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ORIGINAL RESEARCH ARTICLE

Evaluation of Physical Characteristics of Soils Derived from Basement Complex Rocks of the Jos Plateau

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ABSTRACT
The physical characteristics of soils to a large extent influences soil productivity. The objective of this study therefore is to evaluate the physical characteristics of soils derived from basement complex rocks of the Jos Plateau. According to the methodology outlined in the Soil Survey manual, the stratification of the study region into three geologic units—granite gneiss, biotite granite, and migmatite—was the first step in the soil research process. Additionally, soil samples were collected from genetic strata and soil profile pits were dug in each of these geologic units. Following standard procedure soils were analyzed for color, particles size distribution, structure, and bulk density. Results indicated that physical soil characteristics over the geologic units studied were in most cases similar. However significant differences were observed in particle size distribution in the A-horizons. Clay content in the A horizon of these soils generally ranged from a minimum of 8% to a maximum of 28%. Clay content in the A-horizons of the magmatic soils were significantly higher ($P < 0.05$) than soils over granite gneiss but statistically similar ($P > 0.05$) to those of biotite granite. Particle size distribution data indicate that the soils have undergone intensive weathering. Soil structures were on the average moderately developed in the soils studied with angular and sub-angular blocky structures. Although there was evidence of soil compaction to suggest plant root development could be affected or inhibited in these soils.

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KEYWORDS
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INTRODUCTION
Soils derived from the basement complex rocks have some unique morphological characteristics. Valley bottom soils in the rain forest of Nigeria were observed to have poorly drained with the soils dominated by sandy-to-sandy loam textures (Fagbami and Ajayi, 1990). In the tropical rain forest region of Nigeria, flood plain soils generated from basement rock were reported to contain dominating soil textures of loamy sand or sandy loam underlain by a range of alluvial or colluvial materials on three slope positions (upper, middle, and bottom) (Elias and Gbadegesin, 2012). Studies on high, middle, and lower slope positions in Nigeria's tropical rain forest region revealed that the soil is typically deep (130–150 cm), with topsoil textures that are gravel-free sandy clay loam (Atofarati, Ewulo and Ojeniyi, 2012). Soils were noted to have a predominant crumb structure in topsoil and angular blocky structure in the sub soil. Certain studies by Fagbami and Shogunle (1995b) in southwestern Nigeria showed that, lower slope soils are very sandy but changes to loam in the deep subsoil whereas middle slope soils had sandy loam topsoil with a clayey subsoil. For the Ondo state area of southwestern Nigeria, Fagbami and Shogunle (1995a) documented that the soils have sandy textures and grayish brown to brown colors with shallow regolith. The fine earth fraction was reported to have high proportion of coarse sand with the upper horizons being very sandy with many quartz and feldspar fragments. Weakly developed mottled clay horizons with hard Fe/Mn concretions

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were noted to occur especially at the breaks of slope. Furthermore, Oyinlola and Chude's (2010) investigation of basement complex rock derived Alfisols in Nigeria's northern savanna region revealed that the soils' textures ranged from sandy loam to loam. Ande (2010) observed that transition horizons are well developed and have combined features of corresponding horizons with diffuse, wavy to irregular boundaries for upland soils in the tropical rain forest of Nigeria. Textures were also observed to vary from Sandy loam to sandy clay loam in the surface horizons. Following a research of basement complex soils in the northern guinea savanna region, Owonubi, Kparmwang, Raji, and Odunze (2007) noticed the presence of Fe and Mn concretions and masses, extra-structural fissures, and termite voids in the soils. It was further noted that highly vigorous reducing conditions could have prevailed during the redox history of the soils at the bottom slope area and to a lesser extent in the higher slope position soils. Enwezor et al. (1990) noted that northwestern Nigeria basement soils are well drained and shallow with surface textures ranging from loamy sand to sandy loam over argillic subsoils which are usually sandy loam to sandy clay loam with evidence of mangiferrous concretions and quartz/feldspathic fragments. The soils were reported to be poorly aggregated in the surface horizons.

Pedogenesis has profound effect on soil physical properties. Atofarati et al. (2012) observed that silt content of soil was generally low with sand fraction being highest in the topsoil while clay content increased with depth for soils on upper, middle and lower slope positions in the tropical rain forest area of Nigeria. After a study of upland topsoils in Bauchi area of Nigeria, Mustapha and Fagam (2007) reported a range of 57.0 - 82.0 (mean: 69.3), 7.0 – 30.0 (mean: 16.3), 8.0 – 26.0 (mean: 14.2) for sand, silt and clay respectively. Oyinlola and Chude's (2010) investigation of basement complex rock-derived Alfisols in Nigeria's northern savanna region found that the soils contained silt and clay in amounts ranging from 200 to 460 g/kg (mean: 357) and 90 to 270 g/kg (mean: 138 g per kg). After studying some basement complex soil in the northern guinea savanna area, Owonubi, *et al.* (2007) noted that fine clay was the major constituent of total clay in the soils with the ratio of fine to total clay being highest in the Bt-horizons. This was noted as evidence of clay eluviation and illuviation processes in the soils in addition to other soil forming processes. Furthere more, Fagbami and Shogunle (1995b) noted for soils in southwestern Nigeria that bulk density increased from medium (1.4 kg/dm^3) to high (>1.5 kg/dm^3) with soil depth. In addition, air capacity was reported to be high (18%) in the topsoil and low (6%) in the subsoil of the middle slope area; and very high (33%) throughout the profile of the lower slope area.

Consequently, for the Jos Plateau not much information exists on soil physical characteristics especially for those derived from basement complex rocks. Therefore, the objective of this study is to assess the physical attributes of soils formed from basement complex rocks found on the Jos Plateau.

MATERIALS AND METHODS

Field Survey

The land systems map of the Jos Plateau at a scale of 1: 250, 000 (Directorate of Overseas surveys, 1977) was used to identify three parent material: granite gneiss, biotite granite and migmatite within the basement complex area of the Jos Plateau. These three parent materials made up the only focus of the study (Figure 1). In each of these geologic units, sampling points were thus distributed at random. On the Jos Plateau, random profile pits were excavated in each geologic unit. Fourteen profiles in all were excavated, documented, and soil samples were taken from genetic horizons. Profile depth ranged from 30 to 200cm depending on the nature of soil. Observations made in each profile included horizon thickness, soil structure, color, and other miscellaneous properties using the Soil Survey Manual (Soil Survey Division Staff, 1993).

Laboratory Analysis and Statistical Analysis

Laboratory air drying, porcelain pestle and mortar crushing, and sieving were caried out to remove particles larger than 2 mm (gravel and other coarse pieces). On a reciprocating shaker, the soil samples were mixed with a 5% solution of calgon (sodium hexametaphosphate).

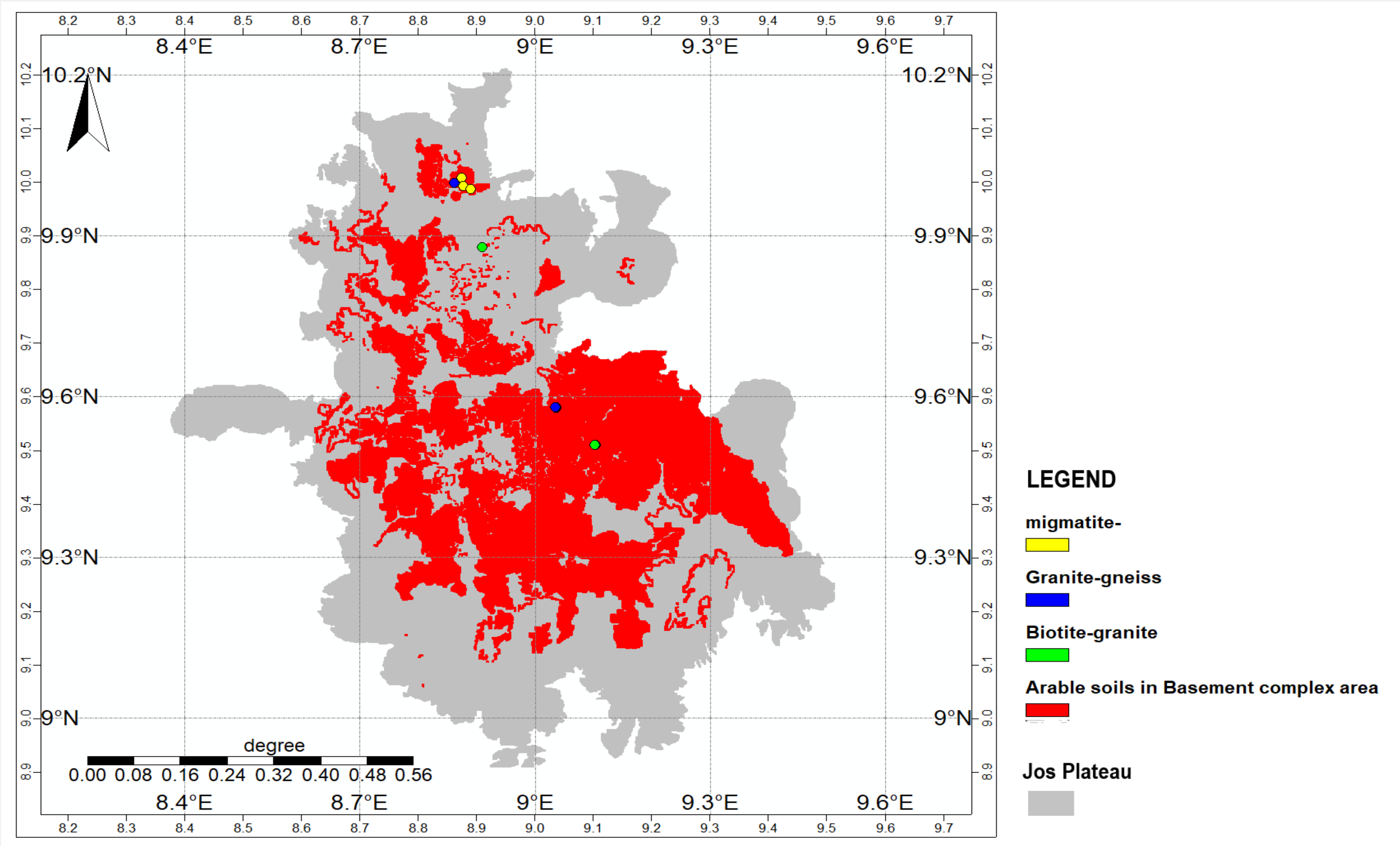

Figure 1: Sampling areas in arable soils of basement complex areas of the Jos Plateau.

To estimate the particle size distribution, the hydrometer method, as described by Gee and Bauder, was utilized (1986). The clod method, as described by Blake and Hartge, was used to determine the bulk density (1986).

Statistical Analysis

Descriptive statistics was performed on soil data with respect to geologic units. The one-way analysis of variance was employed to compare the variation of soil data among geologic units at the 5% probability level.

RESULTS AND DISCUSSION

Soil Morphology

A summary of soil morphological and physical characteristics is presented in and Table 1 to 3. Soil textures over granite gneiss are sandy loam to sandy clay loam and sandy clay to loam in the surface and subsurface soils respectively. Soil derived from biotite granite are mostly sandy clay to loam in texture, whereas the magmatic soil textures are generally sandy loam to sandy clay loam and sandy loam to sandy clay loam. Soil structures were on the average moderately developed in the soils studied. The magmatic soils have angular blocky structures whereas; soils over granite gneiss and biotite granite have sub angular to angular blocky structures. The dominant color in the soils studied is red and yellow and is characteristic of tropical soils as noted by Owonubi (2008). The magmatic soils have a hue of 5YR to 10YR and moderate color saturation. The granite gneiss soils have a hue of 2.5YR to 10YR and moderate color saturation whereas; soils over biotite granite have a hue of 2.5YR to 10YR with low to moderate color saturation. Consequently, there seem to be not much variation in color characteristics among the parent materials. The color traits in these soils mirror those mentioned by Malgwi, Ojanuga, Chude, Kparmwang, and Raji (2000) for several basement complex-derived soils in the northern Guinea savanna of Nigeria.

Particle Size Distribution

In the A horizon, the mean clay contents for soils formed from granite gneiss, biotite granite, and migmatite were 13.80 (± 4.15), 17.50 (± 6.72), and 21.81% (± 2.89), respectively. The magmatic soils had clay contents that were statistically similar to those of biotite granite ($P > 0.05$) but substantially greater ($P > 0.05$) than those over granite gneiss. The distribution of clay over biotite granite and granite gneiss was statistically comparable ($P > 0.05$). Higher clay content in the magmatic soil could be due to greater pedogenic weathering taking place in the soils. The A horizon of these soils typically has clay contents in the range of 8 to 28%. On the other hand, the soils' mean clay concentration frequently fell between a 95% confidence interval of 10.82 to 23.76%.

For soils formed from granite gneiss, biotite granite, and migmatite, the mean clay concentration in the B horizon was 24.67 (± 6.34), 24.00 (± 6.61), and 21.50% (± 7.19) correspondingly. The distribution of clay in the different geologic units was statistically comparable ($P > 0.05$). The B horizon's clay composition typically ranged from a minimum of 10% to a maximum of 40%. Nevertheless, in the B horizon, the 95% confidence interval for the mean varied from 16.93 to 28.70%.

In contrast, the B horizon has a larger clay content than the A horizon. The amount of clay in the A horizons is within the range Owonubi (2008) recorded for several basement complex soils in the Nigerian guinea savanna, but the amount in the B horizons is significantly lower (mean content: 31 to 42%). The B horizons' reduced clay concentration could be attributed to the soils' less severe weathering.

Table 1: Physical and morphological properties of soils over granite gneiss

Landform	Profile	Horizon	Depth	Db	Clay	Silt	Sand	S/C	Texture	Color	Structure
Crest	1	A	0-9	1.93	14	4	82	0.29	SL	10YR 3/4	1FSBK
Upper foot slope	2	A	0-12	1.55	14	10	72	0.71	SL	10YR 5/6	1FSBK
		B	12-30	1.55	22	16	62	0.73	SCL	10YR 4/4	1MSBK
		BC	>30	1.74	24	16	60	0.67	SCL	10YR 4/4	1MSBK
Middle foot slope	3	A1	0-7	1.32	12	22	66	1.83	SL	7.5 YR 4/4	2MSBK
		A2	7-20	1.91	12	18	70	1.50	SL	7.5YR 4/4	2MSBK
		BW1	20-40	1.28	18	20	62	1.11	SL	5YR 4/6	2MABK
		BW2	40-57	1.76	18	22	60	1.22	SL	10YR 5/8	2MABK
		BW3	57-72	1.91	24	16	60	0.67	SCL	1OYR 5/4	2 MABK
		BW4	72-107	1.89	24	18	58	0.75	SCL	-	2MABK
		BC	>107	1.55	20	14	66	0.70	SL	-	2MABK
Middle foot slope	4	Ap1	0-12	1.50	22	20	58	0.91	SCL	5YR 5/6	2MABK
		A2	12-23	1.50	22	12	66	0.55	SCL	5YR 4/3	2MABK
		Bg1	23-45	1.50	40	22	38	0.55	CL	7.5YR 5/8	2MSBK
		Bg2	45-135	1.53	32	14	54	0.44	SCL	10YR 7/4	2MSBK
		Bgc3	135-200	1.54	28	24	48	0.86	SCL	10YR 8/3	2MSBK
Valley	5	Ap	0-39	1.18	14	6	80	0.88	SL	-	-
		B1	39-64	1.95	20	12	68	0.83	SL	-	-
		B2	64-105	1.74	26	16	58	0.67	SCL	-	-

Note: Depth in cm; Db = Bulk density (Mg/m^3); S/C = silt clay ratio; clay, sand and silt are documented in percent
S = SAND; C = CLAY; L = LOAM; 0M = STRUCTURELESS; 1= WEAK; 2 = MEDIUM; 3 = STRONG; VF = VERY FINE; F = FINE; M = MEDIUM; C = COARSE; SBK = SUB-ANGULAR BLOCKY; ABK = ANGULAR BLOCKY; C = CRUMB; CO = COLUMNAR; G = GRANULAR

Table 2: Physical and morphological properties of soils over biotite granite

Land form	Profile	Horizon	Depth	Db	Clay	Silt	Sand	S/C	Texture	Color	Structure
Upper foot slope	6	Ap	0-10	1.57	14	28	58	0.50	SL	10YR 6/4	1FC
		A2	10-30	1.40	20	34	46	0.59	L	10YR 5/6	2FSBK
		Bw1	30-70	1.59	24	34	42	0.71	L	10YR 6/8	2FSBK
		Bw2	70-89	1.70	24	40	36	0.60	L	10YR 6/6	2VFABK
		BC	89-125	1.61	34	24	42	1.42	CL	10YR 4/4	2MFSBK
Middle foot slope	7	Ap	0-15	1.59	10	10	80	1.00	LS	10YR 5/8	1FC
		A2	15-27	1.53	14	12	74	1.17	SL	10YR 5/4	3FABK
		Bw1	27-61	1.56	18	16	66	1.13	SL	10YR 6/4	-
		Bw2	61-90	1.60	24	14	62	1.71	SCL	10YR 4/2	3FCO
		Bw3	>90	1.60	16	18	66	0.89	SL	10YR 7/2	-
Nearly Leveled	8	A1	0-30	1.56	22	26	52	1.18	SCL	7.5YR 5/8	2MABK
		Bw1	30-72	1.53	18	30	52	1.67	L	5YR 3/4	2MABK
		Bw2	72-93	1.56	18	24	58	1.33	SL	5YR 4/6	2MABK
		Bw3	>93	1.56	28	20	52	0.71	SCL	5YR 4/6	2MSBK
Upland Area	9	A1	0-20	1.54	28	16	56	0.57	SCL	2.5YR 3/4	2MSBK
		A2	20-50	1.51	26	16	58	0.62	SCL	2.5YR 4/4	2MABK
		B	50-75	1.54	32	20	48	0.63	SCL	5YR 4/3	2MABK
		CB	75-100	1.56	30	14	56	0.47	SCL	5YR 4/6	1MABK
		C	>100	1.57	34	18	48	0.53	SCL	5YR 4/6	0M
Valley	10	Ap	0-33	1.50	14	14	72	1.00	SL	-	-
		B	33-84	1.59	20	30	66	1.50	L	-	-
		C	84+	1.59	16	18	66	1.13	SL	-	-

Table 3: Physical and morphological properties of soils over migmatite

Land form	Profile	Horizon	Depth	BD	Clay	Silt	Sand	S/C	Texture	Color	Structure
					MIGMATITE						
Upper foot slope	11	Ap	0-7	1.68	22	8	70	0.36	SCL	5YR 3/0	2FG
		Aw	7-38	1.54	24	4	72	0.17	SCL	10YR 6/2	2CABK
		B1	38-65	1.62	20	8	72	0.40	SCL	2.5YR 4/2	2FABK
		Bt2	65-81	1.93	24	14	62	0.58	SCL	2.5YR 4/2	2FABK
Lower foot slope	12	Aw1	0-21	1.49	22	12	66	0.55	SCL	2.5YR 3/0	2MSBK
		Bt1	21-57	1.90	22	12	66	0.55	SCL	2.5YR 4/0	2FABK
		Bt2	57-73	1.89	28	10	62	0.36	SCL	2.5YR 5/0	2FABK
Alluvial terrace	13	Ap1	0-17	1.57	14	32	54	2.29	SL	5YR 4/3	2MABK
		A2	17-34	1.62	20	22	58	1.10	SL	5YR 4/3	2MSBK
		Bwt1	34-55	1.68	28	26	46	0.93	SCL	7.5YR 4/4	2MABK
		Bwt2	55-82	1.71	18	10	62	0.56	SL	10YR 3/4	2MABK
		BC	82-105	1.77	16	22	62	1.38	SL	10YR 3/4	2MABK
		C1	105-130	1.81	12	14	74	1.17	SL	2.5YR 3/2	0M
		C2	130-200	1.73	10	14	76	1.40	SL	2.5YR 3/2	0M
Upland Terrace	14	A1	0-20	1.51	24	20	56	0.83	SCL	-	-
		A2	20-45	1.47	22	18	40	0.82	SCL	-	-
		Bgw1	45-90	1.59	34	20	46	0.59	SCL	-	-
		Bg2	90-125	1.74	28	48	24	1.71	CL	-	-
		BC	125-160	1.67	18	14	68	0.78	SL	-	-

Silt-clay ratios and Bulk Density

The degree of pedogenic weathering in soils has been studied using silt to clay ratios (Lal, 1980; Sombroek and Zonneveld, 1971).Silt-clay ranging between 0.00 and 1.50 in the B horizons suggest moderate to intensive pedogenic processes in these soils. Bulk density values were similar to those cited by Owonubi (2008) as typical of tropical soils, ranging from 1.36 to 1.93 Mg/m3 with a mean of 1.67 Mg/m3. However, using the bulk density classifications provided by the Soil Science Division Staff (2017), a comparison of the bulk density values, and soil texture indicates that soil compaction ranges from medium to high and would most likely affect the development of plant roots except if appropriate management practices are employed. The level of compaction observed in these soils cold be due to low level of soil organic matter in the soils (Brady and Weil, 1999).

CONCLUSION

Stratification of the basement complex into geologic units of granite gneiss, biotite granite and migmatite did not show any significant variation in soil physical properties. However, Soil textures over granite gneiss are sandy loam to sandy clay loam and sandy clay to loam in the surface and subsurface soils respectively. For the A-horizons, Clay content in the magmatic soils were significantly higher than soils over granite gneiss but statistically similar to those of biotite granite. The distribution of clay over biotite granite and granite gneiss was statistically comparable. However, the statistical distribution of clay concentration in the B-horizons among the different geologic units was identical. Silt to clay ratios indicate moderate to intensive pedogenic processes in these soils. The dominant color in the soils studied is red and yellow and is characteristic of tropical soils. Soil structures were on the average moderately developed in the soils studied with angular and sub-angular blocky structures. Although bulk density values suggest plant root development could be affect or inhibited in these soils.

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