Horizon Differences in Selected Physical Properties of Soils formed Over Dissimilar Lithologies in South-EasternNigeria

Onweremadu, E.U[1].,Ahukaemere, C.M[1]., and Orji, O.A[2]
1 Department of Soil Science and Technology, Federal University of Technology, Owerri
P.M.B.1526,Owerri,ImoState,Nigeria
uzomaonweremadu@yahoo.com.
2 Department of Crop and Soil Science, Rivers State University of Science and Technology, Port Harcourt, Rivers State.

Abstract
Horizon differences in soils influence ability of crops to obtain nutrients and indeed support other uses. The study aimed at investigating physical properties of horizons from soils of Southeastern Nigeria formed over three parent materials. Random survey technique guided by the geologic map of the area was used in locating profile pits. Soil profile pits were dug, described and sampled using FAO guidelines. There were differences in soil colour among horizons of soil profiles of similar as well as dissimilar origin. Soils were deep irrespective of origin but soils derived from clay shale showed greater grayish colouration. Soils from false bedded sandstones were more sandy than soils derived from other parent materials with a mean value of 865 g/kg at 0-18 cm depth. Highest silt and clay contents were recorded in soils formed over clay shale at 0-18 cm depth. Bulk density values ranged from 1.22 mg/m^3 (clay shale), 1.40 mg/m^3 (false bedded sandstone) to 1.41 mg/m^3 (granite) at 0-18 cm. Values of available water capacity were 85. 6 g/kg (clay shale), 50 g/kg (granite) and 38 g/kg (false bedded sandstone). Soil physical properties varied due to horizons and parent materials. It is therefore recommended that agronomic requirements should consider these edaphic attributes in the study area.

Keywords: Epipedon, Endopedon, Horizon, Parent material, Soil group.

1.0 Introduction

Soil vary in time, space and depth (Brady and Weil, 2005). A vertical slice through the pedosphere shows varying degree of changes taking place at both the epipedons and endopedons. These changes influence the utilization of these soils for agronomic, engineering, sanitary and aesthetic uses. Shallow rooted crops may explore their nutrients from the epipedons (0-15, 0-20) depths while tree crops go deeper into the endopedons in search of soil nutrients. However, these attributes differ in response to the variation in lithological materials and rate of pedogenesis. Resultantly, some soils become shallow and restrict the rooting habits of crops while thicker ones support extensive and deeper crop rooting habits (Okoye, 2014). Some of the soils are so deep that clay accumulate; forming argillic horizons with high potentials of shrinking and swelling (Idoga *et al*., 2007). Based on the above, it became necessary to investigate physical properties of soils formed over three parent materials in Southeastern Nigeria. This is very important as this region is known to be under threat given varying forms of land degradation. Consequent upon this, the major objective of this study was to investigate horizon changes in selected physical properties of soils of varying origin.

2.0 Materials and Method

2.1 Study Area

Soil samples from soil profiles were collected from Lekwesi, Okigwe, and Ajata, and these soils were formed from granite, false bedded sandstones and clay shales, respectively. The area covered over 200 km square and is located in Imo and Abia States of South-EasternNigeria. The area is associated with plains and hilly terrains and lies within the humid tropics, with annual rainfall ranging from 1,800 to 2,200 mm and mean annual temperature range of 26 to 31 ^{o}C. It has a rainforest vegetation characterized with a variety of plant species. Low technology agriculture is common, and farmers concentrate their activities on arable form of farming and small ruminant animals. Land preparation is by slashing, followed by burning and packing un-burnt debris. Short duration fallowing has resulted to occasional use of inorganic fertilizers in the area.

2.2 Field Studies

Three parent materials namely granite, sandstone and clay shale were identified using geologic map of the study area following a reconnaissance visit. Theses parent materials were located at Lekwesi (granite), Okigwe (false bedded sandstone) and Ajata Umuahia (clay shale). Five (5) soil profile pits were sunk on soils derived from each parent material and designated A, B, C, D and E. In each soil profile, horizons were identified as A, AB, Bt1, and Bt2. Soil samples were collected based on these horizons. Core samplers of the same diameter (7.5 cm) were used to collect samples for bulk density determination. Depths of horizons were averaged of ranges observed on each horizon thickness of soil profiles dug in the field, thus A-horizons ranged from 0-18 cm and so on. Depth of soil profile was measured using roller tape. Soil colour was determined using Munsel colour chart under moist conditions.

2.3 Laboratory Analyses

Particle size analysis was determined using hydrometer method (Gee & Or, 2002). Bulk density values of soils were measured by core method (Grossman & Reinsch, 2002). Available water capacity at field capacity was determined by the method of Soil Survey Staff (2003).

3.0 Results and Discussion

Soil colour and horizon thickness are shown in Table 1. Soils were deep to very deep, ranging from 0 to 185 cm. Variability in depths and thickness of horizons could be attributed to differences in parent materials and rate of pedogenesis among soils. However, Idoga *et al.,* (2007) attributed variation in soil depth to effect of parent material, soil erosion and slope of an area. Soil colour ranged from dark brown, brown, dark grayish brown, grayish brown, gray to red. Soils formed over granite indicated dark brown, dark gray, dark grayish brown to brown colouration at epipedons while epipedons derived from false bedded sandstone were dominated by brown colour with value and chroma ranging from 4/2, 4/4/ 5/4 and 5/3 under moist soil moisture status. At surface horizons, soils formed over clay shale showed a hue of 10 YR and ranged from very dark brown (10 YR 2/2) moist, very dark gray (10 YR 3/1) moist, very dark grayish brown (10 YR3/2) moist to dark gray (10 YR 4/1) moist. There were differences in colouration of AB horizons in these soils of varying lithologic materials. Soils formed over granite varied from dark yellowish brown (10YR 3/4) moist, dark grayish brown (10 YR 4/2) moist, 10 YR 4/6 moist to yellowish brown (10 YR 5/4) moist, 10 YR 5/6 moist. These variations in soil colour despite similarity in parent material could be attributed to differences in soil moisture content and drainage conditions. Earlier, Ibanga (2006) observed that soil colour changes due to differences in soil water content. Similarly, soils formed over false bedded sandstone were dominated by a hue of 5 YR and ranged from reddish brown (5 YR 4/3 moist, 5 YR 5/6 moist) to yellowish red (5 YR 5/4 moist, 5 YR 5/6 moist). The hue of soils formed over clay shale was 7.5 YR with differences in value and chroma as follows: gray (7.5 YR 5/1 moist) and gray (7.5 YR 6/1 moist).

Table 1: Soil Colour Changes in Horizons of Soils Under Moist Conditions

Parent Material	A	B	C	D	E
A – Horizon (0 – 18 cm thick)					
Granite	$10YR^{4}/_{3}$	$10YR^{3}/_{3}$	$10YR^{4}/_{2}$	$10YR^{4}/_{1}$	$10YR^{4}/_{3}$
Sandstone	$7.5YR^{4}/_{2}$	$10YR^{4}/_{4}$	$7.5YR^{5}/_{4}$	$10YR^{5}/_{4}$	$10YR^{5}/_{3}$
Clay Shale	$10YR^{2}/_{2}$	$10YR^{3}/_{1}$	$10YR^{3}/_{2}$	$10YR^{3}/_{1}$	$10YR^{4}/_{1}$
AB-Horizon 18 – 32 cm thick					
Granite	$10YR^{5}/_{4}$	$10YR^{3/4}$	$7.5YR^{5}/_{6}$	$10YR^{4}/_{6}$	$10YR^{4}/_{2}$
Sandstone	$5YR^{4}/_{3}$	$5YR^{5}/_{4}$	$5YR^{4}/_{4}$	$5YR^{4}/_{3}$	$5YR^{5}/_{6}$
Clay Shale	$7.5YR^{5}/_{1}$	$7.5YR^{6}/_{1}$	$10YR^{6}/_{1}$	$7.5YR^{5}/_{1}$	$10YR^{5}/_{1}$
Bt1 $^{6}/_{6}$ – Horizon 32 – 120 cm thick					
Granite	$5YR^{6}/_{6}$	$5YR^{5}/_{8}$	$2.5YR^{5}/_{6}$	$2.5YR^{4}/_{6}$	$2.5YR^{4}/_{8}$
Sandstone	$2.5YR^{4}/_{4}$	$2.5YR^{5}/_{8}$	$2.5YR^{4}/_{8}$	$2.5YR^{7}/_{6}$	$2.5YR^{4}/_{8}$
Clay Shale	$7.5YR^{6}/_{1}$	$7.5YR^{5}/_{1}$	$7.5YR^{7}/_{1}$	$2.5YR^{5}/_{2}$	$2.5YR^{6}/_{1}$
Bt2 – Horizon 120 – 185 cm thick					
Granite	$2.5YR^{5}/_{6}$	$5YR^{4}/_{6}$	$2.5YR^{5}/_{8}$	$2.5YR^{4}/_{8}$	$2.5YR^{6}/_{8}$
Sandstone	$10YR^{4}/_{6}$	$10YR^{4}/_{8}$	$10YR^{5}/_{6}$	$7.5YR^{5}/_{6}$	$7.5YR^{4}/_{8}$
Clay stone	$2.5YR^{5}/_{1}$	$2.5YR^{6}/_{1}$	$5YR^{6}/_{1}$	$5YR^{5}/_{1}$	$5YR^{4}/_{2}$

In Bt1 horizons, soils formed over granite had hues of 5 YR and 2.5 YR as values and chromas varied. Soil colours ranged from yellowish red (5 YR 5/8) moist and reddish yellow (5 YR 6/6) moist to red (2.5 YR 5/6 moist, 2.5 YR 4/6 moist; 2.5 YR 4/8 moist). Also, soils derived from false bedded sandstone exhibited a hue of 2.5 YR in all soil profiles with values and chromas varying. Values and chromas varied as colours changed from reddish brown (2.5 YR 4/4) moist, red (2.5 YR 4/8) moist, 2.5 YR 3/8 moist and light red (2.5 YR 7/6) moist. Soils formed over clay shale had hues of 2.5 and 7.5 YR. These colours were weak red (2.5 YR 5/2) moist, reddish gray (2.5 YR 6/1) moist, gray (7.5 YR 6/1 moist; 7.5 YR 5/1 moist) and light gray (7.5 YR 7/1) moist. Oxidation state and type of particle size fraction influenced colouration of soils. Soils developed on granite were dominated by hue of 2.5 YR in Bt2 horizons, with colours ranging from (2.5 YR 4/8 moist, 2.5 YR 4/3 moist, 2.5 YR 5/6 moist, 2.5 YR 5/8 moist). However, at this horizon, a soil profile had a hue of 5 YR (red 5 YR 4/6 moist). Redder colours were encountered in soil profiles formed over false bedded sandstone at Bt2 horizons (120-185 cm). Soil colours varied from red (10 YR 4/6 moist, 10 YR 4/8 moist; 10 YR 5/6 moist) and red (7.5 YR 4/8 moist, 7.5 YR 5/6 moist). On the other hand, soils derived from clay shale exhibited hues of 2.5 Y and 5 Y indicating high reduction of soils which could suggest closeness to high moisture condition. Generally, soils were gray (2.5 YR 5/1 moist, 2.5 YR 6/1 moist, 5 Y 5/1 moist, 5 Y 6/1 moist) to olive gray (5 Y 4/2 moist).

Table 2 shows variation in the sand-sized fractions among soil profiles and horizons of soil profiles. Generally, soils formed over false bedded sandstone had highest values of sand ranging from 800-900 g/kg, followed by soils formed over granite (650 – 670 g/kg) and clay shale (500-670 g/kg). Highest mean value of sand was reported in AB-horizon (894 g/kg) of the false bedded sandstone (Table 2). This suggests greater translocation of other sized particles to deeper horizons. Mean deviation indicated that sand-sized distribution varied greatly in soils formed over false bedded sandstone (mean deviation = 26.00), followed by clayshale (mean deviation = 20.00) and least in soils formed over granite (mean deviation = 4.20) in A-horizon of soils. However, with depth, soils developed over clay shale exhibited greater dispersion with mean deviation ranging from 25.6 to 38.4 (Table 2). These results showed that changes occur even among soils derived from similar lithologic materials. Although, soil texture is regarded as an inherent property of soils (Brady and Weil, 2005), anisotropy of sand-sized and clay particles as seen in Tables 2 and 4, respectively suggest obvious activity in soil texture. Sand-sized particles dominated in all soil group indicating the contribution of parent materials to the nature of these soils.

Table 2: Changes in Sand Content in Horizons of Soils (g/kg)

Parent Material	A	B	C	D	E	Mean	Mean Derivation
Granite	790	800	795	805	795	797	4.2
Sandstone	880	870	885	890	800	865	26.0
Clay shale	670	600	620	610	590	610	20.0
			AB – Horizon (18 – 32 cm)				
Granite	800	803	805	810	806	805	2.6
Sandstone	900	903	895	890	880	894	6.8
Clay shale	600	590	620	550	560	572	38.4
			Bt1 – Horizon (32 – 120 cm)				
Granite	650	670	700	710	700	686	20.8
Sandstone	810	805	806	808	804	807	2.0
Clay shale	500	585	595	550	500	546	36.8
			Bt2 – Horizon (32 – 120 cm)				
Granite	740	750	745	748	740	745	3.6
Sandstone	820	815	805	800	802	808	7.2
Clay shale	570	550	540	500	500	532	25.6

Silt sized particles differed among soil profiles, horizons and soil groups. Silt content had its lowest limit as 100 g/kg in AB-horizon and upper limit of 225 g/kg in Bt-horizon in soils derived from granite. Similarly, soils derived from false bedded sandstone ranged from 20 g/kg (Bt-horizon) to 80 g/kg in A-horizon. In soils formed over clay shale, silt content ranged from 175 g/kg (A-horizon) to 225 g/kg (AB-horizon). However, mean deviation of silt was highest in soils derived from granite and this measure of dispersion was in the epipedons (A-horizon). This was followed by soils derived over clay shale (mean deviation = 14.8). But the highest value of mean deviation of silt was observed in soils derived from clay shale (mean deviation = 40.00) at Bt2-horizon (120-185 cm depth). Generally, mean values of silt varied from 106-217 g/kg (granite), 23 – 51 g/kg (false bedded sandstone) and 152 – 215 g/kg (clay shale). Silt content did not follow any trend in its distribution as in sand-sized particles.

Table 3: Changes in Silt Content in Horizons of Soils (g/kg)

Parent material	A	B	C	D	E	Mean	Mean Deviation
			A – horizon (10 – 18 cm)				
Granite	120	180	190	170	160	164	19.2
Sand stone	40	80	60	50	30	52	14.4
Clay shale	205	220	180	175	190	194	14.8
			AB – horizon (18 – 32 cm)				
Granite	100	102	110	120	100	106	6.8
Sandstone	45	40	70	60	40	51	11.2
Clay shale	200	225	220	220	210	215	8.0
			Bt1 – Horizon (32 – 120 cm)				
Granite	210	210	220	220	225	217	5.6
Sandstone	45	45	40	30	30	38	6.4
Shale	202	205	200	210	200	203	3.2
			Bt2 – Horizon (120 – 185 cm)				
Granite	200	190	190	205	205	193	7.6
Sandstone	30	25	10	20	20	23	3.6
Shale	190	180	200	200	190	152	40.0

Clay content of soils indicated variations in space (Table 4) among soil profiles, parent materials and in depth. Irrespective of parent material, clay-sized particles formed a district bulge down the soil profile. Soils derived from granite had this distribution: 38.0 g/kg (A-horizon), 89.0 g/kg (AB-horizon), 97 g/kg (Bt1-horizon) and 62 g/kg (Bt2-horizon). Mean values of clay in soils derived from false bedded sandstone showed 63.0 g/kg (A-horizon), 56.0 g/kg (AB-horizon), 155.0 g/kg (Bt1-horizon) and133.0 g/kg (Bt_2-horizon). Similarly, clay content was distributed as follows: 196.0 g/kg (A-horizon), 213.0 g/kg (AB-horizon), 261.0 g/kg (Bt1-horizon) and 276.0 g/kg (Bt2-horizon). However, soils formed over clay shale indicated confined increase in clay content with depth (Table 4). Soils formed over clay shale had highest mean value of clay as seen in Table 4, suggesting that weathering of clay shales releases an abundance of clay sized particles, Clearer argillation was observed in Bt1horizon in soils derived from false bedded sandstone since clay in that horizon (155 g/kg) was 2.72 times greater than that found in AB-horizon (56.0 g/kg).Values of clay in Bt1 clearly supersedes those of AB-horizon since the latter lies within the zone of eluviation (Okoye, 2014). The difference in particle size distributions as seen reflect the difference in the composition of parent materials studied (lrmak, et al 2007; Oguike & Mbagwu, 2009). Table 5 shows value of bulk density in the studied soils. bulk density had minimal mean deviations when compared with other measured physical properties. However, highest mean deviation of bulk density was recorded in soils derived from clay shale at Bt1-horizon, (mean deviation = 0.034) while the least mean deviation of 0.014 was found in the same soil group, implying greater instability in soils formed over clay shale when compared to other two soil groups. In all soil profiles, bulk density increased with depth, and this is consistent with the findings of Ahukaemere (2015) in soils of the area.

Table 4: Changes in Clay Content in Horizons of Soils (g/kg)

Parent Material	A	B	C	D	E	Mean	Mean Deviation
				A – horizon (0 – 18 cm)			
Granite	90	20	15	25	42	38.0	22.0
Sandstone	80	50	55	60	70	63.0	11.6
Clay Shale	125	180	200	215	260	196.0	34.8
				AB – Horizon (18 – 32 cm)			
Granite	100	95	85	70	94	89.0	9.0
Sandstone	60	57	35	50	80	56.0	11.2
Clay Shale	200	185	160	230	290	213.0	37.6
				Bt1 – Horizon (32 – 120 cm)			
Granite	140	120	80	70	75	97	26.4
Sandstone	145	150	154	162	166	155	6.8
Clay Shale	298	210	260	240	296	261	29.0
				Bt2 – Horizon (120 – 185 cm)			
Granite	60	60	65	47	80	62	8.0
Sandstone	150	160	175	180	178	133	35.6
Clay Shale	240	270	260	300	310	276	23.2

Available water capacity (g/kg) generally increased with depth (Table 6). This could be a response to increase in clay content with depth in the three soil groups. Generally, soil derived from clay shale had more available water capacity ranging from 85.6 to 95.0 g/kg (mean value). This was followed by soils derived from granite (50.0 – 64.8 g/kg) while soils formed over false bedded sandstone had 38 g/kg as its lower limit and 72.6 g/kg as its upper limit. Among soil profiles, those under clay shale dispersed more than other soil groups especially at surface horizons. These mean deviations reduced with depth, suggesting more stability in the values of available water capacity with depth. Land use practices may have influenced variability in epipedons while pedogenesis could be responsible for changes in Bt horizons.

Table 5: Changes in Bulk Density among Horizons of Soils (Mg/m^3)

Parent Material	A	B	C	D	E	Mean	Mean Deviation
			A – horizon (0 – 18 cm)				
Granite	1.42	1.45	1.40	1.38	1.41	1.41	0.018
Sandstone	1.39	1.42	1.40	1.36	1.43	1.40	0.020
Clay Shale	1.23	1.19	1.21	1.25	1.22	1.22	0.016
			AB – Horizon (18 – 32 cm)				
Granite	1.46	1.46	1.42	1.40	1.47	1.44	0.026
Sandstone	1.43	1.45	1.46	1.42	1.48	1.45	0.018
Clay Shale	1.29	1.24	1.20	1.33	1.26	1.28	0.028
			Bt_1 – Horizon (32 – 120 cm)				
Granite	1.49	1.51	1.48	1.46	1.55	1.50	0.028
Sandstone	1.46	1.49	1.50	1.53	1.53	1.50	0.022
Clay Shale	1.35	1.29	1.38	1.38	1.31	1.34	0.34
			Bt_2 – Horizon (120 – 185 cm)				
Granite	1.61	1.63	1.58	1.56	1.65	1.61	0.026
Sandstone	1.53	1.61	1.61	1.61	1.60	1.60	0.020
Clay Shale	1.48	1.46	1.49	1.44	1.47	1.47	0.014

Table 6: Available Water Capacity of Horizons of Soils (g/kg)

Parent Material	A	B	C	D	E	Mean	Mean Deviation
			A – horizon (0 – 18 cm)				
Granite	51	49	50	47	53	50.0	1.6
Sandstone	38	36	40	37	39	38.0	1.2
Clay Shale	79	82	88	89	90	85.6	4.1
			AB – Horizon (18 – 32 cm)				
Granite	53	50	51	49	55	51.6	1.9
Sandstone	41	42	45	47	42	43.4	2.2
Clay Shale	88	83	81	91	92	87.0	4.0
			Bt_1 – Horizon (32 – 120 cm)				
Granite	60	61	63	59	65	61.6	1.9
Sandstone	50	58	56	57	56	57.4	1.8
Clay Shale	96	90	92	95	95	93.6	1.8
			Bt_2 – Horizon (120 – 185 cm)				
Granite	65	66	65	64	64	64.8	1.0
Sandstone	70	71	73	75	74	72.6	1.7
Clay Shale	92	95	93	97	98	95.0	2.0

From the results, soil horizons exhibited varying trends in terms of colour, particle size fraction, bulk density and available moisture status. However, the endopedons had higher available moisture, clay contents and bulk density values than the epipedons.

References

Ahukaemere, C.M. (2015). Sequestration and dynamics of carbon and nitrogen in soils of dissimilar lithologies under different land use types in southeastern Nigeria. A Ph.D thesis of Department of soil science and Technology, Federal University of Technology, Owerri Nigeria.

Brady, N.C. & Weil, R.C. (2005). *The nature and properties of soils.* 13th ed., Pearson Prentice Hall

Gee G.W & Or, D. (2002). Particle size distribution In: Dane, J.H. and Topp, G.C. (eds). Methods of Soil analysis, part 4. Physical methods.Soil Science Society of American Book Series No. 5 ASA and SSSA, Madson, WI, 255 – 293.

Grossman, R.B & Reinch, T.G. (2002). Bulk density and linear extensibility in: methods of soil analysis part 4. Physical methods. Dane, J.H and G.C. Topp (eds). Soil Science Soc. Am. Book series No. 5. ASA and SSA Madison, W.I, 201-228.

Ibanga, I.J. (2006). Soil Studies: The pedological approach maesot printing and Computers, Calabar:

Idoga, S., Ibanga, I.J & Malgwi, N.B. (2007). Variation in soil morphological and physical properties and their management implication on a toposequence in Samam area, Nigeria. In: E.O., Uyovbisere, B.A., Raji, Yusuf, A.A., Ogunwale, J.O., Aliyu, L. & Ojeniyi, S.O. (eds). *Soil and Water Management for poverty alleviation and sustainable environment. Proc. of the* 31st Ann. Conf.of the Soil Science Society of Nigeria held at Ahmadu Bello Univ. Zaria, Nigeria, Nov. 13 – 17, 2006, 19 – 26.

Irmak, S, Surueu, A.K & Aydogdu, L.H. (2007). Effects of different parent material on the mineral characteristics of soils in the Arid Region of Turkey. *Pakistan J. of Biological Sciences* 10(4):528-536.

Oguike, P.C & Mbagwu, J.S.C. (2009). Variations in some physical properties and organic matter content of soils of coastal plain sand under different land use types. *World journal of agricultural sciences* 5(1), 63-69.

Okoye, E.O.U. (2014). Soil survey and crop production tit bits. Nigeria. Madol Press Ltd, 142.

Soil Survey Staff (2003). Keys to soil taxonomy. 9th ed. United State Department of Agriculture.