Pertanika J. Sci. & Technol. 24 (1): 71 - 87 (2016)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Morphological and Physico-Chemical Characteristics of Soils in the Tasik Chini Catchment in Pahang, Malaysia

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ABSTRACT

The morphological and physico-chemical properties of 11 soil series representing the major soil types in the Tasik Chini catchment in Pahang, Malaysia were studied. Soil types of the study area showed wide variations in their morphological and physico-chemical properties as a result of mean annual precipitation, soil parent material, vegetation and topography. Analyses showed that low values of silt were recorded in the horizon and the content of clay increased with soil depth. All the soil series contained low amounts of organic matter. Physical properties showed higher values for bulk density in the disturbed soils compared to the undisturbed forest soils. Regarding the chemical properties, these soils were strongly acidic. Electrical conductivity was also very low. Due to low pH, the contents of exchangeable base in all the soil types were very low. The cation exchange capacity of all the soil series were low with values less than 13.34 meq/100g soil.

Keywords: Soil series, morphology, physico-chemical properties, soil profile, Tasik Chini

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, an 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 the 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 to promote plant, animal and human health (Arshad & Martin, 2002). These attributes could be physical, chemical and/or biological properties of the soil (Arshad & Martin, 2002; Doran, 2002; Zornoza *et al*., 2007).

Article history:
Received: 22 September 2014
Accepted: 30 July 2015

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ISSN: 0128-7680 © 2016 Universiti Putra Malaysia Press.

Any disturbing practice will lead to disruptions in the natural equilibrium of the soil, and the expression should be capable of reflecting this alteration. In addition, the climate (mainly temperature and precipitation) can have an important influence on soil properties and dynamics. Soil organic matter content is the result of the balance between inputs (litter and root exudates) and outputs (decomposition and leaching as soluble organic compounds) (Zornoza *et al*., 2007).

Soils are dramatically altered by human activity in 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 urban soils. Specifically, urban soil bulk density, soil microbial biomass and activity and soil organic matter quantity and quality have been studied and found to be affected by urban conditions (Pouyat *et al*., 2002). Deforestation caused by logging, land conversion, road construction and other disturbances by human activities will invariably result in increased erosion rate with larger amounts of sediment being transported into the rivers, lakes, reservoirs and seas. Although erosion is an external process on the land surface, it is greatly accelerated by human activities, and it inundates and contaminates lakes with sediment. Heavy sedimentation rates shorten the lifespan of lakes and reservoirs, destroys aquatic habitats, reduces reservoir' storage capacity and reduces the flood control capacity of reservoirs (Alin & Cohen, 1999).

The recurring process of sedimentation has an impact on Tasik Chini i.e. shallower bottom, while the chemical influx from pesticides and fertilizer that come from agricultural activities increase the chemical concentration in water and sediment. Three characteristics of soil such as erodibility, heavy metal content and adsorption capability of chemical waste influence the degradation process.

The Tasik Chini catchment consists of various land forms comprising 31 soil series (Fig.1). Eleven soil series were selected for the study and they covered nearly 2741.52 ha or 41.10% of the study area. They were the Malacca, Prang, Gong Chenak, Serdang, Tebok, Kedah, Bungor, Kekura, Kuala Brang, Lating and Rasau series. The Malacca soil series is lateritic in nature, highly weathered, brown to reddish brown in colour and is distributed around the Chini Resort. Laterisation 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 and has weakly developed profiles. The Kekura soil series is also a weakly weathered soil, grey in colour. Weathering is not intense and constitutes structural development. The Bungor soil series is a moderately weathered soil, yellowish brown in colour. The Kuala Bang series is a moderately weathered soil, bright reddish brown in colour. The Prang series is also a highly weathered soil, yellowish in colour. The Serdang, Gong Chenak, Tebok, Lating and Kedah series constitutes moderately weathered soils. These 11 soil series are scattered within the lake or around it (Fig.1). According to the USDA soil classification, the Malacca and Prang series belongs to Oxisols; the Bungor, Serdang, Tebok, Gong Chenak, Kedah, Lating and Kuala Brang to Ultisols and the Rasau and Kekura to Entisols. Elaborate studies and clear knowledge of the soil types around Tasik Chini including their characteristics are important in order to predict their potential physical and chemical impact on the quality of the lake water. The aim of this study was to identify the morphological and physico-chemical characteristics of the soil types in the Tasik Chini catchment area.

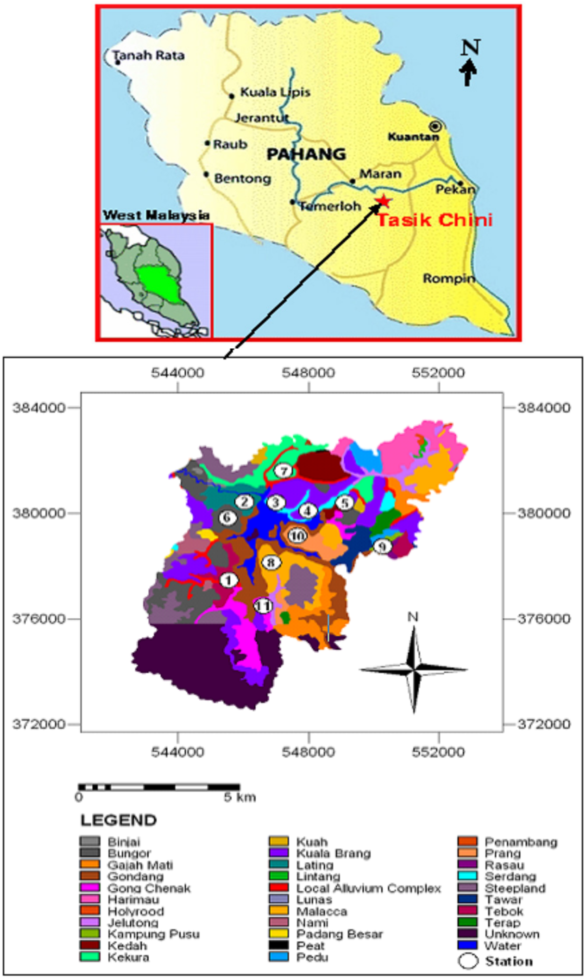

Fig.1: Location map of the study area and sampling stations.

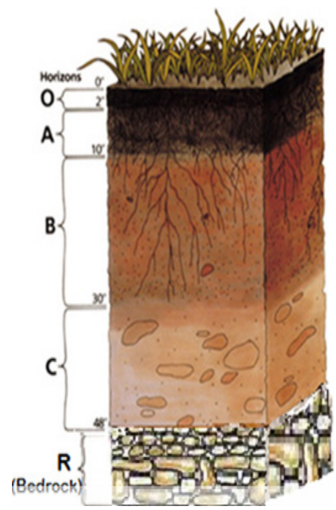

Fig.2: Soil profile

STUDY AREA

Tasik Chini is located in the southeastern region of the state of Pahang in Malaysia. It is approximately 100 km from Kuantan, the capital of Pahang. The lake system, which lies between 3°22′30″ to 3°28′00″N and 102°52′40″ to 102°58′10″E, is made up of 12 open water bodies called "laut" by the local people and it is linked to the Pahang River by the Chini River (Fig.1). A few communities of the indigenous Jakun tribe live around the lake. Tasik Chini is the second largest natural fresh-water lake in Malaysia encompassing 202 ha of open water and 700 ha of Riparian, Peat, Mountain and Lowland Dipterocarp forests (Wetlands International Asia Pacific, 1998). Tasik Chini is surrounded by diversely vegetated low hills and undulating land, which constitute the catchment of the region. There are three hilly areas surrounding the lake, namely, the Ketaya hills (209 m) located southeast, the Tebakang hills (210 m) to the north and the Chini hills (641 m) located southwest. The Tasik Chini catchment is representative of the upstream site of the Pahang River in the town of Pekan, Pahang. The area has a humid tropical climate with two monsoon periods, characterised by the following bimodal pattern: southwest and northeast monsoons that bring an annual rainfall that 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 and 1000 mm.

MATERIALS AND METHODS

Soil Sampling and Morphological Description

Soil sampling was carried out at selected sampling sites located around the lake (Fig.1). Topsoil (0-20 cm) was collected randomly with a Dutch auger (five replicates). Approximately 500 g samples were collected from each sampling site. The soil at every sampling location was dug deep to expose the profile and complete profile descriptions were recorded. Soil samples were also taken from every identifiable horizon within the profile for laboratory analysis. Soil morphological description and soil sampling were done in accordance with the procedures of the Soil Survey Manual (Soil Survey Division Staff, 1993). Soil samples were sealed in plastic bags and transported to the laboratory. In the laboratory the samples were air dried, broken into smaller-sized particles with a wooden mortar and pestle and sieved through a 2-mm sieve.

Soil Analysis

The air-dried and sieved soil samples were used for determination of the physico-chemical characteristics, which included soil particle size distribution, density, organic matter (OM) content, exchangeable acid cations (Al and H), exchangeable basic cations (Ca, Mg, K and Na), cation exchange capacity (CEC), soil pH and electrical conductivity (EC). Particle size distribution was determined by the pipette method together with dry sieving (Abdulla, 1966). Texture of the soils was using the soil texture triangle. 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 weight loss on ignition (Ball, 1964). 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 (McLean, 1965). The exchangeable basic cations were obtained using 1.0 M ammonium acetate extract and the Flame Atomic Absorption Spectrophotometer (FAAS, model Perkin Elmer 3300) (Peech *et al*., 1947; Drohan & Sharpe, 1997). The cation exchange capacity was determined by summation of the acid and basic cations. The electrical conductivity was determined using a saturated gypsum extract (Massey & Windsor, 1967).

Statistical Analysis

Statistical analysis was performed using SAS software. Analysis of variance was performed on soil physical and chemical properties.

RESULTS AND DISCUSSION

Morphological Description

The profile description of the selected soil series was carried out based on hand specimens. The descriptions of the soil series are shown in Table 1.

TABLE 1 : Soil Series Profile Description

Soil Series	Horizon	Depth (cm)	Description
Tebok	A	0-10	Light grey (7.5Y7/1); clay; fine sub-angular blocky; non-sticky, non-plastic, very friable; many fine to coarse roots; clear smooth boundary.
	B	>10	Light grey (10Y8/2); clay; moderate to weak medium and fine sub-angular blocky; non-sticky, non-plastic, friable; common medium roots; clear smooth boundary.
Lating	A	0-8	Dull yellow orange (10YR6/3); heavy clay; strong coarse sub-angular blocky; slightly sticky, slightly plastic; friable; abundant medium and fine roots; clear smooth boundary.
	AB	8-20	Dull yellow orange (10YR6/4); heavy clay; moderate to weak, coarse sub-angular blocky; slightly sticky, slightly plastic; friable to firm; many medium roots; clear smooth boundary.
	BA	20-30	Bright yellowish brown (10YR6/6); heavy clay; moderate, coarse sub-angular blocky; slightly sticky, slightly plastic; firm; common medium roots; clear smooth boundary.
	B	>30	Bright yellowish brown (10YR7/6); heavy clay; moderate, coarse sub-angular blocky; slightly sticky; slightly plastic; firm; few medium roots; clear smooth boundary.
Serdang	A	0-20	Light yellow (2.5Y7/3); clay loam; weak, coarse and medium sub-angular blocky; friable; many fine and medium roots; gradual smooth boundary.
	B	>20	Light yellow (2.5Y7/4); clay loam; weak to moderate, coarse sub-angular blocky; friable; few fine and medium roots; diffuse smooth boundary.
Kuala Brang	A	0-12	Bright reddish brown (5YR5/6); clay; strong medium granular; friable; abundant fine roots, some medium and coarse roots; clear smooth boundary.
	B	>12	Bright reddish brown (5YR5/8); clay; weak coarse and very coarse sub-angular blocky; friable; few fine and medium roots; clear smooth boundary.
Kedah	A	0-8	Bright yellowish brown (10YR 6/6); clay loam; fine granular and weak to medium, very fine sub-angular blocky; loose to very friable; many small roots, many channels, few casts; many pores; distinct boundary.

TABLE 1 : (Continued)

	E	8-18	Bright yellowish brown (10YR6/8); clay loam; weak to moderate fine and medium sub-angular blocky; very friable; many small roots, many channels, common pores; diffuse boundary.
	B	18-30	Bright reddish brown (5YR5/6); clay loam; moderate to weak, fine and medium sub-angular blocky; friable to firm; few roots, common channels, common pores; distinct and irregular boundary.
	C	>30	Bright reddish brown (5YR5/8); clay loam; weak fine and medium sub-angular blocky; friable to firm; roots rare, few channels, common pores; unconsolidated material, little evidence of profile development- stones increasing with depth.
Bungor	A	0-21	Yellowish brown (2.5Y5/4); clay loam; very weak to moderately developed fine and medium sub-angular blocky; friable to firm; many fine and medium roots; few channels, high biological activities, worm casts common; diffuse boundary.
	B	>21	Yellowish brown (2.5Y5/6); silty clay loam; weak, medium and fine sub-angular blocky; friable; moderate biological activities, few fine roots, few channels; diffuse smooth boundary.
Kekura	A	0-10	Grey (7.5Y 6/1); sandy loam; moderate to strong, fine and medium sub-angular blocky; friable to slightly firm; many fine and medium roots; numerous pores due to ant activities; gradual boundary
	AB	10-18	Light grey (10Y8/1); sandy loam; moderate, medium and fine sub-angular blocky; friable to slightly firm; many fine and medium roots, few ant activities; diffuse boundary.
	BA	18-29	Light grey (10Y8/2); sandy loam; weak to moderate, coarse and medium sub-angular blocky; friable; many medium and some fine roots; diffuse boundary.
	B	>29	Pale Yellow (7.5Y8/3); sandy clay loam; weak to moderate, coarse and medium sub-angular blocky; friable; few medium and fine roots; abrupt boundary.
Malacca	A	0-10	Yellowish brown (10YR5/4); clay; weak, fine sub-angular blocky; friable; many fine and medium roots; few ant nests; abundant pores; clear smooth boundary.
	B	>10	Yellowish red (5YR5/6); clay; weak medium and fine sub-angular blocky; friable; many fine and medium roots, few ant nests; many pores, abrupt smooth boundary.
Rasau	A	0-8	Whitish (10YR8/1); sandy loam; medium and fine sub-angular blocky; very friable; many coarse and medium roots; clear and smooth boundary.

TABLE 1 : (Continued)

	AB	8-20	Light brownish grey (2.5Y6/2); sandy loam; medium and fine sub-angular blocky; friable; many coarse and medium roots; clear smooth boundary.
	BA	20-30	Pale yellow (2.5Y8/3); sandy loam; moderate, medium and fine sub-angular blocky; friable; many coarse and medium roots; smooth boundary.
	B	>30	Pale yellow (2.5Y8/3); sandy loam; moderate to weak, medium and fine sub-angular blocky; friable; few medium and fine roots; smooth boundary.
Prang	A	0-15	Dark reddish brown (5YR3/4); clay; weak, fine sub-angular blocky; very friable; many fine and few coarse roots; many fine pores; diffuse boundary.
	B	>15	Yellowish red (5YR4/6); clay; weak, fine sub-angular blocky; very friable; few medium roots; many fine pores; diffuse smooth boundary.
Gong Chenak	A	0-10	Dark brown (10YR 4/3); clay; moderate, medium sub-angular blocky; non-sticky, non-plastic; friable; few fine roots; clear smooth boundary.
	AB	10-18	Brownish yellow (10YR6/8); clay; moderate, coarse sub-angular blocky; non-sticky, non-plastic; friable to firm, no roots; clear smooth boundary.
	BA	18-30	Brownish yellow (10YR6/8) with common medium clear red (10YR4/8); clay; moderate, coarse sub-angular blocky; non-sticky, non-plastic; friable; no roots; clear smooth boundary.
	B	>30	Light grey (10YR7/1) with many medium clear red (10YR4/8); clay; non-sticky, non-plastic; friable; no roots; clear smooth Boundary.

Soil texture. Sand was dominant in the Serdang, Kuala Brang, Rasau and Kekura soil series, ranging from 46.10 to 48.95%, 34.84 to 43.81%, 53.90 to 56.28% and 58.87 to 62.79%, respectively. The Malacca and Gong Chenak series had low levels of sand that ranged from 14.17 to 19.40% and 15.07 to 26.14%, respectively. On the other hand, the Lating series had the lowest level of sand that ranged from 2.02 to 3.48% both in the top soil and at the different horizons. Coarse sand was present in most of the soil types except at the lower horizons of the Lating series and the laterite nodules of the Malacca series. Size distribution and texture of the different soil series are shown in Table 2.

The percentage of silt in the Tebok, Lating, Serdang, Kuala Brang, Kedah, Bungor, Kekura, Malacca, Rasau, Prang and Gong Chenak soil series are shown in Table 2. The highest percentage (46.49%) of silt was recorded in the Kedah series and the lowest (17.71%) in the Kuala Brang soil series. Low levels of silt were recorded in the horizon and maximum levels were found in the topsoil. Khresat *et al*. (1998) emphasised that the proportion of silt decreased with the depth of the horizon in soils in north-western Jordan.

TABLE 2 : Properties, Size Distribution and Texture of Topsoils and Subsoils

Station	Soil Series	Horizon	Depth (cm)	Sand %	Silt %	Clay %	Texture
1	Tebok	A	0 – 10	25.53	29.04	45.43	Clay
		B	> 10	23.08	30.18	46.74	Clay
Top soil (Mean of 5 replications)			0 – 20	28.03	31.52	40.45	Clay
2	Lating	A	0 – 8	3.48	37.14	59.38	Clay
		AB	8 – 20	3.02	34.96	62.02	Clay
		BA	20 – 30	2.65	30.51	66.84	Clay
		B	> 30	2.02	19.39	78.59	Clay
Top soil (Mean of 5 replications)			0 – 20	3.28	31.58	65.14	Clay
3	Serdang	A	0 – 20	48.95	31.10	19.95	Clay loam
		B	> 20	46.10	32.26	21.64	Clay loam
Top soil (Mean of 5 replications)			0 – 20	47.91	31.51	20.58	Clay loam
4	Kuala Brang	A	0 – 12	43.81	17.71	38.48	Clay
		B	> 12	34.84	23.43	41.73	Clay
Top soil (Mean of 5 replications)			0 – 20	41.22	22.22	36.56	Clay
5	Kedah	A	0 – 8	32.71	46.21	21.08	Clay loam
		E	8 – 18	25.84	46.47	27.69	Clay loam
		B	18 – 30	24.88	44.91	30.21	Clay loam
		C	> 30	20.23	39.76	40.01	Clay loam
Top soil (Mean of 5 replications)			0 – 20	27.12	46.49	26.39	Clay loam
6	Bungor	A	0 – 21	37.23	36.80	25.97	Clay loam
		B	> 21	33.89	37.05	29.06	Clay loam
Top soil (Mean of 5 replications)			0 – 20	36.08	36.87	27.05	Clay loam
7	Kekura	A	0 – 8	61.29	23.35	15.36	Sandy loan
		AB	8 – 18	61.21	22.59	16.20	Sandy loam
		BA	18 – 29	60.32	22.21	17.47	Sandy loam
		B	> 29	58.87	22.95	18.18	Sandy loam
Top soil (Mean of 5 replications)			0 – 20	62.79	23.28	13.93	Sandy loan
8	Malacca	A	0 – 10	18.16	35.97	45.87	Clay
		B	> 10	14.17	36.80	49.03	Clay
Top soil (Mean of 5 replications			0 – 20	19.40	30.82	49.78	Clay
9	Rasau	A	0 – 8	55.13	31.39	13.48	Sandy loam
		AB	8 – 20	56.28	29.91	13.81	Sandy loam
		BA	20 – 30	53.90	30.70	15.40	Sandy loam
		B	> 30	54.14	30.32	15.54	Sandy loam
Top soil (Mean of 5 replications)			0 – 20	58.44	28.00	13.56	Sandy loam

TABLE 2 : (Continued)

10	Prang	A	0 – 15	42.13	20.21	37.66	Clay
		B	> 15	33.15	24.46	42.39	Clay
Top soil (Mean of 5 replications)			0 – 20	34.56	25.09	40.35	Clay
11	Gong Chenak	A	0 – 10	26.14	24.05	49.81	Clay
		AB	10 – 18	23.45	24.36	52.19	Clay
		BA	18 – 30	18.02	27.08	54.90	Clay
		B	> 30	15.07	28.05	56.88	Clay
Top soil (Mean of 5 replications)			0 – 20	21.84	24.88	53.28	Clay

Clay content was variable in the studied soils. The highest percentage (78.59%) of clay was recorded in the Lating and the lowest (13.48%) in the Rasau soil series. The Rasau and Kekura series contained low levels of clay while the Tebok, Lating, Kuala Brang, Malacca, Prang and Gong Chenak had higher percentages. The distribution of clay increased with depth in the soil. There was higher clay content in the subsoil compared to the surface soil for all the soils studied. Khresat *et al*. (1998) also concluded that clay content in Pedon increased from 35.40% at the surface to 44.80% below 170 cm depth in the soil in north-western Jordan.

Physical properties of the soils studied. The physical properties of the soils are given in Table 3. All the soil series studied contained low amounts of organic matter (OM). The highest values of OM were recorded in the Lating, Kuala Brang, Malacca, Prang and Gong Chenak soil series, which ranged from 1.12 to 9.34%. These soils were clayey in texture. The distribution of OM was found to decrease with depth of horizon in the soil. High OM in the topsoil was due to decomposition of massive leaf litter, which was observed on the surface. The OM content was the lowest in the sandy soils, such as the Rasau and Kekura soils. Similar results have also been reported by Othman *et al*. (1979) where OM in sandy soils ranged from 0.49 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 categorised in the low to medium class (OM< 10%).

The bulk density values of the 11 soil series ranged from 1.03 to 1.33 g/cm^3 with a mean value of 1.13 g/cm^3. The highest (1.33 g/cm^3) and lowest values (1.03 g/cm^3) were recorded in the Rasau and Prang series, respectively. The bulk densities of topsoil were always lower than those of the subsoil, due to the presence of organic matter. Lemenih *et al*. (2005) indicated that the significant increase in soil bulk density and decrease in percent pore space in the soil was most probably caused by the decline in the soils' organic matter content. Due to the sandy loam texture and low organic matter content in the Rasau and Kekura series, the bulk density values were high. On the other hand, the Lating, Kuala Brang, Prang, Bungor and Gong Chenak soil series were under primary forest and lowland dipterocarp forest vegetation, which apparently resulted in higher content of organic matter and high root penetration. Moreover, the bulk density was lower than that of the Rasau and Kekura soil series. The reported value was close to the one reported by Peh (1978) for soils in a dipterocarp forest at Pasoh Forest Reserve in which the OM recorded was 1.12 g/cm^3. Kamaruzaman (1987) also reported a lower bulk density (0.97 g/cm^3) for undisturbed soils at the Tekan Forest Reserve in Pahang, Malaysia.

TABLE 3 : Physical Properties of Topsoil's and Profiles of 11 Soil Series

Station	Soil Series	Horizon	Depth (cm)	Bulk Density (g/cm³)	True Density (g/cm³)	Porosity %
1	Tebok	A	0 – 10	1.07	2.60	58.85
		B	> 10	1.15	2.66	56.77
Top Soil (Mean of 5 replications)			0 – 20	1.08±0.01	2.62±0.01	59.00±0.160
2	Lating	A	0 – 8	1.06	2.54	58.27
		AB	8 – 20	1.09	2.62	58.40
		BA	20 – 30	1.11	2.64	57.96
		B	> 30	1.14	2.65	56.98
Top Soil (Mean of 5 replications)			0 – 20	1.04±0.05	2.56±0.04	59.23±1.15
3	Serdang	A	0 – 20	1.26	2.72	53.68
		B	> 20	1.32	2.73	51.65
Top Soil (Mean of 5 replications			0 – 20	1.13±0.02	2.67±0.01	57.80±0.80
4	Kuala Brang	A	0 – 12	1.07	2.59	58.69
		B	> 12	1.09	2.60	58.08
Top Soil (Mean of 5 replications)			0 – 20	1.03±0.03	2.56±0.02	59.55±0.75
5	Kedah	A	0 – 8	1.09	2.67	59.20
		E	8 – 18	1.10	2.70	59.24
		B	18 – 30	1.11	2.71	58.96
		C	> 30	1.12	2.72	58.75
Top Soil (Mean of 5 replications)			0 – 20	1.09±0.01	2.64±0.02	58.58±0.28
6	Bungor	A	0 – 21	1.09	2.62	58.40
		B	> 21	1.12	2.64	57.58
Top Soil (Mean of 5 replications)			0 – 20	1.09±0.01	2.65±0.01	58.75±0.30
7	Kekura	A	0 – 8	1.14	2.70	57.83
		AB	8 – 18	1.17	2.73	57.06
		BA	18 – 29	1.19	2.73	56.39
		B	> 29	1.21	2.74	55.76
Top Soil (Mean of 5 replications)			0 – 20	1.21±0.03	2.68±0.01	55.03±1.24
8	Malacca	A	0 – 10	1.09	2.56	57.37
		B	> 10	1.13	2.60	56.54
Top Soil (Mean of 5 replications)			0 – 20	1.12±0.10	2.56±0.02	56.13±3.52
9	Rasau	A	0 – 8	1.19	2.70	56.04
		AB	8 – 20	1.27	2.72	53.25
		BA	20 – 30	1.33	2.73	51.40
		B	> 30	1.27	2.73	53.60
Top Soil (Mean of 5 replications)			0 – 20	1.06±0.03	2.69±0.01	57.5±1.40

TABLE 3 : (Continued)

10	Prang	A	0 – 15	1.06	2.57	58.75
		B	> 15	1.08	2.61	58.62
Top Soil (Mean of 5 replications)			0 – 20	1.03±0.05	2.52±0.02	59.18±2.37
11	Gong Chenak	A	0 – 10	1.06	2.57	58.81
		AB	10 – 18	1.07	2.61	59.15
		BA	18 – 30	1.09	2.70	58.15
		B	> 30	1.12	2.71	58.64
Top Soil (Mean of 5 replications)			0 – 20	1.06±0.05	2.51±0.16	59.49±2.30

Hati *et al*. (2007) and Tiarks *et al*. (1974) noted that the reduction in bulk density could be attributed to higher organic matter content of the soil.

The true density values of the 11 soil series ranged from 2.51 to 2.74 g/cm^3 with an average value of 2.65 g/cm^3. Due to higher content of being sand and lower organic matter content, the highest value of true density recorded (2.74 g/cm^3) was for the Kekura soil series. The Gong Chenak series had the lowest true density value (2.51 g/cm^3). Clearly, the amount of organic matter in a soil markedly affected the particle density (Brady, 1990). Porosity values ranged from 51.40 to 59.55% with an average value of 57.42%. The highest value (59.55%) was recorded in the Kuala Brang series and the lowest (51.40%) in the Malacca soil series. The highest total porosity occurred on undisturbed forest soils of the Kuala Brang, Kedah, Lating, Tebok, Prang, Bungor and Gong chenak soils series. The Malacca soil series was disturbed soil and had the lowest porosity value. The Malacca soil series was distributed throughout the oil palm plantation area. Porosity of the surface soil was slightly higher than that of the subsoil. Pagliai *et al*. (1983) noted that porosity was directly affected by root penetration, storage and movement of water and gases. Lower porosity values in disturbed soils have also been reported by Pagliai *et al*. (1983) and Pagliai (1987).

Chemical properties of the studied soil series. The data on specific chemical properties of the studied soils are given in Table 4. The uniformity of pH values and the low range recorded were the unique features of Malaysian soils. The pH values ranged from 3.14 to 4.82 with an average value of 4.04. Most of the pH values were below 4.50 and were considered very low (pH < 4.50) in the classification by Landon (1991). The value was 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 Prang and Gong Chenak soil series. Zhenghu *et al*. (2007) found that soil pH values increased slightly with depth in the profile, indicating that they experienced moderate leaching and weathering. Low range of electrical conductivity (EC) was recorded in the different soil series. The Malacca series had the lowest value (2.00 dS/m) while the highest value (3.32 dS/m) was recorded for the Kekura series. The mean value of EC was 2.67 dS/m. The values of EC were below 4.00 dS/m, indicating that these soils were not saline. The EC ranged from 2.00 to 3.32 dS/m, and these values were classified as low (Landon, 1991).

TABLE 4 : Chemical Properties of the 11 Soil Series Studied

Station	Soil Series	Horizon	Depth (cm)	OM %	pH	EC dS/m	CEC (cmol c/ kg)
1	Tebok	A	0 – 10	5.93	3.89	3.25	6.28
		B	> 10	3.72	4.27	3.11	8.28
Top Soil (Mean of 5 replications)			0 – 20	6.93±0.20	4.25±0.05	2.70±0.03	6.97±0.52
2	Lating	A	0 – 8	8.09	4.29	2.96	6.50
		AB	8 – 20	5.17	4.36	2.93	6.63
		BA	20 – 30	4.31	4.45	2.78	7.79
		B	> 30	3.88	4.48	2.66	8.62
Top Soil (Mean of 5 replications)			0 – 20	7.26±3.43	4.35±0.05	2.45±0.05	7.97±1.05
3	Serdang	A	0 – 20	1.68	4.38	3.18	4.09
		B	> 20	1.17	4.49	3.15	5.12
Top Soil (Mean of 5 replications)			0 – 20	3.36±0.13	4.27±0.08	2.70±0.02	4.10±0.47
4	Kuala Brang	A	0 – 12	6.23	4.48	2.88	5.54
		B	> 12	5.88	4.53	2.85	5.69
Top Soil (Mean of 5 replications)			0 – 20	7.35±0.78	4.41±0.09	2.44±0.02	5.02±0.87
5	Kedah	A	0 – 8	3.27	4.32	3.17	6.05
		E	8 – 18	2.34	4.41	3.11	7.12
		B	18 – 30	2.13	4.43	3.08	7.91
		C	> 30	1.78	4.49	3.05	9.70
Top Soil (Mean of 5 replications)			0 – 20	4.48±0.66	4.32±0.03	2.56±0.03	7.60±1.33
6	Bungor	A	0 – 21	5.09	4.72	3.12	4.37
		B	> 21	4.36	4.78	3.01	3.90
Top Soil (Mean of 5 replications)			0 – 20	3.95±0.47	4.80±0.09	2.54±0.04	4.34±0.63
7	Kekura	A	0 – 8	2.19	4.56	3.32	2.58
		AB	8 – 18	1.46	4.57	3.29	2.46
		BA	18 – 29	1.34	4.58	3.26	2.47
		B	> 29	1.14	4.59	3.18	2.56
Top Soil (Mean of 5 replications)			0 – 20	2.90±0.19	4.82±0.04	2.55±0.04	2.47±0.37
8	Malacca	A	0 – 10	7.36	3.47	2.18	1.96
		B	> 10	5.63	3.81	2.00	2.06
Top Soil (Mean of 5 replications)			0 – 20	7.16±0.96	3.68±0.09	2.24±0.16	3.47±0.60
9	Rasau	A	0 – 8	2.35	3.14	2.55	3.12
		AB	8 – 20	1.77	3.15	2.44	3.37
		BA	20 – 30	1.10	3.21	2.42	2.75
		B	> 30	1.37	3.25	2.45	2.54
Top Soil (Mean of 5 replications)			0 – 20	2.76±0.38	3.20±0.15	2.21±0.12	3.74±0.34

TABLE 4 : (Continued)

10	Prang	A	0 – 15	6.69	3.32	2.03	2.23
		B	> 15	5.10	3.22	2.02	1.08
Top Soil (Mean of 5 replications)			0 – 20	8.73±0.85	3.31±0.07	2.11±0.14	2.72±0.19
11	Gong Chenak	A	0 – 10	6.75	3.34	2.13	12.81
		AB	10 – 18	5.10	3.35	2.05	13.34
		BA	18 – 30	1.12	3.37	2.22	5.79
		B	> 30	2.03	3.30	2.30	6.09
Top Soil (Mean of 5 replications)			0 – 20	9.34±6.29	3.32±0.16	2.22±0.16	11.27±2.78

The values for the cation exchange capacity (CEC) of the studied soils ranged from 1.08 to 13.34 cmol c/kg soil, with an average value of 5.36 cmol c /kg soil. The values of the CEC of all the top soils were comparatively higher than those down the soil profiles (Table 4). Zhenghu *et al*. (2007) found that the cation exchange capacity (CEC) was higher on the surface than in the subsurface horizons and decreased with depth in all the studied soils. This was due to the effect of the higher organic matter content in the surface and the correlation between organic matter and CEC. The CEC of the Gong Chenak soil series was the highest (13.34 cmol c /kg soil) and that of the Prang series the lowest (1.08 cmol c /kg soil). Due to low pH, the contents of basic cations of all the soils were very low, indicating that the exchange cations in surface soil were dominated by acidic cations like Al and H. The soil of the Rasau series was sandy loam in texture but the CEC was higher compared to those obtained from the Prang and Malacca (clay in texture) soil series. Apparently the Rasau soil had low pH and was dominated by acidic cations of Al and H (3.00 cmol c /kg soil) as opposed to the Malacca (1.65 cmol c /kg soil) and Prang (1.90 cmol c /kg soil) soil series. Razi *et al*. (2005) also reported similar characteristics of acidic soils in their studied area. The range of the CEC values of all the soil series studied were considered low in the classification by Acres *et al*. (1975). In Peninsular Malaysia, more than two thirds of the total land area are covered by acidic soils, of which Ultisols and Oxisols are the most abundant (IBSRAM 1985). Ultisols and Oxisols are soils with low pH, cation exchange capacity and basic cation content (Tessens & Shamshuddin, 1983; Ismail *et al*., 1993; Syed Omar *et al*., 2001). The highly weathered soil materials, having kaolinitic clay mineralogy, showed very low CEC of up to 4 cmol c /kg soil and sum of exchangeable basic cations of <2 cmol c /kg soil (Baert *et al*., 1999).

Correlation Study

The soil erodibility factor (K) represents the effect of soil properties and soil profile characteristics on soil loss in the Tasik Chini catchment area. The physical, chemical and mineralogical soil properties and their interactions that affect the K values are varied, the reason being mainly geogenic.

Anthropogenic activities also affect the principal component of soil in this area. In recent years, Tasik Chini has experienced major development in agricultural activities. Large areas of forest have been converted into oil palm plantations. Illegal logging activities also contributed to the loss of forest area. Agricultural activities resulted in the release of pollutants such as nitrate and phosphate into the soil. Mining activity was the most important man-made reason for soil degradation. Different types of minerals were exposed to the soil surface due to mining, which directly affected the principal soil component. The activities of a few of the indigenous people who live in Tasik Chini also played some role in soil degradation.

CONCLUSION

A detailed study of the morphology and physico-chemical characteristics of a soil is essential in order to understand the behaviour of the soil. The soils in the study area were well weathered and leached. The Malacca and Prang series was highly weathered soils and clayey in texture. The Kuala Brang, Tebok, Lating and Gong Chenak series was moderately weathered soil and clayey in texture. The Kedah, Bungor and Serdang series was also moderately weathered soil but had a clay loam texture. The Rasau series constituted weakly weathered soil with a sandy loam texture. The clay content of all the soil series increased with depth. The highest total porosity occurred in the undisturbed forest soils of the Bungor, Tebok, Lating, Kuala Brang, Prang, Gong Chenak and Kedah series. The lowest total porosity was recorded on the logged soils such as the Malacca, Serdang, Kekura and Rasau series. The present study revealed that all the soil series contained low organic matter content and were highly porous. The distribution of OM decreased with depth. Low values of OM (1.10%) were recorded in the Rasau series and the highest percentage OM (9.34%) was recorded in the Gong Chenak series. The studied soils had acidic pH, low cation exchange capacity and low exchangeable bases. Due to the dominance of acidic cations (Al and H), the CEC of the Rasau series was higher than that of the Malacca and Prang soil series. The Gong Chenak soil was less leached and had higher values for most of the properties considered in the study. The study also indicated that supply of organic matter to the soils and plantations is important in order to increase both the soil OM content and the cation exchange capacity. Productivity of soils depends not only on the plant nutrient stored but also on the physical characteristics of the soils such as bulk density and porosity. Soil properties, such as particle-size distribution, structural stability, organic matter content, soil chemistry and clay mineralogy, affect soil degradation. Mining and deforestation are the main causes of soil degradation and environmental problems in the Tasik Chini catchment area.

ACKNOWLEDGEMENTS

This study was conducted and supported by the Ministry of Science and Technology, Malaysia through the IRPA grant, code: 09-02-02-0117-EA294, Zamalah Scheme and OUP fund (Code: UKM-OUP-FST-2008) UKM.

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