EDAPHIC INFLUENCES ON TREE SPECIES COMPOSITION AND COMMUNITY STRUCTURE IN A TROPICAL WATERSHED FOREST IN PENINSULAR MALAYSIA

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KHAIRIL M, WAN JULIANA WA & NIZAM MS. 2014. Edaphic influences on tree species composition and community structure in a tropical watershed forest in Peninsular Malaysia. A study was conducted to determine tree species composition and community structure, and their relationships with edaphic factors at a watershed forest in Tasik Chini, Peninsular Malaysia. Thirty plots of 0.1 ha were established with a total sampling area of 1.4 ha in inland forest, 0.9 ha in seasonal flood forest and 0.7 ha in riverine forest. A total of 3974 trees with diameter at breast height (dbh) ≥ 5.0 cm were recorded. The inland forest recorded 2061 individuals representing 393 species from 164 genera and 57 families; the seasonal flood forest had 1019 individuals representing 268 species from 137 genera and 57 families; and the riverine forest had 894 individuals representing 260 species from 137 genera and 53 families. *Endospermum diadenum* (Euphorbiaceae) was the most important species in the inland forest with importance value index (SIV_i) of 3.36%, *Streblus elongatus* (Moraceae) in the seasonal flood forest with SIV_i of 4.43% and *Aporusa arborea* (Euphorbiaceae) in the riverine forest with SIV_i of 2.96%. The pH values of all three types of forest soils were acidic, with readings between 4.0 and 4.1. The highest average organic matter was in the inland forest (9.30%), followed by the riverine forest (8.49%) and seasonal flood forest (7.84%). The highest available P and K were in the riverine forest with values of 14.27 ± 1.23 and 175.88 ± 27.95 meq/100 g respectively. Ordinations using canonical correspondence analysis showed that the relationships between tree community and soil properties were weakly associated ($p > 0.05$). However, there were some species that were highly correlated with soil chemical characteristics and organic matter content.

Keywords: Vegetation–environment relationship, Chini Lake, tree species diversity, canonical correspondence analysis (CCA)

INTRODUCTION

Plant associations with environmental factors have been reported in many studies (Teixiera et al. 2008, Rahayu et al. 2012). The abundance of plants is closely related to soil status of an area as soil provides nutrients needed by plants to grow (Rahayu et al. 2012). Relationships between soil properties and plant species abundance have been described in various habitats of grassland (Amorim & Batalha 2007), savanna communities (Barruch 2005) as well as tropical rainforests (Slik et al. 2010, Rahayu et al. 2012). For example, physico–chemical characteristics of soil and topography influence the growth of *Dryobalanops aromatica* and *D. lanceolata* in Sarawak (Hirai et al. 1995). The physico–chemical characteristics of soil also influence the rates of seed and fruit production of these species (Hirai et al. 1995). Edaphic factors seem to have a role in the formation of reserve nutrients for determining the distribution of Dipterocarpaceae in Sarawak (Baillie et al. 1987). The dipterocarp community in Brunei Darussalam, north-west Borneo was found to be associated with soil nutrient concentrations, soil water availability and environmental variables (Rahayu et al. 2012). Variations in soil nutrient concentrations, particularly P, Mg, Ca and K, have been credited as major drivers of habitat associations displayed by Bornean Dipterocarp tree species (Paoli et al. 2008). A study conducted in the National Park at Merapoh, Pahang in Peninsular Malaysia found that floristic composition patterns were highly correlated with edaphic variables as revealed by canonical correspondence analysis (Nizam et al. 2006). The soil pH, inorganic-N and P appeared to be the principal environmental determinants of tree communities. Different soil types in the 50 ha plot in Pasoh Forest Reserve, Peninsular Malaysia was reported to supply different amounts of nutrients for plant growth and P was the main limiting nutrient (Wan Juliana et al. 2009). In their study at Tekam Forest Reserve and Pasoh Forest Reserve in Peninsular Malaysia, Amir and Mona (1990) reported that the distribution and abundance of legumes such as *Koompassia* sp. were highly correlated with chemical properties of soil where they absorbed more N, K, Mg and Zn.

Many comparative studies on floristic patterns of riparian and inland forests in a tropical watershed forest of Peninsular Malaysia were conducted by Fajariah (2004), Foo (2005), Siti Najmi (2005), Norwahidah and Wan Juliana (2009) as well as Khairil et al. (2011). Most of these studies found that the diversity of inland forest was slightly higher than riparian forest. However, there have been no studies to determine patterns of tree species abundance and their relationship with physico–chemical characteristics of soils in a watershed area in Peninsular Malaysia. Thus, this study was aimed at determining the associations between tree species abundance and edaphic factors especially soil acidity in a watershed forest surrounding a natural freshwater lake at Chini, Pekan, Pahang in Peninsular Malaysia.

Based on Khairil et al. (2011), three types of forests, namely, inland, seasonal and riverine forests showed differences in terms of species composition and abundance. Most tropical areas have high soil acidity (Jansen et al. 2000, Metali et al. 2011). We expect soil acidity to be an important factor that determines tree species abundance in the Chini watershed, Pahang. Thus, parameters that contributed to soil acidity such as pH, cation exchange capacity (CEC), H^+, Al^{3+}, acidic and base cation exchange were taken into account besides available P (Wan Juliana et al. 2009), K (Baille et al. 1987) and organic matter (OM) (Nizam et al. 2006), which were well known factors influencing the distribution of plants. Data and information on tree species community, physico–chemical characteristics of soil as well as the relationship between tree species distribution and edaphic factors from this study are important and may be used as a guideline to future ecological research in wetland forest areas.

MATERIALS AND METHODS

Study plots and tree sampling

The Tasik Chini basin includes a lush tropical logged-over forest covering 4975 ha. Tasik Chini is connected to the longest watercourse in Peninsular Malaysia, Pahang River via Chini River which meanders for about 4.8 km (Mushrifah et al. 2005, 2009). There are three types of forests at the Chini watershed, namely, inland forest, seasonal flood forest and riverine forest.

The lake system comprises 12 open water bodies. Most of the area is at low altitude; almost 80% of the area is lower than 250 m above sea level (asl) except for Bukit Chini which has the highest peak of 641 m asl (Wetlands International Asia Pacific 1998).

Thirty plots of 50 m × 20 m each with a total area of 3 ha were established stratifically based on the coverage areas of each of the forest type within the Chini watershed (Figure 1). Fourteen plots were established in the inland forest, nine plots in the seasonal flood forest and seven plots in the riverine forest. The number of study plots differed between the forest types because there were some inaccessible areas especially in the seasonal flood and riverine forests. All plots were at the same altitude and the ranges were between 100 m and more than 200 m. The plots in the seasonal flood and riverine forests were approximately 5–10 m from the water bodies. All trees with diameter at breast height (dbh) of 5 cm and above were measured, identified, and leaf samples were collected and pressed. The specimens were identified using keys by Whitmore (1972, 1973) and Ng (1978, 1989) and by referring to voucher specimens at Universiti Kebangsaan Malaysia.

Soil analysis

Three soil samples were taken from each plot using an auger at depths between 0 and 15 cm. Each sample was about 500 g. The samples were then air dried. Roots, small stones and leaves were separated from the soil. Samples were then sieved through a 2 mm sieve, while lumpy soils were broken up using agate tools. The samples were analysed for physico–chemical characteristics, which include soil particle size distribution,

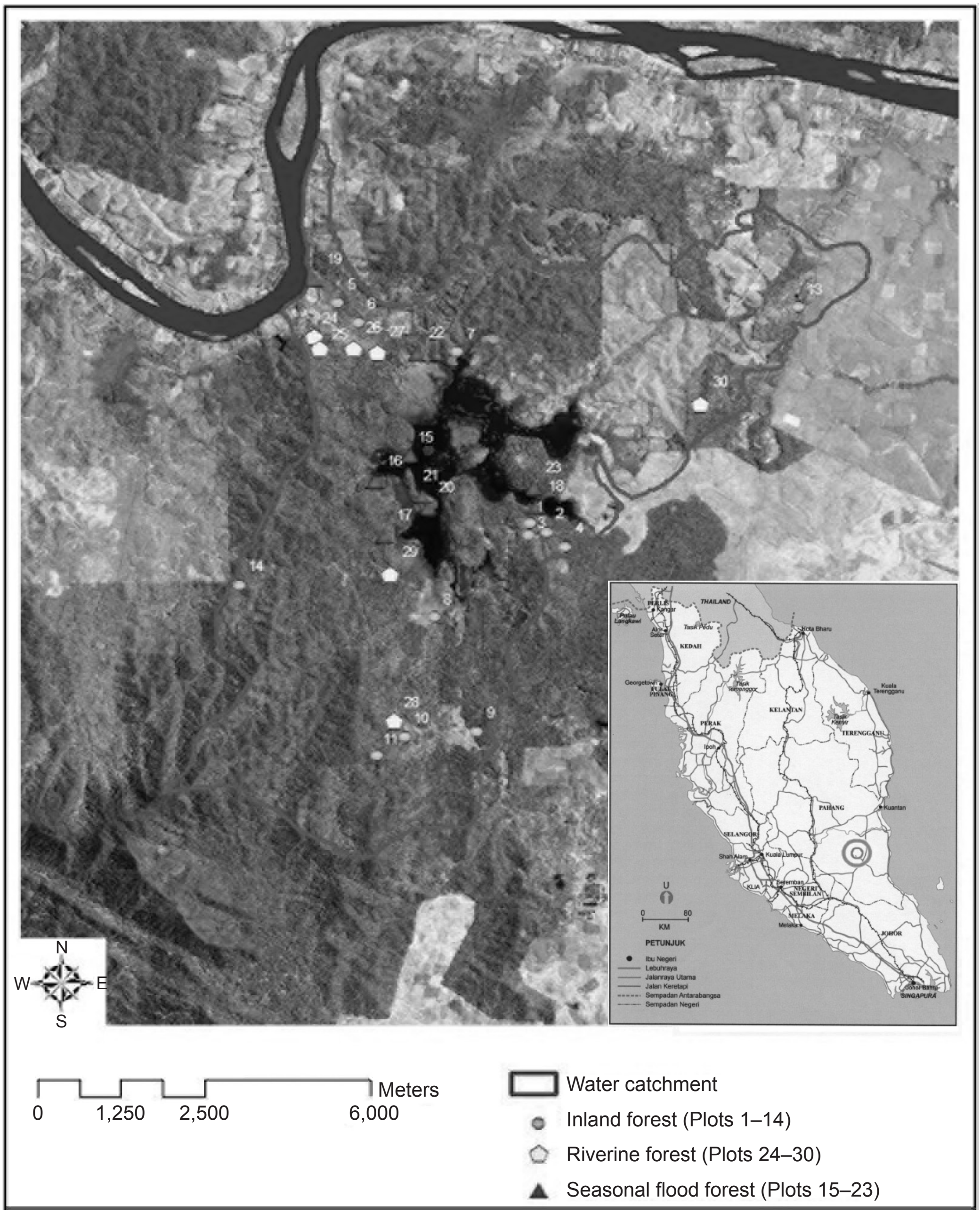

Figure 1 Thirty sampling plots at Chini watershed forest in Pahang; the location of Chini watershed is indicated by the red circle on the map of Peninsular Malaysia

OM content, exchangeable acid cation (Al^+ and H^+), exchangeable basic cation, CEC and electrical conductivity. Available nutrients that were determined include P, K and Mg. Organic matter content was determined by the loss using ignition technique (McLean 1967). The pH of the soil was determined using soil:water ratio of 1:2.5 (Mc Lean 1967, Shamshuddin 1981). The exchangeable acidic cations were measured in 1 M KCl by titration. Exchangeable basic cations were measured in 1 M ammonium acetate extract (Black 1967, Shamshuddin 1981) by atomic absorption spectrophotometry. Cation exchange capacity was obtained by summation of acid and basic cations. Electrical conductivity was determined using saturated gypsum extract (Rowell 1994). Available nutrients extracted using sulphuric acid were determined using flame atomic absorption spectrophotometer.

Data analysis

All trees from the plots were summarised for overall taxonomic composition and quantitative data were analysed to determine species abundance. These include determination of basal area (BA), as well as the density and frequency of occurrence of each species. Based on Brower et al. (1997), the frequency of occurrence indicates the number of subplots in which species occurs and is expressed as the proportion of the total number of samples taken that contains the species in question. As for BA, the parameter was calculated based on the equation from Husch et al. (1982):

$$BA = \frac{\pi}{4} \times D^2 \text{ cm}^2$$

where π = 3.1416 and D = dbh (cm)

To express the structure of a plant community, several characteristics that can be taken into consideration are species composition, species diversity and relative abundance. Parameters used to determine species abundance were density, dominance, frequency and importance value index (IV_i) at species and family levels (Brower et al. 1997). IV_i was calculated to determine species importance. IV_i was calculated by summing up values of relative density (RD), relative dominance (based on BA) (RB) and relative frequency (RF) of each species or family, i.e. $IV_i = RD + RB + RF$ (Brower et al. 1997).

Patterns in tree species composition in relation to measured edaphic variables were analysed using canonical correspondence analysis (CCA) (McCune & Grace 2002). The software CANOCO version 4.0 was used for analysis (David et al. 1999, Nizam et al. 2006). Species with less than four entries in the data matrix were deleted to increase the definition of results (Barruch 2005). Parameters used in the analysis were tree species occurrence and soil variables (pH, Al^{3+}, H^+, OM content, acidic and base cation, available P, K and CEC). Direct ordination of CCA examines the similarity or dissimilarity of floristic composition of vegetation samples, whereby the distances between points on the graph are taken as a measurement of their degree of dissimilarity or difference. The significance of each edaphic variable in determining species compositional changes was assessed through a Monte Carlo permutation test based on 499 random trials at 0.05 significance.

RESULTS AND DISCUSSION

The study recorded 3974 trees from 583 species, 226 genera and 65 families (result not shown). A total of 2061 individuals from 393 species, 164 genera and 57 families were recorded in the inland forest (Table 1). In the seasonal flood forest, a total of 1019 individuals from 268 species, 137 genera and 57 families were recorded, while in the riverine forest, a total of 894 individuals from 260 species, 133 genera and 53 families were recorded (Table 1). In terms of stand density, 1472 ind ha^{-1} were recorded in the inland forest, 1132 ind ha^{-1} in the seasonal flood forest and 1277 ind ha^{-1} in the riverine forest.

There were no significant differences in abundance and tree density between the three forest types (Table 2). Euphorbiaceae had the highest density in inland and riverine forests with 266 and 197 ind ha^{-1} respectively, while Myrtaceae had the highest density in seasonal flood forest with 168 ind ha^{-1}. This result was similar to that of Raffae (2003), Norwahidah and Wan Juliana (2009) and Nurhasyimah (2008), i.e. Euphorbiaceae had the highest density in the inland forest. Euphorbiaceae was also reported as the family with the highest density in riverine forest by Foo (2005) at Kenong Forest Park, by Norsiah (2004) at Chini River, Tasik Chini and by Siti Najmi (2005) at Sungai Jemberau, Tasik Chini. The lower density of tree species in riverine and seasonal flood forests might be due to floods which would disturb the growth of seedlings or saplings or even destroy some of the small trees.

Table 1 Species composition of three forest types in the Chini watershed forest in Pahang

Forest type	Size (ha)	Family	Genus	Species	Ind	Ind ha^{-1}	BA (m^2 ha^{-1})
Inland	1.4	57	164	393	2061	1472	33.15
Seasonal flood	0.9	57	137	268	1019	1132	31.94
Riverine	0.7	53	133	260	894	1277	34.03

Ind = individuals, BA = basal area

Table 2 The leading families with the highest densities recorded in the three forest types at the Chini watershed forest in Pahang

Forest type	Family	Ind	Ind ha^{-1}
Inland	Euphorbiaceae	372	266
Seasonal flood	Myrtaceae	151	168
Riverine	Euphorbiaceae	138	197

Ind = individuals

Forest structure

Endospermum diadenum (Euphorbiaceae) was the most important species in the inland forest with species importance value index (SIV_i) of 3.36% (Table 3). In the riverine forest, *Ganua motleyana* (Sapotaceae) was the most important species with SIV_i of 2.35%, while in seasonal flood forest, *Streblus elongatus* (Moraceae) was the most important species with SIV_i of 4.43%. Euphorbiaceae was the most important family in inland and riverine forests with FIV_i values of 14.25 and 12.91% respectively. Meanwhile, Myrtaceae was the most important family in the seasonal flood forest with FIV_i of 12.36%. These results were similar to those of Foo (2005), Siti Najmi (2005), Nurhasyimah (2008) and Norwahidah and Wan Juliana (2009) where Euphorbiaceae was found to be the most important family in inland forests. Euphorbiaceae was highly abundant in the Chini watershed as this area is a logged-over forest. According to Curtis and Macintosh (1951), a species with SIV_i of more than 10% and a family with FIV_i of more than 40% could be considered the dominant species or family respectively in a particular community. Therefore, there were no dominant species or families identified in these three forest types.

Total BA values were 33.15, 31.94 and 34.03 m^2 ha^{-1} in inland, seasonal flood and riverine forests respectively (Table 1). There were no significant differences in BA between the three forest types. The largest BA values of tree families recorded in the inland forest plot were Euphorbiaceae with 5.09 m^2 ha^{-1} (15.37%), Myrtaceae in the seasonal flood forest with 4.58 m^2 ha^{-1} (14.36%) and Leguminosae in the riverine forest with 4.30 m^2 ha^{-1} (12.63%) (Table 4). *Endospermum diadenum* had the largest BA in the inland forest with a value of 1.91 m^2 ha^{-1} (5.79%), *Streblus elongatus* in the seasonal flood forest with a value of 2.58 m^2 ha^{-1} (8.10%) and *Intsia palembanica* in the riverine forest with 1.49 m^2 ha^{-1} (4.37%) (Table 4). There were no significant differences in BA between the three forest types. Basal area is defined by the dbh of the tree stem. Thus, *I. palembanica* and *S. elongatus* are among the larger trees in Malaysian lowland dipterocarp forests and they contribute the largest values of BA in riverine and seasonal flood forests. *Endospermum diadenum* is a medium to large tree. However, it was highly abundant in the inland forest.

Euphorbiaceae had the highest frequency in inland and riverine forests (97 and 100% respectively), while Myrtaceae had the highest frequency in seasonal flood forest (89%) (Table 5). *Croton argyratus* and *E. diadenum* had the highest frequency in inland forest (47% each); *Pimelodendron griffithianum* in seasonal flood forest (38%) and *Aporosa aurea* in riverine forest (37%) (Table 5). However, Siti Najmi (2005) and Nurhasyimah (2008) reported that *C. argyratus* and *Agrostachys gaudichaudii* had the highest frequency in inland forest. Norwahidah and Wan Juliana (2009) reported that *Desmos dasymaschalus* had the highest frequency in riverine forest.

General soil characteristics

Soil pH of the inland plots showed low pH of 4.00 ± 0.11, seasonal flood forest plots 4.08 ± 0.12 and riverine forest plots 4.09 ± 0.10 (Table 6). The acidic soil found in the three forest types concurred with Othman and Shamshuddin (1982) who stated that most soil in Peninsular Malaysia tropical rainforests was acidic with pH values between 3.5 and 5.5. The common scenario in wet tropical regions has resulted in soil becoming so weathered and leached whereby base cations are leached and replaced by H^+ and Al^{3+} ions that cause high acidity in the soil (Othman & Shamshuddin 1982).

Table 3 The leading families and species with the highest FIV_i and SIV_i in the three forest types at Chini watershed forest in Pahang, Peninsular Malaysia

Forest type	Family	FIV_i (%)	Species	SIV_i (%)
Inland	Euphorbiaceae	14.25	*Endospermum diadenum*	3.36
Seasonal flood	Myrtaceae	12.36	*Streblus elongatus*	4.43
Riverine	Euphorbiaceae	12.91	*Ganua motleyana*	2.35

FIV_i = family importance value index, SIV_i = species importance value index

Table 4 The leading families and species with the highest basal area (BA) in three forest types at Chini watershed, Pahang, Peninsular Malaysia

Forest type	Family	BA (m^2 ha^{-1})	(%)	Species	BA (m^2 ha^{-1})	(%)
Inland (1.4 ha)	Euphorbiaceae	5.09	15.37	*Endospermum diadenum*	1.91	5.79
	Dipterocarpaceae	4.51	13.63	*Sapium baccatum*	1.39	4.20
	Burseraceae	2.54	7.65	*Shorea macroptera*	1.08	3.26
Seasonal flood (0.9 ha)	Myrtaceae	4.58	14.36	*Streblus elongatus*	2.58	8.10
	Leguminosae	3.32	10.41	*Teijsmanniodendron simplicifolium*	1.83	5.75
	Moraceae	3.09	9.68	*Intsia palembanica*	1.21	3.81
Riverine (0.7 ha)	Leguminosae	4.30	12.63	*Intsia palembanica*	1.49	4.37
	Euphorbiaceae	3.13	9.19	*Ganua motleyana*	1.04	3.05
	Dipterocarpaceae	2.86	8.38	*Cynometra malaccensis*	0.89	2.59

Table 5 The leading families and species with the highest frequency in three forest types at Chini watershed, Pahang, Peninsular Malaysia

Forest type	Family	Frequency (%)	Species	Frequency (%)
Inland	Euphorbiaceae	97	*Croton argyratus*	47
	Dipterocarpaceae	71	*Endospermum diadenum*	47
	Burseraceae	70	*Shorea macroptera*	29
Seasonal flood	Myrtaceae	89	*Pimelodendron griffithianum*	38
	Euphorbiaceae	73	*Streblus elongatus*	33
	Leguminosae	71	*Syzygium filiforme*	31
Riverine	Euphorbiaceae	100	*Aporosa aurea*	37
	Annonaceae	71	*Aporosa arborea*	34
	Myrtaceae	71	*Desmos dasymaschalus*	26

Cation exchange capacities in the three forest types were found in low concentrations. Mean CEC values were 7.94 ± 1.45, 8.34 ± 2.08 and 9.01 ± 1.72 meq/100 g in inland, seasonal flood and riverine forests respectively (Table 6). Available macronutrients, i.e. P and Mg were low in the three forest types. Mean available P values were 13.13 ± 1.04, 12.50 ± 0.44 and 14.27 ± 1.23 μg g^{-1} in inland, seasonal flood and riverine forests respectively. Mean available K in the inland forest was 153.93 ± 31.55 μg g^{-1}, seasonal flood forest was 108.69 ± 18.48 μg g^{-1} and riverine forest was 175.88 ± 27.95 μg g^{-1}. Available Mg recorded a content of 66.49 ± 18.45 μg g^{-1}, seasonal flood forest 52.55 ± 11.73 μg g^{-1} and riverine forest 62.28 ± 7.76 μg g^{-1}. These values were considered high based on Landon (1991). ANOVA indicated that there were significant differences in available P ($p < 0.01$), available K ($p < 0.001$), cations K^+

($p < 0.00$ 1), Ca^{2+} ($p < 0.001$), Mg^{2+} ($p < 0.001$) and EC ($p < 0.01$) between the three forest types (Table 6).

Soil–vegetation relationships

A total of 92 species were analysed using CCA (Appendix). The CCA output showed that the species–environment correlations were low, of which eigenvalues were 0.28 for the first axis and 0.24 for the second axis (Table 7). It showed that the strength was only 28 and 24%. The Monte Carlo permutation test also showed that there were no significant differences between the eigenvalues of the three ordination axes ($p > 0.05$). Cumulatively, the first three axes showed that the species–environment relationship was 50.4%. This indicated that the species community was weakly associated with available K, P and soil acidity in Chini watershed.

Figure 2 illustrates the influence of soil variables on canonical axes whereby vectors indicate not only the direction but also the magnitude of influence of each variable. Plot 25 was strongly influenced by available P, plots 4 and 26 by OM, plot 18 by pH and plot 13 by available K. However, most of the plots did not show clear characteristics in relation to soil variable vectors.

Further analysis to look at species preferences in relation to environmental variables is illustrated in the species–environment biplot in Figure 3. Species such as *Teijsmanniodendron simplicifolium* (85) were strongly influenced by acidic cation (Cat A) while *Gironniera subequalis* (36) and

Table 6 Mean ± SE of soil chemical properties and p value at the Chini watershed forests, Pahang

Soil property	Inland (n = 42)	Seasonal flood (n = 27)	Riverine (n = 21)	p value
pH	4.00 ± 0.11	4.08 ± 0.12	4.09 ± 0.10	0.112
Available P ($\mu g\ g^{-1}$)	13.13 ± 1.04 ab	12.50 ± 0.44 b	14.27 ± 1.23 a	0.002**
Available K ($\mu g\ g^{-1}$)	153.93 ± 31.55 a	108.69 ± 18.48 b	175.88 ± 27.95 a	0.000***
Available Mg ($\mu g\ g^{-1}$)	66.49 ± 18.45	52.55 ± 11.73	62.28 ± 7.76	0.089
Exchangeable cations (meq/100 g)				
K^{+}	0.43 ± 0.10 ab	0.32 ± 0.06 a	0.54 ± 0.15 b	0.000***
Ca^{2+}	0.32 ± 0.09 a	0.28 ± 0.06 a	0.58 ± 0.23 b	0.001***
Mg^{2+}	0.62 ± 0.16 a	0.36 ± 0.14 b	0.66 ± 0.15 a	0.000***
Al^{3+}	5.22 ± 0.22	5.70 ± 0.14	5.43 ± 0.16	0.708
H^{+}	1.39 ± 0.08	1.4 ± 0.06	1.99 ± 0.10	0.158
CEC (meq/100 g)	7.94 ± 1.45	8.34 ± 2.08	9.01 ± 1.72	0.402
EC ($mS\ cm^{-1}$)	2.84 ± 0.02 a	2.99 ± 0.03 b	2.88 ± 0.03 ab	0.003**

*p < 0.05, **p < 0.01, *** p < 0.001; CEC = cation exchange capacity, EC = electricity conductivity

Table 7 Summary of the CCA of the vegetation and soil properties at the Chini watershed forest, Pahang

Axis	1	2	3	4	Total inertia
Eigenvalue:	0.279	0.243	0.194	0.162	4.393
Species–environment correlation:	0.882	0.832	0.916	0.743	
Cumulative percentage variance of species data:	6.3	11.9	16.3	20	
of species–environment relation:	19.6	36.8	50.4	61.8	
Sum of all eigenvalues					4.393
Sum of all canonical eigenvalues					1.418
**** Summary of Monte Carlo test ****					
Test of significance of first canonical axis: eigenvalue =	0.279				
F ratio =	1.354				
p value =	0.6400				
Test of significance of all canonical axes: Trace =	1.418				
F ratio =	1.060				
p value =	0.2860				

CCA = canonical correspondence analysis

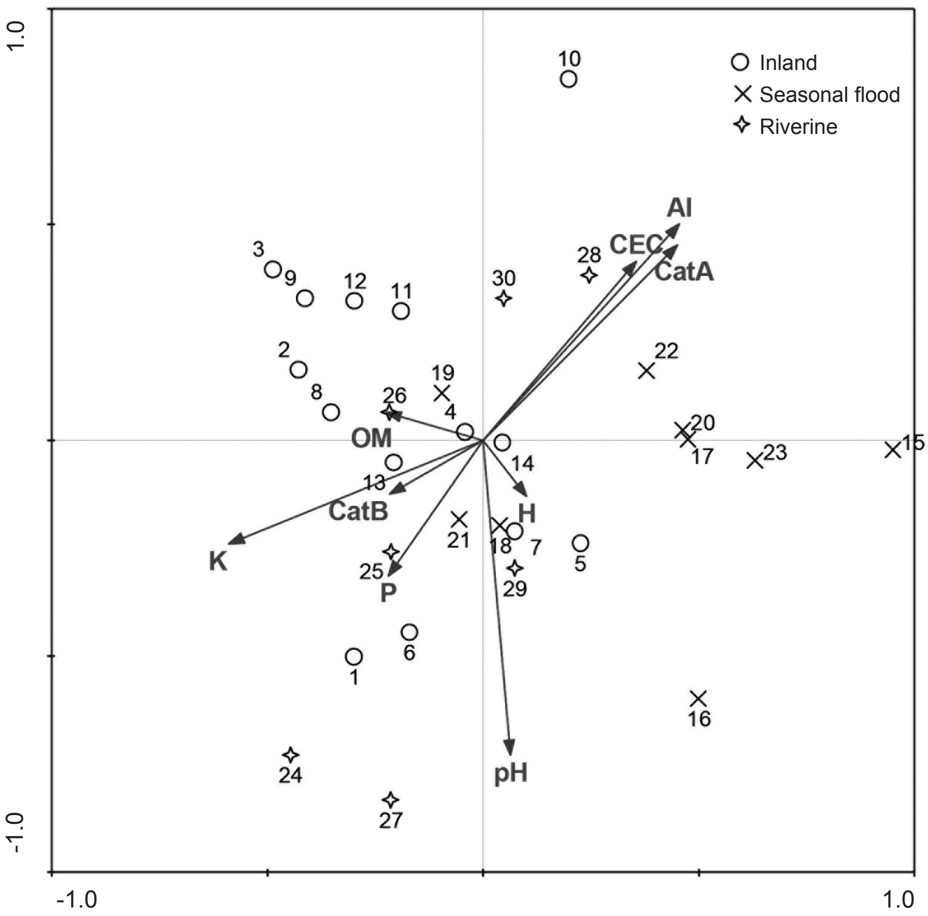

Figure 2 CCA ordination biplot showing the approximate locations of sample plots: location, length and direction of edaphic variables; length and direction of vectors indicate strength and direction of gradients; CCA = canonical correspondence analysis

Gonystylus confusus (38) by bases cation (Cat B). *Archidendron bubalinum* (10), *Mangifera quadrifida* (49), *Ochanostachys amentacea* (58), *Monocarpia marginalis* (55) and *Nauclea officinalis* (56) showed higher affinity to available P while *Aporusa arborea* (5) to available K. *Artocarpus scortechinii* (12), *Dipterocarpus costatus* (27), *Streblus elongatus* (77) and *Syzygium griffithii* (81) were influenced by OM. *Hydnocarpus kunstleri* var. *kunstleri* (41), *Knema conferta* (44) and *T. simplicifolium* (85) were highly influenced by Al^{3+} and CEC. *Dialium platysepalum* (26) were strongly influenced by cation H^+ while *Buchanania sessifolia* (15) by soil pH. The study demonstrated that there were few associations of community abundance with variations in soil characteristics. However, some of the species showed high association with soil parameters.

Edaphic factors play an important role in distribution and floristic variations (Nizam et al. 2006, Amorim & Batalha 2007, Wan Juliana et al. 2009). However, in this study, edaphic factors especially soil acidity showed less influence on the distribution and floristic variations of Chini watershed. The vegetation–environment relationship in this study was weakly associated where the cumulative value of species and environment relationship was just 50.4% ($p > 0.05$) (Table 7). This indicated that soil acidity was not the only factor controlling tree species abundance. A thorough study should be undertaken to determine other environmental factors that influence tree species distribution at the Chini watershed. Factors that should be investigated to study the relationship between species abundance and edaphic factors are available nitrogen and water content of soil as this area has a large natural lake. Besides edaphic factors, water content also influences distribution and floristic variation in certain areas and habitats (Teixiera et al. 2008).

Understanding the relationship between ecological variables and the distribution of plant communities is of great importance in order to

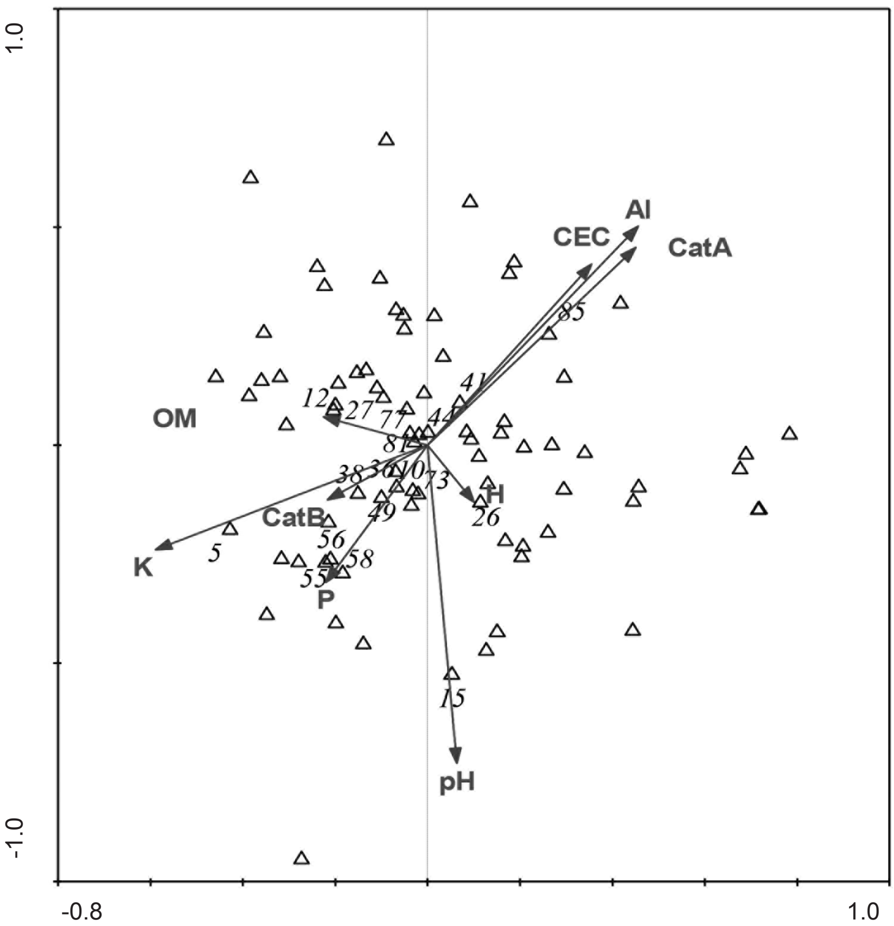

Figure 3 CCA biplot of tree species and soil variables showing species abundance in relation to edaphic variables; species with less than four entries in the data matrix were deleted from the analysis; OM = organic matter, CEC = cation exchange capacity, Cat B = bases cation, Cat A= acidic cation; CCA = canonical correspondence analysis

conserve and manage forest ecosystems. As this area is a Man and Biosphere Reserve site and is being developed as the state park of Pahang, the results from this study can be used as a guide to conserve and manage the Chini watershed.

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Appendix Species that were analysed to identify the relationship between trees species abundance and edaphic factors at the Chini watershed forest in Pekan, Pahang

Species code	Species	Species code	Species
1	*Actinodaphne pruinosa*	47	*Lithocarpus wallichianus*
2	*Aglaia* sp.	48	*Macaranga lowii*
3	*Aidia densiflora*	49	*Mangifera quadrifida*
4	*Antidesma cuspidatum*	50	*Memecylon minutiflorum*
5	*Aporusa arborea*	51	*Mesua grandis*
6	*Aporusa aurea*	52	*Mesua lepidota*
7	*Aporusa prainiana*	53	*Microcos antidesmifolia*
8	*Aporusa falcifera*	54	*Microcos fibrocarpa*
9	*Aporusa nervosa*	55	*Monocarpia marginalis*
10	*Archidendron bubalinum*	56	*Nauclea officinalis*
11	*Artocarpus lanceifolius*	57	*Neoscortechinia kingii*
12	*Artocarpus scortechinii*	58	*Ochanostachys amentacea*
13	*Baccaurea parvifolia*	59	*Paropsia vareciformis*
14	*Barringtonia macrostachya*	60	*Payena lucida*
15	*Buchanania sessifolia*	61	*Pellacalyx axillaris*
16	*Callerya atropurpurea*	62	*Pentace triptera*
17	*Campylospermum serratum*	63	*Pentaspadon motleyi*
18	*Cananga odorata*	64	*Pertusadina eurhyncha*
19	*Champereia manillana*	65	*Pimelodendron griffithianum*
20	*Cinnamomum mollissimum*	66	*Porterandia anisophyllea*
21	*Croton argyratus*	67	*Pouteria malaccensis*
22	*Dacryodes costata*	68	*Rhodamnia cinerea*
23	*Dacryodes rostrata*	69	*Santiria apiculata*
24	*Dacryodes rugosa*	70	*Sarcotheca laxa* var. *laxa*
25	*Desmos dasymaschalus*	71	*Sarcotheca laxa* var. *sericea*
26	*Dialium platysephalum*	72	*Scaphium macropodum*
27	*Dipterocarpus costatus*	73	*Semicarpus curtisii*
28	*Durio griffithii*	74	*Shorea leprosula*
29	*Dyera costulata*	75	*Shorea macroptera*
30	*Elaeocarpus* sp.	76	*Sindora coriacea*
31	*Elateriospermum tapos*	77	*Streblus elongatus*
32	*Endospermum diadenum*	78	*Styrax benzoin*
33	*Garcinia euginiaefolia*	79	*Syzygium cerassiforme*
34	*Garcinia parvifolia*	80	*Syzygium filiforme*
35	*Gironniera parvifolia*	81	*Syzygium griffithii*
36	*Gironniera subequalis*	82	*Syzygium* sp. 1
37	*Gluta wallichii*	83	*Syzygium* sp. 2
38	*Gonystylus confusus*	84	*Syzygium* sp. 3
39	*Gordonia multinervis*	85	*Teijsmanniodendron simplicifolium*
40	*Hopea mengerawan*	86	*Timonius wallichianus*
41	*Hydnocarpus kunstleri* var. *kunstleri*	87	*Vatica pauciflora*
42	*Intsia palembanica*	88	*Vittex pinnata*
43	*Ixonanthes icosandra*	89	*Xanthophyllum affine*
44	*Knema conferta*	90	*Xanthophyllum eurhynchum*
45	*Knema laurina* var. *laurina*	91	*Xerospermum noronhianum*
46	*Koompassia malaccensis*	92	*Xylopia ferruginea*

