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SOILS OF THE NEW TOWNSHIPS OF KETENGAH: ENVIRONMENTS, PHYSICO-CHEMICAL AND MINERALOGICAL PROPERTIES

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SINOPSIS

Tanih di bandar-bandar baru di Ketengah telah disampel dan dikaji untuk mengkelas dan mengetahui sifat fizik-kimia mereka. Tanih di situ didapati berlempung, dengan kandungan pasir kasar yang tinggi terutama di dalam horizon atas. Mineral terbanyak di dalam bahagian lempung ialah kaolinit dan mika. Mineral lain, yang turut hadir, ialah gibsit, goetit, mika-vermikulit dan vermikulit. Ini menyebabkan rendahnya cas dan tepuan bes dan tingginya A1. A1 didapati mengawal tindakbalas penampanan tanah di bawah pH 5.5. Di dalam keadaan lapangan, cas bersih tanah adalah negatif. Kaitan antara sifat tanah dan persekitaran dengan hakisan juga dibincang.

SYNOPSIS

Soils in the new township of Ketengah were sampled and studied in order to calssify them and to know their physico-chemical properties. The soils are found to be clayey, with large amounts of coarse sand especially in the top horizon. The dominant minerals in the clay fraction are kaolinite and mica. Other minerals, present in small amounts, are gibbsite, goethite, mica-vermiculite and vermiculite. This result in the low charge, low base saturation and high A1 saturation. A1 controls the buffering action of the soil below pH 5.5. Under field condition, the net charge of the soil is negative. Soil properties and environments are discussed in relation to soil erosion.

INTRODUCTION

Ketengah (Lembaga Kemajuan Trengganu Tengah) was established in order to develope land in the inner part of Trengganu for agriculture. Farmers are brought into the schemes to become settlers. Basic infrastructures in the form of roads, bridges, schools and community halls are constructed by Ketengah authority. These facilities are concentrated in five new towns, namely Cenih Baru, Sri Bandi, Ketengah Jaya, A1 Muktafi Billah Shah and Bukit Besi (Figure 1).

Lacking in fund, these development centres were built in a hurry, taking little into consideration the possible ecological imbalances. Houses are built on lands which often have not been properly levelled. Within a short span of time, soils are eroded and drains silted up.

The objective of this paper is to characterize the soils in the new township of Ketengah with respect to their physico-chemical properties, mineralogical properties and environments. The data available from this study will be useful to soil scientists (erosion), horticulturists (landscape design), town planners (sewage disposal) and above all engineers (houses, roads etc.).

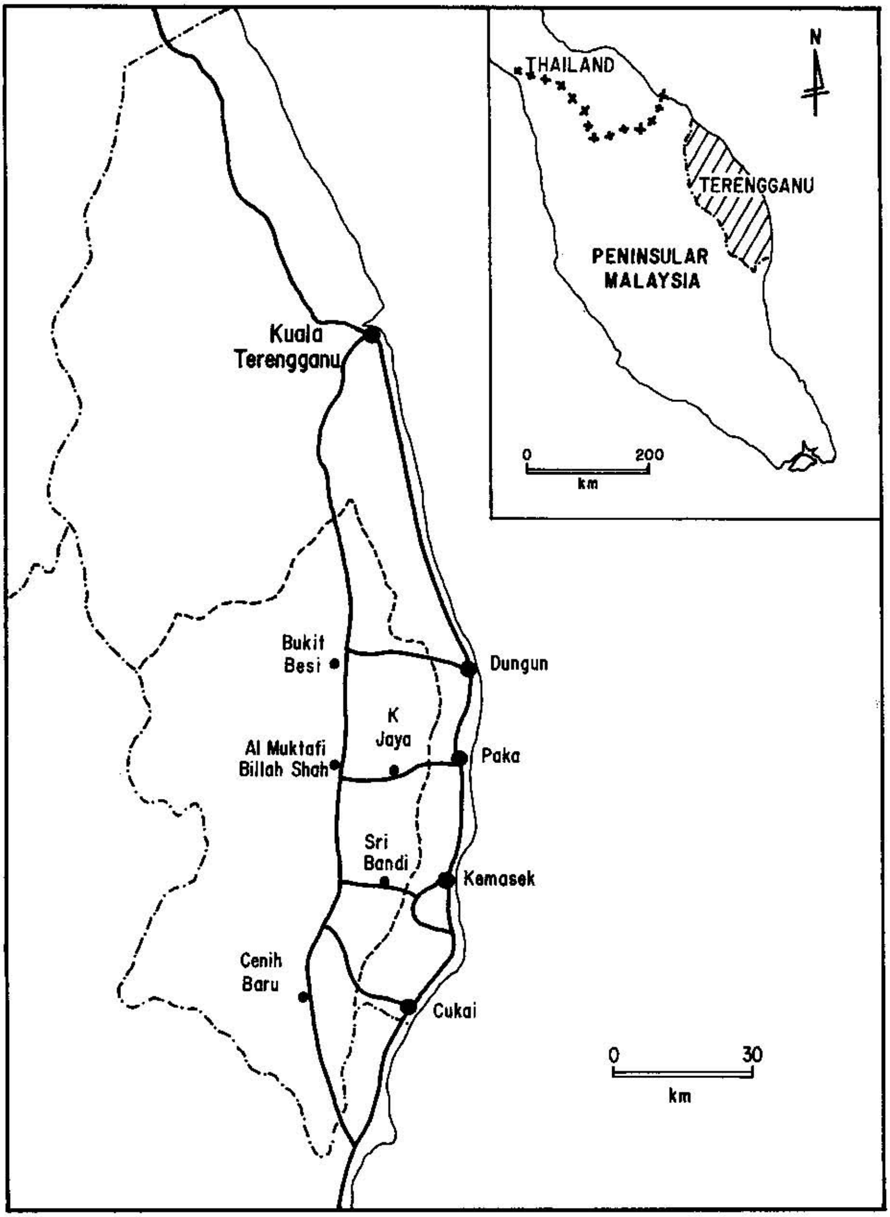

FIGURE 1. A Map of Terengganu Showing the Position of Ketengah Where Bt. Besi, Al Muktafi Billah Shah, Ketengah Jaya, Sri Bandi and Cenih Baru are Situated

MATERIALS AND METHODS

Field data of the soils studied are summarized in Table 1, while profile descriptions are given in the Appendix. The profiles are designated as P1, P2, P3, P4 and P5, which were respectively sampled from Cenih Baru, Sri Bandi, Ketengah Jaya, Al Muktafi Billah Shah and Bukit Besi (Figure 1). In terms of series, P1 belongs to Kuala Brang series, P2, P3 and P4 belong to Rengam series, and P5 belongs to Beserah series. The soils at each town were carefully examined and identified. Observations were made by free traverse at a semi-detailed scale (1 km × 200 m). At each town only one soil series was identified.

TABLE 1. Field Characteristics of Soils in the New Townships of Ketengah, Trengganu (Colour, Texture and Structure Were Taken at 50 cm Depth; All Soils Contain Cutans at Depth)

Profile	Series	Parent Material	Colour	Texture	Structure	Physiography	Classification
P1	Kuala Brang	Shale	10YR 6/8	SCL	Subangular	Hilly	Typic Paleudult
P2	Rengam	Granite	10YR 5/8	SC	Subangular	Rolling	Typic Paleudult
P3	Rengam	Granite	10YR 5/8	C	Subangular	Undulating	Typic Paleudult
P4	Rengam	Granite	10YR 6/8	SC	Subangular	Rolling	Typic Paleudult
P5	Beserah	Granite	10YR 5/8	SC	Subangular	Hilly	Typic Paleudult

pH, CEC (NH_4Cl, NH_4OAc), bases, Al, Fe_2O_3, texture and organic carbon were determined from fine earth ($<$ 2 mm). X-ray diffraction analysis was used to determine clay minerals. Soil buffering was determined by potentiometric titration of 5 g soil, equilibrated in 50 ml 1N kCl, with 0.02N KOH. pH_0, negative and positive charges at pH_0 were determined by the method of Gillman and Uehara (1980). Water dispersible clay (WDC) was estimated after end-over-end shaking for 16 hours.

RESULTS AND DISCUSSION

LOCATION

The towns are built at strategically-selected locations, along the Jerangau-Johor Highways (Figure 1). They are all completely new except Bukit Besi which is being built from the original mining town of the same name. These towns would become the new centres of economic growth, where settlers live and earn their living both from within the town and the surrounding areas. Plans are underway to build roads, schools, hospitals, government offices and other essential public facilities.

ENVIRONMENTS

1/ *Geology.* The most important rock type in the Ketengah is granite. There are also minor bands of slate, argillite, phyllite, schist and quartzite (Anon 1983). The granite is considered to be about 340 – 180 million years (Hutchison 1977). It intrudes through gently deformed, predominantly Permo-Carboniferous sedimentary formation.

More specifically, the granite is a member of Jengai group, whose texture and mineralogy are variable in nature (Rajah et al. 1977). For instance, at Bukit Besi, the quartz grains are very coarse. Quartz grains in the granite at Sri Bandi, Al Muktafi Billah Shah and Ketengah Jaya are medium to fine in size. Other minerals found in Jengai granite are biotite, muscovite, hornblende and feldspar (Rajah et al. 1977).

2/ *Climate.* The annual rainfall in Trengganu is very high. In the Ketengah region itself, the reported annual rainfall is between 3250 – 3500 mm (Anon 1983). The rain comes mainly in the months of November and December. From the climatological data of Dungun (Table 2), one can see that precipitation exceeds evaporation by about 100 mm in the two wettest months. The excess water is either lost as runoff or percolates into the soil. The former can cause severe soil erosion.

TABLE 2. Climatic Data of Dungun, Trengganu Determined by Franklin Newhall System of Computation (Travernier 1975)

Input Data	Jan.	Feb.	Mar.	Apr.	May	Jun	July	Aug.	Sept.	Oct.	Nov.	Dec.
PREC	251	139	239	185	178	105	133	133	168	263	482	271
EVAP	139	122	135	140	152	147	151	150	143	144	138	140
TEMP	25.5	25.7	26.6	27.5	27.7	26.6	26.9	26.6	26.6	26.7	24.0	23.8
ANNUAL RAINFALL : 2847 mm ANNUAL EVAP : 1701 REGIME : ISOHYPERTHERMIC												

3/ *Relief.* In general, the state of Trengganu is hilly, with about 72 percent of its area as steepland (Gopinathan and Paramananthan 1979). A significant portion of Ketengah is considered too steep for agricultural development. In Cenih Baru and Bukit Besi, where houses are constructed for the settlers, the slope is as high as 30 percent or more. Under this condition, adequate conservation measures have to be undertaken to reduce soil erosion.

SOIL PROPERTIES

1/ *Physical properties.* The soils at Bukit Besi (P5), Al Muktafi Billah Shah (P4), Sri Bandi (P2) and Ketengah Jaya (P3) are developed on granite

(Table 1). The soils are characterized by clayey texture with large amounts of coarse and medium sand (Appendix). Quartz gravels are also present, especially in the soils of Beserah series (P5), with more than 35 percent. On account of high amount of sand, leaching is very high and hence fertilizers are mainly lost by leaching. Its agricultural suitability is thus limited by this factor.

Cenih Baru stands on shale and/or argillite derived soils. However, the soils contain significant amounts of sand in the top horizon which may be the result of sandstone interbedding with the shale. But at depth, the percentage of clay is 35 or more. Laterite layer, which is rather common in shale derived soil occurs at 80 – 110 cm depth. This soil is less erodible than the soils of Beserah Series.

The structures at 50 cm depth are coarse to medium subangular blocky for all the profiles. The structures are weakly developed in the soils of Beserah series (P5), while in Rengam series (P2, P3, P4), they are moderate. Weak structures imply the soils are susceptible to erosion. On the basis of the presence of cutans, in the B horizons, and the increase of clay content with depth, the five profiles can be classfied as clayey, kaolinitic family of Typic Paleudult.

2/ *Chemical composition.* Routine chemical data are given in the Appendix. Bases and base saturation are very low. The exchange complex is dominated by A1; in most cases A1 saturation exceeds 60 percent. High A1 saturation is reflected by the rather low pH, which is around 5 or less.

Low in bases in due to the inability of the soil to retain nutrients, as the CEC is less than 5 generally. This phenomenon is common in highly weathered tropical soils dominated by kaolinite. Such soils have to be limed and fertilized regularly so as to make them suitable for plant growth. Incorporation of organic matter into the soil is often recommended. This practice improves the CEC and stabilizes structure, a consequence of which is reduction in soil erosion.

3/ *Clay mineralogy.* Major minerals in the clay fraction of the shale derived soils are kaolinite (7.2 Å) and mica (10 Å, 3.3 Å) (Figure 2). Other minerals in this soil are mica-vermiculite (12.5 Å in Mg and glycolated samples), quartz (4.26 Å) and goethite (4.18 Å).

Soil derived from medium grained granite (P2) contains more or less similar mineralogical composition, in which kaolinite and mica dominate the clay fraction. There are also some 14 Å minerals in this soil. The 14.5 Å reflection in the Mg and glycolated sampled (Figure 3) indicates the presence of vermiculite. Part of the mica in the soil has completely been converted to vermiculite, indicating that the soil is more weathered than the shale derived soil.

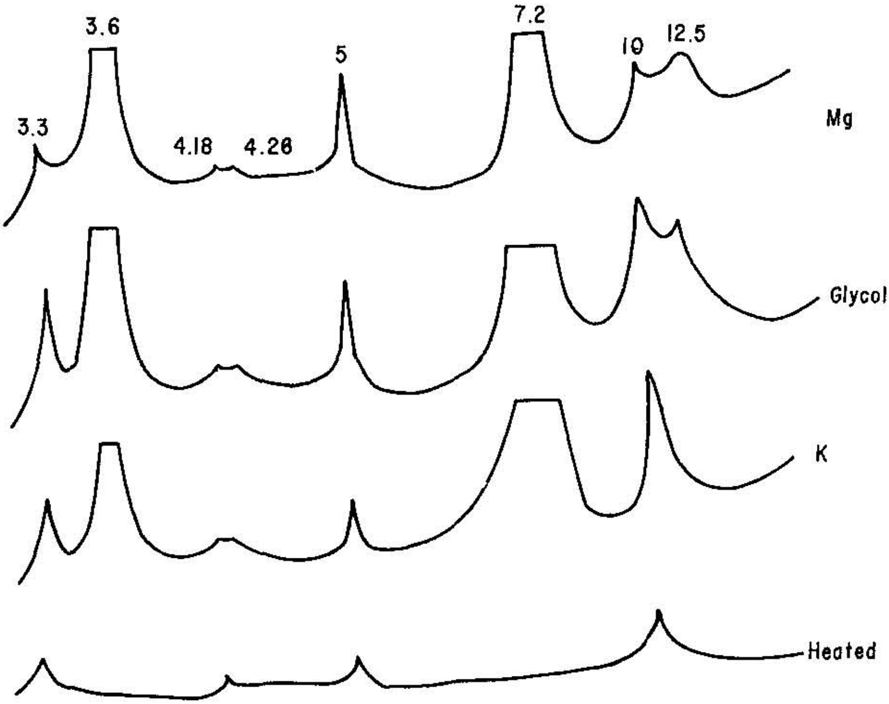

FIGURE 2. X-ray Diffractograms of the Clay Fraction of Soils of Kuala Brang Series (P1) (B_{22t} Horizon)

The dominant mineral in the soil derived from coarse grained granite is also kaolinite. Small XRD peak at 10 Å is present on the diffractograms, pointing to a small amount of mica present in the soil (Figure 4). The presence of gibbsite is shown by the reflection at 4.85 Å.

The amount of gibbsite and geothite in the clay fraction was determined by DSC, while the amount of kaolinite was determined by TGA. DSC curves for Rengam soil (P3) and Beserah soil (P5) are given as illustrations (Figure 5). It was found that gibbsite dehydroxylated at around 250°C. The endothermic peaks at 320 – 350°C show the dehydroxylation of goethite.

Table 3 gives the percentage of kaolinite, gibbsite and goethite in the clay fraction. The amount of kaolinite is very high, with more than 80 percent in some cases. What is given as kaolinite percent may be partly mica as mica dehydroxylates at 500 – 600°C as well. We only know that kaolinite dehydroxylates much more easily than mica. Mica peak (XRD) at 10 Å is quite prominent (Figures 2 and 3) showing the presence of some mica in the soils.

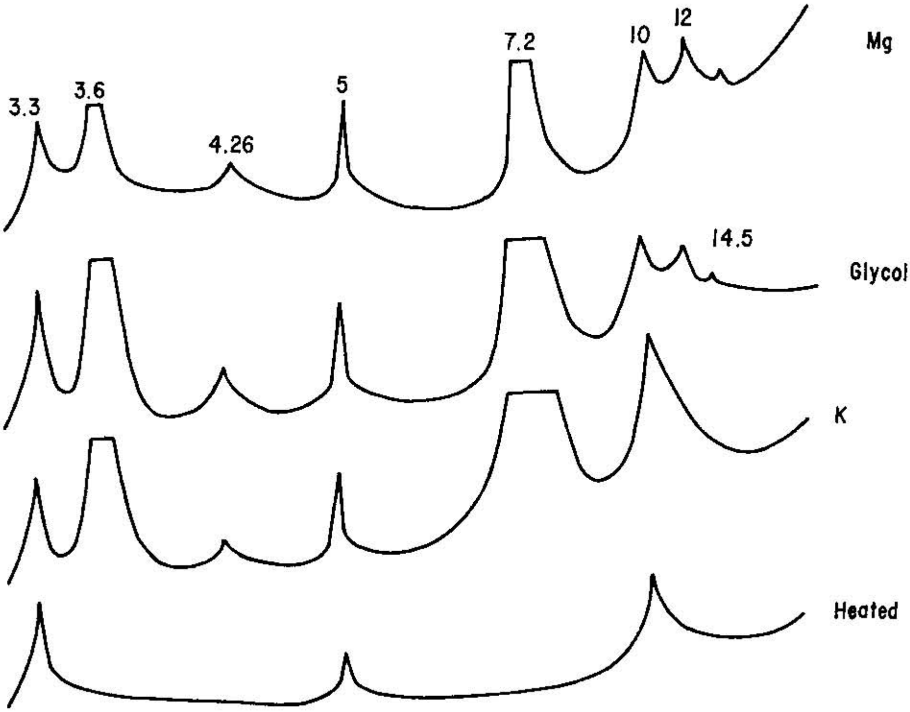

FIGURE 3. X-ray Diffractograms of the Clay Fraction of Soils of Rengam Series (P2) (B_{22t} Horizon)

TABLE 3. The Amount of Kaolinite, Gibbsite and Goethite in the Clay Fraction

Profile	Series	Horizon	Mineral (%)		
			Kaolinite	Gibbsite	Goethite
P1	Kuala Brang	A1	60.8	0.06	0.22
		B_{22t}	59.7	—	0.37
P2	Rengam	A1	65.3	—	—
		B_{22t}	61.9	—	—
P3	Rengam	A1	82.2	0.78	0.27
		B_{22t}	77.7	0.52	0.27
P4	Rengam	A1	81.8	1.96	—
		B_{22t}	76.6	1.41	—
P5	Rengam	A1	72.7	0.87	0.52
		B_{22t}	74.3	0.75	0.47

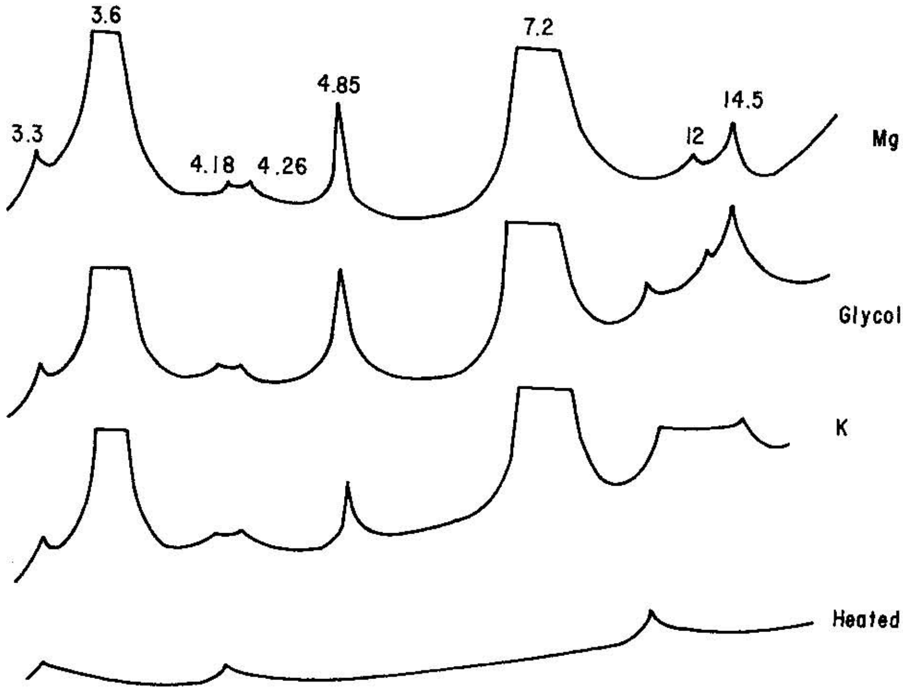

FIGURE 4. X-ray Diffractograms of the Clay Fraction of Soils of Beserah Series (P5) (B_{22t} Horizon)

4/ *Soil buffering.* The soils are strongly buffered at around pH 5 and 8.5 (Figure 6). The buffering action around pH 5 is caused by A1. The comparison betwewn OH^- needed to raise the pH up 5.5 and the amount of A1 in the soil yields the equation:—

$$OH^- = -0.89 + 1.77\ A1$$

$$R^2 = 0.93^{**}$$

$$F_{1:8} = 100.92$$

There is indeed a strong correlation between OH^- and A1 in the soil below pH 5.5

The buffering action between pH 5.5 and 8.3 is not related significantly to any of the parameters considered (Clay %, organic carbon, A1). However, in an earlier study by Shamshuddin and Tessens (1983) for the acid alluvial soils of Peninsular Malaysia it was conclusively proved that kaolinite controlled the buffering of soil above pH 5.5.

Referring to titration curves in Figure 6, one notes that soil in the top horizon is more buffered than that in the B_{22t} horizon. Perhaps this is due

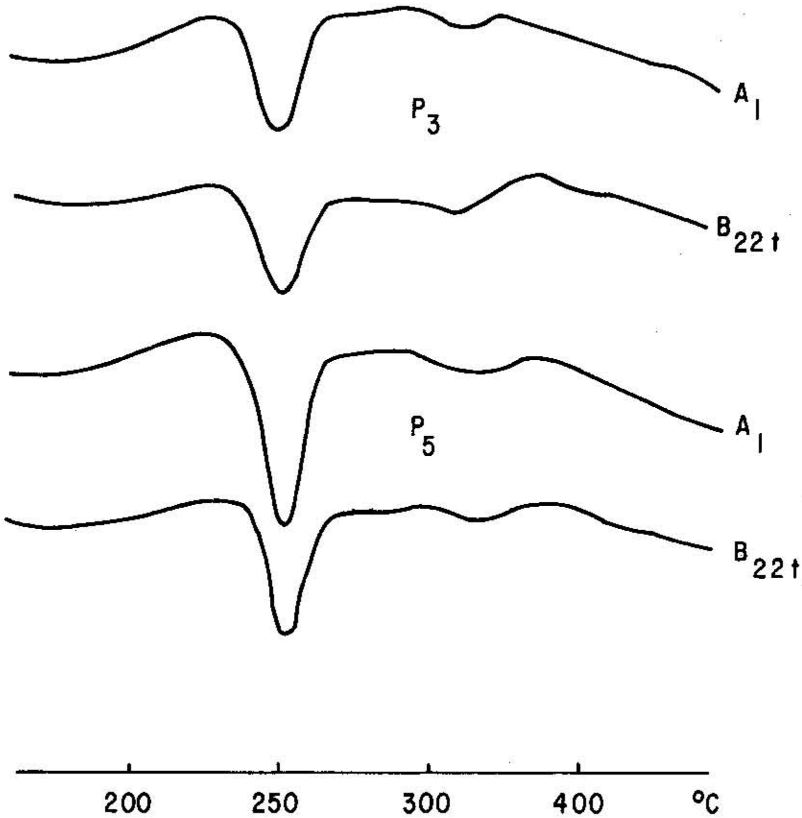

FIGURE 5. DSC Curves of the Clay Fractions of Soils of Rengam (P3) and Beserah (P5) Series

to the presence of more organic matter in the top horizon, but statistical analysis does not yield significant correlation between OH and organic matter.

5/ *Charge properties.* pH in 0.01N KCI is regarded as soil pH in the field condition as 0.01 is close to the ionic strength of leached tropical soils (Tessens and Shamsuddin 1983). In all cases, soil pH_0 is lower than its pH (Table 4). Lower pH_0 than soil pH shows that the soils are net negatively charged under field conditions (Uehara and Gillman 1980).

Net charge at pH_0 is considered as permanent charge (Uehara and Gillman 1980). Data in Table 4 show that the permanent charges in these soils are negative. The low values of permanent charges, mostly below 10 meq/100 g clay, point to the dominance of 1:1 clay mineral. The amounts of vermiculite and/or mica-vermiculite are probably small, otherwise the permanent charge value would have been much higher. Low CEC value (NH_4Cl) indicates that the soils do not contain much 2:1 clay minerals.

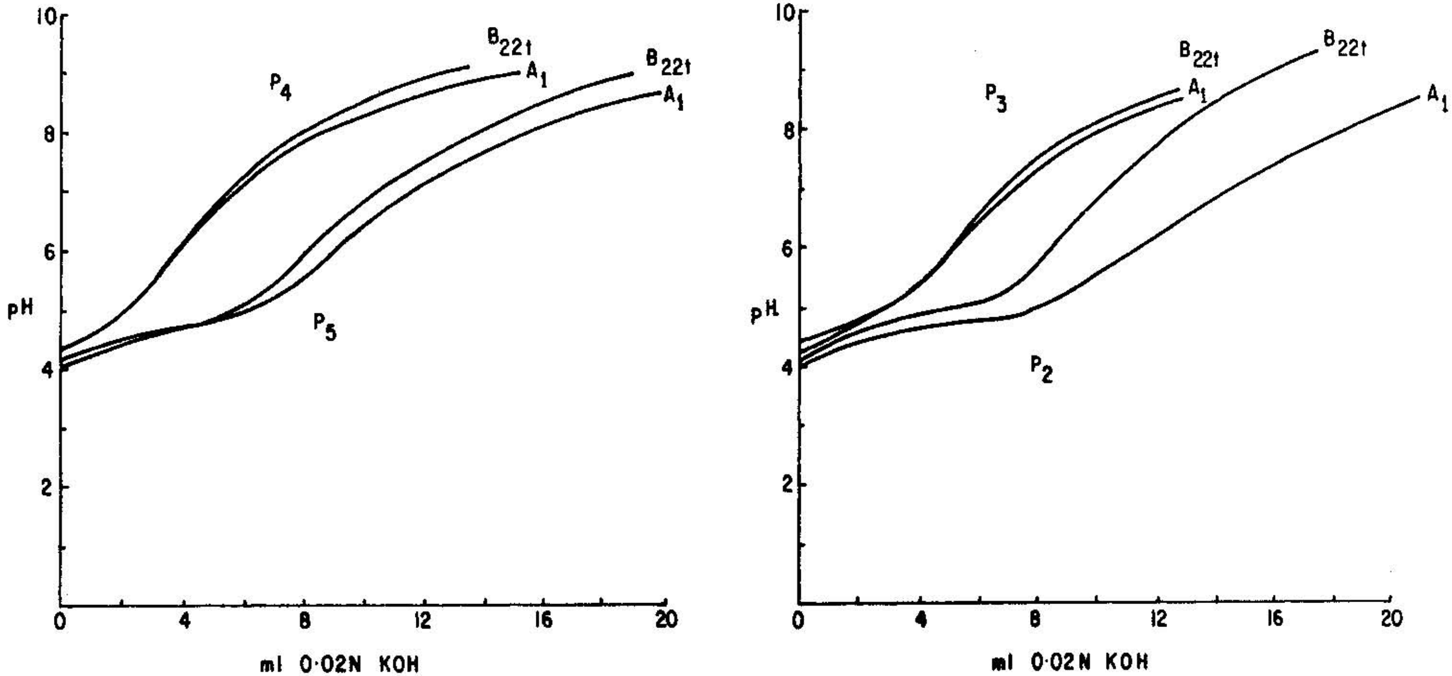

FIGURE 6. Potentiometric Titration Curves of Soils of Rengam

TABLE 4. pH_0, pH (0.01N KCl) and Charges in the Soils

Profile	Horizon	pH_0	pH 0.01N KCl	Charga at pH_0 – ve	Charga at pH_0 + ve	Permanent Charge
				meq/100 g soil		meq/100 g soil
P1	A1	3.05	3.77	2.82	1.00	7.05
	B_{22t}	3.55	3.82	4.65	1.00	11.23
P2	A1	3.05	3.71	3.07	1.30	6.28
	B_{22t}	3.15	3.80	3.79	1.30	11.91
P3	A1	3.20	3.97	2.22	1.30	4.08
	B_{22t}	3.30	4.20	3.79	1.80	3.94
P4	A1	3.20	3.97	2.01	1.30	2.81
	B_{22t}	4.00	4.17	3.01	1.00	5.34
P5	A1	3.35	3.79	3.01	1.10	5.00
	B_{22t}	3.70	4.06	4.10	1.30	6.26

EROSION HAZARD

Soil erosion is a major problem in the new townships of Ketengah. The top soils contain less than 40 percent clay. In order to have stable aggregate, soils dominated by 1:1 clay should have 40 percent or more clay (Ghulam 1983). Further, the presence of large amount of very coarse sand results in the formation of weak to moderate subangular blocky structure (Beserah series). The aggregates break up easily on contact with water. Thus, the top soils disperse easily in water as shown by the high WDC/clay percentage (Appendix).

Soil erosion is promoted by high rainfall. Along Jerangau-Jabor Highways, the annual rainfall is reported to be more than 3500 mm (Anon 1983) which comes mainly in November and December (Table 2). This rain falls with high intensity. Although there is no data available for Ketengah areas, it is known that rainfall intensity at Kota Bharu, during the monsoon, can be as high as 26.67 mm/h (Dale 1960). High intensity rains which fall in large drops possess high kinetic energy that cause dispersion and detachment of soil particles.

From the point of view of texture, the soils are obviously very erodible. In the P3 and P4 for instance, the sand fraction exceeds 60 percent in some horizons. The most erodible of the studied soils is probably the soils of Beserah Series (P5), because not only is the amount of sand content high, but also the sand are mainly in the coarse fraction. From texture and WDC/Clay percentage analysis the soils can be arranged in the following order of erodibility:—

Beserah (P5) > Rengan (P2, P3, P4) > Kuala Brang (P1).

The areas where the towns are built are either hilly or rolling. One has to undertake conservation measures seriously in order to reduce soil loss by erosion. At all time, the soil should be covered either by grass turfing or leguminous plants. Soil conditioners can also be applied to protect steep slopes. Alternatively, one has to make terraces. Such terraces have to be done in such a way that they reduce the water speed on the steep slopes.

SOIL SUITABILITY

The soils are sandy and their CEC are very low, with values less than 5 meq/100 g soil. Applied fertilizers will not be retained by the soils. The terrain varies from undulating to rolling. Thus, the soils are limited by their low fertility and erosion hazard. The soils of Beserah (P5) Series are therefore moderately suitable for rubber and oil palm and not suitable for cocoa. Soils of Rengam Series (P2, P3, P4) are suitable for rubber, oil palm and cocoa with only slight limitation for low fertility and erosion hazard. Soils of Kuala Brang Series (P1) are limited by their moderate depth and steep slope and therefore moderately suitable for rubber, oil palm and cocoa.

CONCLUSION

High rainfall and temperature prevailing in the Ketengah region result in the formation of 1:1 clay minerals and sesquioxides. Consequently, the CEC and bases are low while A1 saturation is high. A1 appears to control the buffering action of the soil below pH 5.5. pH_0 is lower than soil pH, showing that the soils are net negatively charged under field conditions. The soils are clayey, but less than 40 percent clay in the top horizon. Coarse quartz grains are present in large amounts. Consequently, the soils are susceptible to erosion.

ACKNOWLEDGEMENTS

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REFERENCES

Anon, 1983. Feasibility study for the development of mukim Pasir Raja and Jengai, Vol. 2: The Study Area. Projekon.

Dale, W.L. 1960. Rainfall of Malaya: Part II. *J. Trop Geog.*, 14: 11 – 28.

Gillmann, G.P. and Uehara, G. 1980. "Charge characteristics of soils with variable and permanent charge minerals: 11. Experimental. *Soil Sci. Soc. Am. J.*, 44: 252 – 255.

Ghulam, M.H. 1983. *Physical and edaphic characteristics of surface layers of highly weathered soils in Malaysia.* D. Agric. Sc. thesis, Fac. Agric. RUG., Ghent.

Gopinathan, B. and Paramananthan, S. 1979. Steepland soils in Peninsular Malaysia. Paper presented at Malaysian Seminar on Fertility and Management of Deforested Soils. Soc. Agric. Sci. Sabah and Malays. Soc. Soil Sci.

Hutchinson, C.S. 1977. "Granite emplacement and techtonic subdivision of Peninsular Malaysia" *Geol. Soc. Malays. Bull.* 9: 187 – 206.

Rajah, S.S., Chand, F. and Singh, D.S. 1977. "The granitiods and mineralization of the eastern belt of Peninsular Malaysia". *Geol. Soc. Malays. Bull.* 9: 209 – 232.

Shamshuddin, J. and Tessens, E. 1983. "Potentiometric titration of acid soils from Peninsular Malaysia". *Pertanika*, 6(1): 71 – 76.

Tavernier, R. 1975. Private communication.

Tessens, E. and Shamshuddin, J. 1983. *Quantitative Relationship Between Mineralogy and Properties of Tropical Soils.* UPM Press, Serdang.

Uehara, G. and Gillman, G.P. 1980. Charge characteristics of soils with variable and permanent charge minerals: 1. Theory. *Soil Sci. Soc. Am. J.*, 44: 250 – 252.

APPENDIX

Soil Series		: Kuala Brang
Classification		: Typic Paleudult
Physiography		: Hilly
Slope		: 30 – 35%
Parent Material		: Shale
Location		: Chenih, Ketengah, Trengganu
Vegetation		: Secondary forest
Groundwater		: Deep
Drainage		: Well drained
Description		: Shamshuddin, Wan Sulaiman
		Profile Description
Al	0 – 13 cm	Brownish yellow (10YR 6/6); sandy clay loam; moderate, fine, subangular blocky; firm; many, coarse and fine roots; smooth and clear.
B_{21t}	13 – 50 cm	Brownish yellow (10YR 6/8); sandy clay loam; moderate mediu, subangular blocky; firm thin patchy cutans; few, medium roots; diffuse and smooth.
B_{22t}	50 – 80 cm	Brownish yellow (10YR 6/8); sandy clay loam; moderate, medium, subangular blocky; firm; thin patchy cutans; few, medium roots; sharp and smooth.
BCcn	80 – 110 cm	Reddish yellow (7.5YR 6/8); gravelly clay; massive; firm; few, medium roots; diffuse and smooth.
C	+ 100 cm	Reddish yellow (7.5YR 6/8); clay; massive; firm; many coarse, sharp red (2.5YR 4/8) mottles; very few, medium roots.

Hor	Depth (cm)	Texture			WDC/Clay %
		Clay %	Silt %	Sand %	
A1	0 – 13	25.8	17.4	56.8	32.0
B_{21t}	13 – 50	25.0	22.7	52.3	57.0
B_{22t}	50 – 80	32.5	21.9	45.6	37.5
BCcn	80 – 110	47.3	19.7	33.0	0.8
C	110 +	50.6	21.9	27.5	0.7

Bases (meq/100g)					B.S. (%)	Al (meq/100g)	Al. Sat (%)	Fe_2O_3 (%)
Na	K	Mg	Ca	Sum				
0.02	0.22	0.16	0.29	0.67	14.4	2.40	78.2	1.71
0.02	0.12	0.07	0.22	0.57	14.7	2.24	79.7	2.53
0.02	0.07	0.05	0.22	0.38	9.5	2.51	86.9	2.94
tr	0.07	0.03	0.19	0.29	5.5	6.62	95.8	2.80
0.03	0.03	0.02	0.34	0.42	8.5	4.89	92.1	2.72

pH (1:1)			CEC (meq/100 g)		App. CEC (NH_4OAc)	O.C. %
H_2	0.01N (KC1)	1N	NH_4OAc	NH_4Cl		
4.36	3.77	3.44	4.65	3.08	18.02	1.00
4.66	3.86	3.47	3.87	3.05	15.48	0.72
4.78	3.82	3.44	4.00	3.53	12.30	0.66
4.93	4.03	3.54	5.22	4.75	11.04	0.56
4.88	4.05	3.54	4.97	4.50	9.82	0.53

Sample No: 83/1
Date: 7/6/1983

Soil Series	: Rengam
Classification	: Typic Paleudult
Physiography	: Rolling
Slope	: 15 – 20 %
Parent Material	: Granite
Location	: Sri Bandi, Ketengah, Trengganu
Vegetation	: Bushes
Groundwater	: Deep
Drainage	: Well drained
Description	: Shamshuddin and Wan Sulaiman

Profile Description

Al	0 – 10 cm	Yellowish brown (10YR 5/6), coarse sandy clay loam; moderate, medium, crumb; friable; many medium and fine roots; smooth and clear.
B_{21t}	10 – 27 cm	Yellowish brown (10YR 5/8); coarse sandy clay loam; moderate, medium subangular blocky; firm; thin patchy cutans; few, medium roots; smooth and diffuse.
B_{22t}	27 – 66 cm	Yellowish brown (10YR 5/8); coarse sandy clay loam; moderate, medium, subangular blocky; firm, thin patchy cutans; smooth and diffuse.
B_{23t}	66 + cm	Brownish yellow (10YR 6/8); coarse sandy clay; moderate, medium, subangular blocky; firm, thin patchy cutans.

Hor	Depth (cm)	Texture			WDC/Clay %
		Clay %	Silt %	Sand %	
Al	0 – 10	28.2	13.1	58.7	53.1
B_{21t}	10 – 27	23.0	9.7	67.3	68.5
B_{22t}	27 – 66	29.3	12.3	58.4	4.7
B_{23t}	66 +	15.6	15.1	49.3	0.6

Bases (meq/100g)					B.S. (%)	Al	Al. Sat (%)	Fe_2O_3 (%)
Na	K	Mg	Ca	Sum		(meq/100g)		
tr	0.21	0.02	0.32	0.55	12.2	2.74	83.3	1.47
tr	0.07	0.80	0.27	1.14	35.6	2.44	68.2	2.15
tr	0.12	0.03	0.19	0.34	9.5	2.56	88.3	1.91
tr	0.26	0.04	0.19	0.49	15.9	1.88	79.3	1.88

pH (1:1)		CEC (meq/100g)				
H_2O	0.01N (KCl)	1N	NH_4OAc	NH_4Cl	App. CEC (NH_4OAc)	O.C. %
4.68	3.71	3.41	4.50	3.10	15.95	1.56
4.54	3.81	3.42	3.20	3.20	13.91	0.79
4.61	3.80	3.55	3.58	3.28	12.22	0.65
4.56	3.85	3.54	3.08	2.88	8.65	0.52

Sample No: 83/2
Date: 7/6/1983

Soil Series	: Rengam
Classification	: Typic Paleudult
Physiography	: Undulating
Slope	: 20%
Parent Material	: Granite
Location	: Ketengah Jaya, Ketengah, Trengganu
Vegetation	: Bushes
Groundwater	: Deep
Drainage	: Well drained
Description	: Shamshuddin and Wan Sulaiman

Profile Description

Al	0 – 10 cm	Yellowish brown (10YR 5/6); sandy clay loam; moderate, medium, crumbs; friable; many, fine and medium roots; smooth and clear.
B_{21t}	10 – 42 cm	Brownish yellow (10YR 6/8); sandy clay loam. moderate, medium, subangular blocky; thin patchy cutans; few, medium roots, smooth and diffuse
B_{22t}	42 – 96 cm	Yellowish brown (10YR 5/8); clay; moderate, medium, subangular blocky; thin patchy cutans; few, medium roots; smooth and diffuse.
B_{23t}	96 + cm	Yellowish brown (10YR 5/8); clay; moderate, medium, subangular blocky; thin patchy cutans, few, medium roots.

Hor	Depth (cm)	Texture			
		Clay %	Silt %	Sand %	WDC/Clay %
Al	0 – 10	22.5	5.7	71.8	44.4
B_{21t}	10 – 42	33.6	6.0	60.4	0.5
B_{22t}	42 – 96	50.4	8.2	41.4	0.4
B_{23t}	96 +	48.8	7.4	43.8	0

Bases (meq/100g)						Al		
Na	K	Mg	Ca	Sum	B.S. (%)	meq/(100g)	Al.Sat (%)	Fe_2O_3 (%)
0	0.13	0.06	0.27	0.46	16.7	1.41	75.4	1.76
0	0.07	0.02	0.22	0.31	10.9	1.46	82.5	1.13
0	0.03	0.02	0.24	0.29	10.7	1.50	83.8	3.59
0.02	0.08	0.08	0.27	0.45	13.7	1.41	75.8	4.28

pH (1:1)			CEC (meq/100g)			
H_2O	0.01N (KCl)	1N	NH_4OAc	NH_4Cl	App. CEC (NH_4OAc)	O.C. %
4.58	3.97	3.75	2.75	1.78	12.22	1.49
4.86	4.10	3.86	2.85	2.18	8.48	0.92
5.16	4.20	3.85	2.70	2.18	5.36	0.79
5.25	4.33	3.85	3.28	2.18	0.72	0.77

Sample No: 83/3
Date: 8/6/1983

Soil Series : Rengam
Classification : Typic Paleudult
Physiography : Rolling
Slope : 30 – 35%
Parent Material : Granite
Location : Durian Mas
Vegetation : Secondary forest
Groundwater : Deep
Drainage : Well drained
Description : Shamshuddin and Wan Sulaiman

Profile Description

Al	0 – 10 cm	Yellowish brown (10YR 5/6); sandy clay loam; moderate; medium, crumbs; friable; many, fine and medium roots; roots; smooth and clear

B_{21t}	10 – 42 cm	Yellowish brown (10YR 5/8); sandy clay; moderate, medium, subangular blocky friable; thin patchy cutans; few, finel and medium roots; smooth and diffuse.
B_{22t}	42 – 92 cm	Brownish yellow (10YR 6/8); sandy clay; moderate, medium, subangular blocky; friable; thin patchy cutans; few, fine and medium roots; smooth and diffuse.
B_{23t}	92 + cm	brownish yellow (10YR 6/8); clay; moderate, medium, subangular blocky; friable; thin patchy cutans; few, fine and medium roots.

Hor	Depth (cm)	Texture			WDC/Clay %
		Clay %	Silt %	Sand %	
A1	0 – 10	25.2	4.4	70.4	36.8
B_{21t}	10 – 42	37.7	6.1	56.2	0.9
B_{22t}	42 – 92	37.6	6.4	56.0	0.8
B_{23t}	92 +	49.9	9.5	40.6	0.2

Bases (meq/100g)					B.S. (%)	Al (meq/100)	Al.Sat (%)	Fe_2O_3 (%)
Na	K	Mg	Ca	Sum				
tr	0.10	0.06	0.29	0.45	12.6	1.23	73.2	2.27
tr	0.06	0.01	0.17	0.24	9.1	1.22	83.6	3.09
tr	0.10	0.02	0.25	0.37	17.8	1.12	75.2	3.44
tr	0.06	0.08	0.19	0.33	15.0	1.13	77.4	4.17

pH (1:1)		CEC (meq/100g)			App. CEC (NH_4OAc)	O.C. %
H_2O	0.01N (KC1)	1N	NH_4OAc	NH_4C1		
4.63	3.97	3.76	3.58	2.03	14.04	1.43
4.53	4.03	3.85	2.65	1.83	7.03	0.93
4.66	4.17	3.87	2.08	1.98	5.53	0.78
4.85	4.26	3.90	2.20	1.60	4.40	0.67

Sample No: 83/4
Date: 8/6/1983

Soil Series : Beserah
Classification : Paleudult
Physiography : Hilly
Slope : 20%
Parent Material : Granite
Location : Granite
Location : **Bukit Besi, Ketengah, Terengganu**
Vegetation : Secondary forest
Groundwater : Deep
Drainage : Well drained
Description : Shamshuddin and Wan Sulaiman

Profile Description

Al	0 – 23 cm	Yellowish brown (10YR 5/8); gravelly sandy clay loam; moderate, medium, subangular blocky; firm, many, medium and fine roots; smooth and clear
B_{21t}	23 – 65 cm	Yellowish brown (10YR 5/8; gravelly sandy clay; moderate, medium, subangular blocky; very firm; thin patchy cutans; many, medium dan fine roots; smooth and diffuse.
B_{22t}	65 – 102 cm	Yellowish brown (10YR 5/8); gravelly sandy clay; moderate, medium to coarse, subangular; firm; thin patchy cutans; few medium and coarse roots; smooth and diffuse.
BC	102 + cm	Yellowish brown (10YR 5/8); gravelly sandy clay; massive; very few coarse roots.

Hor	Depth (cm)	Texture			WDC/Clay %
		Clay %	Silt %	Sand %	
Al	0 – 23	38.2	4.5	57.3	25.4
B_{21t}	23 – 65	34.8	4.7	60.5	3.3
B_{22t}	62 – 102	47.7	5.5	46.8	0.8
BC	102 +	47.7	4.7	47.3	0.3

Bases (meq/100g)					B.S. (%)	Al (meq/100g)	Al.Sat (%)	Fe_2O_3 (%)
Na	K	Mg	Ca	Sum				
0.02	0.09	0.01	0.22	0.32	6.6	2.26	87.6	2.88
0.03	0.09	0.08	0.22	0.42	13.9	2.39	85.1	3.57
0.02	0.17	0.01	2.16	2.46	29.9	2.09	45.9	3.81
tr	0.06	0.02	1.35	1.43	44.7	1.93	57.4	3.79

pH (1:1)			CEC (meq/100g)			
H_2O	0.01N (KCl)	1N	NH_4OAc	NH_4Cl	App. CEC (NH_4OAc)	O.C. %
4.59	3.79	3.52	4.83	3.43	12.64	2.73
4.87	3.95	3.60	3.03	2.95	8.71	0.98
5.02	4.06	3.67	3.08	2.68	6.46	0.72
5.15	4.06	3.67	3.20	3.20	6.71	0.51

Sample No: 83/5
Date: 9/6/1983