Rock weathering and soil formation in Malaysia

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Abstrak (Abstract)

The term *soil* is a collective and general term that can describe all kinds of soils. To different people the term *soil* means different things. To the housewife it is the material found in gardens and in which flowers and vegetables are grown. A geologist considers the soil to be the loose material covering the rocks he/she wants to examine. An engineer looks at soils as materials that he/she has to manipulate or move to build foundations or dams or the material that can be used as road-bed material. To an agriculturalist, the soil is a medium for the growth of plants. A general definition of soil is that it is a natural body occurring on the earths surface and supporting or capable of supporting plants and consisting of minerals and organic materials. It is characterized by related horizons formed by the interaction of climate and vegetation on various parent materials (weathered rock) over varying periods of time and modified by local relief.

Soils can be divided into three broad groups — *in situ* soils, alluvial soils and organic soils. *In situ* soils are formed by the weathering of rocks in place. Alluvial soils are formed by the transport by water, wind or ice of weathered material and deposited in some place other than the original place of weathering. Organic soils are soils formed by the accumulation of organic soil material on the earth's surface either in waterlogged depressions or at high altitudes.

Soils are formed by the weathering of rocks. In temperate areas, low temperatures and low rainfall result in soils which are shallow and often rich in nutrients. Both diurnal and seasonal changes in temperature, presence of ice and frost are important soil forming factors in these areas. Physical weathering plays an important role in soil formation. In contrast, in the Tropics, continuous high temperatures and heavy rainfall results in soils which are deep and low in nutrients. Chemical weathering plays an important role in soil formation. In the Tropics therefore both the high temperature and high rainfall act on the different parent materials or rocks to produce the different soil types. The nature of the rock type, its chemical composition, texture of the rock and its weatherability can be expected to strongly influence the nature and characteristics of the soils formed over the different rock types.

The weathering of three igneous rock types namely granite, rhyolite and basalt are used in this paper to illustrate the influence of the parent rock on the genesis, physical, chemical and mineralogical properties of the soils developed over them. Both granite and rhyolite are acid igneous rocks which have similar chemical and mineralogical composition — consisting essentially of quartz, feldspar with minor amounts of muscovite and biotite, but differ in grain-size. In contrast, the basalt is a basic igneous rock and consists mainly of ferromagnesian minerals such as pyroxene, amphibole and plagioclase feldspar. The rates of weathering of these rock types under a tropical environment differ considerably.

Granite being a coarse grained rock can weather quite quickly. The free quartz which is coarse is relatively resistant to weathering and remains in the soil as coarse sand while the feldspar and micas (especially biotite) weather rapidly to give rise to clay-sized minerals — kaolinite and illite. Thus the resultant soil (e.g. Rengam Series) is deep (> 3 metres) has a brownish yellow colour and a coarse sandy clay texture. Chemically these soils have a low cation exchange capacity (CEC) (< 16 cmol(+)kg^{-1} clay) and a free iron content of less than 5%. The clay mineralogy is dominated by kaolinite with little goethite and some illite.

Rhyolite being fine grained rock is often a more compact rock which is more difficult to weather. Consequently the soils developed on this rock type tend to be shallow to moderately deep (< 1 metre). The soil developed over this rock type (e.g. Penyabong and Kulai Series) have fine sandy clay to silty clay textures. Silt contents often exceed 30% indicating a younger soil. Colours tend to be yellow to light gray. Chemically these soils tend to have a moderate CEC values (16–24 cmol(+)kg^{-1} clay). Free iron content is less than 5% and the clay mineralogy may be dominated by illite with smaller amounts of kaolinite.

Basalt being a fine grained basic igneous rocks is a highly weatherable rock type in the Tropics. The mineral present viz. pyroxene, amphiboles and calcium-rich plagioclase all weather rapidly to clay-sized particles. The soils developed over such rock types (e.g. Kuantan Series are deep (> 3 m) and have clay textures, red or brown colours and strong fine structures with a high porosity. These soils often have very

Table 1. Influence of geology (parent materials) on the soil characteristics and soil management.

NATURE OF ROCK TYPE					SOIL CHARACTERISTICS								MANAGEMENT IMPLICATIONS
Name	Origin	Grain-size	Dominant Minerals	Chemical Character	Colour	Texture	Soil Depth (cm)	Common Diagnostic Horizon	Clay % Consistence	Iron Content (%)	CEC cmol/kg soil	Trace Elements	
Granite	Acid Igneous	Coarse	Quartz, K-Feldspar, K-Mica, Fe-Mica	High silica. Moderate K. Low iron	Brownish yellow Strong brown	cosc	150 + V. deep	argillic	30–50/ friable	2–5	6–8	High Boron	Erodibility. Prone to large landslips. Low fertility.
Rhyolite	Acid Igneous	Fine	Quartz, K-Feldspar, K-Mica, Fe-Mica	High silica. Moderate K. 'Low iron'	Brown yellow –yellow	fsc-sic	50–100 Shallow to deep	argillic	30–40 silt > 20 /firm	2–5	6–8	High Boron	Firm consistence, less weatherable. High K levels. Steep terrain.
Basalt	Basic Igneous	Fine	Fe-rich minerals. Little Quartz	High Fe, Mg, Ca	Red/Brown	c	150 + V. deep	oxic	70 +/ friable	10–15	< 4	Low Boron High Ni/Cr	Prone to moisture stress. P-fixation. B deficiency. Ni/Cr toxicity possible.
Serpentinite	Ultrabasic Igneous	Coarse	No quartz. Fe, Ca/Mg rich. No quartz.	High Fe. High Ni/Cr. Low B	Reddish Brown	c	150 + V. deep	oxic	70 +/ friable	10–20	< 4	Low B. High Ni/Cr	P-fixation. Ni/Cr toxicity. B deficiency.
Sandstone	Sedimentary	Coarse	Quartz, others variable	High silica	Brownish yellow to reddish yellow	scl	75–150 Mod. to deep	argillic spodic on very sandy area	18–35/ friable	< 5 but variable	< 5	Low	Erodibility. Moisture stress. Low fertility especially K-levels.
Mudstone/ shale	Sedimentary	fine	kaolinite/ quartz	Variable	Light gray yellow to red	sic-c	75–150 Mod. to deep	argillic to oxic depending on iron content	35–70/ friable to firm	Variable 2–10	Variable 5–30	Low	***Low iron soils*** — impeded drainage and strong compact soils. ***High iron soils*** — well drained fine structured friable soils. Variable fertility. Somewhat higher K-levels.
Riverine Alluvium	Alluvium	Variable clay to sands	Quartz	Variable	Light gray to brownish yellow	Variable sands to clays	Deep > 100	Cambic/ argillic	Variable 5–70	< 5	Variable but often low 5–10	Low	Poor drainage. Low fertility status (especially K).
Marine Alluvium (Clay)	Alluvium	Fine	Montmorillonite	High in magnesium and calcium sulfate/sulfides	Blueish to gray to black	sic-c	Deep > 100	Cambic sulfuric/ Sulfidic	30–70 + silt 30+	Low < 5	High > 15	Low	Poor drainage/flooding. Salinity. Low K levels. High Mg/Ca levels. Acid sulfate conditions.
Beach Sands	Alluvium	Coarse	Quartz	Very low in all elements except SiO_2	White to yellow	sand	Deep 100 +	Spodic/ None	0–10	Low	Very low	Very low	Very low nutrient retention. Very low moisture retention. Acute trace element deficiency.

low CEC values (< 8 cmol(+)kg^{-1} clay) with free iron contents exceeding 10%. The clay mineralogy is dominated by goethite, gibbsite and some kaolinite.

From the above discussion it can be seen that in a tropical environment, the nature of the rock — its chemical composition, mineralogy and grain-size determines to a large extent the depth, colour, texture, structure, the CEC and clay mineralogy of the soils developed over them. These properties play an important role in the management of these soils. The influence of the geology for a range of rock types and alluvial deposits on the soil characteristics and soil management implications for agriculture are summarised in the attached table.

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