcium; total N = total nitrogen; OM = organic matter content.

by calcium ions. Moreover, species that are further away from the soil gradients are said to have a weak association with the soil factors such as *Aglaia malaccensis* (1), *Gonystylus affinis* (18), *Heritiera javanica* (20), and *Streblus elongatus* (42). Although they are positioned close to each other, they are not influenced by edaphic factors. Other factors might influence tree species distribution in a forest such as a gap area and canopy (Toniato and Oliveira-Filho, 2004).

The variations in species distributions within the study plots showed that there were strong correlations between edaphic factors and species distribution patterns. These results are also observed in other forest reserves such as Bukit Lagong Forest Reserve, Sungai Lalang Forest Reserve, and Gunung Raya Forest Reserve. For instance, a study by Natasha *et al*. (2020) in Sungai Lalang Forest Reserve, found that *Scaphium linearicarpum* (Malvaceae) was strongly correlated to nitrogen (N) while *Shorea parvifolia* (Dipterocarpaceae) had a positive association with phosphorus (P). Further in Bukit Lagong Forest Reserve, Zawani *et al*. (2020) reported that available potassium influenced tree species distribution of *Cratoxylum arborescens* (Hypericaceae), *Pellacalyx axillaris* (Rhizophoraceae), and *Shorea maxwelliana* (Dipterocarpaceae) while *Memecylon* sp. (Melastomataceae) was influenced by organic matter. Hence, it is apparent that different forest habitats display varied spatial distribution among tree species regarding soil properties.

CONCLUSION

This study shows that Kota Damansara Forest Reserve has diverse tree species composition, despite its status as a secondary lowland forest. The significant amount of tree biomass in KDFR as a measure of forest productivity depicted the importance of the forest reserve as a carbon sink for terrestrial ecosystems. KDFR harbors high species diversity (H'= 3.43) which is contributed by high species richness (DMG = 8.45) and high species evenness (J'= 0.89). In addition, redundancy analysis indicated that tree species distribution is related to soil chemical properties. As this area is classified as an amenity forest and research forest, the results from this study can be used as a guide to conserve any species of interest and manage the forest reserve.

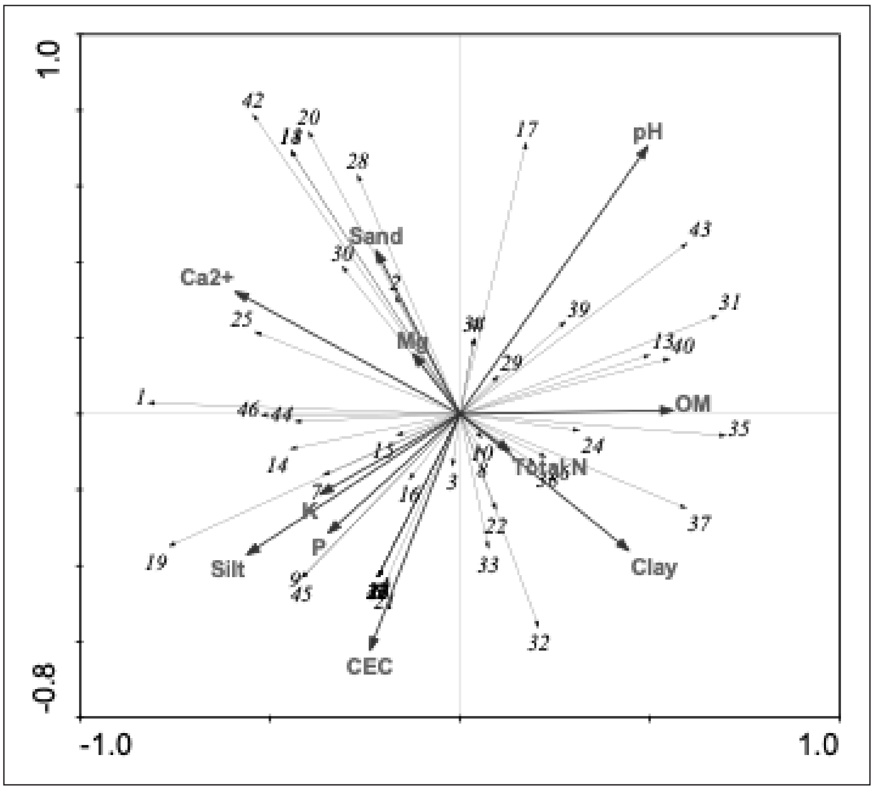

Fig. 3. Redundancy analysis (RDA) biplot of species and soil variables showing the species occurrence about edaphic variables. The length and directions of vectors indicate the strengths and direction of gradients. Note: pH = soil pH; Mg = available Mg; P = available phosphorus; K = available potassium; CEC = cation exchange capacity; Ca^{2+} = ion calcium; total N = total nitrogen; OM = organic matter content.

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