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The Physico-chemical Properties of Four Soil Series in Tasik Chini, Pahang, Malaysia

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ABSTRACT

A total of 20 topsoil (0-20 cm) and 36 subsoil (0-50 cm) samples were collected from four soil series namely the Malacca, Rasau, Bungor and Gong Chenak. The Physico-chemical properties such as particle size distribution, texture, Organic Matter content (OM), density, porosity, pH, Cation Exchange Capacity (CEC), Electrical Conductivity (EC), available nutrients and the presence of selected heavy metals were analyzed by the standard methods. The analysis showed that the subsoil and topsoil of the Rasau soil series consisted mainly of sandy loam, whereas the Bungor, Malacca and Gong Chenak soil series were mainly of clayey texture. The organic matter content of the Rasau soil series was very low; for the Malacca and Bungor series the organic matter content was low. The Gong Chenak soil series contained comparatively high OM content. Soil physical properties showed higher bulk density values in the disturbed soil horizons than in the undisturbed forest soils. All the soils studied had low pH and low electrical conductivity. The cation exchange capacity of all the soil series was low with values of less than 13.34 meq/100 g soil. The available phosphorus (P) and magnesium (Mg) values of all the soil series were low and very low, while available potassium (K) values were acceptable. Result of heavy metals analysis indicated that some heavy metals such as Pb, Zn, Cu, Co, Ni, Cr and Cd were present in all the soil series but occurred in low concentrations below the critical level.

Key words: Physico-chemical properties, available nutrients, heavy metals, soil profile, soil texture, bulk density, porosity

INTRODUCTION

Soils are the essential components of the environment and foundation resources for nearly all types of land use, besides being the most important component of sustainable agriculture (Bech *et al*., 2008). Therefore, assessment of soil quality, and its direction of change with time is an ideal and primary indicator of sustainable agricultural land management (Doran, 2002). Soil quality indicators refer to measurable soil attributes that influence the capacity of a soil to function, within the limits imposed by the ecosystem, to preserve biological productivity and environmental quality, and promote plant, animal and human health (Arshad and Martin, 2002). These attributes could be physical, chemical and/or biological properties of the soil (Arshad and Martin, 2002; Doran, 2002). Soils are dramatically altered by human activities in

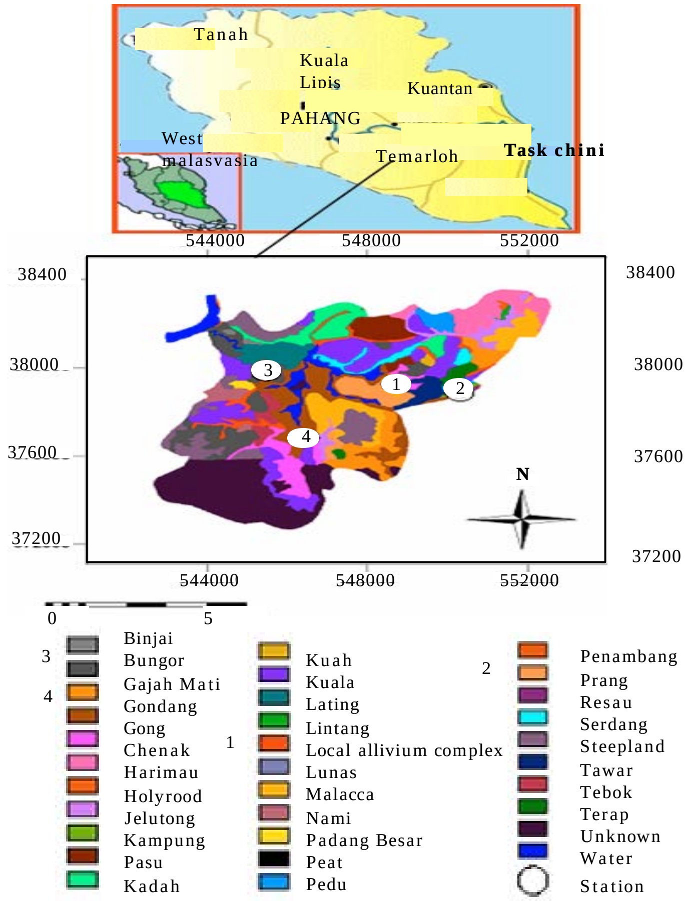

Fig. 1: Soil map of the tasik chini catchment area

agriculture and urban environments, and these alterations distinguish these soils from those in other systems and within urban environments (Scharenbroch *et al.*, 2005). Research has enabled assessment of the unique physical, biological and chemical properties of soils.

The Tasik Chini catchment consists of various land forms comprising of thirty one soil series, only four major soil series have been selected in this study (Fig. 1). The four series are the Malacca, Bungor, Rasau and Gong Chenak. The land area around Tasik Chini has been developed for agriculture, settlements and tourism. Developmental activities have significantly affected the ecological, biological and hydrological functions of the lake system. These activities also include logging, which is interrelated with the erosion and sedimentation of solids into the Tasik Chini's water body and this could eventually decrease the lake depth in the long-term. The Malacca soil series is lateritic in nature, brown to reddish brown in colour and is distributed around the Chini Resort. Laterization usually occurs when silicates are washed out, but the remaining sesquioxides of aluminium and iron accumulate and impart a deep red colour to the soil (Brady, 1990). The Rasau soil series is a weakly weathered soil, whitish in colour; the Bungor soil series is a moderately weathered soil, yellowish in colour. The Gong Chenak soil series is found nearer Lubok Itek and is formed from recent alluvium. It has also been identified around the Tasik Chini. These four major soil series are scattered within the lake (Fig. 1). Elaborate studies and clear knowledge on the soil types around the Tasik Chini including the soil characteristics are important in order to predict their potential physical and chemical impact on the well being of the lake water. The objective of this study is to quantify the physical and chemical characteristics of soils in the Tasik Chini Catchment.

Tasik Chini is located in the southeast region of the state of Pahang in Malaysia. It is approximately 100 km from Kuantan, the capital of Pahang. The lake system lies between 3°22' 30" to 3°28' 00" N and 102° 52' 40" to 102° 58' 10"E and comprises 12 open water bodies called "laut" by the local people and linked to the Pahang River by the Chini River. A few communities of the indigenous Jakun tribe live around the lake. Tasik Chini is the second largest natural fresh-water lake in Malaysia and is made up of 202 hectares of open water and 700 ha of Riparian, Peat, Mountain and Lowland Dipterocarp forest (Wetlands International Asia-Pacific 1998). Tasik Chini is surrounded by diversely vegetated low hills and undulating land which constitute the watershed of the region. There are three hilly areas surrounding the lake namely Bt. Ketaya (209 m) located southeast, Bt. Tebakang (210 m) at the north and Bt. Chini (641 m) southwest. The Tasik Chini Catchment is representative of the upstream site of the Pahang River in the town of Pekan. The area has a humid tropical climate with two monsoon periods, characterized by the following bimodal pattern: southwest and northeast monsoons that bring an annual rainfall which varies from 1488 to 3071 mm. The mean annual rainfall is 2,500 mm and the temperature ranges from 21 to 32°C. The potential evapotranspiration (PE) is between 500 to 1000 mm.

MATERIALS AND METHODS

Soil sampling: Soil sampling was derived from selected soil series, which located around the Tasik Chini area (Fig. 1). Soil sampling was carried under five days field trip on December 2006. Topsoil (0-20 cm) was collected randomly with a Dutch auger. Approximately 500 g samples were collected from each sampling station. The soil profile at every sampling location was dug (0-50 cm) and complete profile descriptions were recorded. Soil samples were also taken from every identifiable horizon within the profile for laboratory analysis. Soil profile description and soil sampling were done in accordance with the procedures of the Soil Survey Manual (Soil Survey Division Staff, 1993). Soil samples were put in tight plastic bags and transported to the laboratory. In the laboratory the samples were air dried, broken into smaller size particles with a wooden mortar and pestle and sieved through a 2 mm sieve. Five replicates of each soil sample taken from the profile and topsoil were analyzed.

Soil analysis: The air dried and sieved soil samples were used for determination of the physico-chemical characteristics which include soil particle size distribution, density, organic matter content, exchangeable acid cations (Al and H), exchangeable basic cations (Ca, Mg, K and Na), cation exchange capacity (CEC), soil pH, electrical conductivity, available nutrients and for some selected heavy metals (i.e. Pb, Zn, Cu, Co, Ni, Cr and Cd) in the soil. Particle size distribution was determined by the pipette method together with dry sieving (Abdulla, 1966). Texture of the soils was obtained by plotting the percentage ratio of sand, silt and clay using the textural triangle (Soil Survey Staff, 1998). Soil bulk density was obtained using the open ended metal cylinder (Ring) method (Rowell, 1996) and true density was calculated using the equation derived by Adams (1973). Porosity was calculated using the true and bulk densities. Organic matter content was obtained by loss on ignition. The pH of the soil was determined by the soil: water ratio of 1:2.5 (Metson, 1956). The exchangeable acid cations (Al and H) were obtained by titration with 1.0 M KCl extract. The exchangeable basic cations were extracted with 1.0 M ammonium acetate solution

(Thomas, 1982) and determined using the Flame Atomic Absorption Spectrophotometry (FAAS) (Perkin Elmer 3300). The cation exchange capacity was determined by summation of the acid and basic cations. Available P, K and Mg were extracted by ammonium acetate-acetic acid extractant and, K and Mg were determined using Flame Atomic Absorption Spectrophotometry (FAAS) (Thomas, 982). Available P was determined using the Ultra Violate Spectrophotometry (Helios Gamma 9423 UVG 1702E). The content of total heavy metals in soils were determined by acid digestion with a mixture of HNO_3-HF-$HClO_4$ (Chen, 2005), carried out by FAAS for Zn, Ni, Co and Cr and Graphite Furnace Atomic Absorption Spectrophotometry (GFAAS) (Perkin Elmer, Analyst 800) for Cd, Pb and Cu.

RESULTS AND DISCUSSION

Soil profile: The Malacca soil series contains two horizons respectively the A and B of depth 0-6 and >6 cm; the A horizon is strongly brown in colour (7.5YR5/6) whereas the B horizon is yellowish red (5YR5/6). The boundary between the A and B horizons is sharp. In soil description by Paramananthan (2000), the A horizon is noted as Ap whereas the B horizon is noted as Bo_1 which stands for the occurrence of the oxic horizon. The soil is clayey in texture, has a weak medium and a fine sub-angular blocky structure. It is very friable and contains fine sub-rounded petroplinthite. The parent material of this soil is shale. Most of the Malacca series soils were planted with tree crops mainly rubber and oil palm. Certain portions of this soil were found under primary forest vegetation.

The Rasau soil series consist of soils that have a weakly developed profile. They contain four horizons respectively the A, AB, BA and B at depths of 0-8, 8-20, 20-30 and >30 cm. They are whitish (10YR8/1) in colour and sandy loam in texture. The dominant whitish colour in this soil comes from its whitish sandy parent material, intensified further by leaching processes. The Rasau series is well drained and the parent material is alluvial deposits. Some of the area under this soil had been used for shifting cultivation and oil palm plantations. A small area was found under primary forest vegetation.

The Bungor soil series has two horizons, the A and BA at depths of 0-25 and >25 cm. The A horizon is dark grayish-brown in colour (10YR4/2) whereas the BA horizon is brownish yellow (10YR6/6) to yellowish in colour. The soil has clay texture, a weak medium and a fine subangular blocky structure. The parent material of the soil is mixed sandstone/shale. The profile of the soil is formed from the weathering of low-grade metamorphic rocks with ambiguous horizon divisions. In Paramananthan (2000), the soil profile extended to a depth of 300 cm. The current study only describes the top two horizons which are easily distinguishable in the field.

The Gong Chenak soil series contain four horizons, the A, AB, BA and B of depth 0-6, 6-13, 13-30 and >30 cm. The soil profile at the lake margin was formed by a mixture of hill soil of the Malacca series covered by lake sediment. The soil profile appearance represents the Malacca series at the lower profile and the lake sediment on the upper region. The Malacca series gives it a reddish (5YR4/4) colour and the lake sediment gives a grayish (10YR4/2) colour to the topsoil. This soil series was formed from recent alluvium. This soil was under primary forest and lowland dipterocarp forest vegetation.

Soil texture: The low silt content is a very noticeable feature of the Malacca and Bungor soil series. The Rasau and Gong Chenak soil series have higher silt content. The surface layers have comparatively lower silt content except for the Rasau series (Table 1). The Rasau soil has dominant sandy texture with sand content of more than 54%. The soil is sandy loam. All the other soils series

Table 1: Properties, size distribution and texture of the four soil series studied

	Soil series	Location	Horizon on	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
	Malacca	03°25' 27" N	A	0-6	28	6	66	Clay
		102°56' 36" E	B	> 6	24	9	67	Clay
Top soil (Mean of 5 replications)				0-20	39	11	50	Clay
	Rasau	03°26' 09" N	A	0-8	55	32	13	Sandy loam
		102°56' 18" E	AB	8-20	56	30	14	Sandy loam
			BA	20-30	54	31	15	Sandy loam
			B	> 30	54	30	16	Sandy loam
Top soil (Mean of 5 replications)				0-20	58	28	14	Sandy loam
	Bungor	03°17' 03" N	A	0-25	12	4	84	Clay
		102°13' 54" E	BA	>25	11	5	84	Clay
Top soil (Mean of 5 replications)				0-20	14	5	81	Clay
	Gong Chenak	03°26' 16" N	A	0-6	6	33	61	Clay
		102°55' 51" E	AB	6-13	10	24	66	Clay
			BA	13-30	28	37	35	Clay loam
			B	> 30	26	36	38	Clay
Top soil (Mean of 5 replications)				0-20	3	25	72	Clay

studied are predominantly of clayey texture. For the Malacca soil series there is a decrease in sand content with depth whereas in the Gong Chenak soil series there is an increase in sand content with depth. The decrease and increase in sand content in the Malacca and Gong Chenak soil series is compensated by increase and decrease in silt content, respectively.

The clay content in the respective soil profiles do not differ. The range of clay content in the Malacca, Rasau, Bungor and Gong Chenak soil series is as follows: 66-67, 13-16, 81-84 and 61-66, respectively. In the Gong Chenak soil series the clay content is in the lower horizons (BA, B) and is low because of the different parent material of the horizons. The surface layer in all of the soil series showed records of slightly lower clay content.

Physical properties of the soils studied: All the soil series studied contained low amounts of organic matter (OM) ranging from 1.10 to 7.40%, with an average of 3.90%. The distribution of OM was found to decrease with depth. In contrast, the OM content was the lowest in the sandy soils, such as the Rasau soil. Similar results have also been reported by Yaacob *et al.* (1979) where OM in sandy soils ranged from 0.40 to 1.56%. Due to intensive weathering and erosion in Malaysia, all the soil series studied contained less than 10% organic matter in the soil. According to the classification of Acres *et al.* (1975), OM in the studied soils was categorized in the low to medium class (OM< 10%). The bulk density values of the four soil series ranged from 1.06 to 1.33 g cm^{-3} with a mean value of 1.18 g cm^{-3}. Due to the sandy loam texture and low organic matter content in the Rasau series, the bulk density value was the highest (1.33 g cm^{-3}). This value is close to that reported by Peh (1978). The true density values of the four soil series ranged from 2.56 to 2.74 g cm^{-3} with an average value of 2.65 g cm^{-3}. Porosity values ranged from 51.40 to 58.75% (Table 2) with an average value of 55.44%. Porosity of the surface layer was slightly higher than that of the subsoil. The Bungor soil series was formed under forest vegetation, and had the highest values for porosity. The Malacca soil series was disturbed soil and had the lowest porosity. The Malacca series was distributed throughout the oil palm plantation area. Porosity of the surface soil was slightly higher than that of the subsoil. Higher porosity values in undisturbed soil have been reported by Pagliai *et al.* (1983) and Pagliai (1987).

Table 2: Physical properties of the four soil series studied

	Soil series	Horizon	Depth (cm)	Om (%)	Bulk density ($g\ cm^{-3}$)	True density ($g\ cm^{-3}$)	Porosity (%)
	Malacca	A	0-6	7.36	1.09	2.56	57.37
		B	>6	5.63	1.13	2.60	56.54
Top soil (Mean of 5 replications)			0-20	7.16±0.96	1.12±0.10	2.56±0.02	56.13±3.52
	Rasau	A	0-8	2.35	1.19	2.70	56.04
		AB	8-20	1.77	1.27	2.72	53.25
		BA	20-30	1.10	1.33	2.73	51.40
		B	>30	1.37	1.27	2.73	53.60
Top soil (Mean of 5 replications)			0-20	2.76±0.38	1.06±0.03	2.69±0.01	60.5±1.4
	Bungor	A	0-25	6.69	1.06	2.57	58.75
		BA	>25	5.10	1.08	2.61	58.62
Top soil (Mean of 5 replications)			0-20	8.73±0.85	1.03±0.05	2.52±0.02	59.18±2.37
	Gong Chenak	A	0-6	6.75	1.12	2.57	56.42
		AB	6-13	5.10	1.11	2.61	57.65
		BA	13-30	1.12	1.25	2.74	54.15
		B	>30	2.03	1.29	2.71	52.28
Top soil (Mean of 5 replications)			0-20	9.34±6.29	1.06±0.05	2.51±0.16	57.49±2.30

Chemical properties of the four soil series studied: The uniformity of pH values and the narrow range recorded are unique features of Malaysian soils. The pH values ranged from 3.02 to 3.81. Most of the pH values were below 3.47 and are considered low in the classification by Acres *et al.* (1975). The value is normal for forest soils where the weathering and leaching processes occur continuously in addition to the decomposition of organic matter effect. Most profiles showed a slight increase in the pH values down the profile, with the exception of the Bungor and Gong Chenak soil series. The value of electrical conductivity was below 2.55 $mS\ cm^{-1}$, which is also classified as low.

The value of the Cation Exchange Capacity (CEC) of the subsoil of the Malacca, Rasau, Bungor and Gong Chenak series ranged from 1.96 to 2.06 meq/100g, 2.54 to 3.37 meq/100g, 1.08 to 2.23 meq/100 g and 5.79 to 13.34 meq/100 g, respectively. The values of the CEC of all the top soils were comparatively higher than those lower in the soil profiles. This can be attributed to higher organic matter content in the top soil. The CEC of the Gong Chenak soil series was the highest (11.26 meq 100 g) and that of the Malacca series the lowest (1.96 meq/100 g) (Table 3). There was a decreasing distribution pattern from the top to the bottom of the soil profile. The basic cations were very low, meaning that the exchange base at the soil surface was dominated by acidic cations of Al and H. Similar results were also reported by Razi *et al.* (2005). The overall values of the CEC in the top soil and soil profiles were very low; however they were within the values of the respective soil series as described by Paramananthan (2000). The range of the CEC values of all the soil series studied were considered low in the classification by Acres *et al.* (1975).

Available nutrients in the soil profiles and topsoil: The amount of available phosphorus in the Malacca, Rasau, Bungor and Gong Chenak soil series ranged from 3.70 μg to 6.96 μg g, 4.66 to 7.96 $\mu g\ g^{-1}$, 3.92 to 7.00 $\mu g\ g^{-1}$ and 6.04 to 9.88 $\mu g\ g^{-1}$, respectively (Table 4). All the soil series had slightly higher P content in the surface layer. These values are considered low compared to the range (3-10 $\mu g\ g^{-1}$) of soil P reported by the Department of Agriculture (DOA 1997). Zahara

Table 3: Chemical properties of the four soil series studied

Soil series	Horizon	pH	ES mS cm^{-1}	Exchangeable base cation (meq/100 g soil) Mg^{+2}	Na^{+}	Ca^{+2}	K^{+}	CEC (meq/100 g soil)
Malacca	A	3.47	2.18	0.11	0.10	0.08	0.07	1.96
	AB	3.81	2.00	0.07	0.13	0.12	0.09	2.06
Top soil (0-20 cm)		3.68±0.09	2.24±0.16	0.21±0.10	0.08±0.01	0.3±0.05	0.2±0.06	3.47±0.60
Rasau	A	3.14	2.55	0.09	0.26	0.09	0.08	3.12
	AB	3.15	2.44	0.04	0.25	0.02	0.06	3.37
	BA	3.21	2.42	0.03	0.26	0.01	0.05	2.75
	B	3.15	2.45	0.03	0.24	0.02	0.05	2.54
Top soil (0-20 cm)		3.65±0.15	2.21±0.12	0.18±0.03	0.11±0.04	0.14±0.04	0.07±0.02	3.74±0.34
Bungor	A	3.32	2.03	0.08	0.14	0.06	0.05	2.23
	BA	3.02	2.02	0.03	0.17	0.05	0.03	1.08
Top soil (0-20 cm)		3.67±0.07	2.11±0.14	0.18±0.05	0.14±0.01	0.14±0.04	0.04±0.02	2.72±0.19
Gong Chenak	A	3.34	2.13	0.17	0.17	0.03	0.14	12.81
	AB	3.31	2.05	0.19	0.20	0.05	0.10	13.34
	BA	3.26	2.22	0.16	0.14	0.06	0.06	5.79
	B	3.30	2.30	0.13	0.21	0.07	0.05	6.09
Top soil (0-20 cm)		3.77±0.16	2.22±0.16	0.25±0.13	0.32±0.02	0.58±0.12	0.15±0.09	11.26±2.78

Table 4: Available nutrients in the soil profile and topsoil of the studied soils

Station	Soil series	Location	Horizon on	Depth (cm)	Available nutrient (µg g^{-1}) PO_4^{-2}	K^{+}	Mg^{+2}
	Malacca	03°25' 27" N	A	0-6	6.96	30.45	23.72
		102°56' 36" E	B	> 6	6.26	23.75	11.18
Top soil (Average of 5 replications)				0-20	5.38±1.31	32.98±11.98	21.72±6.80
	Rasau	03°26' 09" N	A	0-8	7.96	34.73	18.42
		102°56' 18" E	AB	08-20	6.68	25.64	14.80
			BA	20-30	6.26	21.26	3.49
			B	> 30	5.54	21.05	4.02
Top soil (Average of 5 replications)				0-20	6.55±1.27	48.94±8.35	24.33±4.08
	Bungor	03°17 03" N	A	0-25	6.04	20.72	26.00
		102°13' 54" E	BA	> 25	5.82	10.63	3.45
Top soil (Average of 5 replications)				0-20	5.94±1.20	42.65±8.20	24.1±6.90
	Gong Chenak	03°26' 16" N	A	0-6	9.44	39.81	23.53
		102°55' 51" E	AB	06-13	9.02	35.20	24.20
			BA	13-30	8.18	20.35	15.60
			B	> 30	6.04	21.26	12.28
Top soil (Average of 5 replications)				0-20	8.96±0.88	55.93±10.58	35.32±9.78

and Sharifuddin (1979) mentioned that Malaysian soils require the addition of a large amount of phosphorus because of the presence of large amounts of clay and amorphous materials. All soil series had slightly higher value of P in the surface layer and decreased with depth (Table 4). The value of available K in the Malacca, Rasau, Bungor and Gong Chenak soil series ranged from 18.16 to 48.94 µg g^{-1}, 21.05 to 56.20 µg g^{-1}, 10.63 to 51.88 µg g^{-1} and 20.35 to 70.08 µg g^{-1}, respectively. All the soils had slightly higher K values in the surface layer and this amount decreased with depth. According to Landon (1991), the classification of K content was high (>10.63 µg g^{-1}) and also

Table 5: Heavy metal content of the four studied soils

			Pb	Zn	Cu	Co	Ni	Cr	Cd
	Soil series	Horizon	($\mu g\ g^{-1}$)						
	Malacca	A	25.29	53.62	6.38	23.43	12.60	19.69	0.49
		B	30.88	56.98	7.96	24.53	13.94	22.12	0.08
Top soil (0-20 cm)		Mean	30.43	57.90	6.72	39.11	16.56	19.10	0.48
(5 replications)		SD	6.06	8.52	0.99	1.13	1.64	2.65	0.02
	Rasau	A	5.10	2.18	1.01	8.86	11.77	0.42	0.98
		AB	5.40	2.58	0.97	11.47	6.42	0.88	0.43
		BA	8.69	2.53	0.41	13.73	4.39	1.09	0.13
		B	6.40	1.54	0.11	15.50	2.92	0.91	0.06
Top soil (0-20 cm)		Mean	11.74	4.17	1.05	31.24	10.38	0.63	0.93
(5 replications)		SD	1.67	0.29	0.20	1.25	1.57	0.19	0.05
	Bungor	A	46.86	59.43	7.99	12.38	9.59	10.83	1.25
		BA	49.72	55.45	6.83	14.42	15.64	9.66	0.90
Top soil (0-20 cm)		Mean	50.94	56.29	7.08	31.87	16.08	8.85	1.12
(5 replications)		SD	7.70	4.55	0.80	2.53	2.99	1.16	0.23
	Gong Chenak	A	31.76	8.33	2.36	18.53	7.89	2.44	0.31
		AB	35.41	11.04	1.91	21.87	8.76	3.84	0.28
		BA	16.13	6.61	1.50	22.32	9.37	3.41	0.18
		B	19.33	7.04	2.82	23.39	8.91	3.69	0.09
Top soil (0-20 cm)		Mean	36.45	10.96	3.69	35.24	11.61	2.77	0.29
(5 replications)		SD	4.93	2.01	0.48	1.49	1.01	0.36	0.03
Critical threshold			100-400	70-400	60-125	25-50	70-100	75-100	3-15
(Kabata-Pendias and Pendias, 2001)									

considered as satisfactory. The variation of K in soil might be due to supply of nutrients, soil properties, plants population and moisture availability. The range of magnesium values for the Malacca, Rasau, Bungor and Gong Chenak soil series were 11.18 to 32.43 $\mu g\ g^{-1}$, 3.49 to 29.68 $\mu g\ g^{-1}$, 3.45 to 35.76 $\mu g\ g^{-1}$ and 12.28 to 47.13 $\mu g\ g^{-1}$, respectively. Available phosphorus and magnesium were considered low and very low respectively when compared with available potassium (Landon, 1991). Similar results were reported by Sahibin *et al.* (2002) for soil in a fruit orchard in Cameron Highlands, Pahang, Malaysia. Choudhury and Khanif (2003) found that Mg contents in Malaysian soils were below the critical deficiency level of 0.40 meq/100 g.

Heavy metal content in the topsoil and subsoil: Heavy metal content in the topsoil and subsoil of the four soil series is shown in Table 5. The heavy metals present in the soil included Pb, Zn, Cu, Co, Ni, Cr and Cd. In general heavy metal content in the subsoil and topsoil of the Malacca and Bungor soil series were higher than that of the Rasau and Gong Chenak. The heavy metal content of Zn, Co, Ni and Cr in the topsoil of the Malacca series was higher than that of the other soil series. The Bungor soil series had higher amounts of Pb, Cu and Cd in the subsoil than in the topsoil. In the Malacca soil series, the content of Pb, Zn, Cu, Co, Ni and Cr seemed to increase with depth. The Rasau soil series had the lowest content of heavy metals. When the content of heavy metals in the topsoil or subsoil (all the soil profiles) is below the threshold limit, their concentration is considered as potentially non-toxic (Kabata-Pendias and Pendias, 2001). The results also showed that anthropogenic areas (oil palm, rubber plantation and cultivated area) in the Tasik Chini Catchment contained higher concentrations of heavy metals than those of the forested or uncultivated soils. The Malacca and Bangur soil series were located in the disturbed area. Due to anthropogenic influences, these soil series contained higher concentrations of heavy metals in the topsoil and lower horizons compared to that other soil series. This was probably due to the use of agricultural fertilizers and pesticides, organic compounds (e.g., manures and composts), soil amendments (e.g., lime and gypsum) and in waste materials recycled to soil.

CONCLUSIONS

The soils in the study area were weathered and leached, had acidic pH, low cation exchange capacity and low exchangeable bases. The soils contained low organic matter content and were highly porous. The available nutrient content was very low. The CEC of all the studied soils were very low. The available P and Mg content in the study area were low and very low. Evidence collected from the soil analysis suggests that all the studied soils are infertile. The study also indicated that supply of organic matter to the soils and plantations is important in order to increase both the soil OM and the cation exchange capacity. The capacity of soils to be productive depends not only on the plant nutrient stores but also on the physical characteristics of the soils such as bulk density and porosity. Results of the analysis indicate that high concentration of heavy metals in the soil of the study area was originated mainly from the anthropogenic activities. This study also highlights the necessity of immediate control measurement for the quality of soil and the exceptionally severe heavy metal pollution in the study area to minimize the rate of contamination and extent of future pollution problems.

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