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ASSOCIATION OF TREE COMMUNITIES WITH SOIL PROPERTIES IN A SEMI DECIDUOUS FOREST OF PERLIS, PENINSULAR MALAYSIA

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ABSTRACT

Plant community distribution is associated with environmental factors, particularly, the soil properties of habitats. This study was conducted to determine the effect of soil properties on the association of tree communities within three distinct habitats in a semi-deciduous forest in Perlis State Park (PSP), Perlis. Eighteen plots of 40 × 60 m (0.24 ha each) with sampling areas of 1.92 ha (8 plots) in Setul Formation, 0.96 ha (4 plots) in Granite and 1.44 ha (6 plots) in Kubang Pasu Formation (totalling 4.32 ha) were established at the PSP. All trees with 5.0 cm and above diameter at breast height (dbh) were enumerated, while the top soil samples were collected from each plot for soil analyses. A total of 412 tree species, 207 genera, and 68 families were recorded; 270 tree species from 152 genera and 57 families in the Setul forest; 204 tree species of 130 genera and 50 families in the Granite forest; and 109 tree species from 76 genera and 31 families in the Kubang Pasu forest. Euphorbiaceae was the most represented family at Setul, Granite and Kubang Pasu with 36, 19 and 12 species, respectively. Soil properties significantly varied among the study sites. Setul had loam, Kubang Pasu had clay-loam, and Granite had the sandy-loam texture. The soils were acidic and had low to high concentrations of available nutrients. Ordinations using canonical correspondence analysis indicated that the soil factors play an important role in the distribution and diversity of plants in these forest habitats.

Keywords: canonical correspondence analysis, Perlis State Park, semi-deciduous forest, vegetation–environment relationship

INTRODUCTION

In tropical rain forest, the tree species composition varies with the type of habitat (Richards 1952) and their distributions are often associated with environmental factors (Newbery & Proctor 1984; Fujii *et al.* 2018). Studies conducted in different tropical regions had emphasized the influence of environmental factors, especially soil properties, on plant species distributions (Wentworth 1981; Oliveira-Filho *et al.* 2001; Nizam *et al.* 2013). Relationships between soil variables and plant species distribution had been discovered in various habitats, such as in granite and limestone areas (Nizam *et al.* 2013), grasslands (Cachovanová *et al.* 2012), savannas (Barruch 2005) and the tropical rain forests (Silk *et al.* 2010; Sukri *et al.* 2012).

Peninsular Malaysia is predominantly of the rainforests type and comprise only a small restricted part of a semi-deciduous forest. The semi-deciduous forest in Peninsular Malaysia is located near Kra Isthmus, a transitional zone where Malesian and Indochinese floristic regions intersect (van Steenis 1979; Whitmore 1984; Middleton 2003). The State of Perlis, which is situated in the northernmost of Peninsular Malaysia, is the only part in this country with a semi-deciduous forest (Faridah-Hanum 2006).

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The Perlis State Park (PSP) exhibits a semi-deciduous forest with most areas consisting of limestone hill forests and a small portion of granite-based parent material. This study aimed to determine the association between the tree communities and their soil properties under different forest habitats with different rock formations. This study is timely because the increasing human pressures on limestone and granite habitats compromise their integrity, diversity and functions. Limestone forests are being replaced by plantations, agricultural crops and forages to increase their productivity.

MATERIALS AND METHODS

Study Site and Tree Sampling

A semi-deciduous forest in PSP, Perlis, Peninsular Malaysia, was selected as the study site (latitude 6°34'N to 6°43'N, longitude 100°10'E to 100°13'E) (Fig. 1). Tree samplings were conducted in 18 plots of 40 × 60 m each, covering a survey area of 4.32 ha. Due to different topography of the selected forest habitats, several plots were selectively established to avoid rocks and huge boulders. As such, the number of plots that were established also varied between forest habitats of different geological formations; eight plots (1.92 ha) in the Setul, six plots (1.44 ha) in the Kubang Pasu, and four plots (0.96 ha) in the Granite. All trees with 5 cm and above diameter at breast height (dbh) were enumerated and identified using the published keys (Whitmore 1972; Whitmore 1973; Ng 1978; Ng 1989).

Since the number of plots in each forest habitat was unequal as mentioned earlier, the rarefaction analysis was conducted using EcoSim software program (Gotelli & Entsminger 2003) to produce the rarefaction curves. Rarefaction allows comparison of the observed richness and diversity between sites even though sampling efforts are not equal, or samples differ in the total number of individuals (Lee & Chao 1994). The rarefaction analysis of the study site confirmed that although the sampling efforts between habitats were unequal, nevertheless the species richness was of the same trend with the actual observation in the survey plots (Zakaria *et al.* 2015).

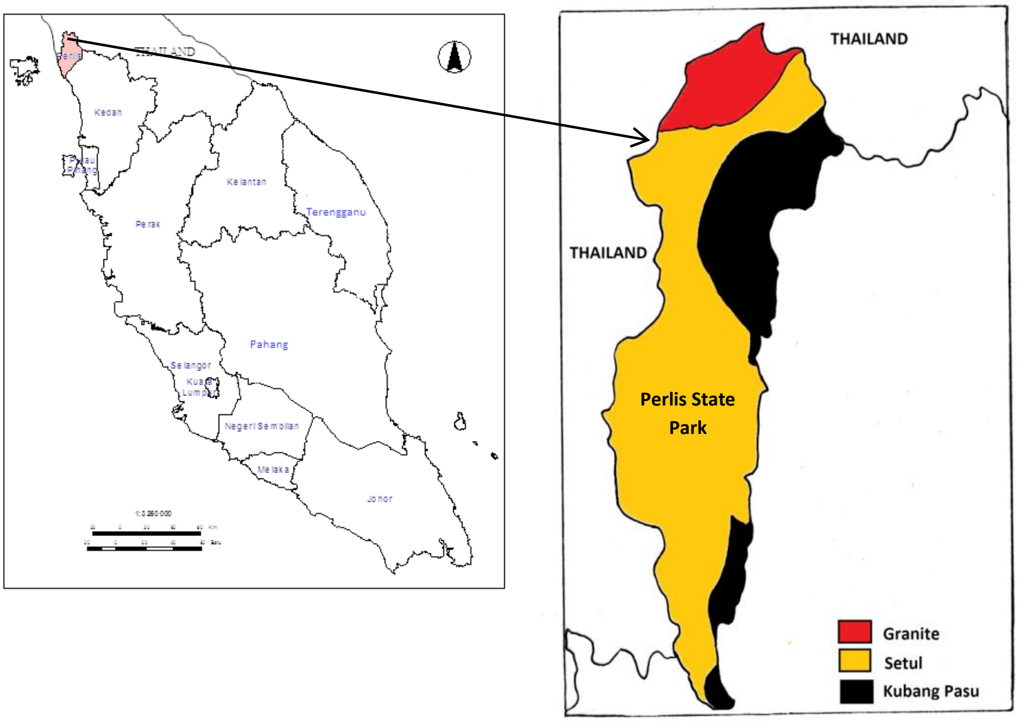

Figure 1 Location of the Perlis State Park in the state of Perlis, Peninsular Malaysia

Soil Sampling and Analysis

Using the soil corer, the top soil samples at 0-15 cm depth were collected from 18 established plots of various habitats within the PSP. Five replicate samples were obtained from each plot and air dried at room temperature. The replicates were then homogenized together to represent one composite sample from each plot. Root fragments and unwanted materials were removed and the soils were lightly ground and passed through a 2 mm mesh sieve before analysis.

The soil samples were analyzed for physical properties, i.e., particle size distribution and organic matter (OM) content as well as chemical properties, i.e., exchangeable acid cations (Al^{3+} and H^{+}), exchangeable base cations (K^{+}, Mg^{2+}, Na^{+} and Ca^{2+}) and available nutrients (phosphorus (P), potassium (K) and magnesium (Mg). OM content was measured using loss on ignition techniques, while the soil pH was recorded based on soil–water ratio of 1:2.5 (McLean 1967). By titration, the exchangeable acid cations were analyzed in 1 M KCl while the exchangeable base cations used the 1 M ammonium acetate extract (Black 1967; Shamshuddin 1981). To determine the cation concentrations, the extracts were run using the Perkin-Elmer Atomic Absorption Spectrophotometer (AAS) Model 3300. Available nutrients (P, K and Mg) in the soil samples were extracted using 1 M ammonium acetate–acetic acid. The concentration of P in the extract was recorded using Ultraviolet (UV) spectrophotometer, whilst K and Mg concentrations were measured using the AAS.

Data Analysis

The enumerated trees in the plots were investigated for overall floristic composition. The soil parameters among the study plots were tested for significant difference using t-test. Association between tree communities and soil variables was analyzed using the multivariate techniques of canonical correspondence analysis (CCA) (ter Braak 1987; ter Braak & Prentice 1988; ter Braak 1992), which is available in CANOCO for Windows 4.56 (ter Braak 2009). Tree species with four occurrences, or less, were not included in the analysis because they weaken the uniformity when assigned to the groups (Legendre & Gallagher 2001; Barruch 2005). The species with four occurrences or less were disregarded to limit the number of species to less than 200 and consequently increase the accuracy of the results of CCA ordination diagram. Thus, 161 tree species were selected for the CCA. Detrended Correspondence Analysis (DCA) was first conducted on the species data to confirm their unimodality and subsequently justify the appropriateness of using CCA (Lepš & Šmilauer 2003). Soil variables selected for the CCA were soil pH, available P, available magnesium (Mg^{2+}), calcium (Ca^{2+}), natrium (Na^{+}), potassium (K^{+}) content, ammonium-N (NH_4-N) and nitrate-N (NO_3-N). The abundance values were log-transformed prior to matrix processing because their distributions were skewed toward extremely large values (ter Braak 1995). The correlation significance between matrices was tested using Monte-Carlo permutation test based on 499 random trials at a 0.05 significant level (Lepš & Šmilauer 2003). The ordination diagrams were subsequently plotted by CANODRAW 4.14 to illustrate the association patterns of tree communities in relation to soil properties.

RESULTS AND DISCUSSION

Tree Species Composition

A total of 4,300 trees were recorded within the sampling area of 4.32 ha at Perlis State Park. The floristic composition included 412 tree species, 207 genera and 68 families. The Setul habitat showed high species richness of 270 species from 1,722 trees; belonging to 152 genera and 57 tree families and the plots in Granite habitat showed 204 tree species, from 1,245 trees; belonging to 130 genera and 50 families and the plots in the Kubang Pasu habitat contained 109 tree species from 1,333 trees, belonging to 76 genera and 31 families. In all three habitats, Euphorbiaceae was the most represented family with 36 species in Setul, 19 species in Granite and 12 in Kubang Pasu. On the contrary, 11 families were represented by only one species with a single individual in Setul, Granite and Kubang Pasu habitats. These families include Actinidiaceae (*Saurauia pentapetala*), Ancistrocladaceae (*Ancistroclados* *tectorius*), Anisophylleaceae (*Anisophyllea apetala*), Convolvulaceae (*Erycibe albida*), Ctenolophonaceae (*Ctenolophon parvifolius*), Hypericaceae (*Cratoxylum formosum*), Magnoliaceae (*Magnolia elegans*), Oleaceae (*Chionanthus macrocarpus*), Opiliaceae (*Milientha suavis*), Oxalidaceae (*Sarcotheca griffithii*) and Rhizophoraceae (*Gynotroches axillaris*). Hence, these species were not considered in the analysis of species association with soil variables.

Soil Properties

The three habitats have different soil properties as follows: the soil in Setul was loam whereas those in Granite and Kubang Pasu were sandy and silty-loam, respectively. Granite habitat had the lowest silt and clay contents but had the highest sand content at more than 69% among all study sites (Table 1). The high sand content in Granite is related to sandy parent material; the quartz sand derived from granitic hill was washed out and deposited a long time ago as reflected by the high sandy materials and extremely low clay and silt contents (Osumi 1979; Zaidey *et al.* 2010). In terms of OM content, the Granite soil had the significantly lowest OM content (3.12 ± 0.08) followed by the Setul soil (6.97 ± 1.96) and Kubang Pasu soil (10.72 ± 2.01) (Table 1). The lowest OM content in Granite 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 (Paul & Clark 1996). Overall, it is apparent that the amount of OM in the study sites is generally low. This low OM content is due to the high decomposition rate of OM in tropical rainforest soils (Longman & Jenik 1987).

The low soil pH in Granite (4.39), Setul (5.64) and Kubang Pasu (5.98) indicated that the soils were strongly to moderately acidic. The soil pH in Granite was significantly lower than those of Setul and Kubang Pasu (Table 1). Granite soil has the highest acidity probably because it originated from the acidic parent rocks (Juo 1981) and the decomposition of OM also adds to the acidification of surface soil (Zaidey *et al.* 2010). A similar study recorded that most soils in Peninsular Malaysia tropical rainforests are acidic with pH values between 4.5 and 5.5 (Othman & Shamshuddin 1982).

Table 1 Summary of soil variables in Setul, Granite and Kubang Pasu habitats at Perlis State Park, Perlis

Soil parameters	Granite (mean ± s.e.)	Setul (mean ± s.e.)	Kubang Pasu (mean ± s.e.)	p value
Organic matter (OM) (%)	3.12 ± 0.08^a	6.97 ± 1.96^b	10.72 ± 2.01^b	$p < 0.05$
Sand (%)	69.75 ± 2.12^a	41.45 ± 4.68^b	36.60 ± 8.52^b	$p < 0.01$
Silt (%)	14.15 ± 0.77^a	35.61 ± 3.89^b	44.20 ± 2.17^b	$p < 0.01$
Clay (%)	16.05 ± 1.42	21.42 ± 2.80	19.20 ± 2.23	NS
Soil pH	4.39 ± 0.12^a	5.64 ± 0.35^b	5.98 ± 0.30^b	$p < 0.01$
Exchangeable cations (meq/100g)				
Ca^{2+}	0.94 ± 0.27^a	5.5 ± 2.05^b	7.87 ± 2.18^b	$p < 0.05$
Mg^{2+}	0.41 ± 0.02^a	0.75 ± 0.16^b	0.95 ± 0.44^a	$p < 0.05$
Na^+	0.20 ± 0.04	0.13 ± 0.02	0.13 ± 0.02	NS
K^+	0.32 ± 0.03^a	0.50 ± 0.06^{ab}	0.57 ± 0.12^b	$p < 0.01$
Al^{3+}	0.60 ± 0.16	0.19 ± 0.14	0	NS
H^+	0.50 ± 0.03	0.35 ± 0.04	0.34 ± 0.02	NS
CEC	2.92 ± 0.2^a	7.58 ± 2.09^b	9.87 ± 2.54^b	$p < 0.05$
Available nutrients (ug/g)				
Phosphorus (P)	9.04 ± 0.31^a	7.18 ± 0.69^b	7.27 ± 0.37^b	$p < 0.05$
Nitrate-N (NO_3-N)	27.00 ± 1.5	34.39 ± 6.45	30.96 ± 4.94	NS
Ammonium-N (NH_4-N)	3.59 ± 0.46^a	18.64 ± 3.57^b	30.81 ± 3.57^b	$p < 0.01$
Magnesium (Mg)	28.56 ± 0.51	105.35 ± 48.56	139.49 ± 66.78	NS
Potassium (K)	175.02 ± 8.43^a	227.27 ± 32.4^b	253.80 ± 26.35^{ab}	$p < 0.05$

Note: Mean values in a row with the same letter were not significantly different.

The cation exchange capacity (CEC in Granite was the lowest (2.92 ± 0.20 meq/100 g,) was significantly different from those in Setul (7.58 ± 2.09 meq/100 g) and Kubang Pasu (9.87 ± 2.54 meq/100 g). CEC varies with the clay–humus content of the soil. Clay soils usually have large CEC, whereas sandy soils have low CEC (Cruickshank 1972). The sites showed various concentrations of available macronutrients, namely magnesium (Mg), potassium (K) and phosphorus (P), and soluble nutrients, i.e., ammonium-N and nitrate-N (Table 1). The phosphorus concentration in Granite plots (9.04 ± 0.31 μg/g) was significantly higher than those in Setul (7.18 ± 0.69 μg/g) and Kubang Pasu (7.27 ± 0.37 μg/g). The available magnesium (Mg) in Granite (28.56 ± 0.51 μg/g), Setul (105.35 ± 48.56 μg/g) and Kubang Pasu (139.49 ± 66.78 μg/g) did not differ significantly.

The available inorganic soil nitrogen is in the form of nitrate-N (NO_3-N) and ammonium-N (NH_4-N). The concentrations of these two soluble nutrients showed a consistent trend; the Granite habitat had lower concentration than the Setul and Kubang Pasu habitats. Ammonium-N was significantly low at Granite (3.59 ± 0.46 μg/g), higher at Setul (18.64 ± 3.57 μg/g) and the highest at Kubang Pasu (30.81 ± 3.57 μg/g). Nevertheless, the concentration of nitrate-N was not significantly different among the habitats. The lowest availability of inorganic soil nitrogen in Granite habitat was in line with the OM in the habitat. Tan (2009) mentioned that soil inorganic N content increases linearly as organic matter increases in the soil. The inorganic N was characterized by a large NO_3-N, which exceeds the NH_4-N at all the habitats; this might be attributed to the drier conditions in the study sites (Yamashita *et al.* 2003).

Relationships between Tree Communities and Soil Variables

DCA confirmed that the data on tree communities were unimodal with the length of gradient of the first axis at 5.758 (Table 2), which was greater than 4 standard deviation (SD) before being analyzed by CCA (Lepš & Šmilauer 2003). The eigenvalue produced by the DCA axis 1 (0.758) was high, indicating an environmental gradient where most species vary essentially in their abundance (ter Braak 1995).

Plots in Granite (symbol x) were clustered together, while plots in Setul (symbol ○) and Kubang Pasu (symbol +) exhibited the gradient that occurs from granite to limestone (Fig. 2). These DCA ordination plots indicated the approximate locations of the sample plots. The plots that clumped together represented the plots with relatively similar floristic attributes, while the separated plots indicate dissimilar floristic composition. The unclearly separated plots in Kubang Pasu and Setul proved that Kubang Pasu Formation is overlain by Setul Formation (Basir & Zaiton 2002). Therefore, these habitats shared similar needs for mineral nutrient elements and other edaphic variables.

Table 2 Summary of the Detrended Correspondence Analysis (DCA) of the vegetation data in 18 plots at the Perlis State Park, Perlis

Axes	1	2	3	4	Total inertia
Eigenvalues	0.758	0.464	0.393	0.174	6.527
Length of gradient	5.758	3.879	3.012	2.509	
Cumulative percentage variance of species data	11.6	18.7	24.7	27.4	
Sum of all eigenvalues					6.527

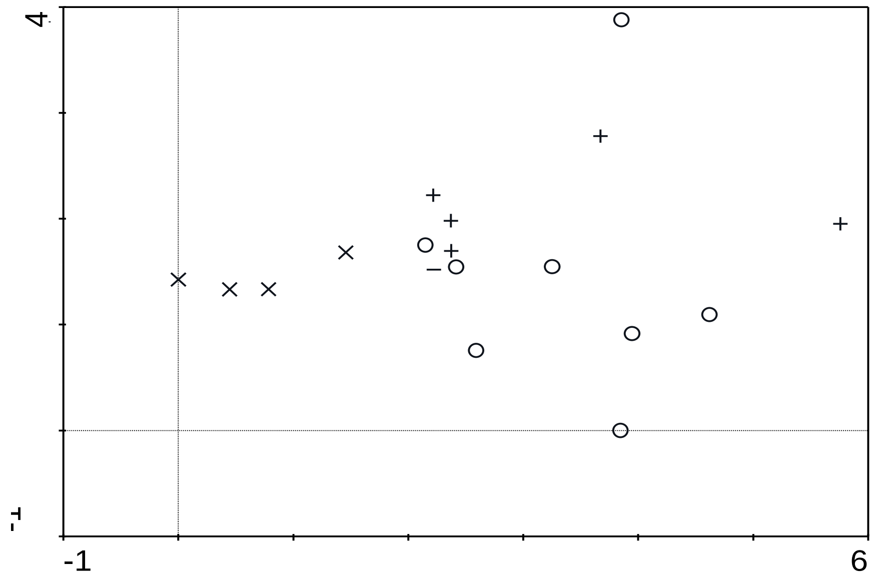

Figure 2 DCA ordination diagram of plots based on the abundance of tree species at Perlis State Park, Perlis
Notes: x = plots in Granite; ○ = plots in Setul; + = plots in Kubang Pasu.

Based on the CCA analysis, the species–environment correlations were high on the first and second axes with values of 0.988 and 0.974, respectively (Table 3). The eigenvalue was 0.561 for the first axis and 0.444 for the second axis. Additionally, the cumulative variation explained by the first three axes of the species-environment relationship was 55.2%. The Monte-Carlo permutation test also indicated a significant difference on the eigenvalues among the ordina-tion axes (p = 0.002). The CCA ordination plot showed the approximate locations of sample plots and the locations, lengths and directions of soil chemical variables (Fig. 3). Plots in Granite (1-4) were clustered together and associated with available phosphorus. Meanwhile, Setul and Kubang Pasu plots did not cluster into the well-defined group. Their plots were mostly assembled on the bottom right part of the diagram and were strongly correlated with several soil variables, i.e., magnesium (Mg), potassium (K), calcium (Ca), pH, available nitrate-N (NO_3) and available ammonium-N (NH_4).

The CCA biplot of species and soil variables showed the species occurrence in relation to soil variables (Fig. 4). Most species were clumped on the centre part of the diagram and correlated with several soil variables such as available phosphorus (P) and available ammonium-N (NH_4). Some species such as *Antidesma cuspidatum* (47) were clearly associated with calcium, whilst *Ficus annulata* (102) and *Duabanga grandiflora* (88) were strongly associated with ammonium-N (Fig. 4; Table 4). Furthermore, *Hopea ferrea* (34) had strong association with sodium. *Aglaia affinis* (93) had strong association with magnesium, whilst *Bombax valetonii* (23) was strongly associated with potassium and magnesium. However, *Alstonia macrophylla* (19), *Terminalia subspathulata* (30), *Senna timorensis* (87), *Ficus aurata* (103) and *Colona merguensis* (155) showed a weak association with soil factors when they are farther away from all the soil gradients (Fig. 4; Table 4).

Table 3 Summary of the canonical correspondence analysis (CCA) of the vegetation and soil chemical properties in the 18 plots at Perlis State Park, Perlis

Axes	1	2	3	4	Total inertia
Eigenvalues	0.561	0.444	0.356	0.301	4.238
Species-environment correlations	0.988	0.974	0.961	0.987	
Cumulative percentage variance of species data	13.2	23.7	32.1	39.2	
Cumulative percentage variance of species-environment relation	22.7	40.8	55.2	67.5	
Sum of all eigenvalues					4.238
Sum of all canonical eigenvalues					2.464

The variations in species distribution within the study plots were strongly correlated to edaphic factors and vegetation distribution pattern. Calcium and pH were some factors that strongly influenced the vegetation pattern in the limestone study area (Setul and Kubang Pasu), whereas sodium and phosphorus strongly affected the vegetation pattern in Granite area. Soils which developed on granite are low in calcium and magnesium (Burnham 1974), whereas soils that developed on limestone parent material such as in Setul and Kubang Pasu are mainly high in calcium and pH (Gauld & Robertson 1985).

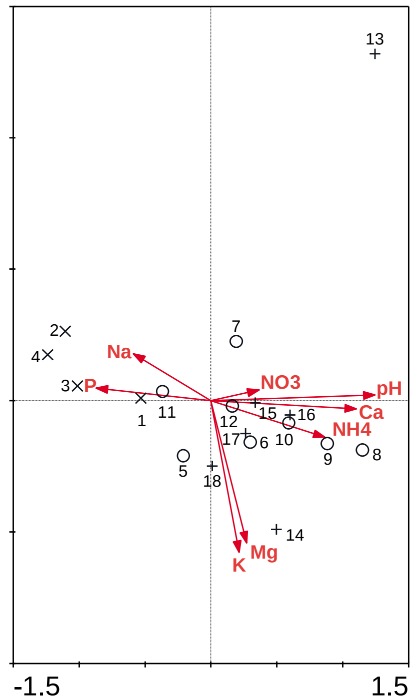

Figure 3 CCA ordination plot showing the approximate locations of sample plots and location, length and directions of soil variables
Notes: x = plots in Granite (1-4); ○ = plots in Setul (5-12); + = plots in Kubang Pasu (13-18).

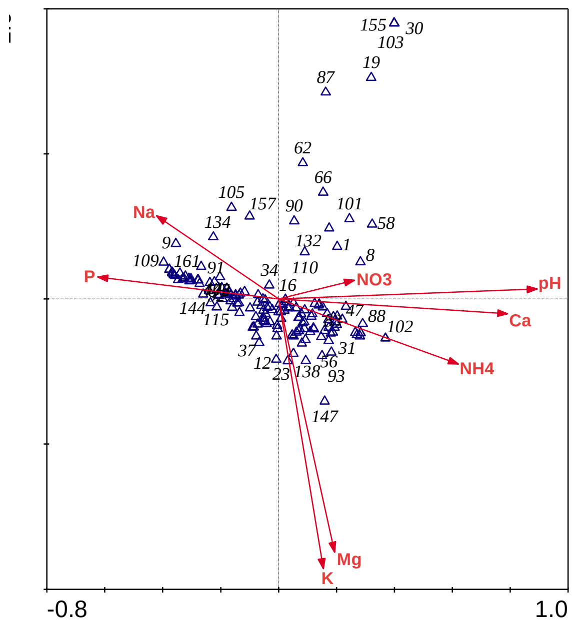

Figure 4 Canonical correspondence analyses of the biplot for tree species and soil variables at the Perlis State Park
Note: Numbers denote the species in the plots as listed in Table 4.

Table 4 List of species with code numbers referring to diagram in Fig. 4

Species code	Species	Species code	Species
1	*Alangium kurzii*	61	*Sapium baccatum*
2	*Boea oppositifolia*	62	*Sauroupus suberosus*
3	*Buchanania arborescens*	63	*Trigonostemon villosa*
4	*Dracontomelon dao*	64	*Lithocarpus cantleyanus*
5	*Gluta elegans*	65	*Casearia capitellata*
6	*Gluta velutina*	66	*Homalium longifolium*
7	*Parishia insignis*	67	*Hydnocarpus castanea*
8	*Pentaspodon curtisii*	68	*Hydnocarpus curtisii*
9	*Semecarpus cochinchinensis*	69	*Hydnocarpus filipes*
10	*Semecarpus curtisii*	70	*Osmelia maingayi*
11	*Swintonia floribunda*	71	*Garcinia eugeniifolia*
12	*Alphonsea curtisii*	72	*Garcinia hambroniana*
13	*Goniothalamus tenuifolius*	73	*Garcinia nigroleniata*
14	*Mitrephora maingayi*	74	*Garcinia parvifolia*
15	*Orophea cuneiformis*	75	*Kayea kunstleri*
16	*Polyalthia glauca*	76	*Mesua ferrea*
17	*Xylopia ferruginea* var. *oxyantha*	77	*Stemonurus malaccensis*
18	*Xylopia magna*	78	*Cryptocarya ferrea*
19	*Alstonia macrophylla*	79	*Cryptocarya rugulosa*
20	*Kibatalia maingayi*	80	*Litsea machilifolia*
21	*Ilex cymosa*	81	*Barringtonia scortechinii*
22	*Radermachera glandulosa*	82	*Abdulmajidia rimata*
23	*Bombax valetonii*	83	*Leea aequata*
24	*Durio lowianus*	84	*Callerya artropurpurea*
25	*Canarium littorale* f. *rufum*	85	*Cynometra malaccensis*
26	*Dacryodes rubiginosa*	86	*Saraca cauliflora*
27	*Dacryodes rugosa*	87	*Senna timoriensis*
28	*Lophopetalum javanicum*	88	*Duabanga grandiflora*
29	*Parastemon urophyllus*	89	*Lagerstroemia floribunda*
30	*Terminalia subspathulata*	90	*Lagerstroemia ovalifolia*
31	*Tetrameles nudiflora*	91	*Memecylon caeraleum*
32	*Dipterocarpus costatus*	92	*Memecylon minutiflorum*
33	*Dipterocarpus fagineus*	93	*Aglaia affinis*
34	*Hopea ferrea*	94	*Aglaia argentea*
35	*Hopea latifolia*	95	*Aglaia simplicifolia*
36	*Parashorea stellata*	96	*Aglaia spectabilis*
37	*Shorea macroptera*	97	*Aphanamixis polystachya*
38	*Shorea siamense*	98	*Chisocheton ceramicus*
39	*Vatica cinerea*	99	*Chisocheton patens*
40	*Diospyros andamanica*	100	*Chukrasia tabularis*
41	*Diospyros buxifolia*	101	*Artocarpus dadah*
42	*Diospyros scortechinii*	102	*Ficus annulata*
43	*Diospyros sumatrana*	103	*Ficus aurata*
44	*Diospyros venosa*	104	*Ficus fistulosa*
45	*Elaeocarpus rugosus*	105	*Ficus microcarpa*
46	*Erythroxylum cuneatum*	106	*Ficus oligodon*
47	*Antidesma cuspidatum*	107	*Ficus sundaica*
48	*Aporosa aurea*	108	*Ficus variegata*
49	*Baccaurea griffithii*	109	*Streblus elongatus*
50	*Chondrostylis kunstleri*	110	*Streblus ilicifolius*
51	*Cleistanthus hirsutulus*	111	*Streblus macrophyllus*
52	*Croton argyratus*	112	*Streblus toxoides*
53	*Croton cascarilloides*	113	*Horsfieldia polyspherula*
54	*Croton laevifolius*	114	*Honsfieldia sucosa*
55	*Dimorphocalyx muricatus* var. *minor*	115	*Horsfieldia tomentosa*
56	*Drypetes longifolia*	116	*Knema laurina*
57	*Koilodepas longifolium*	117	*Knema patentinervia*
58	*Macaranga andamanica*	118	*Ardisia crassa*
59	*Macaranga lowii*	119	*Ardisia pachysandra*
60	*Mallotus peltatus*	120	*Maesa ramentacea*

Tabel 4 Continued

Species code	Species	Species code	Species
121	*Syzygium cerasiforme*	141	*Pometia pinnata*
122	*Syzygium glaucum*	142	*Xerospermum noronhianum*
123	*Ochna integerrima*	143	*Chrysophyllum roxburghii*
124	*Galearia fulva*	144	*Palaquium hexandrum*
125	*Galearia maingayi*	145	*Palaquium microphyllum*
126	*Xanthophyllum affine*	146	*Eurycoma apiculata*
127	*Xanthophyllum griffithii*	147	*Pterocymbium javanicum*
128	*Prunus grisea*	148	*Pterospermum javanicum*
129	*Aidia densiflora*	149	*Pterospermum pectiniforme*
130	*Diplospora malaccensis*	150	*Pterygota alata*
131	*Ixora pendula*	151	*Sterculia cordata*
132	*Morinda elliptica*	152	*Sterculia gilva*
133	*Psydrax* sp. 7	153	*Sterculia parviflora*
134	*Psydrax* sp. 8	154	*Tetramerista glabra*
135	*Dimocarpus longan* ssp. *longan*	155	*Colona merguensis*
136	*Guioa bijuga*	156	*Grewia viminea*
137	*Harpullia cupanioides*	157	*Pentace strychnoidea*
138	*Nephelium costatum*	158	*Schoutenia accrescens*
139	*Nephelium lappaceum*	159	*Teijsmanniodendron coriaceum*
140	*Paranephelium macrophyllum*	160	*Vitex pinnata*
		161	*Vitex siamica*

CONCLUSION

The differences in floristic patterns between limestone (Setul and Kubang Pasu) and granite habitats at PSP suggested that environmental gradients influenced floristic composition. The soil properties such as organic matter, moisture, clay, silt, calcium and pH were among the factors that strongly associated with the limestone habitats, while sand and available phosphorus were strongly correlated with granite. Differences in the availability of elemental mineral nutrient between the soils of granite and limestone may have also contributed to the contrasting vegetation. In relation to soil properties, the different habitats displayed varied spatial distributions among the tree species. Identifying the key underlying gradients, abiotic conditions and major soil influences on the vegetation pattern is essential to gain information about the ecology of particular species and to formulate plans to protect and conserve this fragile habitat.

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