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

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Running title: Association of tree communities with soil properties

ABSTRACT

Distribution of vegetation communities is associated with environmental parameters especially the soil properties of habitats. This study was conducted in a semi-deciduous forest in Perlis State Park (PSP), Perlis to determine the association of tree communities with the soil properties of three distinct forest habitats in this location. Eighteen plots of 40 m × 60 m (0.24 ha each) with sampling area 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 in the PSP. All trees with diameter at the breast height (dbh) of 5.0 cm and above were enumerated, whilst top soil samples were collected from each plot for soil analyses. A total of 412 tree species, 207 genera, and 68 families were enumerated in all study plots: 270 tree species from 152 genera and 57 families were found 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 analyses showed significant variation in the soil properties of the study sites. The soil at Setul had loam texture, that at Kubang Pasu displayed clay-loam texture, and that at Granite has sandy-loam texture. In summary, the soils were acidic, and low to high concentrations of available nutrients were found in the forest habitats. Ordinations using canonical correspondence analysis indicated that soil factors play an important role in the distribution and diversity of plants in these study sites.

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

INTRODUCTION

Tree species composition varies with the type of habitat in tropical rain forest (Richards 1952), and their distributions are often associated with environmental factors (Newbery and Proctor 1984; Baillie *et al*. 1987). Many studies conducted in different parts of tropics emphasised 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 have been discovered in various habitats, such as granite and limestone habitats (Nizam *et al*. 2013), habitats of grassland (Amorim and Batalha 2007), savanna communities (Barruch 2005), and tropical rain forest (Silk *et al*. 2010; Sukri *et al*. 2012).

Forests of Peninsular Malaysia are predominantly under rainforests, and only a small restricted part of semi-deciduous forests is found in this area. 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 Sate of Perlis, which is situated in the northernmost of the Peninsular Malaysia, is the only area in this country with semi-deciduous forest (Faridah-Hanum 2006). The Perlis State Park (PSP) exhibits a semi-deciduous forest with most areas consisting of limestone hill forests and a small portion composed of granite-based parent material. This study aimed to determine the association between tree communities and their soil properties in 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 function. Limestone forests are being replaced by plantations, 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 our study site (latitude 6° 34' to 6° 43' N, longitude 100° 10' to 100° 13' E) (Figure 1). Tree samplings were conducted in 18 plots (40 m × 60 m each), covering survey area of 4.32 ha. Due to different topography of the selected locations of the forest habitats, thus several plots were selectively established to avoid rocks and huge boulders. As such, the number of plots managed to be established varied between forest habitats; 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, of different geological formations. All trees with diameter at breast height (dbh) of 5 cm and above were enumerated and identified using published keys (Whitmore 1972; Whitmore 1973; Ng 1978; Ng 1989).

Since the number of plots in each forest habitat was unequal as mentioned earlier, hence rarefaction analysis was conducted using EcoSim software program (Gotelli and Entsminger 2003) to produce rarefaction curves. Rarefaction allows observed richness and diversity between sites being compared though sampling efforts are not equal, or samples differ in the total number of individuals (Lee *et al* 2002). 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).

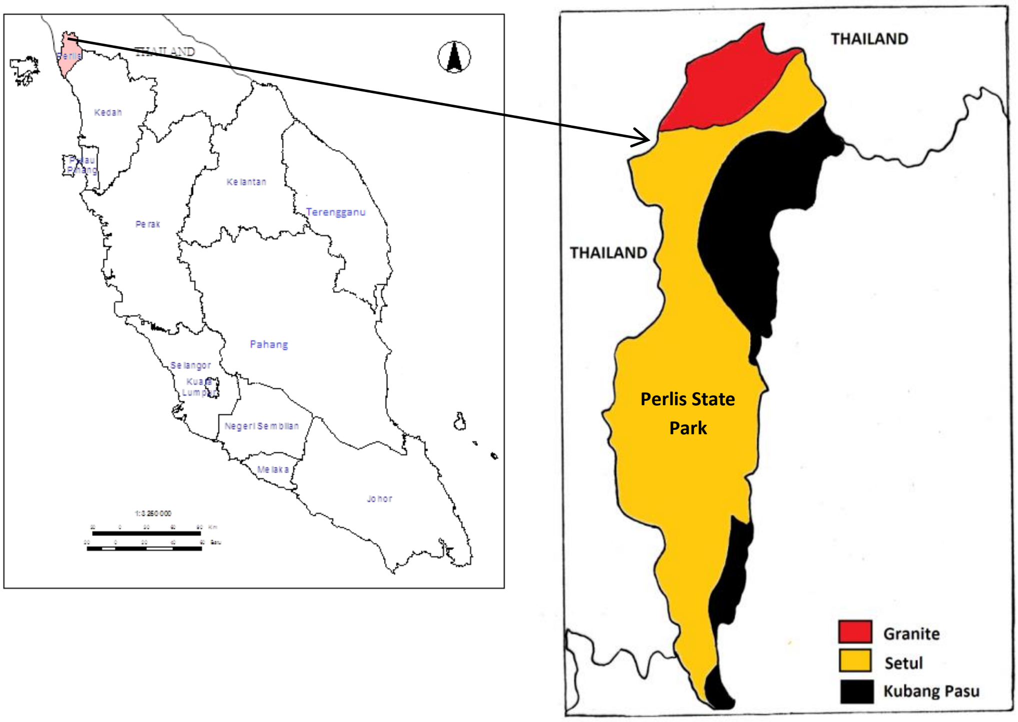

Figure 1. Location of the Perlis State Park in the state of Perlis, Peninsular Malaysia

Soil sampling and analysis

Top soil samples at 0–15 cm depth were collected using soil corer 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 homogenised 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.

All soil samples were analysed for physical properties, i.e. particle size distribution and organic matter (OM) content and 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, whilst soil pH was recorded based on soil–water ratio of 1:2.5 (McLean 1967). Exchangeable acid cations were investigated in 1 M KCl by titration, whilst exchangeable base cations were analysed in 1 M ammonium acetate extract (Black 1967; Shamshuddin 1981). The extracts were run using the Perkin-Elmer Atomic Absorption Spectrophotometer (AAS) Model 3300 to determine the cation concentrations. 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

All enumerated trees in the plots were investigated for overall floristic composition. Values of soil parameters among the study plots were tested for significance using t-test. Association between tree communities and soil variables was analysed using multivariate techniques of canonical correspondence analysis (CCA) (ter Braak 1987; ter Braak and Prentice 1988; ter Braak 1992), which is available in CANOCO for Windows 4.56 (ter Braak 2009). Tree species with less than or equal to four occurrences were not included in the analysis because they weaken the uniformity when assigned to the groups (Legendre and Gallagher 2001; Abd Rahman *et al* 2002; Barruch 2005). We selected species with four occurrences or less 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 thus justify the appropriateness of using CCA (Lepš and Šmilauer 2003). The 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). As recommended by ter Braak (1995), all abundance values were log-transformed prior to matrix processing because their distributions were skewed towards extremely large values. The correlation significance between matrices was tested using Monte-Carlo permutation test based on 499 random trials at a 0.05 significant level (Lepš and 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

The tree enumeration was recorded at 4300 trees within the sampling area of 4.32 ha in the PSP. The floristic composition includes 412 tree species, 207 genera and 68 families. The Setul habitat displayed high species richness of 270 species from 152 genera and 57 tree families from 1722 trees; the plots in Granite habitat showed 204 tree species, 130 genera and 50 families from 1245 trees; and the plots in the Kubang Pasu habitat contained 109 tree species, 76 genera and 31 families from 1333 enumerated trees. 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 and 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 had loam texture, whereas those in Granite and Kubang Pasu had sandy- and silty-loam textures, respectively. Granite habitat had the lowest silt and clay contents but 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 reflecting by the high sandy materials and extremely low clay and silt contents (Osumi 1979; Zaidey *et al*. 2010). In terms of OM content, the soil of PSP indicates percentages in the range of 2.92% to 18.69% with a mean value of 7.36±1.25. The soil in Granite showed the significantly lowest OM content with a mean percentage of 3.12±0.08 ($P<0.05$), followed by that in Setul with a mean value of 6.97±1.96 and Kubang Pasu with a mean value of 10.72±2.01 (Table 1). Overall, the amount of OM in the study sites is considered low. The low OM content in the soil of tropical rainforests is due to the high decomposition rate of OM (Longman and Jenik 1987).

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**
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 with the same letter were not significantly different

The soil pH showed low mean values of 4.39, 5.64 and 5.98 in Granite, Setul and Kubang Pasu, respectively, indicating that the soils were strongly to moderately acidic. The soil pH in

Granite was significantly lower ($p<0.01$) than that in Setul and Kubang Pasu (Table 1). Granite soil has the highest acidity probably because it originated from acidic parent rocks (Juo 1981), and the decomposition of OM leads to the acidification of surface soil (Tange *et al*. 1998; Zaidey *et al*. 2010). This finding also agrees with a study (Othman and Shamshuddin 1982) which stated that most soils in Peninsular Malaysia tropical rainforests are acidic with pH values between 4.5 and 5.5.

The cation exchange capacity (CEC) for H^+, Al^{3+}, Ca^{2+}, Mg^{2+}, Na^+, and K^+ showed mean value of 7.31±1.35 meq/100g. The CEC in Granite showed the lowest mean value of 2.92±0.20 meq/100 g, which was significantly different ($p<0.05$) from that in Setul (7.58±2.09 meq/100 g) and Kubang Pasu (9.87±2.54 meq/100 g). The CEC varies in size 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 i.e. magnesium (Mg), potassium (K), phosphorus (P), and soluble nutrients i.e. ammonium-N and nitrate-N (Table 1). The phosphorus concentration in Granite plots was significantly higher than those in Setul and Kubang Pasu with mean concentrations of 9.04±0.31, 7.18±0.69 and 7.27±0.37 μg/g, respectively ($p<0.05$). The mean concentrations of available magnesium (Mg) in Granite, Setul, and Kubang Pasu were 28.56±0.51, 105.35±48.56, and 139.49±66.78 μg/g, respectively. Nevertheless, these values did not differ significantly.

The available inorganic nitrogen in the soil is in the form of nitrate-N (NO_3-N) and ammonium-N (NH_4-N). Overall, the mean values for both NO_3-N and NH_4-N of soils at the PSP were 31.60±3.25 and 19.35±3.07 μg/g, respectively. The concentrations of these two soluble nutrients showed a consistent trend, wherein Granite habitat displayed lower concentration than Setul and Kubang Pasu habitats did. The mean concentration of ammonium-N was 3.59±0.46 μg/g at Granite, 18.64±3.57 μg/g at Setul, and 30.81±3.57 μg/g at Kubang Pasu, and the values were significantly different ($p<0.01$). Nevertheless, the concentration of nitrate-N was not significantly different among the habitats with values of 27.0±1.50 μg/g at Granite, 34.39±6.45 μg/g at Setul, and 30.96±4.94 μg/g at Kubang Pasu (Table 1). The inorganic N in the study sites is characterised by a large NO_3-N, which exceeds the NH_4-N at all habitats; this might be attributed to the drier conditions in the study sites (Yamashita 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 was 5.758 (Table 2), which is greater than 4 standard deviation (SD) before being analysed by CCA (Lepš and 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).

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

Axes	**1**	**2**	**3**	**4**	**Total inertia**
Eigenvalues	0.758	0.464	0.393	0.174	6.527
Lengths 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 shows the DCA ordination plot indicating the approximate locations of sample plots and locations. Plots in Granite (symbol x) were clustered together, whilst plots in Setul (symbol ○) and Kubang Pasu (symbol +) exhibited the gradient that occurs from granite to limestone. The plots clumped together represent the plots with relatively similar floristics, whilst 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 and Zaiton 2002). Therefore, these habitats shared similar needs for mineral nutrient elements and other edaphic variables.

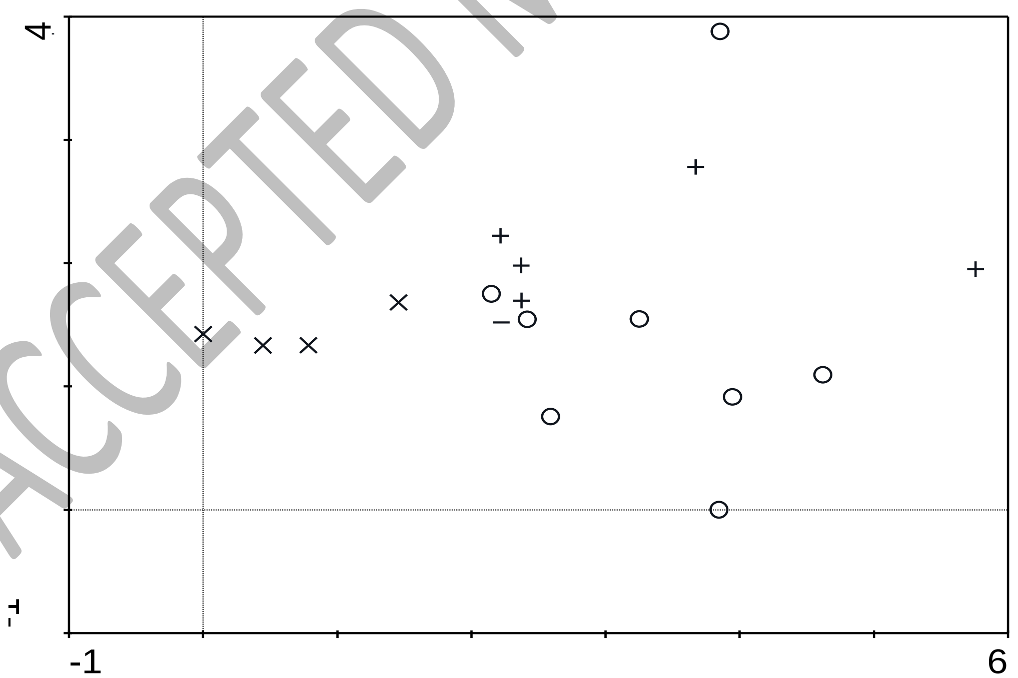

Figure 2. DCA ordination diagram of plots based on the abundance of tree species at Perlis State Park, Perlis. x = plots in Granite; ○ = plots in Setul; + = plots in Kubang Pasu.

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 indicates a significant difference on the eigenvalues among the ordination axes ($p = 0.002$). Figure 3 shows the CCA ordination plot with the approximate locations of sample plots and locations, lengths and directions of soil chemical variables. 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).

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	
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 CCA biplot of species and soil variables in Figure 4 shows the species occurrence in relation to soil variables. 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. 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. Based on Figure 4, *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 soil gradients.

The variations in species distribution within the study plots were strongly correlated to edaphic factors and vegetation distribution pattern. Calcium and pH are 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 and Robertson 1985).

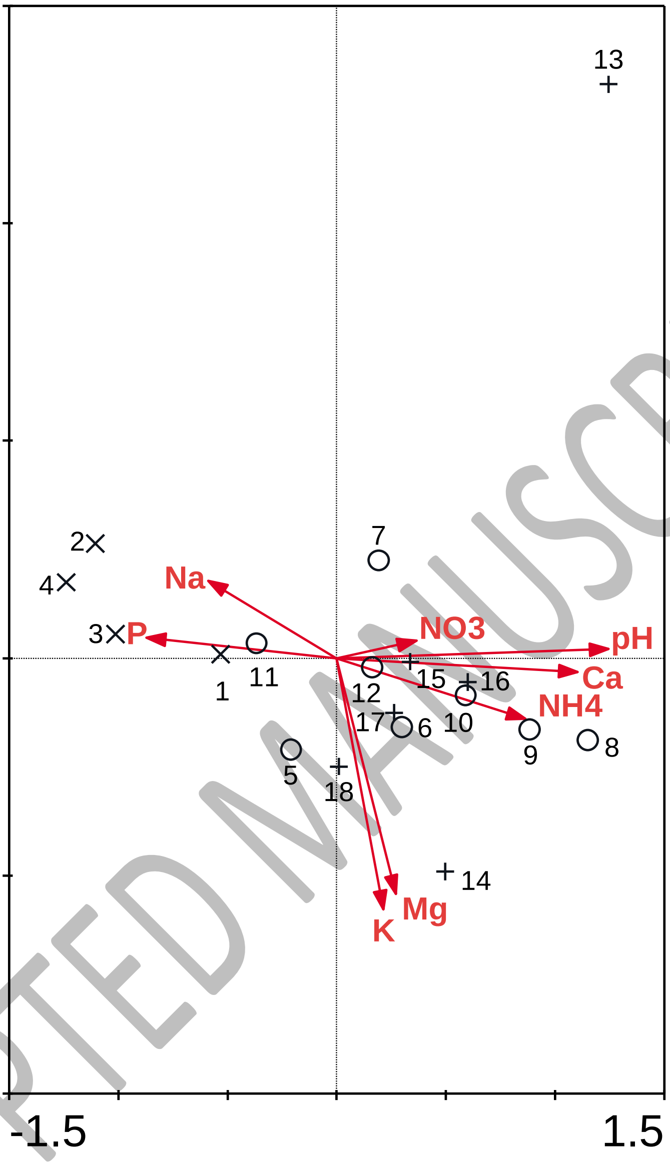

Figure 3. CCA ordination plot showing the approximate locations of sample plots and location, length and directions of soil variables. x = plots in Granite (1-4); ○ = plots in Setul (5-12); + = plots in Kubang Pasu (13-18)

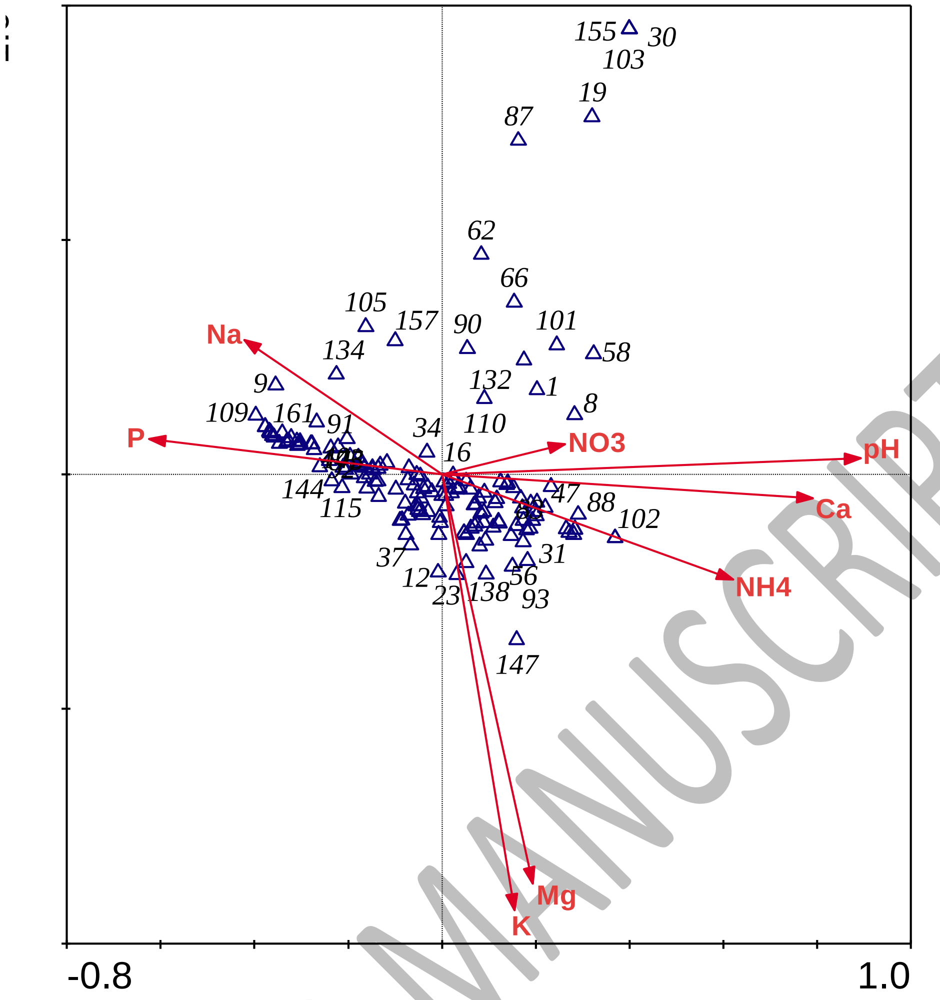

Figure 4. Canonical correspondence analyses of the biplot for tree species and soil variables at the Perlis State Park. Numbers denote the species in the plots as listed in Table 4

Table 4 List of species number denote in diagram of Figure 4

Species code	Species	Species code	Species
1	*Alangium kurzii*	37	*Shorea macroptera*
2	*Boea oppositifolia*	38	*Shorea siamense*
3	*Buchanania arborescens*	39	*Vatica cinerea*
4	*Dracontomelon dao*	40	*Diospyros andamanica*
5	*Gluta elegans*	41	*Diospyros buxifolia*
6	*Gluta velutina*	42	*Diospyros scortechinii*
7	*Parishia insignis*	43	*Diospyros sumatrana*
8	*Pentaspodon curtisii*	44	*Diospyros venosa*
9	*Semecarpus cochinchinensis*	45	*Elaeocarpus rugosus*
10	*Semecarpus curtisii*	46	*Erythroxylum cuneatum*
11	*Swintonia floribunda*	47	*Antidesma cuspidatum*
12	*Alphonsea curtisii*	48	*Aporosa aurea*
13	*Goniothalamus tenuifolius*	49	*Baccaurea griffithii*
14	*Mitrephora maingayi*	50	*Chondrostylis kunstleri*
15	*Orophea cuneiformis*	51	*Cleistanthus hirsutulus*

16	*Polyalthia glauca*	52	*Croton argyratus*
17	*Xylopia ferruginea* var. *oxyantha*	53	*Croton cascarilloides*
18	*Xylopia magna*	54	*Croton laevifolius*
19	*Alstonia macrophylla*	55	*Dimorphocalyx muricatus* var. *minor*
20	*Kibatalia maingayi*	56	*Drypetes longifolia*
21	*Ilex cymosa*	57	*Koilodepas longifolium*
22	*Radermachera glandulosa*	58	*Macaranga andamanica*
23	*Bombax valetonii*	59	*Macaranga lowii*
24	*Durio lowianus*	60	*Mallotus peltatus*
25	*Canarium littorale* f. *rufum*	61	*Sapium baccatum*
26	*Dacryodes rubiginosa*	62	*Sauroupus suberosus*
27	*Dacryodes rugosa*	63	*Trigonostemon villosa*
28	*Lophopetalum javanicum*	64	*Lithocarpus cantleyanus*
29	*Parastemon urophyllus*	65	*Casearia capitellata*
30	*Terminalia subspathulata*	66	*Homalium longifolium*
31	*Tetrameles nudiflora*	67	*Hydnocarpus castanea*
32	*Dipterocarpus costatus*	68	*Hydnocarpus curtisii*
33	*Dipterocarpus fagineus*	69	*Hydnocarpus filipes*
34	*Hopea ferrea*	70	*Osmelia maingayi*
35	*Hopea latifolia*	71	*Garcinia eugeniifolia*
36	*Parashorea stellata*	72	*Garcinia hambroniana*
73	*Garcinia nigroleniata*	119	*Ardisia pachysandra*
74	*Garcinia parvifolia*	120	*Maesa ramentacea*
75	*Kayea kunstleri*	121	*Syzygium cerasiforme*
76	*Mesua ferrea*	122	*Syzygium glaucum*
77	*Stemonurus malaccensis*	123	*Ochna integerrima*
78	*Cryptocarya ferrea*	124	*Galearia fulva*
79	*Cryptocarya rugulosa*	125	*Galearia maingayi*
80	*Litsea machilifolia*	126	*Xanthophyllum affine*
83	*Leea aequata*	127	*Xanthophyllum griffithii*
84	*Callerya artropurpurea*	128	*Prunus grisea*
85	*Cynometra malaccensis*	129	*Aidia densiflora*
86	*Saraca cauliflora*	130	*Diplospora malaccensis*
87	*Senna timoriensis*	131	*Ixora pendula*
88	*Duabanga grandiflora*	132	*Morinda elliptica*
89	*Lagerstroemia floribunda*	133	*Psydrax* sp. 7
90	*Lagerstroemia ovalifolia*	134	*Psydrax* sp. 8
91	*Memecylon caeraleum*	135	*Dimocarpus longan* ssp. *longan*
92	*Memecylon minutiflorum*	136	*Guioa bijuga*
93	*Aglaia affinis*	137	*Harpullia cupanioides*
94	*Aglaia argentea*	138	*Nephelium costatum*
95	*Aglaia simplicifolia*	139	*Nephelium lappaceum*
96	*Aglaia spectabilis*	140	*Paranephelium macrophyllum*
97	*Aphanamixis polystachya*	141	*Pometia pinnata*
98	*Chisocheton ceramicus*	142	*Xerospermum noronhianum*
99	*Chisocheton patens*	143	*Chrysophyllum roxburghii*
100	*Chukrasia tabularis*	144	*Palaquium hexandrum*
101	*Artocarpus dadah*	145	*Palaquium microphyllum*

102	*Ficus annulata*	146	*Eurycoma apiculata*
103	*Ficus aurata*	147	*Pterocymbium javanicum*
104	*Ficus fistulosa*	148	*Pterospermum javanicum*
105	*Ficus microcarpa*	149	*Pterospermum pectiniforme*
106	*Ficus oligodon*	150	*Pterygota alata*
107	*Ficus sundaica*	151	*Sterculia cordata*
108	*Ficus variegata*	152	*Sterculia gilva*
109	*Streblus elongatus*	153	*Sterculia parviflora*
110	*Streblus ilicifolius*	154	*Tetramerista glabra*
111	*Streblus macrophyllus*	155	*Colona merguensis*
112	*Streblus toxoides*	156	*Grewia viminea*
113	*Horsfieldia polyspherula*	157	*Pentace strychnoidea*
114	*Honsfieldia sucosa*	158	*Schoutenia accrescens*
115	*Horsfieldia tomentosa*	159	*Teijsmanniodendron coriaceum*
116	*Knema laurina*	160	*Vitex pinnata*
117	*Knema patentinervia*	161	*Vitex siamica*
118	*Ardisia crassa*		

CONCLUSION

This study reveals the differences in floristic variation pattern between limestone (Setul and Kubang Pasu) and granite habitats in PSP, suggesting that environmental gradients influence the floristic pattern. The soil properties such as organic matter, moisture, clay, silt, calcium and pH were among factors that strongly associated with limestone, while sand and available phosphorus were strongly correlated with Granite. Differences in the availability of mineral nutrient elements between the soils of granite and limestone may also contribute to the contrasting vegetation. Different habitats display varied spatial distributions among tree species in relation to soil properties. Identifying the key underlying gradients, abiotic conditions and major soil influences on 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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