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Association of Liana Communities with their Soil Properties in a Lowland Forest of Negeri Sembilan, Peninsular Malaysia

(Perhubungan Komuniti Liana dengan Ciri Tanah dalam Suatu Hutan Tanah Rendah di Negeri Sembilan, Semenanjung Malaysia)

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ABSTRACT

A study was conducted in a lowland forest at Pasoh Forest Reserve (FR), Negeri Sembilan, to determine the association between liana communities and its soil properties. Liana species inventory and soil samplings were carried out in 16 plots (40 m × 40 m each) established within the 50 ha permanent plot of Pasoh FR. All lianas with diameter at breast height (dbh) of 1 cm and above were measured, tagged and identified, whilst soil samples were analysed for texture, pH, base cations, available nutrients that include Mg, P and K, and inorganic nitrogen of ammonium-N and nitrate-N. The liana inventory recorded a total of 1628 individuals which comprised of 167 species and 65 genera from 31 families. The most speciose family was Annonaceae which was represented by 33 species, followed by Connaraceae and Leguminosae with 20 species and 19 species, respectively. Density-wise, the Leguminosae recorded the highest density of 41 stems/ha, whilst at species level, Byttneria maingayi *(Sterculiaceae) showed the highest density of 25 stems/ha. The most important species based on the highest important value (IV_i) was* Byttneria maingayi *with an IV_i of 7.5%. Soils analyses showed that the soil texture was dominated by clay, and the organic matter content was low with mean percentage of 3.98±0.21%. In general, the soils of the study site were acidic, whilst available nutrients were in the range of low to high concentrations. Canonical Correspondence Analysis (CCA) showed a low species-environment correlation with eigenvalues of the first and second axes of 0.178 and 0.154, respectively. Nevertheless, the CCA species ordination diagram shows that several liana species are closely associated with soil factors such as soil pH, inorganic nitrogen and available nutrients of Mg, K and P, thus indicates the role of soil factors in influencing floristic distribution patterns of vegetation communities in the forest habitats.*

Keywords: Edaphic factors; environmental gradient; florisitic pattern; species distribution; vegetation-environment relationships

ABSTRAK

Satu kajian telah dijalankan di Hutan Simpan Pasoh, Negeri Sembilan untuk menentukan hubungan antara komuniti liana dengan ciri-ciri tanah kawasan kajian. Inventori spesies liana dan pensampelan tanah telah dilakukan dalam 16 plot (40 m × 40 m setiap satu) dalam plot kekal 50 ha Hutan Simpan Pasoh. Semua liana yang berdiameter pada paras dada (dbh) 1 cm dan ke atas telah diukur, ditanda dan dicam, manakala sampel tanah dianalisis untuk menentukan tekstur, pH, kation bes, nutrien tersedia termasuk Mg, P dan K, dan nitrogen tak organik iaitu ammonium-N dan nitrat-N. Inventori liana merekodkan sejumlah 1628 individu yang mengandungi 167 spesies dan 65 genus daripada 31 famili. Annonaceae merupakan famili yang mempunyai bilangan spesies paling banyak diwakili 33 spesies, diikuti Connaraceae dan Leguminosae masing-masing dengan 20 spesies dan 19 spesies. Daripada segi kepadatan, Leguminosae merekodkan kepadatan tertinggi dengan 41 batang/ha, manakala pada peringkat spesies, Byttneria maingayi *(Sterculiaceae) menunjukkan kepadatan tertinggi sebanyak 25 batang/ha. Spesies paling penting berdasarkan nilai kepentingan tertinggi (IV_i) ialah* Byttneria maingayi *dengan nilai kepentingan 7.5%. Analisis tanah menunjukkan tekstur tanah didominasi oleh liat, dan kandungan bahan organik adalah rendah dengan min peratusan 3.98±0.21%. Secara umum, tanah di kawasan kajian adalah berasid, manakala nutrien tersedia mempunyai julat kepekatan rendah hingga tinggi. Analisis Kesepadanan Kanonikal (CCA) menunjukkan korelasi spesies-persekitaran yang rendah dengan nilai-nilai eigen paksi pertama dan kedua masing-masing ialah 0.178 dan 0.154. Bagaimanapun, rajah ordinasi CCA bagi spesies liana menunjukkan beberapa spesies liana adalah berkait rapat dengan faktor tanah seperti pH tanah, nitrogen tak organik dan nutrien tersedia seperti Mg, K dan P, dan ini menunjukkan peranan faktor tanah dalam mempengaruhi corak taburan flora bagi komuniti vegetasi dalam habitat-habitat hutan.*

Kata kunci: Corak flora; faktor edafik; kecerunan persekitaran; perhubungan vegetasi-persekitaran; taburan spesies

Introduction

Lianas that are also known as woody climbers are among groups of plants that are difficult to census and study due to their morphological characteristics. Researchers often face difficulties in identifying lianas because of the problems in locating and collecting leaves which are usually located at the top of the tree canopy. Nevertheless, the importance of liana communities in many aspects of forest dynamics has led many researches being conducted on this plant group over the last two decades (Perez-Salicrup et al. 2001; Putz & Mooney 1991; Schnitzer & Bongers 2002). The positive effects of lianas on the ecology and forest ecosystems are seen in the important role they play in creating niches for pioneer tree species, providing valuable habitats and connections among tree canopies that enable arboreal animals to traverse the treetops as well as providing an important food source for animals (DeWalt et al. 2000; Schnitzer et al. 2000; Schnitzer & Carson 2001). In terms of negative effects on the ecology and forest ecosystem, lianas are considered as plants of low macro-economic importance (Parren 2003). Lianas negatively affect tree seedlings, saplings and adults by physical suppression by adding a considerable amount of weight that the trees must bear and also by shading the canopy of the trees (Bertault et al. 1993; Neil 1984; Schnitzer et al. 2000). Due to this, lianas are considered as structural parasites on other plants (Stevens 1987).

In Malaysia, several studies on this plant group have been conducted either in Peninsular Malaysia or Sabah and Sarawak, which focused mainly on their abundance and climbing habits in primary and logged over forests (Appanah et al. 1993; Appanah & Putz 1984; Putz et al. 1984; Putz 1985), to understand their role and impact on forest management. Another study by De Walt et al. (2006) looked on liana habitat association and community structure in Sepilok, Sabah. Nevertheless, little is known on the ecological factors that associate liana distribution in the Peninsular Malaysian lowland forest. Studies on ecological factors that influence the liana abundance are much needed to understand their distribution patterns and role in the forest ecosystems. As such, in this paper we report results on the association of liana communities with their soil properties in a lowland forest at Pasoh Forest Reserve, Negeri Sembilan, Malaysia. The result from this study is anticipated to provide significant information to the management authorities for conservation and managing this plant group in the Malaysian tropical rain forest.

Material and Methods

Study Area

The study area was an old-growth lowland dipterocarp forest at the Pasoh Forest Reserve, Negeri Sembilan (latitude 2˚59'N, longitude 102°18'E), which is located in the state of Negeri Sembilan, about 70 km southeast of Kuala Lumpur (Figure 1). The total area of Pasoh FR is 2450 ha, whereby the main part of the reserve consists of lowland dipterocarp forest of the Keruing-Meranti type, with a core area of about 600 ha of undisturbed forest surrounded by a buffer zone of regenerating logged-over lowland forest (Kochummen et al. 1990; Manokaran & Kochummen 1990). In the undisturbed primary forest, a 50 ha (500 m × 1000 m) permanent research plot was established between 1985 and 1988 by the Forest Research Institute of Malaysia (FRIM) in collaboration with the Smithsonian Tropical Research Institute, to monitor long term changes in a primary forest. Background and details on the construction of the plots were described in Abdul Rahim et al. (2004). Pasoh FR generally receives relatively high mean annual rainfall of 1733 mm, while the mean monthly temperature is 24.5°C for 2003-2005 (Konishi et al. 2006). The soil series of the study area is Bungor-Malacca Association (data provided by the Malaysian Soil Science Division), which develops mainly from shale, granite and fliviatile granite alluvium parent materials (Allbrook 1973). The topography consists mainly of flat alluvial areas, with smaller expanses of swales, riverine areas, and gently rolling hills with slopes of between 3° and 10° (Okuda et al. 2003).

Plots Establishment and Liana Census

Sixteen plots of 40 × 40 m^2 each (total 2.56 ha) were established randomly within the 50 ha permanent plot of Pasoh FR, with locations of the study plots representing all soil types within the 50 ha plot, i.e. dry alluvial, wet alluvial, shale and laterite (Figure 2). In these plots, all lianas with diameter of 1.0 cm and above were enumerated, tagged and identified. Enumeration of lianas was quite challenging as their stems exhibit a great diversity of morphologies which require a more flexible measuring technique than that for trees. Thus, the point of diameter measurement followed methodologies suggested by Schnitzer et al. (2006). Leaves specimens of each measured liana individual were collected for species identification. The Orang Asli (aborigines) who are good at climbing and locating the liana leaves was employed used to collect the leaves specimens. The identification of the specimens was made possible using keys in the *Tree Flora of Malaya* (Ng 1978; 1989; Whitmore 1972, 1973), *Malesian Seed Plants* (van Balgooy 1997) and with the assistance of experienced botanists.

Soil Analysis

In all 16 study plots, five topsoil samples from 0-20 cm depth were taken at four corners and one in the middle of the plots. The five samples were then bulked together to represent soil sample of each study plot. Particle size distribution was determined using the pipette method together with dry sieving (Abdulla 1966). Texture of soil was obtained by plotting the sand, silt and clay content in the triangle of the texture. Organic matter (OM) content was determined by loss-on-ignition method, igniting soils for 16 h at 400° C (Avery & Bascomb 1982). Chemical properties such as pH and nutrient contents were analysed using method as described by Wan Rasidah et al. (1989, 1990). The soil pH was measured using pH meter in soil: water ratio of 1.0: 2.5. Soils were extracted with 1 M potassium chloride (KCl) for exchangeable acidic cations (Al^{3+} and H^{+}), which were determined by titration. As for exchangeable base cations (K^{+}, Na^{+}, Ca^{2+} and Mg^{2+}), the soil sample were extracted in 1 M ammonium acetate, the extract was then determine by flame atomic absorption spectrophotometer (FAAS).

Available macronutrients and micronutrients in the soil were extracted using 1 M ammonium acetate-acetic acid. The extract was run under the ultraviolet (UV) spectrophotometer for the determination of phosphorus (P), while the availability of potassium (K) and magnesium (Mg) in the extracts was determined using the atomic absorption spectrophotometer (AAS).

DATA ANALYSIS

All lianas enumerated in the plots were summarized for overall floristic composition and abundance, which include determination of liana density and basal area (BA). The species importance value (IV_i) determines the most important species in the liana community, whereby the IV_i was calculated as follows: $IV_i = ((R_d + R_b + R_f)/3)x100$, where R_d is relative density, R_b is relative dominance (based on basal area), and R_f is relative frequency of occurrence of each species (Brower et al. 1997).

Association of liana communities with the measured soil variables were analysed using canonical correspondence analysis (CCA) (Ter Braak & Prentice 1988; Ter Braak 1992) which was performed using CANOCO version 4.0 (Ter Braak & Smilauer 1998). Species with only one to three entries in the data matrix were deleted to increase the definition of the results. Altogether, there were 167 liana species encountered in all 16 plots, and after the deletion, only 78 species were involved in the CCA. The abundance data of liana species were used in the analysis, whilst the soil variables that involved in the CCA were soil pH, organic matter content (OM), phosphorus (P) content, potassium (K) content, magnesium (Mg), nitrate-N, ammonium-N and total cation exchange capacity (CEC). We have limited the number of soil variables involved in the CCA to eight variables, to avoid overlapping in the ordination diagram that would create difficulty in visualizing the diagram. The significance of each edaphic variable in determining the species compositional changes was assessed through a Monte Carlo permutation test based on 99 random trials at a 0.05 significance level (Ter Braak 1990).

RESULTS AND DISCUSSION

LIANA FLORISTIC COMPOSITION AND ABUNDANCE

A total of 1628 liana individuals with diameter at breast height (dbh) of 1.0 cm and above were enumerated in all 16 study plots at the Pasoh FR, Negeri Sembilan. Floristic composition of the lianas comprises of 167 species in 65 genera and 31 families (Table 1). Comparing the liana floristic composition in this study with other similar studies that were carried out in the Malaysian rainforests, Appanah et al. (1993) reported 57 liana species at Genting Highlands, Pahang, whilst Putz and Chai (1987) recorded 79 liana species at the Lambir National Park, Sarawak. In addition, De Walt et al. (2006) recorded 107 species in 32 families and 67 genera at Sepilok, Sabah. These results illustrate that different forest habitats contained different floristic compositions of liana communities.

From Table 1, the most speciose family was Annonaceae with 33 species, followed by Connaraceae and Leguminosae that contained 20 species and 19 species, respectively. Early works on lianas at Pasoh FR also reported Annonaceae as the most speciose family of liana communities (Appanah et al. 1993; Gardette 1996). Annonaceae was also reported as one of the dominant liana family in Asia (Appanah et al. 1993). In terms of genera, the Annonaceae indicated the highest number with nine genera, followed by Leguminosae with seven genera and Rubiaceae with six genera (Table 1). Generally, most species that were encountered are common, and distributed in various forest habitats of Peninsular Malaysia (Turner 1995). In addition, there were two families that were represented with only one species and one individual in the study plots, namely, Rutaceae and Smilacaceae; with the least number of species and individuals, these two families are considered as the most uncommon families within the study plots.

Density-wise, the total liana density per hectare in the study plot was 636 stems/ha. At family level, the highest density was shown by Leguminosae which was represented with 104 stems/ha, accounting for about 16% of the total density (Table 2). Connaraceae and Annonaceae were the second and third most dense families accounting for 96 stems/ha (15%) and 74 stems/ha (12%), respectively. Species wise, *Byttneria maingayi* (Sterculiaceae) showed the highest density of 64 stems/ha (4%), followed by *Combretum nigrescens* and *Caesalpinia parviflora* with 51 stems/ha (3%) and 33 stems/ha (2%), respectively. Total basal area (BA) of all liana individuals within the study plots was 4.20 m^2, which reflects BA per hectare of 1.64 m^2/ha. The highest basal area was also dominated by the Leguminosae of 0.41 m^2/ha, followed by Connaraceae and Sterculiaceae with both of them showed the BA of 0.18 m^2/ha (Table 2). As for species, *Byttneria maingayi* (Sterculiaceae) showed the highest BA of 0.18 m^2/ha, followed by *Caesalpinia parviflora* (0.15 m^2/ha) and *Combretum nigrescens* (0.10 m^2/ha). With high density and basal area indicated by *B. maingayi*, hence the species was expected to be the most important species with IV_i of 7.5%, while the most important family was Leguminosae with IV_i of 18.5% (Table 2). As a comparison with other liana studies in different forest ecosystems, in a lowland forest of Panama, the total BA of lianas was 98.15 m^2/ha (De Walt et al. 2000) whereby the highest BA at family level was recorded by Hippocrateaceae of 23.73 m^2/ha.

TABLE 1. Number of genera and species for all families present in all study plots at Pasoh FR, Negeri Sembilan

No	Family	No. of genera	No. of species	No. of individuals
1	Ancistocladaceae	1	1	17
2	Annonaceae	9	33	193
3	Apocynaceae	5	14	100
4	Araceae	1	1	3
5	Celastraceae	2	6	66
6	Combretaceae	1	3	140
7	Connaraceae	4	20	245
8	Convolvulaceae	2	6	18
9	Dillieniaceae	1	4	57
10	Euphorbiaceae	1	1	4
11	Gentiaceae	1	1	2
12	Gnetaceae	1	6	42
13	Icacinaceae	1	1	3
14	Leguminosae	7	19	267
15	Linaceae	1	1	10
16	Loganiaceae	1	8	44
17	Malphigiaceae	1	2	6
18	Melastomataceae	1	2	4
19	Menispermaceae	4	6	23
20	Moraceae	1	1	6
21	Myrsinaceae	1	1	8
22	Olacaceae	1	2	8
23	Rhamnaceae	2	5	30
24	Rubiaceae	6	11	94
25	Rutaceae	1	1	1
26	Smilacaceae	1	1	1
27	Sterculiaceae	1	1	167
28	Thymeliaceae	1	1	10
29	Tiliaceae	1	1	3
30	Verbenaceae	2	5	45
31	Vitaceae	2	2	11
	Total	65	167	1628

Moreover, Mascaro et al. (2004) reported the mean total BA of lianas in a wet tropical forest of La Selva, Costa Rica was 78.74 m^2/ha, thus the comparison clearly indicates that the BA of liana in this study is far lower than those described in the respected areas.

GENERAL SOIL CHARACTERISTICS

The analyses of particle size indicate that the soils of the study area were dominated by clay texture whereby seven out of the 16 plots showed this soil texture. In terms of organic matter content, the soil in the study area indicates mean percentage organic matter of 3.98±0.21% (Table 3), which indicates low organic matter content. This was also confirmed by Yamashita and Takeda (2003) in their analysis of the soils at Pasoh FR where the organic matter content was as low as 3.56%. The low organic matter content in the soil of tropical rainforests is because of high decomposition rate of the organic matter, whereby high temperature and moisture in the tropics enable microorganisms to decompose organic residues at a high rate (Longman & Jenik 1987).

The mean soil pH of 3.44 ± 0.06 indicates an acidic condition of the soils in the study plots. The acidic soil found in the study plots is typical of soil pH in tropical rain forests of Peninsular Malaysia with pH between 3.5 to

TABLE 2. Summary of tree density, basal area (BA) and Importance Value (IVi) of five leading families and species of liana communities in study plots at Pasoh Forest Reserve, Negeri Sembilan

	Family		Species	
		stems/ha		stems/ha
Density	Leguminosae	104	*Byttneria maingayi*	64
	Connaraceae	96	*Combretum nigrescens*	51
	Annonaceae	74	*Caesalpinia parviflora*	33
	Sterculiaceae	64	*Agelaea borneensis*	21
	Combretaceae	54	*Bauhinia bidentata*	21
		m^2/ha		m^2/ha
Basal Area	Leguminosae	0.41	*Byttneria maingayi*	0.18
	Connaraceae	0.18	*Caesalpinia parviflora*	0.15
	Sterculiaceae	0.18	*Combretum nigrescens*	0.10
	Annonaceae	0.15	*Bauhinia bidentata*	0.08
	Rubiaceae	0.13	*Rourea minor*	0.05
		%		%
Importance Value (IV_i)	Leguminosae	18.5	*Byttneria maingayi*	7.5
	Connaraceae	14.4	*Caesalpinia parviflora*	5.6
	Annonaceae	12.2	*Combretum nigrescens*	5.2
	Sterculiaceae	7.5	*Bauhinia bidentata*	3.2
	Rubiaceae	6.8	*Rourea minor*	2.6

TABLE 3. Summary of soil data in all study plots at Pasoh FR, Negeri Sembilan

Soil Parameter	Mean Value ± s.e
pH	3.44 ± 0.06
Organic matter content (%)	3.98 ± 0.21
Exchangeable cations	(meq/100 g)
H^+	0.61 ± 0.03
Al^{3+}	1.09 ± 0.12
Ca^{2+}	1.37 ± 0.05
Mg^{2+}	0.54 ± 0.02
Na^+	1.84 ± 0.04
K^+	4.03 ± 0.14
Cation exchange capacity (CEC)	9.48 ± 0.40
Available nutrients	(μg/g)
Phosphorus (P)	6.81 ± 0.36
Nitrate-N (NO_3-N)	5.08 ± 0.45
Ammonium-N (NH_4-N)	3.50 ± 0.32
Magnesium (Mg)	36.99 ± 2.35
Potassium (K)	801.6 ± 20.4

5.5 (Othman & Shamsuddin 1982). This common scenario in the wet tropical regions has resulted soil becoming so weathered and leached (Lal & Greenland 1979) whereby base cations are leached by H^+ and Al^{3+} ions that caused the high acidity in the soil. In earlier study, Yamashita and Takeda (2003) reported the soil pH at Pasoh FR was in the range of 3.9 – 4.8, whilst Wan Juliana (2001) noted that the analysis of parent material groups at Pasoh FR showed that the soil pH was lower in shale soils, followed by those derived from laterized shale while the alluvial soils were the least acidic.

The cation exchange capacity (CEC) in this study showed mean value of 9.48 ± 0.40 meq/100 g (Table 3). A lower amount of CEC was found by Wan Juliana (2001) where the CEC for soils of Gajah Mati and Terap series in Pasoh FR was 5.42 meq/100 g and 5.00 meq/100 g respectively. In Table 3, the mean value of available phosphorus (P), magnesium (Mg) and potassium (K) were 6.81±0.36, 36.99±2.35 and 801.6±20.4 µg/g, respectively. Othman and Shamsuddin (1982) stated that high concentration of phosphorus in the soil is related to high content of organic matter in the soil. On the other hand, Friesen et al. (1980) stated that phosphorus concentration is also influenced by the soil pH, whereby the phosphorus concentration decreases with the increase of soil acidity. Inorganic nitrogen element in the form of nitrate-N (NO_3-N) and ammonium-N (NH_4-N), which are among important macronutrients for plant growth, were also determined of which the NO_3-N and NH_4-N concentrations were 5.08±0.45, 3.50±0.32, respectively. Similar to phosphorus, the concentration of these two forms of nitrogen element in the soil is also influenced by pH of the soil (Runge 1983). A previous study by Yamashita et al. (2003) reported the inorganic N pool in Pasoh FR ranged from 1.4 to 5.5 µg/g for ammonium-N (NH_4-N) and from 12.2 to 19.3 µg/g for nitrate-N (NO_3-N).

ASSOCIATION OF LIANA COMMUNITIES WITH SOIL VARIABLES

The canonical correspondence analysis (CCA) of the vegetation and environmental data is summarized in Table 4; the CCA output indicates that the species environment correlations were low of which eigenvalus (a measure of the strength of an axis or the amount of variation along an axis) were 0.181 for the first axis and 0.153 for the second axis. The cumulative variation explained by the first three axes of the species-environment relationship in the CCA was 53.0%. From the Monte Carlo permutation test, there was significant difference between the eigenvalues for the three ordination axes ($p = 0.002$). The sample ordination by CCA on the 16 study plots is shown in Figure 3. The direction and length of arrows radiating from the centre of the ordination diagram indicate the direction and strength respectively between plots and soil variables. From Figure 3, the plots were reasonably separated floristically in the ordination space of the first two canonical axes, where it is apparent that the plots that are floristically similar are close to each other. Further, the figure also illustrates the influence of the soil variables on canonical axes whereby vectors indicate not only the direction but also the magnitude of influence of each variable. From the diagram, it is apparent that the soil variables varied between each plot as they were clearly separated, and this indicates that there was a soil gradient in relation to liana composition in different plots. A strong influence of the vectors can be seen for three plots, of which Plot 2 was strongly influenced by NO_3-N, plot 5 by NH_4-N and plot 14 by pH factor. However, most of the other study plots did not show clear association to soil variables vectors. The CCA ordination clearly shows how plots that are located adjacent to each other within the similar soil type (see Figure 2) are floristically similar as they are positioned close to each other as displayed in the ordination diagram. For instance, plots 4, 8, 9 and 10 which are within the laterite soil type are clumped together indicating close similarity in terms of its floristic composition and abundance. Nonetheless, if the study plots are located farther away from each other within the same soil type, for example plots 1, 2, 11 and 13 of dry alluvial soil type, the ordination displays that the sample points are separated from each other very clearly, thus inferring that within the same soil type, there might also be soil gradient that influences the floristic composition between the study plots. This scenario has been observed on tree communities at the National Park, Merapoh, whereby within a one-hectare plot, tree floristic composition was varied between selected subplots which

TABLE 4. Summary of the CCA of the vegetation and environment data of 16 study plots at Pasoh FR, Negeri Sembilan

Axes		1	2	3	4	Total inertia
Eigenvalues	:	0.181	0.153	0.122	0.097	1.429
Species-environment correlations	:	0.975	0.986	0.956	0.961	
Cumulative percentage variance						
of species data	:	12.6	23.4	31.9	38.7	
of species environment	:	21.0	38.8	53.0	64.2	
Sum of all eigenvalues						1.429
Sum of all canonical eigenvalues						0.861

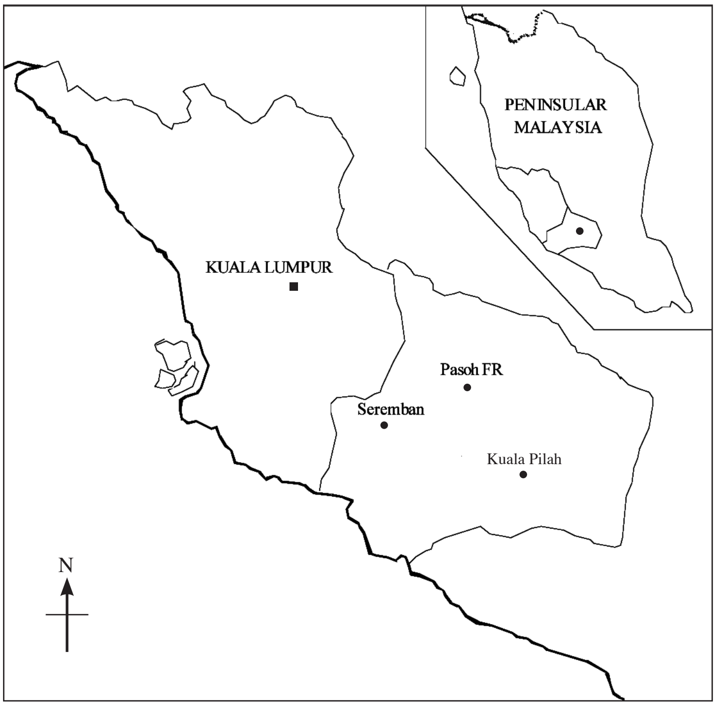

FIGURE 1. Location of Pasoh FR in the state of Negeri Sembilan, Peninsular Malaysia

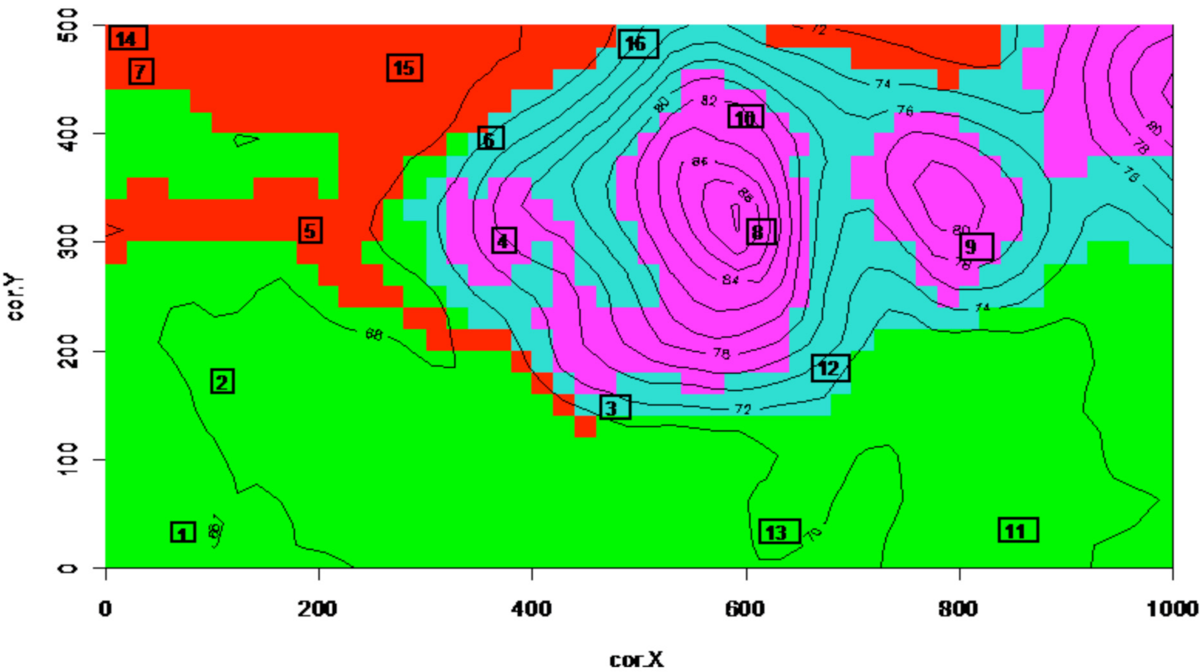

FIGURE 2. The position of 16 plots of 40 m × 40 m demarcated in the 50-ha plot at Pasoh FR. Dimensions are in metres and North is facing upward direction. The colour code indicates soil types: Red=Wet Alluvial (Plots 5, 7, 14, 15); Green=Dry Alluvial (Plots 1, 2, 11, 13); Turqoise=Shale (Plots 3, 6, 12, 16); and Magenta=Laterite (Plots 4, 8, 9, 10) (Source: Soil Survey Staff 1998)

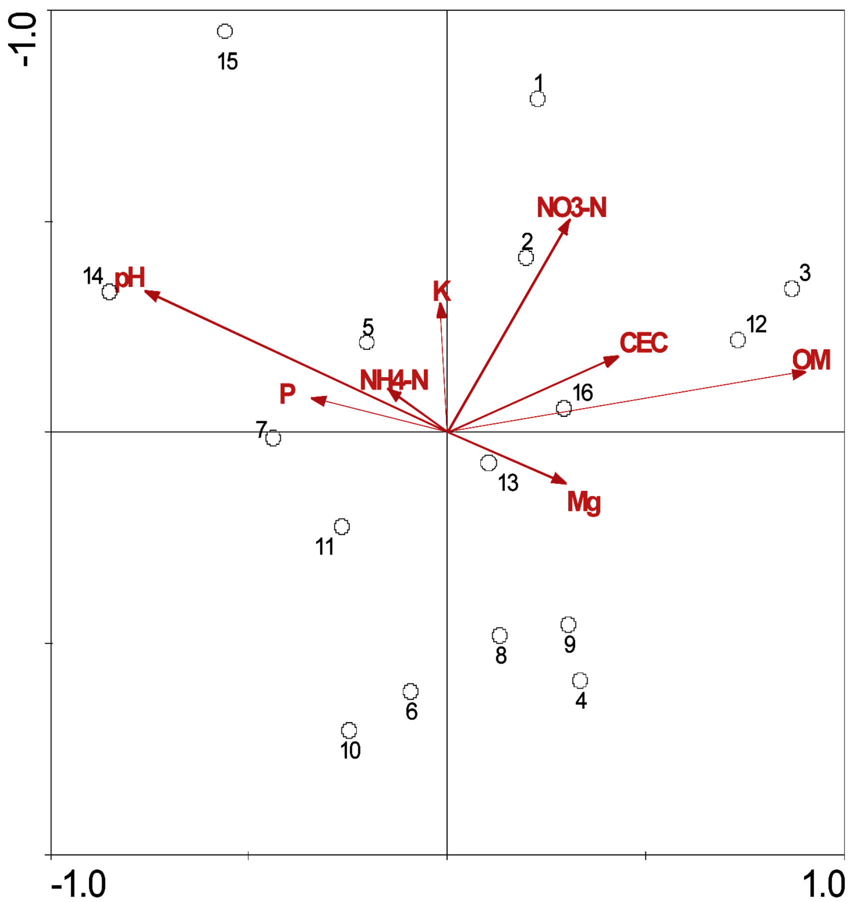

FIGURE 3. Canonical correspondence analysis (CCA) ordination plot showing the approximate locations of sample plots and locations, lengths and directions of soil variables. Plots 1, 2, 11, 13 = Dry Alluvial; Plots 5, 7, 14, 15 = Wet Alluvial; Plots 3, 6, 12, 16 = Shale; Plots 4, 8, 9, 10 = Laterite. Legend: pH= soil pH; Mg = available Mg; P= available P (phosphorus); OM = organic matter content; CEC= total cation exchange capacity; K= available K (potassium); NH_4-N= ammonium-N and NO_3-N= nitrate-N

was associated with the gradient of soil properties in the plot (Nizam et al. 2006).

The CCA species ordination diagram (Figure 4) illustrates the liana species distribution pattern in relation to soil variables whereby each number on the points represents the species that are listed in Table 5. Although there is no clear pattern can be observed from Figure 4, the ordination diagram indicates some formation of cluster associated with specific soil variables. There were several liana species that were distributed along the pH gradient such as *Bauhinia praesignis* (10), *Uvaria hirsuta* (72) and *Salacia vimenia* (55) which are shown in the upper left of the diagram, indicating the occurrence of these species to the acidic habitats. Subsequently, *Cyathostemma hookeri* (22), *Agelaea macrophylla* (2) and *Cnestis palala* (14) were distributed along the NH_4-N gradient, while *Ancistrocladus tectorius* (5), *Willughbeia oblonga* (78) and *W. angustifolia* (76) were closely associated with NO_3-N gradient. The diagram also indicates that several liana species were apparently distributed along the gradient of macronutrients of phosphorus (P), potassium (K) and magnesium (Mg). A clump of liana species that were associated with Mg includes *Spatholobus maingayi* (58), *S. macropterus* (57), *Byttneria maingayi* (11), *Erycibe tomentosa* var. *tomentosa* (30), *Uncaria attenuata* (69), *Desmos dumosus* (26), *Connarus planchionanus* (18) and *Uvaria pauci-ovulata* (73). As for potassium (K) gradient, three liana species, i.e. *Sphenodesma petandra* (59), *Tetracera fagifolia* (65) and *Enkleia malaccensis* (29) were seen to have a close association with this gradient, while three other liana species, i.e. *Loeseneriella pauciflora* (40), *Connarus monocarpos* (17) and *Premna integifolia* (47) were distributed closely with phosphorus gradient.

Remco et al. (1998) had demonstrated the association between liana species to soil variables in South Island New Zealand, where five lianas species (*Clematis vitalba*, *Lonicera japonica*, *Passiflora mollissima*, *Rubus fruticosus* and *Senecio mikanioides*) favoured mainly soil with higher pH. Besides, De Walt et al. (2006) observed a cluster of liana species that included *Agelaea trinervis, Caesalpinia parviflora*, *Combretum nigrescens*, *Spatholobus oblongifolius* and *Strychnos ignatii* favouring alluvial soils which contained high total nitrogen, phosphorus and nitrate in Sepilok, Sabah. As a comparison to tree communities, several studies reported the influence of soil properties on tree community structure in various forests (e.g. Ashton

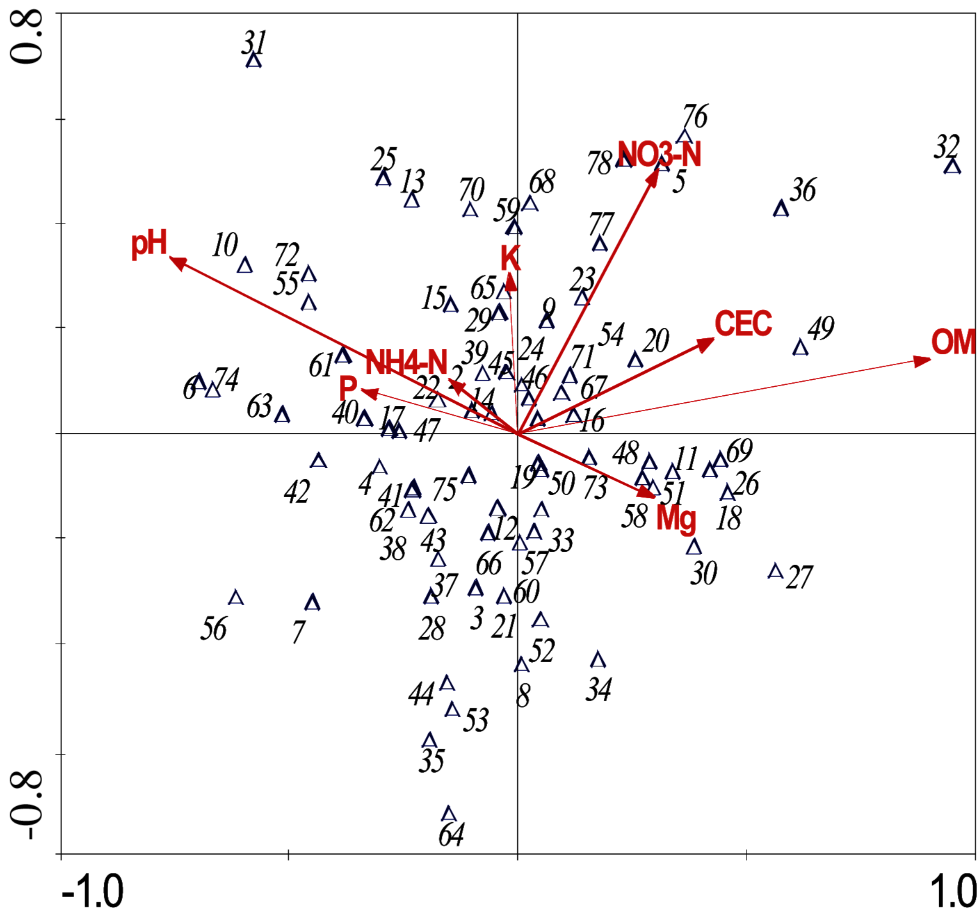

FIGURE 4. Canonical correspondence analysis (CCA) biplot of species and soil variables showing the species occurrence in relation to the soil variables. List of species and their numbers as in Table 5. Legend: pH= soil pH; Mg = available Mg; P= available P (phosphorus); OM = organic matter content; CEC= total cations exchange capacity; K= available K (potassium); NH_4-N= ammonium-N and NO_3-N= nitrate-N

TABLE 5. List of liana species and its number for the CCA ordination diagram in Figure 4

No.	Species	No.	Species
1	*Agelaea borneensis*	40	*Loeseneriella pauciflora*
2	*Agelaea macrophylla*	41	*Milletia erianthea*
3	*Agelaea trinervis*	42	*Milletia sericea*
4	*Nothocissus spicifera*	43	*Mitrella kentii*
5	*Ancistrocladus tectorius*	44	*Olax imbricata*
6	*Arcagelisia flava*	45	*Oxyceros curtisii*
7	*Artabotrys crassifolius*	46	*Parameria polyneura*
8	*Artabotrys grandifolius*	47	*Premna integifolia*
9	*Bauhinia bidentata*	48	*Rourea emarginata*
10	*Bauhinia praesignis*	49	*Rourea mimusoides*
11	*Byttneria maingayi*	50	*Rourea minor*
12	*Caesalpinia parviflora*	51	*Rourea rugosa*
13	*Canthium horridum*	52	*Salacia grandiflora*
14	*Cnestis palala*	53	*Salacia macrophylla*

cont.

continue Table 5.

15	*Combretum nigrescens*	54	*Salacia maingayi*
16	*Connarus ferrugineus*	55	*Salacia vimenia*
17	*Connarus monocarpus*	56	*Spatholobus gyrocarpus*
18	*Connarus planchionanus*	57	*Spatholobus macropterus*
19	*Connarus semidecrandus*	58	*Spatholobus maingayi*
20	*Connarus villosus*	59	*Sphenodesme petandra*
21	*Coptosapelta flavescens*	60	*Sphenodesme racemosa*
22	*Cyathostemma hookeri*	61	*Strychnos flavescens*
23	*Cyathostemma viridiflorum*	62	*Strychnos ignatii*
24	*Dalbergia rostrata*	63	*Strychnos septemnervis*
25	*Derris malacensis*	64	*Tetracera akara*
26	*Desmos dumosus*	65	*Tetracera fagifolia*
27	*Desmos dunalii*	66	*Tetracera macrophylla*
28	*Embelia lampinii*	67	*Tetracera maingayi*
29	*Enkleia malaccensis*	68	*Tinomiscium petiolare*
30	*Erycibe tomentosa var. tomentosa*	69	*Uncaria attenuata*
31	*Fagerlindia fasciculata*	70	*Uncaria sclerophylla*
32	*Ficus* sp.	71	*Urceola lucida*
33	*Fissistigma fulgens*	72	*Uvaria hissata*
34	*Fissistigma lanuginosum*	73	*Uvaria pauci-ovulata*
35	*Fissistigma manubriatum*	74	*Ventilago malacensis*
36	*Friesodelsia biglandulosa*	75	*Ventilago oblongifolia*
37	*Gnetum latifolium*	76	*Willughbeia angustifolia*
38	*Gynocthodes coriacea*	77	*Willughbeia coriacea*
39	*Indrarouchera griffthiana*	78	*Willughbeia oblonga*

1976; Clark et al. 1998; Nizam et al. 2006). In Pasoh FR, Davies et al. (2003) observed that tree floristic composition and stand structure across the 50-ha plot varied in relation to edaphic and topographic factors. Prior to this, Newbery et al. (1996) stated that in dipterocarp forest (and other rain forest types), topographic variation is considerably more important than soil chemistry in relation to tree species distribution. Nonetheless, the environmental gradient in particular the soil gradient plays an important role in influencing the distribution of vegetation communities of a particular forest ecosystem.

Conclusion

The study demonstrated that there were associations of liana species with soil variables. It showed that soil factors have an important influence on the distribution patterns of liana communities at Pasoh FR. The ecological information on liana communities as exemplified in this study is hoped to provide a better understanding of the characteristic elements on vegetation distribution of the lowland forests. Moreover, understanding the relationships between ecological variables and distribution of lianas communities may enhance the chance in conserving and managing the lianas in the forest ecosystems in the future.

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