Malays. Appl. Biol. (2020) 49(1): 159–171

THE ASSOCIATION OF TREE SPECIES DIVERSITY AND ABUNDANCE WITH THE SOIL EDAPHIC FACTOR IN A LARGEST TROPICAL RECREATIONAL FOREST OF TERENGGANU, PENINSULAR MALAYSIA

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Accepted 12 June 2020, Published online 30 June 2020

ABSTRACT

A study was conducted to investigate the association between tree species composition with soil edaphic factor in Chemerong Recreational Forest, the largest recreational forest in Terengganu, Peninsular Malaysia. Two types of forest were chosen which are riparian forest and inland forest. Four plots with the dimension of 50 m × 20 m each were established with two plots at each forest type with total study site of 0.4 ha. A total of 1158 trees (≥1 cm diameter) from 263 species, 125 genus and 50 families were recorded. The higher species number was recorded in the inland forest with 175 species, 103 genus and 45 families compared to riparian plot with 154 species, 109 genera and 39 families. *Lijndenia laurina* was found to be the important species in the riparian forest with Important Value Index (*IVi*) of 5.22% while *Mangifera caesia* at the inland forest with 3.21%. The Shannon-Weiner diversity indexes (*H*') was considered high in all two types of forest with 5.04 at the riparian forest and 5.14 at the inland forest. Sorenson's community similarity coefficient (CCs) showed the tree species communities, between the two types of forest had low similarities with 0.38. A total 33 endemic species in Peninsular Malaysia were found at Chemerong Recreational Forest. Fifty-five species in this study were listed in the International Union for Conservation of Nature IUCN red list of threatened species 2019. Significant differences were found in phosphorus, electric conductivity, ammonium nitrate, moisture content and organic matter between these forests. Canonical Correspondence Analysis (CCA) showed less association between species composition with the physico-chemical characeyeristics of soil in this study indicating the soil edaphic factor is not the main factor controlling the species distribution at this site.

Key words: Riparian forest, soil chemistry, Canonical Correspondence Analysis (CCA), recreational forest, Peninsular Malaysia

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INTRODUCTION

Malaysia is one of the world's Mega Diversity countries and has an estimated 20.62 million hectares of natural forests in 2012, covering 62.5% of the country's land area (UNDP, 2017). Malaysia has over 150 major rivers; as well a variety of tropical wetlands, forest, coastal and marine ecosystems, representing several Global 200 Eco regions, and it is recognized as one of 17 mega-diverse countries in the world (UNDP, 2017). Peninsular Malaysia has about 13.68 million hectares land area and about 5.77 million hectares are forested area around 85.29% (Forestry Department Peninsular Malaysia, 2016). Forested area has 4.92 million hectare permanent reserved forests, a 4.16 million hectare Inland Forest, 0.25 million hectares peat swamp forests, 0.11 million hectares Mangroves and 0.40 million hectares plantation forest (Forestry Department Peninsular Malaysia, 2016). The tropical rainforest in Peninsular Malaysia covers about 5.87 million hectares or 45% of its total land (UNDP, 2017). Dipterocarp forests account for about 85% of the country's forested areas and are commonly composed of species from the genera *Anisoptera, Dipterocarpus, Dryobalanops, Hopea, Shorea* and *Parashorea* (Ashton, 2008).

Terengganu state has rich and diverse biodiversity and their forest resources are seen to have the potential to generate the economy from horticultural, medicinal plants, timber and also as a tourist and recreational centre. Chemerong Recreational Forest is located in Pasir Raja Forest Reserve, which is a primary forest located in Dungun District, Terengganu, Peninsular Malaysia. It covers an area of 300 hectares and is located about 30 km from Al-Muktafi Billah Shah town and 100 km from the capital city of Terengganu, Kuala Terengganu. The recreational forest was first developed in 1993 and was the largest recreational forest in Terengganu (Forestry Department of Malaysia, 2006; 2008). In the vast Pasir Raja Forest Reserve bordering the Taman Negara, Malaysia's premier National Park, stands the world's oldest 1300 years old and largest Chengal tree (*Neobalanocarpus heimii*). In addition, the highest waterfall (305 m) lies in Pasir Raja Forest Reserve and the nearby Chemerong Recreational Forest. Nevertheless, the Gunung Berembun (Berembun Mountain), which is close to the recreational forest is one of the best places for hiking in Terengganu. As one of the tourist attractions sites in Terengganu, Chemerong Recreational Forest received more than 20,000 people each year and considered as one of the important recreational forests in Terengganu (Forestry Department of Malaysia, 2016). Although Pasir Raja was gazetted as a permanent forest reserve, however some parts of the area had been deforested and not far from the recreational forest, there was an oil palm plantation area. All the while these activities may affect the ecosystem and biota of this area.

Studies on the tree species distribution at different forest types of Malaysian tropical forest were done previously by many researchers (Proctor *et al.,* 1983; Condit *et al.,* 1999; Nizam *et al.,* 2011; Khairil *et al.,* 2011; Khairil *et al.,* 2014a; 2014b). The tree species distribution of these forest types was influenced by few factors such as altitude (Proctor *et al.,* 1983), soil types (Nizam *et al.,* 2011; Khairil *et al.,* 2014a; 2014b) and their location which are intact with water bodies such as stream, lake and river (Khairil *et al.,* 2011; 2013; 2014b). According to Khairil *et al.* (2011) the riparian forest and seasonal flood forest had lower species diversity and composition compared to the inland forest at Chini watershed, the second largest natural lake in Peninsular Malaysia. The tree species community at some riparian area and seasonal flood area were influenced by the water as sometimes these areas were inundated, especially during the raining season (Khairil *et al.,* 2011; Khairil *et al.,* 2014a; 2014b). In addition, the gap area along the rivers and beside the lake may influence the occurrence of selected tree species in the riparian area (Teixeira *et al.,* 2008).

Soil plays an important role in plant growth as it provides useful major and minor nutrient elements and mineral and this contributes to the occurrence and distribution of tree species of tropical forest (Deyn *et al.*, 2004; Sukri *et al.,* 2012; Baldeck *et al.*, 2013; Khairil *et al.,* 2014b; 2015). Studies on the relationship between tree species abundance and distribution with the soil physico-chemical characteristics in tropical forest in Malaysia were done by many previous researchers (Davies *et al.*, 2005; Nizam *et al.,* 2006; Katabuchi *et al.,* 2012; Khairil *et al.*, 2014a; 2015). Most of the studies only cover the trees with ≥5 cm diameter (dbh) and none of the studies mentioned cover the lower tree dbh size. To date, there was no detailed study conducted on the tree species composition and seedlings in Chemerong Recreational Forest. Nevertheless, tree species diversity and abundance of Terengganu are less documented compared to its neighbouring states, Kelantan and Terengganu. According to Memiaghe *et al.* (2016), small-diameter tree populations are also important to the demographic rates and nutrient cycling, thus in this study, we sampled the trees with the size of 1cm diameter and above in this area. By this sampling, the important features of the tree species composition and structure can be determined. Furthermore, by analysing the soil physico-chemical characteristics, the association between species abundance with the soil edaphic factor in this area also can be determined. The study conducted was following these hypotheses:

1. The tree species diversity and abundance of the tree species are significantly different between the inland and riparian forest at Chemerong Recreational Forest.
2. When comparing the soil physico-chemical characteristics of riparian and inland forest, the elements such as P, Ca, Mg, organic matter, electrical conductivity (EC) may significantly different between these forest types.
3. The distribution and composition of the tree species in Chemerong Recreational Forest may have associated with soil edaphic factors. In this study, soil edaphic factor can be an important factor in shaping these patterns.

MATERIALS AND METHODS

Study site

Dungun is a coastal district state of Terengganu and considered as the second largest district after Hulu Terengganu. District of Dungun can be divided into 11 mukim; Besul, Hulu Paka, Jengai, Jerangau, Kuala Abang, Kuala Dungun, Kuala Paka, Kumpal, Rasau, Sura and Pasir Raja (Forestry Department of Malaysia, 2016). Total population in the district of Dungun is 149,851 people and Kuala Dungun is the capital city of this district. The Chemerong Recreational Forest is located in Pasir Raja Forest Reserves, Dungun, Terengganu and the distance to Kuala Dungun town is almost 30 km while the distance to the capital city of Terengganu, Kuala Terengganu is around 100 km (Forestry Department of Malaysia, 2008) (Figure 1). The Chemerong Recreational Forest is the largest permanent recreational forest in Terengganu, Peninsular Malaysia with the size of 300 ha and was gazetted in 1960 under the control by the Terengganu Forestry Department (Forestry Department of Malaysia, 2016).

Plot establishment

Two forest types were recognized in Chemerong recreational forests which were riparian forest; the forest beside the river and inland forest which is approximately more than 200 m away from the river bank. Stratified sampling method was used to build the study plots at these two forest types. Four plots with the size of 50 m x 20 m (0.1 ha) were established in this study which two plots at the riparian forest (05° 49.424'N, 102° 00.043'E & 05° 19.419'N, 103° 00.197'E) and another two plots at the inland forest (05° 39.413'N, 102° 59.989'E & 05° 39.4141'N, 103° 19.901'E) (Figure 1).

Plants sampling

All trees with the diameter 1 cm and above were selected and the leaves were collected for identification purpose. The process of identification conducted was based on Ng (1978; 1989) and Whitmore (1972; 1973) and with the help of senior botanist from Universiti Malaysia Terengganu (UMT) and Universiti Kebangsaan Malaysia (UKM). The density, important value index (*IVi*), composition and diversity of the tree species were based on Magurran (1988) and Brower *et al.* (1997). The Sorenson's community similarity index was analysed to measure the degree of species similarity between the two types of forest using the BIODAP software following Magurran (2011).

Soil sampling

Five soil samples were collected from each plot and total up to 20 samples at the depths of 0 to 15 cm by using an auger. Each soil samples with approximately 200 g in weight were then sent to the Universiti Sultan Zainal Abidin (UniSZA) lab for air-drying. The roots, small stones and leaves were separated from the soil and were sieved through a 2 mm sieve while lump soils were crushed using agate tools. These samples were then analysed for their physico-chemical characteristics, which were soil particle size distribution, organic matter content, exchangeable acid cation Aluminium (Al^+) and Hydrogen (H^+), exchangeable basic cation, cation exchange capacity (CEC), electrical (EC), as well as available nutrients of Phosphorus (P), Magnesium (Mg) and Potassium (K). The soil organic matter compounds were analysed based on the loss ignition technique following Black (1968). The pH of the soil was determined using a soil: water ratio of 1:2.5 (Rowell, 1994; Shamshuddin, 1981). The exchangeable acidic cations (Al^+ and H^+) were measured in 1.0 M KCl extract by titration while exchangeable basic cations of Magnesium (Mg^{2+}) and Potassium (K^+) were measured in 1.0 M ammonium acetate extract by Atomic Absorption Spectrophotometry, (Perkin Elmer, AA analyst 100, Norwalk, USA) (Black, 1968; Shamshuddin, 1981). Cation exchange capacity was obtained by summation of acid and basic cations. Electrical conductivity was determined using saturated gypsum extract following Rowell (1994). Available nutrients of Phosphorus (P), Ammonium Nitrate ($NH^{4+}NO^{3-}$) using flow injection auto-analyser (FIA star 5000 Analyser and FOSS TECATOR 5027 Sampler for the auto sampler, Sweden), available Mg and K were extracted using sulphuric acid and determined using an Atomic Absorption Spectrophotometer (FAAS) (Perkin Elmer, AA analyst 100, Norwalk, USA) (Rowell, 1994).

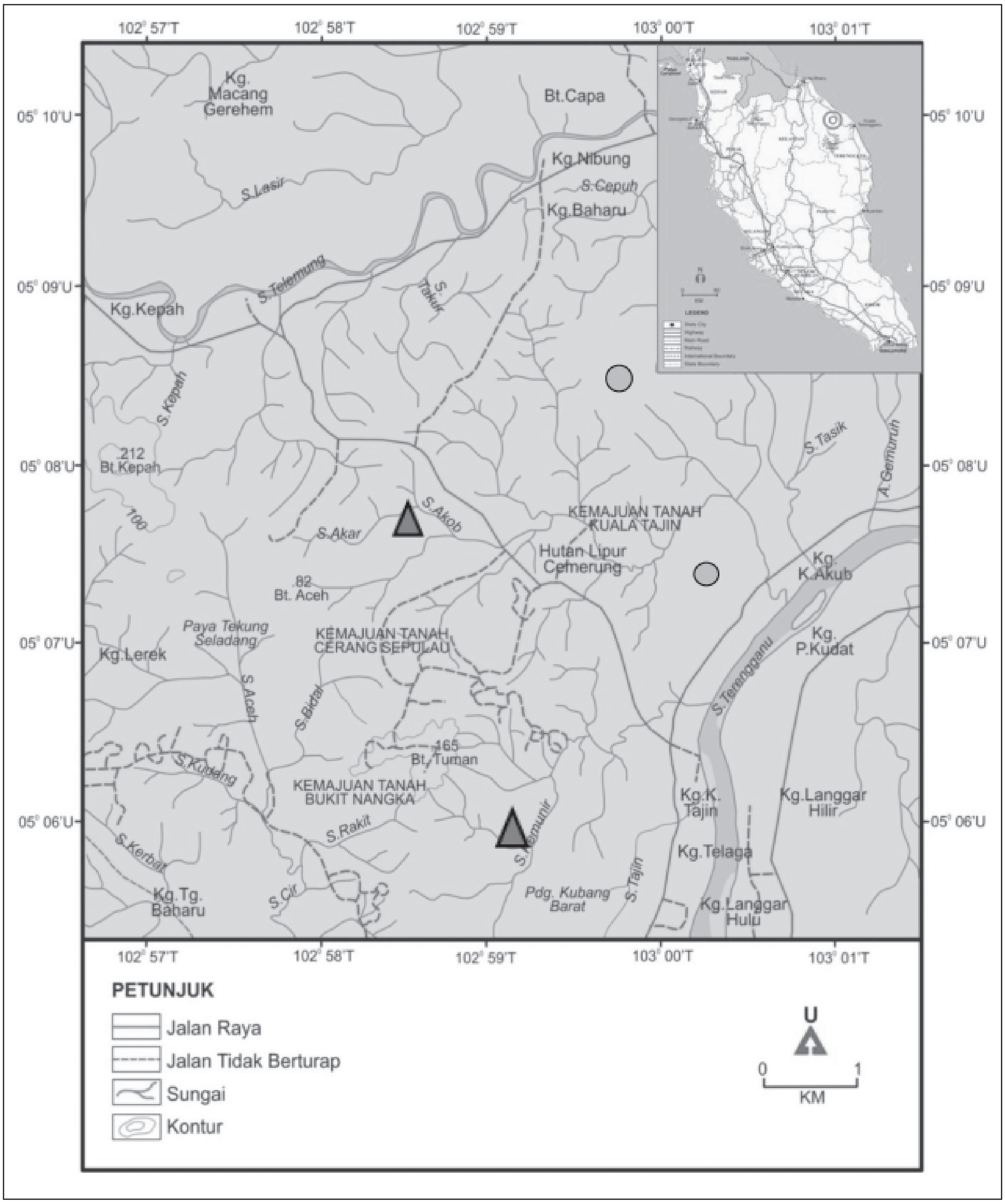

Fig. 1. The location of research plots at the Chemerong Recreational Forest, Dungun, Terengganu.
Notes: ▲ = riparian plot. ● = inland plot. ◎ = Study site location.

Statistical Analysis

Normality test and T-test was conducted to compare the mean of the soil parameter of two forest types by using the MINITAB 16 software. Canonical correspondence analysis (CCA) was conducted to investigate the patterns in tree species distribution in relation to edaphic variables by using the PCORD version 5.0 (McCune & Grace, 2002; Baruch, 2005). The CCA method was used to illustrate the relationships between the two set factors (soil, N= 15 and trees N=263). The occurrences of the species with less than 3 within the subplots were eliminated to ease the CCA analysis following Baruch (2005). Direct ordination of CCA examines the strength of floristic abundance with edaphic factors (Nizam *et al.,* 2006; Khairil *et al.,* 2014b).

RESULTS AND DISCUSSION

Tree species composition and abundance

A total of 1158 individual trees with 1 cm diameter were recorded in this study which consisted of 263 species, 125 genus and 50 families. The inland forest plot had higher individuals and species number with 636 individuals from 175 species, 103 genera and 39 families, whereas Riparian forest plot recorded 516 individuals from 154 species, 109 genera and 39 families (Table 1). In terms of class size, trees with the size of 1–4.99 cm dbh had the highest composition with 2335 ind/ha at inland forest plot and 1800 ind/ha at riparian forest plot (Table 2). *Lijndenia laurina* (Melastomataceae) had the highest density of the riparian forest with 200 individuals (ind)/ hectare (ha) followed by *Shorea macroptera* (Dipterocarpaceae) with 120 ind/ha and *Gaertnera vaginans* with 95 ind/ha. Meanwhile *Streblus elongatus* (Moraceae) was the most dense species in the inland forest plot with 140 ind/ha followed by *Gluta elegans* and *Mangifera caesia*

Table 1. Taxonomic composition of tree species at Chemerong Recreational Forest, Pasir Raja Forest Reserve, Terengganu, Malaysia

Number	Family	Riparian			Inland		
		Genera	Species	Ind	Genera	Species	Ind
1	Alangiaceae	nil	nil	nil	1	1	1
2	Anacardiaceae	2	3	7	4	6	10
3	Anisophylleaceae	1	2	5	1	3	35
4	Annonaceae	7	8	29	8	13	36
5	Apocynaceae	3	3	3	nil	nil	nil
6	Bombacaceae	1	1	1	4	6	15
7	Burseraceae	3	5	19	nil	nil	nil
8	Celastraceae	1	1	2	2	2	11
9	Chrysobalanaceae	1	1	1	1	1	1
10	Ctenolophonaceae	1	1	3	1	1	3
11	Dilleniaceae	1	1	6	nil	nil	nil
12	Dipterocarpaceae	5	8	41	7	14	47
13	Ebenaceae	1	4	9	1	9	39
14	Elaeocarpaceae	1	1	1	nil	nil	nil
15	Erythroxylaceae	1	1	2	nil	nil	nil
16	Euphorbiaceae	8	10	18	9	16	32
17	Fagaceae	2	3	7	1	2	2
18	Flacourtiaceae	2	2	3	3	3	7
19	Gnetaceae	nil	nil	nil	1	1	1
20	Guttiferae	4	12	33	2	9	27
21	Icacinaceae	1	1	1	nil	nil	nil
22	Lauraceae	7	7	24	5	5	11
23	Lecythidaceae	1	2	2	1	3	19
24	Leguminosae	6	6	18	5	6	13
25	Loganiaceae	1	1	4	nil	nil	nil
26	Melastomataceae	2	2	42	3	5	18
27	Meliaceae	2	2	7	2	5	15
28	Moraceae	3	4	13	4	4	36
29	Myristicaceae	3	4	13	3	5	45
30	Myrsinaceae	1	1	2	2	2	3
31	Myrtaceae	1	12	28	3	15	46
32	Ochnaceae	1	1	5	1	1	4
33	Olacaceae	2	2	3	nil	nil	nil
34	Oxalidaceae	1	1	1	nil	nil	nil
35	Pandaceae	nil	nil	nil	1	1	1
36	Polygalaceae	1	3	12	1	3	14
37	Rhizophoraceae	2	2	18	1	1	9
38	Rosaceae	1	2	2	1	1	1
39	Rubiaceae	13	16	69	11	15	61
40	Rutaceae	1	1	1	nil	nil	nil
41	Sapindaceae	2	2	5	4	5	21
42	Sapotaceae	4	5	11	3	4	15
43	Simaroubaceae	1	1	1	nil	nil	nil
44	Sterculiaceae	2	2	5	1	1	1
45	Thymelaeaceae	nil	nil	nil	1	1	1
46	Theaceae	2	3	5	nil	nil	nil
47	Tiliaceae	1	1	1	1	1	3
48	Ulmaceae	1	2	14	1	3	18
49	Verbenaceae	1	1	19	2	2	7
50	Violaceae	nil	nil	nil	1	1	7
	Total	109	154	516	104	177	636

Table 2. The tree species composition based on the diameter class size at inland and riparian forest plot

Size class (cm) dbh	Inland (0.2 ha)		Riparian (0.2 ha)	
	Ind	Ind/ha	Ind	Ind/ha
1.00–4.99	467	2335	360	1800
5.00–9.99	115	575	84	420
10.0–14.99	21	105	36	180
>15.00	39	195	36	180
Total	642	3210	516	2580

Table 3. Density of the five most dense tree species in inland and riparian forest of Chemerong Recreational Forest, Terengganu

Forest Types	Species	Family	Ind/ha	Coverage (%)
Riparian	*Lijndenia laurina*	Melastomataceae	200	7.75
(n= 516 ind)	*Shorea macroptera*	Dipterocarpaceae	120	4.65
	Gaertnera vaginans	Rubiaceae	95	3.68
Inland	*Streblus elongatus*	Moraceae	150	4.67
(n=636 ind)	*Gluta elegans*	Anacardiaceae	120	3.74
	Mangifera caesia	Anacardiaceae	110	3.43

Table 4. Value of Importance (SIV_i) of the species at both forest types in Chemerong Recreational Forest

Forest Type	Spesies	Family	Rd (%)	Rf (%)	Rc (%)	*IVi* (%)
Riparian	*Lijndenia laurina*	Melastomataceae	7.75	1.66	4.85	5.22
	Shorea macroptera	Dipterocarpaceae	4.65	1.66	3.12	4.24
	Gaertnera vaginans	Rubiaceae	3.68	1.66	2.99	3.16
	Vitex vestita	Verbenaceae	3.68	1.66	3.21	2.27
	Monocarpia marginalis	Annonaceae	2.71	1.66	3.15	2.22
Inland	*Mangifera caesia*	Anacardiaceae	3.43	1.37	6.25	3.21
	Streblus elongatus	Moraceae	4.37	1.37	6.42	2.95
	Gluta elegans	Anacardiaceae	3.74	1.37	4.14	2.70
	Mangifera griffithii	Anacardiaceae	3.12	1.02	1.46	2.45
	Swintonia floribunda	Anacardiaceae	2.65	1.37	2.28	2.39

Note: Rd – Relative density; Rc – Dominance; Rf – Relative frequency.

with 120 and 110 ind/ha respectively (Table 3). This result was dissimilar to previous studies in Peninsular Malaysia where Euphorbiaceae was reported to have the highest density of the inland forest (Raffae 2003; Norwahidah, 2005; and Khairil *et al.,* 2011) and riverine forest (Foo, 2005; Khairil *et al.,* 2011; 2014a).

Importance value index (*IVi*)

Lijndenia laurina (Melastomataceae) was the most important species at the riparian forest with the S*IVi* of 5.22%, followed by *Shorea macroptera* (Dipterocarpaceae) and *Gaertnera vaginans* with 4.24% and 3.16% respectively. In the inland forest, the trend was different as *Mangifera caesia* was the most important species with the S*IVi* of 3.21%, followed by *Streblus elongatus* (Moraceae) and *Gluta elegans* (Anacardiaceae) with 2.95% and 2.70% respectively (Table 4). The result observed in this study was different to Khairil *et al.* (2011; 2014b) as they found the important species at inland forest of Chini watershed was *Endospermum diadenum* (Euphorbiaceae) whereas *Ganua motleyana* (Sapotaceae) was the most important species in a riverine forest plot. According to Brower (1997), a species with S*IVi* of more than 10% can be considered as the dominant species in a particular community. Based on the results, all the species recorded from both forest types have *IVi* % of less than 10%, indicating that none of the species are dominant at Chemerong Recreational Forest.

Species diversity and similarity

The Species Diversity Index (*H*') calculated for inland forest was 5.14 and was slightly higher than a riparian forest with H' of 5.04. According to Magurran (2011), the value of H' usually lies between 1.5 and 3.5, although in exceptional cases, the value can exceed 4.5. Therefore, the values of the diversity index in these two forest types were considered exceptionally high. In terms of Community similarity, we found the value of the Sorenson Community Coefficient (*CCs*) index for both communities was low with the value of 0.38. This indicated only 38% of the tree species occurring at both forest types are similar while the other 62% of the tree species between both forest types were dissimilar.

Endemism and conservation status

According to Ng *et al.* (1991) there were 2,830 plant species found to be endemic to Peninsular Malaysia while the total number of endemic trees is 746 species. The endemic tree species in this study represented 4.42% of endemic trees in Peninsular Malaysia, which consists of 33 species and 15 families (Table 5). In terms of conservation status of the tree species, at least 55 species in this study, equivalent to 20.7% of the total species recorded were listed in the International Union for Conservation of Nature (IUCN) Red Data Book in 2016 and Malayan Plant Red list (Chua *et al.,* 2010) (Table 6).

Soil characteristics

Soils from both forest types were acidic with pH less than 6 (Table 7). This result was similar with other previous researches conducted in tropical forest of Malaysia by Paoli *et al.* (2008); Adzmi *et al.* (2010); Khairil *et al*. (2014a; 2014b) and Khairil and Burslem, (2018) where they also found that most of the soil pH was between 4–6 with high concentrations of Al^{3+}. Mean available P was higher in the riparian forest compared to the inland forest while the mean of available K and Mg, organic matter (OM) and moisture content were slightly higher in the inland forest compared to riparian forest (Table 8). This result was similar to Khairil

Table 5. Endemic tree species in Peninsular Malaysia that can be found at Chemerong Recreational Forest, Terengganu, Peninsular Malaysia

Family	Species	Location
Annonaceae	*Cyathocalyx pruniferus*	Kl, Tg, Pk, Ph, Sl, Ml, Jh
Annonaceae	*Popowia fusca*	Prk, Ph, Sp
Annonaceae	*Xylopia magna*	Ked, Kt, Tg, Prk, Pah, Sel, NS
Annonaceae	*Goniothalamus umbrosus*	Pn, Kl, Tg
Apocynaceae	*Kopsia macrophylla*	Kl, Tg, Pk, Ph, NS, Ml, Jh
Chrysobalanaceae	*Atuna penangiana*	Pen, Kl, Tg, Pk, Jh
Dilleniaceae	*Dillenia reticulata*	Ml, Pah, Tg
Ebenaceae	*Diospyros ismailii*	Ked, Tg, Ph, Sel, Joh
Ebenaceae	*Diospyros nutans*	Kt, Prk, Ph, Sel, NS, Ml
Ebenaceae	*Diospyros scortechinii*	Kt, Tg, Prk, Ph, NS
Ebenaceae	*Diospyros argentea*	Tg, Pk, Ph, Sl, NS, Ml, Jh
Ebenaceae	*Diospyros lanceifolia*	Peninsular Malaysia
Euphorbiaceae	*Aporosa globifera*	Ked, Pn, Kl, Ph
Euphorbiaceae	*Aporosa nervosa*	Peninsular Malaysia
Euphorbiaceae	*Croton erythrostachys*	Tganu, Pah, Sel, NS, Ml, Joh
Flacourtiaceae	*Casearia clarkei*	Pen, Prk, Sel, Ml
Flacourtiaceae	*Scaphocalyx spathacea*	Ktan, Pah, Sel, NS, Ml, Joh
Guttiferae	*Garcinia opaca*	Prk, Pah, Sel
Lauraceae	*Alseodaphne* sp. 1	Jh, Tg
Lauraceae	*Litsea spathacea*	Pn, Kl, Pk, Ph, Sl
Lauraceae	*Beilschmiedia insignis*	Kl, Pk, Ph, Sl
Lauraceae	*Cinnamomum mollissimum*	Pen, Kt, Tg, Prk, Ph, Sel
Myrtaceae	*Syzygium conglomeratum*	Sl, Ml, Jh, Sp
Oxalidaceae	*Sarcotheca monophylla*	Pk, Ph, Sl, Ml
Rubiaceae	*Saprosma scortechinii*	Kd, Tg, Pk, Ph
Rubiaceae	*Psydrax maingayi*	Tg, Ph, Prk, Sel, NS, Ml, Joh
Rubiaceae	*Morinda corneri*	Tg, Ph
Rubiaceae	*Gaertnera obesa*	Ml, Jh. Sp
Rubiaceae	*Urophyllum ferrugineum*	Pk, Jh
Rubiaceae	*Psychotria griffithii*	Tg, Pk, Sl, NS, Ml, Jh
Sapindaceae	*Trigonachras* sp. 1	Tg
Sapotaceae	*Madhuca tubulosa*	Tg, Jh
Theaceae	*Adinandra maculosa*	Ph, Kl, Tg, Pk, Sl, Ph

Notes: Tg = Terengganu; Pk = Perak; Jh = Johor; Kl = Kelantan; Sl = Selangor; Ph = Pahang; Ml = Melaka; Sel = Selangor; NS = Negeri Sembilan; Ked = Kedah; Sp = Singapore; Pen = Penang; Ph= Pahang.

Table 6. The species status which require conservation based on Red Data Book (IUCN 2016)

No	Species	Family	Conservation Status
1	*Aglaia crassinervia*	Meliaceae	Lower Risk/near threatened
2	*Aglaia forbesii*	Meliaceae	Lower Risk/least concern
3	*Aglaia malaccensis*	Meliaceae	Lower Risk/near threatened
4	*Aglaia odoratissima*	Meliaceae	Lower Risk/least concern
5	*Amesiodendron chinense*	Sapindaceae	Lower Risk/near threatened
6	*Anisophyllea corneri*	Anisophylleaceae	Lower Risk/least concern
7	*Anisophyllea disticha*	Anisophylleaceae	Lower Risk/least concern
8	*Anisoptera laevis*.	Dipterocarpaceae	Endangered
9	*Aquilaria malaccensis*	Thymelaeaceae	Vulnerable
10	*Atuna penangiana*	Chrysobalanaceae	Vulnerable
11	*Beilschmiedia insignis*	Lauraceae	Lower Risk/least concern
12	*Bhesa paniculata*	Celastraceae	Lower Risk/least concern
13	*Brackenridgea hookeri*	Ochnaceae	Lower Risk/least concern
14	*Calophyllum soulattri*.	Guttiferae	Lower Risk/least concern
15	*Canarium littorale*	Burseraceae	Lower Risk/least concern
16	*Cotylelobium lanceolatum*	Dipterocarpaceae	Vulnerable
17	*Cratoxylum arborescens*	Guttiferae	Lower Risk/least concern
18	*Cyathocalyx pruniferus*	Annonaceae	Lower Risk/least concern
19	*Dacryodes costata*	Burseraceae	Lower Risk/least concern
20	*Dacryodes rostrata*	Burseraceae	Lower Risk/least concern
21	*Diospyros argentea*	Ebenaceae	Lower Risk/least concern
22	*Diospyros ismailii*	Ebenaceae	Lower Risk/least concern
23	*Diospyros nutans*	Ebenaceae	Lower Risk/least concern
24	*Diospyros scortechinii*	Ebenaceae	Lower Risk/least concern
25	*Dipterocarpus crinitus*	Dipterocarpaceae	Endangered
26	*Dipterocarpus grandiflorus*	Dipterocarpaceae	Critically endangered
27	*Dipterocarpus oblongifolius*	Dipterocarpaceae	Lower Risk
28	*Dyera costulata*	Apocynaceae	Lower Risk/least concern
29	*Euonymus javanicus*	Celastraceae	Lower Risk/least concern
30	*Garcinia opaca*	Guttiferae	Lower Risk/least concern
31	*Gnetum gnemon*	Gnetaceae	Least Concern
32	*Hopea griffithii*	Dipterocarpaceae	Vulnerable
33	*Horsfieldia irya*	Myristicaceae	Lower Risk/least concern
34	*Knema conferta*	Myristicaceae	Lower Risk/least concern
35	*Koompassia malaccensis*	Leguminosae	Lower Risk/conservation dependent
36	*Litsea spathacea*	Lauraceae	Lower Risk/least concern
37	*Madhuca tubulosa*	Sapotaceae	Lower Risk/conservation dependent
38	*Mangifera caesia*	Anacardiaceae	Lower Risk/least concern
39	*Myristica cinnamomea*	Myristicaceae	Lower Risk/least concern
40	*Ochanostachys amentacea*	Olacaceae	Data Deficient
41	*Popowia fusca*	Annonaceae	Lower Risk/least concern
42	*Prunus arborea* var. arborea	Rosaceae	Lower Risk/least concern
43	*Prunus polystachya*	Rosaceae	Lower Risk/least concern
44	*Santiria apiculata*	Burseraceae	Lower Risk/least concern
45	*Santiria laevigata*	Burseraceae	Lower Risk/least concern
46	*Sarcotheca monophylla*	Oxalidaceae	Lower Risk/near threatened
47	*Scaphium macropodum*	Sterculiaceae	Lower Risk/least concern
48	*Shorea curtisii* ssp. *curtisii*	Dipterocarpaceae	Lower Risk/least concern
49	*Shorea guiso*	Dipterocarpaceae	Critically Endangered
50	*Shorea leprosula*	Dipterocarpaceae	Endangered
51	*Shorea macrantha*	Dipterocarpaceae	Critically Endangered
52	*Shorea multiflora*	Dipterocarpaceae	Lower Risk/least concern
53	*Vatica maingayi*	Dipterocarpaceae	Critically endangered
54	*Vatica umbonata*	Dipterocarpaceae	Lower Risk/least concern
55	*Xylopia magna*	Annonaceae	Lower Risk/least concern

Table 7. The average chemical composition of soil and variance analysis for each forest type in Chemerong Recreational Fores, Terengganu, Peninsular Malaysia

Soil content	Riparian forest	Inland forest	P value
pH	4.04 ± 0.23	3.90 ± 0.23	0.188
Available P (meq/100 g)	2.91 ± 1.13	1.59 ± 0.30	0.002**
Available K (meq/100 g)	100.95 ± 35.05	121.25 ± 24.61	0.626
Available Mg (meq/100 g)	26.46 ± 11.06	32.31 ± 31.50	0.587
Electric conductivity (dS/m)	19.21 ± 0.24	23.02 ± 0.38	0.017*
Ammonium nitrogen	5.55 ± 2.25	12.41 ± 2.81	0.000***
Nitrate (NO3) (meq/100 g)	6.85 ± 5.26	17.15 ± 4.37	0.000***
Cation exchange capacity (CEC)	7.98 ± 0.86	8.12 ± 0.64	0.673
Cation acid (meq/100 g)	3.93 ± 0.82	3.75 ± 0.57	0.575
Cation base (meq/100 g)	4.05 ± 0.26	4.37 ± 0.56	0.111
Moisture content (%)	5.27 ± 4.27	8.91 ± 2.11	0.027*
Organic matter (OM)	4.84 ± 1.32	7.77 ± 1.48	0.000***

Note: p< 0.05*; p< 0.005**; p< 0.001*.

Table 8. Matrix correlation of soil content in Chemerong Recreational Forest

	pH	OM	CEC	Mg	K	P	% Clay	% Silt
OM	-0.442							
CEC	-0.221	0.164						
Mg	-0.002	-0.093	-0.034					
K	0.005	-0.081	-0.08	0.986***				
P	0.386	-0.465	-0.166	-0.136	-0.087			
% Clay	0.379	-0.565**	0.019	-0.23	-0.211	0.709***		
% Silt	-0.023	0.574**	0.045	0.128	0.123	-0.369	-0.469*	
% Sand	-0.344	0.001	-0.046	0.093	0.079	-0.342	-0.528	-0.501*

Note: *p< 0.05, **p< 0.01, ***p< 0.001.

et al. (2014a; 2014b) where they found the OM in inland forest was higher than in the seasonal flood and riverine forest. There are significant differences in available phosphorus (P) ($p<0.01$), nitrate (NO^{3-}) ($p<0.001$), electric conductivity (EC) ($p<0.05$), organic matter (OM) ($p<0.001$) and moisture content ($p<0.05$) between the two types of forests (Table 6). Throughout, the correlation between the physico-chemical content of soil in this study was moderate. Available P, for instance, had a positive correlation with the percentage of clay ($p<0.001$) (Table 7). This indicated the soil content, which had high available P may have a higher percentage of clay. There were also positive correlations between available Mg and available K ($p<0.001$), silt with OM ($p<0.01$), but negative correlation was found between clay with silt ($p<0.05$), clay with OM ($p<0.01$) and silt with sand ($p<0.05$) (Table 6). Soil with high percentage of clay may have less percentage of silt and OM.

Soil-plant relationship

The Canonical Correspondence Analysis (CCA) on the soil-plant relationship was conducted based on the selected 39 tree species (Table 9). The selection of the plant species was based on their occurrence within the subplots where the occurrences less than three were eliminated to ease the CCA following Barruch (2005). The eigenvalues for the first and second CCA axes had low values of 0.568 and 0.234 respectively Moreover, the total inertia observed in the CCA analysis was only 0.655 and only 56% of the variation was explained by the first axis, which suggests that the overall association between the species and environmental matrices was low. Based on the Monte-Carlo permutation test, there was no significant difference of the eigenvalues for the three ordination axes ($p >0.05$). The percentage variance of the species environment relation given was cumulatively from the CCA, which can be obtained by weighted regression (Nizam *et al.,* 2006; Khairil *et al.,* 2014a; 2015) (Table 10). The inland and riparian forest tree group was not clearly separated on the CCA ordination diagram. Nevertheless the vector for soil available P, Mg and pH were the longest among the soil variables, which suggests that these elements may have an important influence on species' distributions. The species preference in relations to environmental variables is illustrated in the species–environment bi-plot in Figure 2. At least nine tree species had significant association with soil

Table 9. The list of 39 out of 265 selected tree species in Canonical Correspondence Analysis (CCA) at Chemerong Recreational Forest, Terengganu, Malaysia

Code	Species	Code	Species
1	*Anisophyllea disticha* (Jack) Baill.	21	*Knema laurina* (Blume) Warb. var. *laurina*
2	*Anisophyllea scortechinii* King	22	*Lijndenia laurina* Zoll & Moritzi
3	*Artocarpus scortechinii* King	23	*Lindera lucida* (Blume) Boerl.
4	*Baccaurea parviflora* (Müll. Arg.) Müll. Arg.	24	*Monocarpia marginalis* (Scheff.) J. Sinclair
5	*Barringtonia scortechinii* King	25	*Ochanostachys amentacea* Mast.
6	*Brackenridgea hookeri* (Planch.) A. Gray	26	*Palaquium rostratum* (Miq.) Burck
7	*Calophyllum canum* Hook.f.	27	*Pellacalyx axillaris* Korth.
8	*Canarium littorale* Blume	28	*Ryparosa wallichii* Ridl.
9	*Ctenolophon parvifolius* Oliv	29	*Saprosma scortechinii* King & Gamble
10	*Cynometra malaccensis* Meeuwen	30	*Shorea guiso* (Blanco) Blume
11	*Dacryodes rostrata* (Blume) H.J. Lam	31	*Shorea macrantha* Brandis
12	*Diospyros buxifolia* (Blume) Hiern	32	*Shorea macroptera* Dyer
13	*Dryobalanops oblongifolia* Dyer ssp. *occidentalis* P.S. Ashton	33	*Streblus elongatus* (Miq.) Corner
		34	*Syzygium griffithii* (Duthie) Merr. & L.M. Perry
14	*Euonymus javanicus* Blume	35	*Vitex vestita* Wall. ex Schauer
15	*Gaertnera obesa* Hook.f. ex C.B. Clarke	36	*Xanthophyllum affine* Korth. ex Miq.
16	*Garcinia eugeniifolia* Wall. ex T. Anderson	37	*Xanthophyllum griffithii* Hook.f. ex A.W. Benn. ssp. *erectum* Meijden
17	*Garcinia nigrolineata* Planch. ex T. Anderson		
18	*Gironniera nervosa* Planch.	38	*Xerospermum noronhianum* (Blume) Blume
19	*Goniothalamus macrophyllus* (Blume) Hook.f. & Thomson	39	*Xylopia ferruginea* (Hook.f. & Thomson) Hook.f. & Thomson var. *ferruginea*
20	*Knema conferta* (King) Warb.		

Table 10. The summary of CCA vegetation analysis with the edaphic factor at Chemerong Recreational Forest

Axis	1	2	3	Total inertia
Eigenvalues	0.568	0.234	0.103	0.655
Variance in species data				
% of variance explained	56.5	33.2	11.6	
Cumulative % explained	56.5	89.7	101.3	
Pearson Correlation, Spp-Envt*	0.973	0.968	0.985	
Kendall (Rank) Corr., Spp-Envt	0.667	0.667	1.000	

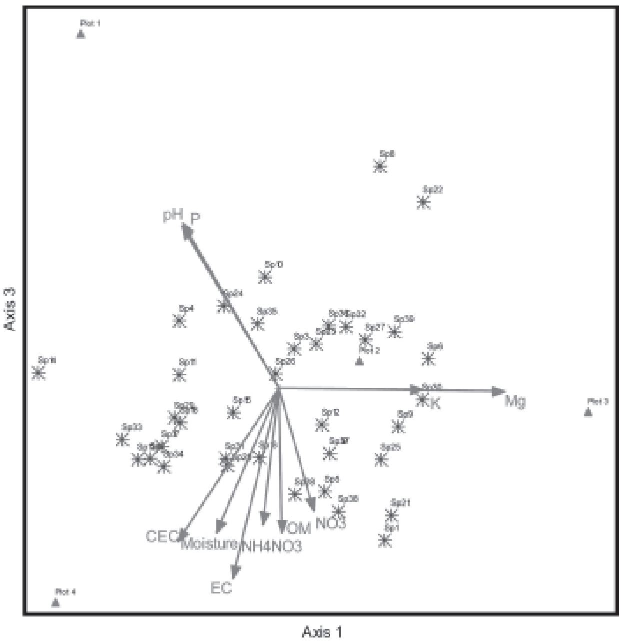

Fig. 2. CCA bi-plot for the species and variables of soil which show the relationship of tree species distribution with physico-chemical of soil.

Table 11. List of the species which were highly influenced by the physico-chemical of soil elements

Code	Species	n	Habitat description	Family	Elements
5	*Barringtonia scortechinii*	9	In undisturbed coastal, swamp, and mixed dipterocarp forests up to 700 (-1300) m altitude. Often on alluvial sites or near rivers, but also on hillsides and ridges. On sandy to clay soils, also on limestone.	Lecythidaceae	NO_3
16	*Garcinia eugeniifolia*	14	Forest understorey. Lowland forest.	Cluisaceae	Air dry moisture
20	*Knema conferta.*	28	In undisturbed mixed dipterocarp, swamp and kerangas forests up to 600 m altitude. On alluvial sites near or along rivers and streams. On sandy soils.	Myristicaceae	CEC
24	*Monocarpia marginalis*	16	Undisturbed lowland forest up to 1000 m altitude. Usually on hillsides and ridges with sandy soils. In secondary forests usually present as a pre-disturbance remnant.	Annonaceae	Available P, pH
6	*Palaquium rostratum*	17	In undisturbed mixed dipterocarp, kerangas, swamp, coastal and sub-montane forests up to 1200 m altitude. Growing both in alluvial sites as well as on ridges, mostly on sandy soils, but also on clay and limestone.	Sapotaceae	Available P, pH
8	*Ryparosa wallichii*	5	In undisturbed mixed dipterocarp forests up to 800 m altitude. Usually on hillsides and ridges with clay to sandy soils. In secondary forests usually present as a pre-disturbance remnant tree.	Flacourtiaceae	OM, EC
30	*Shorea guiso*	4	In undisturbed forests up to 400 m altitude. Usually on ridges with sandy and limestone soils. Scattered in lowland forest on red soils, most common in slightly seasonal climates.	Dipterocarpaceae	Available K, Mg
31	*Shorea macrantha*	4	In undisturbed mixed dipterocarp forests up to 700 m altitude. On alluvial and dry sites (hillsides and ridges) on clayey to sandy soils, also on limestone.	Dipterocarpaceae	CEC
38	*Xerospermum noronhianum*	17	In undisturbed mixed dipterocarp to sub-montane forests up to 1500 m altitude. Mostly on hillsides and alluvial sites with sandy to clay soils.	Sapindaceae	NO_3, OM

Notes: NO_3; Nitrate, CEC; cation exchange capacity, OM; organic matter, EC; electrical conductivity.

parameters, for instance by soil pH, EC, air dry moisture, available Mg, K, P and organic matter (OM). The list of species influenced by the edaphic factors is shown in Table 11.

Besides soil edaphic factor, other environmental factors should also be taken into consideration in future research such as altitude, topography, soil water content and forest gap (John *et al.,* 2007; Baldeck *et al.,* 2013; Khairil *et al.,* 2014a; 2015) in investigating the factors shaping the pattern of the tree species diversity and composition in this area. Based on Whitmore, (1990); Itoh *et al.* (1995); John *et al.* (2007) and Baldeck *et al.* (2013), besides the physico-chemical characteristics of soil, sunlight, topography and altitude are among the important factors influencing the distribution of several tropical plant species.

CONCLUSION

Both riparian and inland forests in this study were significantly different in terms of species diversity and composition as well as their soil physico-chemical contents. The soil edaphic factor has shown a less association with species composition in this study indicating the soil edaphic factor is not the main factor controlling the species distribution at this site. Further study is suggested to investigate other environmental factors that shape the pattern of the tree species diversity and composition in this area. Understanding the plant-soil relationship is of great importance to conserve and manage the forest ecosystems in the future. As a one of the important ecotourism sites in Terengganu, Malaysia, Chemerong Recreational Forest deserves attention from the stakeholders and state government to preserve this area and other reserve forests to ensure the natural green asset and other biotas in the state will still remain.

ACKNOWLDEGMENTS

We would like to thank Dr. Shamsul Khamis (UKM) and Mr. Razali bin Salam (UMT) for their help during plants identification process. This study was also funded by UniSZA Seed Money Grant UniSZA/11/GU (36).

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