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Soil Properties and Variation between Three Forest Types in Tropical Watershed Forest of Chini Lake, Peninsular Malaysia

(Ciri dan Variasi Tanah antara Tiga Jenis Hutan dalam Hutan Lembangan Tropika, Tasik Chini, Semenanjung Malaysia)

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ABSTRACT

Three forest types were recognized at Chini watershed namely inland, seasonal flood and riverine forests. The soil physico-chemical characteristics from the three forest types were investigated to determine the soil properties variation within a landscape scale. Thirty sampling stations were established, represented by fourteen inland, nine stations in seasonal flood forest and seven in riverine forest. In each station, three soil samples were taken at 0-15 cm depth by using an auger. The study showed 71% of the soil in the inland forest was found to be dominated by clay, 44% of the soil in the seasonal flood forest by clay loam and 42% of the soil in the riverine forest was dominated by silty clay. The pH of all three types of forest studied was acidic and insignificantly different. Organic matter content in the study sites was moderate. The mean of electric conductivity (EC) and cation exchange capacity (CEC) values in the studied soils were low. Based on ANOVA, there were significant differences of the available P and K, K^+, Ca^{2+} *and* Mg^{2+} *cations and electrical conductivity amongst the three forest types (*$p < 0.05$*). Cluster analysis showed that the variations of the soil physico-chemical characteristics between the three forest types were low thus indicating that the soil physico-chemical investigated in this study were not the only main contributing factors in floristic variation of the three forest types in Chini watershed.*

Keywords: Chini watershed forest; soil physic-chemical properties; soil variation

ABSTRAK

Tiga jenis hutan telah dikenal pasti di lembangan Chini iaitu hutan pedalaman, banjir bermusim dan riparia. Suatu kajian ke atas sifat fizik-kimia tanah di ketiga-tiga jenis hutan ini dijalankan untuk menentukan variasi ciri tanah pada skala landskap. Sebanyak tiga puluh stesen persampelan telah dibina yang diwakili oleh empat belas stesen di hutan pedalaman, sembilan stesen di hutan banjir bermusim dan tujuh stesen di hutan riparia. Tiga sampel tanah diambil pada kedalaman 0-15 cm menggunakan auger, di setiap stesen. Kajian mendapati sebanyak 71% tanah di hutan pedalaman didominasi oleh liat, 44% tanah di hutan banjir bermusim didominasi oleh lom liat dan 42% tanah di hutan riparia didominasi oleh kelodak liat. Ketiga-tiga jenis hutan menunjukkan nilai pH yang berasid dan tidak berbeza secara signifikan. Nilai kandungan organik tanah adalah sederhana di tapak kajian. Nilai min kekonduksian elektrik (EC) dan keupayaan pertukaran kation (CEC) kajian ini adalah rendah. Berdasarkan analisis ANOVA, terdapat perbezaan yang signifikan ($p<0.05$*) bagi nilai P dan K tersedia, kation-kation* K^+, Ca^{2+} *dan* Mg^{2+} *dan kekonduksian elektrik tanah di antara tiga jenis hutan. Analisis kluster menunjukkan variasi ciri fizik-kimia tanah antara tiga jenis hutan adalah rendah. Kajian ini mendapati kandungan fizik-kimia tanah bukanlah satu-satunya faktor yang mempengaruhi variasi tumbuhan di tiga jenis hutan di lembangan Chini.*

Kata kunci: Ciri fizik-kimia tanah; lembangan Chini; variasi tanah

INTRODUCTION

Tasik Chini is an inland riverine swamp that supports a unique biodiversity of species. The watershed includes several rivers, a lake, swamps and inland forest. Chini watershed recorded an exceptionally high diversity of flora and fauna (Khairil et al. 2011; Mushrifah et al. 2005). Due to its wealth of natural resources, Chini watershed has been declared as a Man and Biosphere Reserve by UNESCO since May 2008.

Despite the status, land area around Tasik Chini has been developed for agriculture, settlement and tourism. These activities involve felling of trees which contributes to erosion, occurrence and sedimentation of solid material into the Chini lake (Sahibin et al. 2009). This may decrease the lake depth in the long-term. Tasik Chini is also proposed to be gazetted as a Pahang State Park (Rancangan Tempatan Daerah Pekan 2002-2015), Chini watershed deserves more attention, especially with regards to conservation activities, in order to ensure the preservation of its tree species composition and physical environment.

Previous studies indicated that tree species abundance has been shown to be co-related with the physico-chemical status of soil in many areas (Mata et al. 2011; Nizam et al. 2006; Teixeira et al. 2008). Soil contains nutrients that are required by plants to grow (Othman & Shamshuddin 1982). Hirai et al. (1995) reported soil physico-chemical characteristics and topography influences the growth of *Dryobalanops aromatica* and *Dryobalanops lanceolata* in Sarawak. The physico-chemical makeup of the soil also influences the production rate of seeds and fruits of plants species (Whitmore 1984). An investigation on physical factors of an ecosystem is therefore important to elucidate the possible limiting factors in controlling plant species abundance.

Khairil et al. (2011) showed a distinct floristic variation amongst three forest types in Chini namely, inland, seasonal flood and riverine forests. The three forest types were suggested based on the forest habitats and distinct tree species assemblages in those areas. The finding leads to a research question, whether the soil properties variation is consistent with the floristic variation found in Chini watershed forest. Thus, the objective of this study was to determine the physico-chemical characteristics of the soil and its nutrient concentrations in the three types of forest in the Chini watershed. Information obtained on the soil status in Chini watershed is expected to be a baseline data for other ecological studies and conservation activities here.

MATERIALS AND METHODS

Chini watershed is located in the state of Pahang and approximately 100 km from Kuantan town (Figure 1). Tasik Chini basin includes a lush tropical secondary rain forest covering an area of 4975 ha from which many rivers and streams feed the lake (Mushrifah et al. 2005, 2009). The area of the lake is not constant and the size can be between 150 and 350 ha due to flood especially during the rainy season which is between October and November (Chong 2001).

Additional details on the background of the study area can be referred to Khairil et al. 2011 and 2014. A total of thirty sampling stations were established during this study. Stratified random sampling design based on the three forest types was utilised. Fourteen stations in the inland forest, nine stations in the seasonal flood forest and seven stations in the riverine forest were established (Figure 1). Approximately 500 g of soil at a depth between 0-15 cm

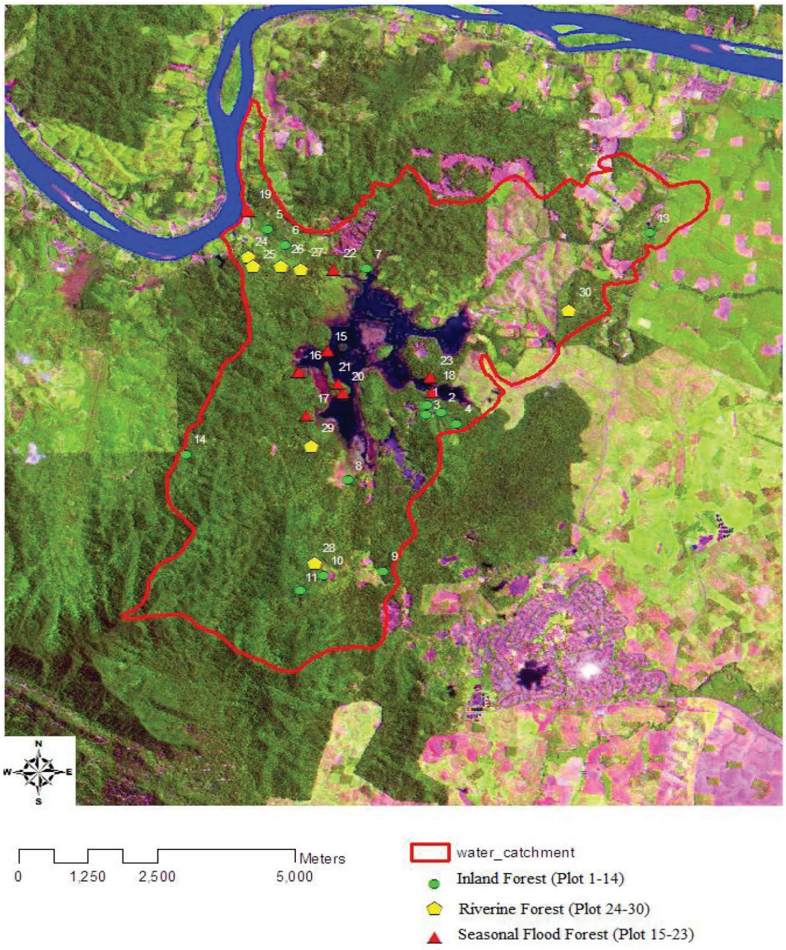

FIGURE 1. The location of sampling stations within the 4975 ha Chini watershed area on a SPOT 5 Satelite image overlayed with topographic features base map to differentiate the habitat of the three forest types, i.e. inland forest (filled green circle), riverine forest (filled yellow hexagon) and seasonal flood forest (red triangle)

were sampled using an auger with three replicates for each sampling station. Soil samples were then air-dried at room temperature. Roots, small stones and leaves were separated from the soil. Samples were then sieved and soil lumps were crushed.

Physical soil properties including soil texture was obtained by plotting the percentage ratio of sand, silt and clay using the soil texture triangle (Rowell 1994; Shamshuddin 1981). Particle size distribution was determined by the pipette method as well as drying and sieving (Shamshuddin 1981).

Chemical soil properties were organic matter content that was determined by loss on ignition technique. Soil pH was determined in a soil to water ratio of 1:2.5 (Shamshuddin 1981). Exchangeable acidic cations (Al^+ and H^+) were measured in 1.0 M KCl extracted by titration. Exchangeable basic cations ($Ca^{2+,}$ $Mg2^+$, Na^+ and K^+) were extracted using 1.0 M ammonium acetate extract (Shamshuddin 1981) and were determined by an Atomic Absorption Spectrophotometer (AAS). The cation exchange capacity was obtained by the summation of acid and base cations. Electrical conductivity was determined in a saturated gypsum extract (Rowell 1994). Available nutrient extracted using double acid was determined by a Flame Atomic Absorption Spectrophotometer (FAAS).

Data analysis utilised one way analysis of variance (ANOVA) to determine the differences of mean values of the physico-chemical properties amongst the three forest types. Correlation analysis was used to determine the correlation among the soil parameters. The cluster analysis using Ward hierarchical classification was adopted to identify soil sample grouping of the thirty stations (McCune & Grace 2002).

RESULTS AND DISCUSSION

PHYSICAL CHARACTERISTICS

Table 1 shows the studied physical parameters at all sampling areas. Based on the texture, 71% of the soil

TABLE 1. Mean (±SE) of soil particle (%), soil texture and organic content (%) of the 30 sampling stations in the three forest types at Chini watershed forests, Pahang

Station	% Silt	% Clay	% Sand	Texture	% OM
Inland Station					
1	9.0±1.0	64.8±1.4	26.1±0.9	Clay	13.0±0.3
2	16.8±1.0	50.4±0.2	32.7±0.9	Clay	11.1±0.6
3	25.0±0.9	44.1±0.5	30.8±1.0	Clay	13.1±2.6
4	7.6±0.8	70.0±0.8	22.3±0.4	Clay	16.9±0.2
5	20.8±0.5	16.3±1.0	62.7±1.0	Sandy Loam	6.8±2.9
6	24.6±4.8	14.9±4.8	109.7±0.1	Sandy Loam	3.8±0.1
7	28.1±4.4	13.9±11.0	57.9±6.9	Sandy Silt Loam	4.2±0.1
8	15.0±0.8	40.6±0.3	44.3±1.0	Clay	8.5±1.1
9	44.4±0.6	18.4±2.2	37.0±1.0	Clay	13.2±0.5
10	30.7±1.7	25.7±2.3	43.5±0.6	Clay	6.3±0.4
11	34.6±2.9	29.9±2.3	35.4±5.2	Clay	4.2±0.7
12	9.7±1.4	80.0±1.5	10.2±0.6	Clay	18.5±1.4
13	6.4±0.9	27.1±0.2	66.4±0.7	Sandy Loam	6.1±0.1
14	27.5±0.8	25.6±0.6	46.8±1.1	Clay	3.8±0.3
Seasonal Flood Station					
15	13.1±5.4	80.1±5.6	6.6±0.2	Clay	11.9±0.8
16	29.1±1.0	20.4±0.2	50.4±1.3	Sandy Loam	4.6±0.4
17	18.7±1.0	18.0±0.9	63.2±0.8	Sandy Loam	5.2±0.3
18	27.5±2.1	47.3±1.6	25.0±0.5	Clay Loam	15.1±1.1
19	18.2±0.6	21.6±2.8	60.0±3.3	Sandy Loam	4.1±0.6
20	34.0±0.6	7.3±0.7	44.7±0.5	Clay Loam	5.7±0.4
21	17.6±1.2	22.0±0.8	60.3±0.4	Clay	6.0±0.5
22	29.3±0.8	39.6±0.2	30.9±0.9	Clay Loam	6.7±0.3
23	31.3±1.2	33.9±1.0	34.6±0.8	Clay Loam	14.9±1.3
Riverine Station					
24	40.8±1.2	32.5±0.6	26.6±1.7	Clay Loam	7.3±0.8
25	40.9±0.4	48.0±0.3	11.0±0.3	Clay	10.8±1.1
26	47.9±1.1	38.0±0.6	14.0±1.3	Silty Clay	11.2±0.5
27	52.5±0.5	41.5±0.9	5.9±0.3	Silty Clay	12.1±0.8
28	29.1±5.1	31.9±5.2	38.9±0.4	Silty Clay	7.5±0.7
29	29.5±0.4	24.4±0.4	46.0±0.7	Clay Loam	4.9±0.5
30	11.2±0.6	15.5±2.9	46.0±3.3	Sandy Loam	5.4±0.1

in the inland forest was dominated by clay. Clay can be classed based on a portion of at least 40% clay, 35% sandy clay and at least 40% silty clay (Nyle & Ray 1996). This texture is not so suitable for the provision of nutrients to the plants. Soil physical characteristics with high proportion of clay will become tacky and will decrease water movement (Shamshuddin 1981). Meanwhile, about 44% of the soil in the seasonal flood forest was dominated by clay loam and 42% of the soil in the riverine forest was dominated by silty clay (Table 1). Since the riverine and seasonal flood forest is usually influenced by the flood, thus the texture of the soil in both areas was slightly different from the inland forest.

According to Nyle and Weil (1996), an ideal loam may be defined as a mixture of sand, silt and clay particles that exhibit the properties of the individual components in about equal proportions. A loam in which clay is dominant is classified as clay loam. The texture of loam is more suitable for plantation activities because its structure is not too compact, allowing roots to penetrate while water and air in the soil are balanced (Othman & Shamshuddin 1982; Shamshuddin 1981).

The mean percentage of organic matter in the inland forest was 9.3±0.8% (ranged from 3.8±0.1 to 18.5±1.4), seasonal flood forest was 7.8±0.8% (4.1±0.6 to 15.1±1.1) and riverine forest with 8.4±0.6% (4.9±0.5 to 12.1±0.8) (Table 1). Organic matter content between 4 and 10% is considered moderate by Landon (1991). The percentage of organic matter in the inland stations in this study were similar to the value recorded by Sahibin et al. (2009) in their study at Bukit Ketaya and Bukit Tebakang, Tasik Chini that had the highest value of 10.2%. Sahibin et al. (2009) reported that the organic matter at the Tasik Chini area ranged from 4.3% to 13.2% and at the river bank of Sungai Chini it was 3.3% to 7.1%. The organic matter recorded at this area were slightly higher than that found by Norlailatul Wahidah (2006) at Rantau Abang, Terengganu where the mean organic matter was between 0.5 and 1.8% and that reported by Nizam et al. (2006) at National Park, Merapoh, Pahang, where the mean organic matter was at 5.83±0.3%. In this study, the inland forest had the highest organic matter content since it was not been flushed by the flood during the flood seasons. Thus, they can keep more organic matter compared with seasonal and riverine forest. The level at which organic matter accumulates in soils is determined by the balance of gain and losses of organic carbon. The gains are principally governed by the amounts and types of plant and animal residue added to the soil each year, while the losses result from the oxidation of existing soil organic matter, as well as erosion (Nyle & Weil 1996). Othman and Shamshuddin (1982) suggested that the distribution of organic matter in tropical forests were low because of a high amount of rainfall and high temperature.

CHEMICAL PROPERTIES

Our results indicated that the soils in the three types of Chini forest were acidic (Table 2). The mean pH in the inland forest ranged between 3.65±0.02 and 4.24±0.01. Meanwhile the mean pH in the seasonal flood forest ranged from 3.80±0.02 to 4.37±0.01 and in the riverine forest between 3.82±0.01 and 4.16±0.01. This value is normal for forest soils where weathering and leaching processes occur continuously besides the acidifying effect of organic matter decomposition (Sahibin et al. 2009).

Cation exchange capacity (CEC) is the total sum of exchangeable cation that can adsorb by the soil. CEC was used as a measurement of fertility, nutrient retention capacity and the capacity to protect groundwater from cation contamination. The higher amount of CEC could increase the fertility of the soil (Neil & Weil 2014). The mean range of the total CEC in this study was between 5 and 15 meq/100 g (Table 2) which is considered low (Landon 1991). The range of mean values of the cation exchange capacity in the inland forest was between 4.59±0.10 and 12.99±0.14 meq/100 g. In the seasonal flood forest, the range of mean values was between 4.63±0.16 and 16.70±0.21 meq/100 g while in the riverine forest, the range was between 5.66±0.34 and 13.88±0.27 meq/100 g. Overall, riverine forest has the highest CEC with 9.01±1.72 meq/100 g followed by seasonal flood with 8.34±2.08 meq/100 g and inland forest with 7.94±1.45 meq/100 g. Sahibin et al. (2009) reported that the CEC adjacent to the Chini Lake area was 6.5 while it was 3.2 meq/100 g in the inland area. In other studies, Norlailatul Wahidah (2006) reported that the CEC at Rantau Abang was 0.47 - 2.19 meq/100 g.

Wan Juliana et al. (2009) reported that the CEC of the alluvial soil at Pasoh Forest Reserve was 2.99 meq/100 g, shale soil was 6.3 meq/100 g while lateritic soil was 6.3 meq/100 g. The cation exchange capacity is dependent to the content of clay and organic matter. The higher the percentage of clay and organic matter, the higher the CEC (Othman & Shamshuddin 1982; Shamshuddin 1982).

The range of mean values of electrical conductivity (EC) in the inland forest was between 2.71±0.12 and 3.30±0.88 mS/cm. In the seasonal flood, forest range was between 2.64±0.11 and 3.06 ±0.28 mS/cm while in the riverine forest range between 2.72±0.34 and 3.11±0.03 mS/cm. Overall, the mean value of the EC at inland forest was the highest with 2.99±0.03 compared with seasonal flood and riverine with 2.84±0.02 and 2.88±0.03 mS/cm, respectively and the amount were significantly different among these three forest types ($p<0.01$). The value of EC in the seasonal flood and riverine were less maybe caused by the dilution during the flood season since flood water has the capacity to flush the salt in soil. However, the values recorded from these three types of forest were considered low, indicating that the sites have low salt content and are suitable for plants growth. A higher index of electrical conductivity could disturb the growth and development of plants (Landon 1991; Shamshuddin 1981).

SOIL NUTRIENTS

The results indicated that the mean of available P in all stations was low (Table 3). The mean range of P in the inland

TABLE 2. The mean (±SE) of soil pH, cations, cation exchange capacity (CEC) and electrical conductivity (EC) of the 30 sampling stations in the three forest types at Chini watershed forests, Pahang

Station	pH	Ca 2^+	Mg $^{2+}$	Na$^+$	K$^+$	CEC	EC mS/cm
		(meq/100g)					
Inland forest							
1	4.24±0.01	0.41±0.01	0.65±0.04	0.35±0.01	0.49±0.02	5.20±0.14	2.93±0.03
2	4.17±0.02	0.38±0.04	0.63±0.06	0.3±0.02	0.41±0.02	8.29±0.26	3.06±0.03
3	4.04±0.01	0.3±0.01	0.51±0.02	0.29±0.02	0.41±0.01	8.08±0.15	2.80±0.08
4	4.08±0.03	0.48±0.12	0.54±0.14	0.5±0.10	0.64±0.14	5.76±0.53	2.70±0.03
5	4.18±0.06	0.38±0.03	0.76±0.01	0.42±0.01	0.31±0.01	7.81±0.17	2.80±0.03
6	4.10±0.03	0.4±0.01	0.83±0.07	0.5±0.16	0.44±0.03	6.17±0.22	3.23±0.08
7	4.24±0.03	0.25±0.01	0.56±0.08	0.39±0.07	0.48±0.09	9.80±0.17	3.30±0.08
8	3.98±0.02	0.75±0.35	0.78±0.12	0.33±0.04	0.5±0.17	9.26±0.72	2.99±0.03
9	3.76±0.04	0.21±0.01	1.13±0.20	0.5±0.02	0.87±0.10	11.18±0.15	2.79±0.03
10	3.65±0.02	0.3±0.08	0.39±0.00	0.57±0.06	0.27±0.02	13.00±0.11	2.71±0.12
11	3.73±0.06	0.2±0.01	1.09±0.13	0.61±0.04	0.46±0.03	8.39±0.28	2.93±0. 14
12	3.86±0.12	0.16±0.00	0.25±0.04	0.41±0.02	0.21±0.05	4.59±0.10	3.26±0.51
13	3.92±0.03	0.2±0.02	0.44±0.04	0.42±0.02	0.3±0.03	5.16±0.16	3.22±0.15
14	3.96±0.09	0.13±0.01	0.14±0.02	0.38±0.01	0.25±0.04	5.69±0.56	3.14±1.09
Seasonal flood forest							
15	4.22±0.02	0.35±0.02	0.37±0.03	0.63±0.11	0.45±0.03	16.70±0.21	2.97±0.03
16	4.37±0.01	0.17±0.03	0.19±0.01	0.3±0.01	0.2±0.01	10.25±0.25	2.74±0.08
17	4.04±0.02	0.18±0.01	0.16±0.02	0.25±0.02	0.28±0.04	7.84±0.33	2.71±0.11
18	4.32±0.02	0.4±0.25	0.31±0.01	0.33±0.05	0.47±0.02	7.34±0.16	2.95±0.08
19	3.86±0.08	0.35±0.02	0.88±0.03	0.34±0.02	0.3±0.05	5.53±0.13	2.75±0.08
20	4.09±0.02	0.16±0.01	0.2±0.04	0.24±0.03	0.4±0.11	9.00±0.20	2.64±0.11
21	4.14±0.03	0.22±0.03	0.18±0.01	0.28±0.05	0.18±0.00	4.63±0.16	2.72±0.27
22	3.80±0.02	0.43±0.10	0.3±0.04	0.44±0.07	0.27±0.02	10.25±0.13	3.02±0.03
23	3.84±0.13	0.26±0.03	0.64±0.15	1.25±0.29	0.29±0.05	5.69±1.91	3.06±0.28
Riverine forest							
24	4.07±0.02	0.58±0.11	0.64±0.04	0.34±0.03	0.56±0.07	8.79±0.18	2.74±0.03
25	4.15±0.02	0.96±0.27	1.16±0.08	0.42±0.02	1.06±0.08	11.61±0.25	3.11±0.03
26	4.16±0.01	0.29±0.06	0.36±0.17	0.24±0.02	0.34±0.07	9.03±0.43	3.04±0.09
27	4.37±0.06	1.26±0.39	0.7±0.14	0.35±0.02	0.6±0.08	11.88 ± 0.19	2.72±0.12
28	3.99±0.07	0.18±0.01	0.45±0.02	0.50±0.03	0.49±0.04	5.66±0.34	2.72±0.34
29	3.89±0.04	0.32±0.01	0.72±0.11	0.50±0.04	0.41±0.07	13.88±0.27	3.08±0.23
30	3.82±0.01	0.44±0.01	0.57±0.04	0.41±0.00	0.32±0.02	8.37±0.48	2.76±0.08

forest was between 10.99±0.33 and 15.65±0.21 (µg/g). In the seasonal flood forest the range was between 11.40±0.09 and 13.75±0.29 (µg/g) while in the riverine forest, the range was between 12.66±0.21 and 16.98±0.16 (µg/g). Overall, the mean P in the inland forest was 13.13±1.04 (µg/g), 12.5±0.44 (µg/g) in the seasonal flood forest and 14.27± 1.23 (µg/g) in the riverine forest (Table 4). Phosphorus is an important component for plant growth and also helps plants to accelerate the production of roots, flowers and fruits (Kalpage 1979; Othman & Shamshuddin 1982).

The mean of available K in the study site was also low. The mean range of K in the inland forest was between 71.09±2.48 and 229.13±0.06 (µg/g). In the seasonal flood forest the range was between 71.94±2.48 and 152.82±10.51 (µg/g) while in the riverine forest, the range was between 104.98±0.59 and 221.78±7.38 (µg/g). The overall mean of available K in the inland forest was 153.93±31.55 (µg/g), seasonal flood forest was 108.69±18.48 (µg/g) and riverine was 175.88±27.95 (µg/g). Potassium support plants in the photosynthesis process and it also protects the plants from disease (Kalpage 1979; Othman & Shamshuddin 1982).

The mean of magnesium (Mg) in the inland forest was from 22.14±3.17 to 116.34±12.14 (µg/g). In the seasonal flood forest, the range was from 38.30±7.58 to 96.67±12.11 (µg/g) while in the riverine forest, the range was from 104.98±0.59 to 221.78±7.38 (µg/g). In general, the mean of available Mg in the inland forest was 66.49± 18.45 (µg/g), seasonal flood forest was 52.55±11.73 (µg/g) and riverine was 62.28±7.76 (µg/g). Based on Landon (1991), if the value of available Mg is more than 54.0 (µg/g), it is considered high.

Based on the mean of the soil nutrients (Table 4), it was clear that the soil in riverine forest has higher amount of available P and available K compared to inland and seasonal flood forest. It can be considered soil in the riverine was more fertile since the available P and K was the major elements for plants growth. This may be due to the influence of water content in the soil since riverine

TABLE 3. Available nutrients in the soil of the 30 sampling stations in the three forest types in Chini watershed forest, Pahang

Station	P(μg/g)	K(μg/g)	Mg(μg/g)
Inland Forest			
1	11.10±0.18	220.84±3.63	53.88±0.11
2	12.15±0.22	220.84±3.63	53.24±0.63
3	11.74±0.29	229.13±0.06	51.84±0.67
4	14.16±0.55	92.49±8.52	41.38±0.73
5	10.99±0.33	71.09±2.48	94.67±8.73
6	14.94±1.08	172.89±16.17	116.34±12.14
7	15.48±0.15	208.34±33.63	48.49±15.13
8	13.44±0.15	195.99±32.99	52.04±4.71
9	15.65±0.21	188.00±9.68	108.21±30.46
10	12.86±0.42	102.06±4.69	61.67±7.07
11	14.02±1.30	124.00±18.02	97.99±18.56
12	11.20±0.40	86.89±16.04	41.40±3.97
13	12.39±0.67	126.47±24.49	72.57±14.39
14	13.65±1.18	128.16±24.67	22.14±3.17
Seasonal Flood Forest			
15	12.32±0.21	117.66±5.05	41.49±3.75
16	13.44±0.18	143.16±18.86	38.30±7.58
17	13.75±0.29	78.89±1.24	38.97±0.34
18	12.52±1.02	152.82±10.51	47.59±0.67
19	11.40±0.09	88.05±4.24	96.67±12.11
20	12.08±0.21	92.56±13.49	47.43±3.07
21	12.42±0.18	138.52±9.98	42.33±2.94
22	12.86±0.32	71.94±2.48	46.36±0.63
23	11.71±0.14	94.60±5.19	73.79±1.09
Riverine Forest			
24	16.98±0.16	215.48±13.77	215.48±13.77
25	16.33±0.24	221.78±7.38	221.78±7.38
26	12.66±0.21	209.29±5.78	209.29±5.78
27	13.78±0.71	197.57±4.75	197.57±4.75
28	11.27±0.27	158.43±17.39	158.43±17.39
29	15.79±0.07	123.65±23.42	123.65±23.42
30	13.07±0.91	104.98±0.59	104.98±0.59

TABLE 4. The mean (±SE) of soil chemical properties of the three forest types and the p value based on the analysis of variance (ANOVA) at the Chini watershed forests, Pahang

Soil properties	Inland forest (*n*=42)	Seasonal flood forest (*n*=27)	Riverine forest (*n*=21)	*p* value
pH	4.00 ± 0.11	4.08 ± 0.12	4.09 ± 0.10	0.112
Available P (μg/g)	13.13 ± 1.04^{ab}	12.50 ± 0.44^{b}	14.27 ± 1.23^{a}	0.002**
Available K (μg/g)	153.93 ± 31.55^{a}	108.69 ± 18.48^{b}	175.88 ± 27.95^{a}	0.000***
Available Mg (μg/g)	66.49 ± 18.45	52.55 ± 11.73	62.28 ± 7.76	0.089
Cations (meq/100g)				
K^+	0.43 ± 0.10^{ab}	0.32 ± 0.06^{a}	0.54 ± 0.15^{b}	0.000***
Na^+	0.43 ± 0.06	0.45 ± 0.19	0.40 ± 0.05	0.706
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***
Cation exchange capacity	7.94 ± 1.45	8.34 ± 2.08	9.01 ± 1.72	0.402
Electric conductivity (EC) (mS/cm)	2.99 ± 0.03^{a}	2.84 ± 0.02^{b}	2.88 ± 0.03^{ab}	0.003**

Note: Values with similar alphabet were not significantly different with *$p<0.05$, **$p<0.01$, and *** $p<0.001$

forest is frequently inundated during flood and rainy season. Thus it helps the uptake of the P and K by the soil in riverine forest. The ANOVA of the chemical properties of soil showed that there were significant differences of available P ($p< 0.01$), available K ($p< 0.001$), cations K^+ ($p< 0.0001$), Ca^{2+} ($p< 0.001$), Mg^{2+} ($p< 0.001$) and EC ($p< 0.01$) between the three types of forest.

The correlation between the physico-chemical characteristics of soil at the Chini watershed was examined and is shown in Table 5. The clay negatively correlated with silt where r=-0.664 (p<0.001). The results indicated that soil with a high percentage of clay will have a lower percentage of silt. In addition, silt is also negatively correlated with the percentage of sand where r=-0.632 (p<0.001). Furthermore, clay was fairly correlated with organic matter (OM) where r=0.379 (p<0.001). Based on a study by Nyle and Ray (1996), clay is permeable and can hold organic matter in the soil. Sand content negatively correlated with OM (r=-0.619, p<0.001). This indicates that soil with a high percentage of sand will have less organic matter. Sand cannot hold organic matter in the soil and this reduces the level of organic matter, especially during the rainy season.

Nevertheless available P was significantly correlated to available K (r = 0.304, p< 0.001). Soil with a high content of available P will also have a high content of available K but the correlation is low. The available Mg in this study negatively correlated with pH (r = -0.233, p< 0.05) but again the correlation is low. It shows that acidic soil will have a higher content of available Mg.

Three sub-groupings were differentiated in a dendogram from Ward's hierarchical classification (linkage level = 1.6), corresponding to the plots from each site (Figure 2). The soil group in Group 1 was dominated by the seasonal flood forest with seven plots, five inland plots and two riverine plots. Groups 2 and 3 were dominated by the inland forest plot with three and six plots, respectively. Based on the dendrogram, seasonal flood soil type occurred only in Groups 1 and 2 and the riverine soil type occurred only in Groups 1 and 3 while inland soil type occurred in all three groups.

Based on Khairil et al. (2011) the variation of tree species in the three forest types was clearly clustered. On the other hand, the dendrogram of soil characteristics in this study did not support the differences between the three forest types at Chini watershed. Our results indicated that soil characteristics alone cannot explain floristic variation in the three forest types and there must be other environmental factors that should be integrated to find the remaining source of variation among the three forest types at Chini watershed. Based on Felfili (1995), Medley (1992) and Teixiera et al. (2008), besides soil characteristics, the altitude, topography and water content are also factors that influence the tree species distribution and floristic variation in particular areas and habitats. Whitmore (1984) suggested that the gap area and canopy were also one of the factors influencing tree species distribution in a forest.

CONCLUSION

This study showed that some physico-chemical characteristics of the soil were significantly different among the three forest types. The inland forest was dominated by clay, the seasonal flood forest was dominated by clay loam and the riverine forest was dominated by silty clay. Organic matter in the forests was low and there was no significant difference of organic matter among the forest types. Based on chemical properties, there were significant differences between available P, available K, cations K^+, Ca^{2+}, Mg^{2+} and EC among the three types of forest. Further studies should be taken to see whether any other environmental factors could be the source of floristic variation of tree species between the forest types. Element such as soil moisture or water availability in the soil should be taking into consideration since these three types of forest were located in a watershed area.

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TABLE 5. The correlation matrix of soil physico-chemical properties at Chini watershed, Pahang

	pH	OM	Mg	K	P	CEC	% clay	% silt
OM	0.079							
Mg	-0.233*	-0.172						
K	0.386	0.159	0.156					
P	0.027	-0.191	0.098	0.304***				
CEC	-0.092	-0.109	-0.032	0.166	0.082			
% clay	0.176	0.379***	0.017	0.113	-0.037	-0.033		
% silt	-0.024	0.171	-0.320***	0.055	-0.004	0.218	-0.664***	
% sand	-0.151	-0.619***	0.404	-0.19	0.044	-0.254	-0.161	-0.632***

Notes *p<0.05, **p<0.01, ***p<0.001, OM= organic matter, CEC= cation exchange capacity

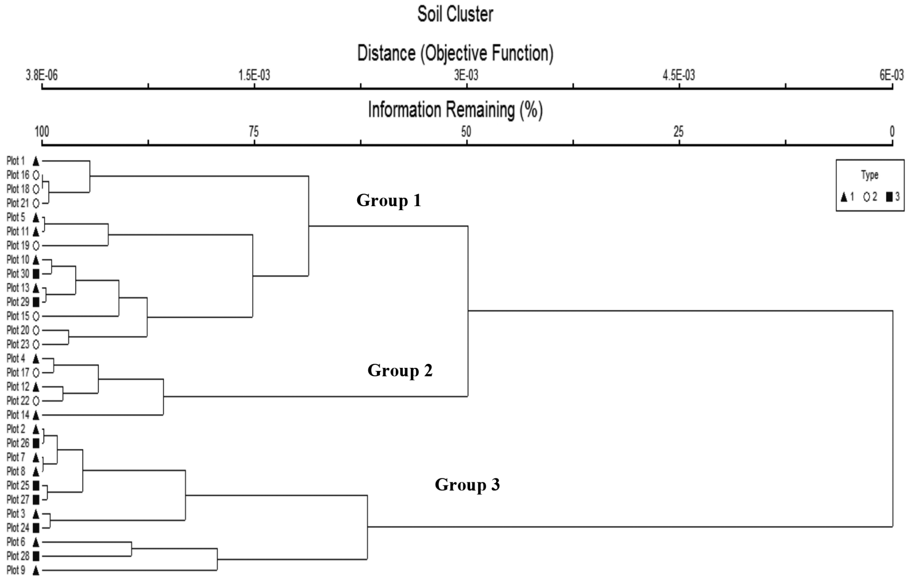

FIGURE 2. Dendrogram (using Ward hierarchical classification) showing the grouping of the thirty soil samples at Chini watershed forest. (Plot 1-14 Inland forest; Plot 15-23 Seasonal Flood forest; Plot 24-30 Riverine forest)

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