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Full Length Research Paper

Morphogenetic characterization of soils formed from basement complex rock in the humid tropical rainforest of Nigeria

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The morphogenetic and physico-chemical properties of four soil units occupying different slope facets on a rolling landscape were studied to understand distribution of soils on a typical landscape. The soil colours range from dark brown to reddish brown (10YR3/3-5YR3/3) in the surface and strong brown (7YR4/6) to yellowish red (5YR5/8) in the sub soil. The texture varies from loam/sandy clay loam in the surface to clay/clay loam in the sub soil. The solum was moderately acidic to neutral (5.5 - 8.0) at the surface and strongly acidic to moderately acidic (4.65 - 5.80) in the sub soils. The soils are characterized by low exchangeable bases and cation exchange capacity. Pedon 1 on the crest was classified as Typic Hapludult (Haplic Acrisols). Pedon 2 at the mid slope was classified as Dystric Hapludult (Dystric Luvisol) while Pedons 3 and 4 were classified as Albic plinthudult (Albic plinthosols) and Dystric Haplaquent (Dystric Gleysols) respectively. Pedogenesis was influenced by physiographic positions resulting in different soil types on the landscape. Where similar parent material exists, different soil types were formed due to different exposure to morphogenesis processes such as eluviation, illuviation, deposition, cementation of pedi-sediments and multiple stratification as determined by the position of the pedon on the landscape.

Key words: Morphogenesis, pedoturbation, quartz vein, plinthite, argillic horizon, base saturation.

INTRODUCTION

Theories had been put forward to explain the genesis of soils formed from rocks of the basement complex in the humid tropical zone of Nigeria. Smyth and Montgomery (1962) observed that weathered rock materials from which the soils develop have a complicated history reflecting the influence of previous climatic variation, cycles of erosion and periods of intense soil forming activities. Distinct erosional phases in South western Nigeria and the superficial deposits of pediment and secondary sediment have been observed. Ojanuga (1978) noted that multiple stratification of soil parent materials of varying Pedi sediments (over saprolite) and existence of inherited pedological features tend to indicate that cycles of erosion must have alternated repeatedly with cycles of pedogenesis. Cyclic changes in climate in West Africa were also reported by Thomas and Thorp (1985).

Smyth and Montgomery (1962) reported that on a landscape shoulder, the soil properties reflect a combination of characteristics inherited during erosional evolution of the landscape. This is as a result of pedologic processes acting on the present surface. The relative importance of these processes was considered to vary within the same landscape segments because different soil types have been noticed to be associated with different parts of the landscape. Ojo-Atere et al. (1988) also reported from the study of upper slope soils that the surface horizons may be developed in transported material while the subsurface horizons may be derived from the underlying rock. The soils of the basement complex vary a lot in soil characteristics, therefore intense understanding of the slope processes and spatial distribution is of great importance for sustainable management of the soil.

This research was conducted with objective of studying the spatial distribution of soils on a rolling topography using morphogenetic and physico-chemical properties.

METHODS

The study area

The area of study lies approximately within longitude 4° 30E and 4° 50E and latitude 7°21N and 7°30N.

The area is chracterised by rolling landscape of 3 - 9%. The land use consisted of a mixture of bush regrowth and arable crops. The area had been under cultivation for more than ten years. The area of study has humid tropical climate with distinct dry and wet seasons of about 4 and 8 months, respectively. The mean annual rainfall and air temperature of the area is 1300 mm and 13°C, respectively. This area specifically is underlain by coarse/medium grained granite gneisses (Boesse and Ocan, 1988). The terrain is unique with schist intrusion existing at the mid slope/lower slope facets on the landscape.

Field work

Representative soil units were identified from mini pits during reconnaissance field study after which profile pits were dug. Soil samples were collected from the horizons designated in the profile pits. The soils were described according to Soil Survey Staff (2003). Samples were prepared and routinely analyzed following the guidelines of IITA (1979). The parameters that were determined include: Sand, silt clay, pH, %C and cations from which sum of bases and effective cation exchange capacity were calculated for each horizon. The soils were classified according to USDA Soil Taxonomy (1999) and FAO/UNESCO (1994). At series level Smyth and Montgomery (1962) classification was used.

RESULTS AND DISCUSSION

Morphological description of the study area

The landscape consists of soils that occupy gentle to moderate slope (3.4 - 9.0%) positions. Four pedons were identified on different slope facets (Table 1). The upland soils (that is, on the mid slope to hill crest) have deeply weathered profiles with surface texture being sandy clay loam or sandy loam to loam (Pedons 1 and 2). The colour of the upland soils from surface to subsoil gradually changed from dark brown (10YR 3/3) to reddish brown (5YR 3/3). The darker values of the surface soils were attributed to organic matter content. The structure of Pedons 1 and 2 was strong, gradually changing from medium to coarse sub-angular blocky in the sub soils. Pedon 2 maintains the rock structure up to about 68 cm from the land surface showing the various bands of light and dark minerals. Their descriptions in general are similar to that of partly residual soils described by Ojanuga (1978) in South western Nigeria.

Transition horizons are also well developed in the upland pedons. They have combined features of the corresponding horizons with diffuse way to irregular boundary. Horizon boundary in Pedons 1 and 2 is gradual and wavy to diffuse and irregular. This could be due to gradual transformation, homogenization, various pedoturbation or erosional/depositional processes. Generally, these upland soils have a layer of gravel accumulation. This could be due to any of the previously mentioned processes or their combinations. Eluviation and illuviation are active in all the profiles as evidenced by clay skin. Mass movement is important in pedon 2 because stones and gravels are oriented down slope. The prominent quartz vein diffusing to the surface horizon serves as the source of the gravels. The materials greater than 2 mm vary from 1.80 to 56.4% (Table 1).

The lowland pedons are very different from upland pedons due to formation of frequent Manganese nodules which also is a function of seasonal change in water table. Upland soils are also well drained thus having brown to reddish colour which become yellow down the landscape indicating the influence of soil moisture. Similar colour changes were reported by Okusami and Oyediran (1985)

Soil physical and chemical properties

The textures vary from sandy clay loam to sandy loam for surface horizons. While the B horizons are clay, the C horizons vary from clay loam to loam except in pedon 1 where the C horizon is also clay. The lower silt content in pedon 1 indicates higher degree of weathering than mid slope soils with medium to high silt content while high silt content reflects the deposition process in the lowland pedons (Table 2). These materials increase with increasing depth to a maximum level and decrease in the C horizons.

The chemical properties are also displayed in Table 2.

The organic carbon content in surface horizons are relatively high, between 1.56 to 3.98%. The organic C decreases down the profile. Okusami and Oyediran (1985) observed similar distributions in soils of Ife area in Nigeria. The pH of the surface soils varies from slightly acidic to neutral (6.0 – 7.5), while that of sub soils are moderately acidic to strongly acidic. Aluminum saturation is low on the surface and increases down the profile. The dominant exchangeable bases are Ca and Mg in the surface soils. Potassium and Na are low (0.01 – 0.06 Cmol/kg). Exchangeable Mg is high in the surface horizons (1.25 – 10 Cmol/kg) probably as a result of nutrient recycling and in B-horizons because of the increased CEC. associated with higher clay content. Base saturation decreases down the profiles randomly from the surface. Base saturation is highly variable, it ranges from 85.08 to 99.53% in the surface and 26.32 to 97.77% in the sub soil.

Surface horizons have more variable composition being area of active depositional processes. The distribution tends to be more uniform in the saprolite according to the degree of weathering it had undergone. The base saturation decreases concomitantly with increase in

Table 1. Morphologic description of soils from Ile -Ife rolling landscape.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Pedon 1												
A	0 – 12	7.5YR 4/2	-	SCL	sab	Fr	-	I	-	FM	DS	-
AB	12 – 27	7.5YR 4/2	-	SCL	sab	Fr	-	I	-	FM	cw	-
Bt	27 – 67	7.5YR 5/6	-	Slg C	sab	Fr	-	I	Fe-Mn	FM	cw	-
BC	67 – 130	7.5YR5/6	Yellow	C	M	Fr	-	I	-	F	dw	C
C	130-190	7.5YR5/6	Yellow	C	M	Fr	-	I	-	F	-	A
Pedon 2												
A	0 – 12	10YR3/3	-	Sl SL	Cr, Ls	Fr sl P	-	I	-	f,m	ds	-
AB	12 – 28	10YR4/4	-	gSL	W Gr	Fr -	-	I	Fe Mn	f, m	cw	-
Bt	28 – 68	7.5YR5/6	-	C	sab	F p	F M	I	-	F	ds	-
Bw	68 – 115	7.5YR/5/6	Yellow, red	C	sab	Fr SP	-	I	-	-	ds	C
Pedon 3												
A	0 – 6	10YR3/2	-	L	Cr	Fr sl S	-	I	-	F	cw	-
E	6 – 20	10YR4/4	-	slg, SCL	sab	Fr SP	ff	I	f	F	cs	-
Bt	20 – 50	7.5YR5/6	-	C	sab	F SP	m	I	-	F	ds	-
Bw	50-70	5YR5/8	Red, yellow,	Slg,C	sab	F SP	f	I	f	F	gs	-
CBcx	70-105	2.5YR4/6	Yellow	C	sab	Fr SP	f	I	mFe, Mn	F	gs	C
Ccx	105-157	10YR6/8, 5YR4/6, 10YR5/6	Pink, yellow	CL	ab	F SP		I	cFe	-	-	M
Pedon 4												
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]		
	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]	[illegible]		[illegible]		
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		

Texture: SCL- sandy clay loam, slgC-slightly gravelly clay, C-clay, g-gravelly, SL-sandy loam; Structure: sab-sub angular blocky, M-massive w-weak, cr-crumbs, ls-loose; Consistence: Fr-firm, p-plastic, sl p- slightly plastic ; Cutan: f-few, c-common, m-many; Drainage: I- well drained, II-moderately well drained, III-somewhat poorly drained, IV-poorly drained; Concretions: Fe-Mn- iron –manganese; Roots: F-fine, M-mediun. Boundary:ds-diffuse wavy, cw-clear wavy, dw-diffuse wavy, ds-diffuse-smooth; weatherable minerals: f-few, c-common, m-many, a-abundant.

Table 2. Physical and chemical properties of soils formed from rocks of basement complex in the humid tropical rainforest of Nigeria.

Hor	Depth	%Gravel	%Sand	%Silt	%clay	pH H_2O	Al^{3+}	Ex.ac	Ca^{2+}	Mg^{2+}	K^+	Na^+	SB	ECEC	BS	%C	Tex
Pedon 1																	
A	0 - 12	12.8	52	28	28	6	0.2	0.4	6.25	4.29	0.03	0.01	10.58	10.94	96.71	3.98	SCL
AB	27 - Dec	33.9	57.7	11.2	11.2	5.75	0.1	0.4	1.25	1.83	0.02	0.01	3.11	3.51	88.6	1.08	SCL
Bt	27 - 67	47	40	10.2	10.2	5.55	0.01	0.4	1.5	4.29	0.02	0.01	7	7.4	94.46	0.49	C
BC	67 -130	21	33.9	15	15	4.84	0.4	1.6	1.25	1.17	0.02	0.01	2.45	4	60.05	0.43	C
C	130 -190	21.2	32.3	18.4	18	4.75	1.2	1.8	1.2	1.08	0.01	0.01	2.35	4.15	56.63	0.18	C
Pedon 2																	
A	0 - 5	44.8	69.4	13.6	17	6.4	0.1	0.2	5	4.29	0.05	0.01	10.35	10.55	98.1	3.82	SL
AB	28 - Dec	58.5	69.1	14.9	16	6.3	0.1	0.4	1.25	1	0.02	0.01	2.28	2.68	85.08	0.78	SL
Bt	28 - 68	56.4	45.2	7.2	47	4.9	1.6	2.4	0.25	0.92	0.06	0.02	1.25	3.65	34.25	0.74	SC
BW1	68 - 115	29.9	35	14	51	4.7	1.8	2.8	0.25	0.71	0.03	0.01	1	3.8	26.32	0.2	C
BW2	115 - 155	16-6	49.4	19.6	31	4.65	2	3	0.25	0.79	0.01	0.01	3.31	6.31	52.4	0.2	SCL
Pedon 3																	
A	0 – 6	25	64.7	15.1	7.2	20.2	0.1	0.5	10	2.21	0.05	0.02	12.28	12.78	96.09	3.7	SCL
E	20-Jun	21	59.4	18.6	8	22.2	0.1	0.4	5	1.08	0.02	0.01	6.11	6.5	94	1.29	SCL
B	20 - 50	34.5	37.6	17.7	5.7	50.7	0.2	0.6	25	1.25	0.02	0.01	26.88	26.88	97.77	0.66	C
2BWt	50 - 70	33.5	33.2	11.2	5.4	55.6	1.4	2	1.25	1.46	0.04	0.01	2.16	4.16	57.98	0.27	C
2BW2	70 - 105	28.4	36.7	15.9	5	47.4	1.3	2	1.25	0.96	0.03	0.01	2.25	4.25	52.94	0.12	C
2Ccx	105 - 157		43.2	18.5	5.1	38.3	1.3	2	1.25	0.79	0.01	0.01	2.06	4.06	50.74		CL
Pedon 4																	
A	0 – 10	2.2	56	20	24	5.8	0	0.3	4.5	1.76	0.02	0.01	6.29	6.32	99.53	1.56	L
BA	20 – 46	2.7	46.1	27.1	27	6	0.1	0.3	10	1.88	0.03	0.01	11.9	12	99.17	1.17	SCL
Bt	20 – 46	24.2	48.9	15.9	36	5.3	0.8	1.5	2.5	1.08	0.01	0.01	3.6	5.1	70.39	0.59	SCL
BWt	46 – 63	38.8	46.3	15.3	39	5.3	0.5	1.2	1.25	1.13	.0.01	0.1	2.4	3.6	66.67	0.43	SC
BW2	63 – 90	26.6	48.9	18.9	34	5.5	0.7	1.1	2.5	1.33	0.02	1	3.8	4.9o	66.67	0.54	SCL

Ex.ac: exchangeable acidity; SB: sum of bases; ECEC: effective cation exchange capacity; BS: base saturation; %C: percent Carbon; Tex-texture.

exchangeable acidity. On the crest, the soil is formed from coarse granitic rock with deep weathering giving rise to kaolinised sub soils. The position on the landscape seems to be stable thus allowing a lot of residual accumulation of weathered materials. On the crest, moderate cementation of pediments characterizes soil formation as evidence in the medium to coarse sub angular block structure in the surface horizons. This was similar to the observation of Folster and Von (1977) that locally restricted and rather moderate cementation of pediments characterizes soil formation in South western Nigeria. The existence of inherited pedological features such as smooth round nodules also suggested multiple stratification of soil parent materials that is, varying pedisediments over saprolite. These coupled with clear wavy boundary, indicates that cycles of erosion must have alternated repeatedly with cycles of pedogenesis. In pedon 2 located at mid slope, the presence of flecks of white mica, saprolite and quartz veins indicate another parent material different from the crest. The characteristics is similar to soils formed from sericite schist described by Smyth and Montgomery (1962).

Soil pedogenetic characterization

On the crest, the soil is formed from coarse granitic rock with deep weathering giving rise to kaolinised sub soils. Quartz vein was very prominent in pedon 2 and it diffuses to the BA horizon which is attributed to its position and elevation, which made accumulation of hill creep materials possible. This quartz gravel was tracea-ble to the prominent quartz veins which diffuses to the transition horizon (AB) and probably colluvial deposits. Soil residuum in the middle slopes is identified by massive and strong structure. Hence various pedogenic processes have contributed to soil development. Fasina et al. (2007) reported similar result where different hydro-lytic and geomorphic processes in various landscape positions cause differences in type and distribution of soil taxi on the landscape.

Pedon 3 at lower slope showed influence of deposition at surface soils with the presence of eluvial (E) horizon. The B horizons consists of argillic horizon formed from eluviation of deposited materials from upper slope and illuvial clay as evident from the underlying saprolitic horizon with coarse mineral nodules (Manganese) which indicate residual formation. Thus, soil profile variation therefore occurs due to landform processes of transfor-mation and deposition. These have led to non-uniformity and discontinuity in parent materials. Therefore the profile seems to be developed from two parent materials: Transported material and the underlying rock (granite gneiss and schist) as indicated from the profile morphology (Table 1). This view was supported by Graham et al. (1990) and Ande (1995) reported that different parent materials are still possible in areas under laid by a single type of rock. They also reported from the study of upper slope soils that the surface horizons may be developed in transported material while the subsurface horizons may be derived from the underlying rock. Pedon 1 on the crest was classified as Typic Hapludult (Haplic Acrisols-Igbajo series) due to its low CEC, increasing clay with depth and low base saturation of < 99%. While Pedon 2 at the mid slope was classified as Dystric Hapludult (Dystric luvisol-Mamu series), and Pedons 3 and 4 at lower and valley bottom were classified as Albic plinthudult (Albic plinthosols-Oba series) and district Haplaquent (Dystric Gleysols-Jago series), respectively.

Conclusion

In conclusion, landscape invariably influences the pedogenetic processes leading to formation of different soil types on the landscape. Pedogenesis was influenced by physiography resulting in different soil types on the landscape. Where similar parent material exists, different soil types were formed due to different exposure to morphogenesis processes such as eluviation, illuviation, deposition, cementation of pedisediments, and multiple stratification as determined by the position of the pedons on the landscape.

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