ISSN: 2006-1110 *http://www.irdionline.com/duncan_article.html*

Journal of Environmental Research and Policies, Volume 8, Number 3, 2013

OCCURRENCE AND DISTRIBUTION OF PEDOGENIC HORIZONS IN SOILS OF AKWA IBOM STATE, NIGERIA

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ABSTRACT

This study was to investigate the occurrence and distribution of pedogenic horizons that developed from parent materials in Akwa Ibom State. Based on the geological formation and the geomorphic units, the state was divided into four major parent materials: Sandstone /shale, coastal plain sand, quaternary fluvio-marine beach ridge sand and recent alluvial parent materials. In each parent material, three profile pits were sunk at representative location. A total of 12 profile pits were sited and were described in accordance with FAO (2006) guidelines for soil profile description. The study showed that Ochric epipedon is the dominant diagnostic surface horizon in soils of Akwa Ibom State. In the sub-surface horizon, argillic and/ or kandic horizon is dominant in soils developed from sandstone /shale and coastal plain sand parent materials. Cambic horizon is dominant in soil developed from recent alluvial parent material and as well as some parts of quaternary beach ridge sands with weakly developed B-horizon. Ultisols, Inceptisols and Entisols are the dominant soil order of USDA soil classification system in the state. This correlated with Acrisols, Cambisols, Gleysols, Fluvisols and Arenosols of FAO/ WRB. Vertisols are also present but in restricted areas.

Keywords: Diagnostic horizon, Akwa Ibom State soils, Pedogenic horizon, B-horizon

INTRODUCTION

Soil formation consists of two overlapping steps, parent material formation from parent rock through weathering processes and the differentiation of the parent material into horizons by additions, removals, translocations and transformations processes (pedogenic processes) (Asadu *et al*., 2012). Soil forming factors (climate, organisms, topography, parent material and time) and soil forming processes (additions, removals, translocations and transformations) combine to affect the overall soil body, which is recognized and described as pedon with different genetic horizons (Ibanga, 2006.).

The resulting soil horizon properties such as thickness of the horizon, colour, texture, structure, chemical properties of the horizons are used in soil classification by different classification systems. In USDA classification system, diagnostic horizons are used in assigning soil to soil order category (Soil Survey Staff, 2008). In World Reference based, soil classification is based on soil properties defined in term of diagnostic horizons (WRB, 2014).

Also properties of pedogenic horizons in combination with other land attributes (site characteristics) and economic considerations are used in soil survey interpretation (land evaluation). For instance, in land suitability evaluation system, properties of soil horizons are matched with agronomic requirements of crop to determine the suitability of the soil for that particular crop (Dent and Young, 1981). Soil horizon properties are also used to monitored soil degradation and resilience due to land use changes. Therefore, proper understanding of the occurrence and distribution of pedogenic horizons in soil of an area will help in soil classification, land evaluation, soil quality assessment, environmental monitoring and land use changes.

Akwa Ibom State is underlain by a simple pattern of sedimentary geological formation. Over 70 % of the state is on tertiary coastal plain sands. The tertiary coastal plain sands is divided into two: the older coastal plain sands (older Benin formation) (sandstone) (Oligocene – Pleistocene) occupying the northern parts of the state and the younger coastal plain sands (coastal plain sand) occupying central flat-lying portion of the state. About 20 % of the state is underlain by Quaternary fluvio-marine beach ridge sands and mangrove mudflat occupying the coastal and estuaries areas of the state. Recent alluvial deposits occur along the banks and floodplains of Imo, Kwa Iboe and Cross Rivers that drained the state. Late cretaccous and early eocene shale occur in Ini and parts of Itu Local Government Areas of the state (Petters *et al*., 1989; Usoro and Akpan 2010).

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These constitute the parent materials which give rise to soils in Akwa Ibom State. Therefore, the objective of this study was to investigate the occurrence and distribution of pedogenic horizons that developed from these parent materials in the state.

MATERIALS AND METHODS

Description of the Study Area

Akwa Ibom State is located in the South-South Nigeria within latitudes $4^0 30^|$ and $5^0 30^|$N and longitudes $7^0 30^|$ and $8^0 20^|$ E. The State is underlain mainly by younger coastal plain sands, beach ridge sands, sandstone (older coastal plain sands) / shale and alluvial deposits parent materials (Petters *et al*., 1989). Physiographically, the landscape can be divided into six sub-geomorphic units: the Atlantic Ocean shoreline and beach, mangrove swamps and floodplain with recent alluvial sediments, level to gently undulating sandy plains, sandstone hills, ridges and steep sided valleys and Obotme upland area. No portion of the state exceeds 175m above sea level. The climate is humid tropical with annual rainfall of about 2500 mm with 1-3 dry months in the year. Mean annual temperature varies between 27-28^{0}C with relative humidity of 75-80 % (Petters *et al*., 1989; Usoro and Akpan 2010).

Field Sampling

Based on the geological formation and the geomorphic units, the state was divided into four major parent materials or sub- units. The major parent materials or sub-units were: sandstone / shale parent material or northern sub-unit with undulating, ridges and steep sided valleys; coastal plain sand parent material with level to gently undulating topography or central sub-units; quaternary fluvio-marine beach ridge sands or southern sub-unit with nearly level topography; recent alluvial parent material along the banks and river floodplains. In each parent material, three profile pits were sunk at representative location. A total of 12 profile pits were sited and were described in accordance with FAO (1990) guidelines for soil profile description. The arrangements of pedogenic horizons were giving special attention. Soil samples were collected based on genetic horizons for laboratory analysis.

Laboratory Analysis

The samples were air dried before grinding and sieved with a 2 mm sized sieve. The samples were analyzed in accordance with standard laboratory procedures for the following parameters: **Particle size distribution** was determined by the hydrometer method as described by Gee and Bauder (1986).**Organic carbon** was determined by the dichromate wet-oxidation method as described by Nelson and Sommers (1996). **Cation exchange capacity** was determined by method described by Sumner and Miller (1996).

RESULTS AND DISCUSSION

1. Occurrence and distribution of pedogenic horizons in soils developed from sandstone/ shale parent material

The properties of pedogenic horizons of soils developed from sandstone /shale parent material are shown in Tables 1, 2 and 3. The soil colour of the surface horizon varies from dark brown (7.5YR 3/2, 7.5YR 3/4) to dark reddish brown (5YR 3/4). The Ap horizon has low color values but is too thin to be recognized as a mollic or umbric epipedon. The soil structure is mostly granular with abrupt smooth to gradual smooth boundaries. The soil texture varies from loamy sand to sandy loam. The clay content of the surface horizon is less than 15 %. The organic carbon varied from 0.6 to 1.7 % indicating low to high. The cation exchange capacity (CEC) varied from 9.0 to 17.3 cmol/kg indicating low to moderate. These soil properties justify considering the horizon as the ochric epipedon of USDA classification system (Soil Survey Staff, 2008). In the B-horizon, the colour varies from strong brown (7.5YR 4/6), light reddish brown (5YR 6/4), yellowish red (5YR 4/6) and reddish yellow (7.5YR 6/6, 7.5YR 6/8). The texture varies from sandy loam, sandy clay loam to sandy clay. The clay content of the underlying horizon is more than 3 % higher than the clay content of the overlying horizon.The soil structure varies from sub- angular blocky to angular blocky structure. No lithologic discontinuity between the overlying horizon and the underlying horizon, indicating that they are formed from uniform parent material (no stratification). Organic carbon varied from 0.3 to 0.9 % indicating very low organic carbon in the underlying horizon compare to the overlying horizon. Organic carbon decreases with depth. The CEC varied from 8.0 to 12.3cmol/kg, indicating low CEC. The low CEC in the B-horizon is an indication that clay type is a low activity, 1:1 type of clay mineral (kaolinite) in highly leached (due to high rainfall) acidic soil (Ibanga, 2006).

The yellowish brown colour could be attributed geoethite. These soil properties justify considering the horizon as the kandic and/ or argillic subsurface horizon of USDA classification system (Soil Survey Staff, 2008) or argic horizon of World Reference Base (WRB, 2014).

2. Occurrence and distribution of pedogenic horizons in soils developed from coastal plain sand parent material

The properties of pedogenic horizons of soils developed from coastal plain sand parent material are shown in Tables 4, 5 and 6. The soil colour of the surface horizon is dark brown (7.5YR 3/2, 7.5YR 3/3, and 7.5YR 4/4). The epipedons have either a Munsell color value of 4 or more, (moist) or Ap horizon that has both low color values and low chroma but is too thin to be recognized as a mollic or umbric epipedon. The soil structure varies from weak fine granular to weak medium granular structure. The soil texture varies from sand to sandy loam. The surface texture of coastal plain sand has more percentage sand than the sandstone. Organic carbon varied from 1.5 to 2.2 %, indicating high organic carbon. CEC varied from 10.0 to 17.3 cmol/kg, indicating low to moderate. These soil properties also justify considering the horizon as the ochric epipedon of USDA classification system (Soil Survey Staff, 2008). In the B-horizon, the soil colour varies from strong brown (7.5YR 5/6), reddish yellow (7.5YR 6/6, 7.5YR 6/8) to yellowish red (5YR 5/6, 5YR 5/6). The soil texture varies from loamy sand, sandy loam to sandy clay loam. The B-horizon of coastal plain sand has less percentage clay than the sandstone/shale. This shows that illuviation is more pronounced in sandstone /shale than coastal plain sand. The soil structure varied from sub-angular blocky to angular blocky structure. Organic carbon varied from 0.8 to 0.9 %, indicating low organic carbon content in the B-horizon compare to overlying horizon. CEC varied from 9.5 to 11.7cmol/kg, indicating low CEC; lower than the sandstone/shale. The low CEC in the B-horizon is an indication that clay type is a low activity, 1:1 type of clay mineral (kaolinite). These soil properties justify considering the horizon as the kandic subsurface horizon of USDA classification system (Soil Survey Staff, 2008) or argic horizon of World Reference Base (WRB, 2014). About 70 % of soils developed from coastal plain sand parent material belong to the **Utisols** Soil Order of the USDA soil classification system, while remaining 30 % may belong to the inceptisols and or Entisols.

3. Occurrence and distribution of pedogenic horizons in soils developed from quaternary fluvio-marine beach ridge sand parent material

The properties of pedogenic horizons of soils developed from quaternary fluvio-marine beach ridge sand parent material are shown in Tables 7, 8 and 9. The soil colour of the surface horizon varies from very pale brown (10YR 7/3), brown (10YR 4/3) to dark brown (10YR 3/3). The surface horizons have either a Munsell color value of 4 or more, (moist), or Ap horizon that has low color values but is too thin to be recognized as a mollic or umbric epipedon. The soil texture is sandy, with clay content ranging from 4.6 to 4.8 % .The soil structure is crumb. Organic carbon varied from 1.1 to 1.2 %, indicating moderate organic carbon in the surface horizon. CEC varies from 3.1 to 5.1 cmol/kg, indicating very low CEC. These soil properties justify considering the horizon as the Ochric epipedon of USDA classification system (Soil Survey Staff, 2008). In the B-horizon, the soil colour varies from dark brown (10YR 4/4), brownish yellow (10YR 6/8) to yellowish brown (10YR 5/8). The soil texture is sandy. The texture is sandy in all horizons (A, B and C horizons). Soil structure is sub-angular blocky structure. Organic carbon varied from 1.0 to 1.1 %, indicating moderate organic carbon in the B-horizon. CEC varied from 3.8 to 4.8 cmol/kg, indicating very low. The properties of the B-horizon are not much different from that of the surface horizon. The B-horizon does not really fits cambic horizon because the alternation is not pronounced. This is an indication of weak development of pedogenic horizons. This could be attributed to the fact that the soil consists mostly of quartz sands, that are resistant to weathering needed to form diagnostic horizon ((Soil Survey Staff, 2008). About 60 % of soils developed from quaternary fluvio-marine beach ridge sand belong to the **Entisols Soil Order (Psamments)** of USDA classification system (Soil Survey Staff, 2008). The reaming 40 % could be inceptisols.

4. Occurrence and distribution of pedogenic horizons in soils developed from recent alluvial parent material

The profile pits of soils developed from recent alluvial parent material are shown in appendixes 10, 11 and 12.

The soil colour of the surface horizon varies from brown (7.5YR 4/3), dark brown (7.5YR 4/2) to greyish brown (7.5YR 5/2) with reddish brown (5YR 4/4) to yellowish red (5YR 4/8) mottles. The epipedons have either a Munsell color value of 4 or more, (moist) , or Ap horizon that has low chroma but is too thin to be recognized as a mollic or umbric epipedon. The texture varies from sandy clay loam to sandy clay, with clay ranging from 22.80 to 30.80 % in the surface horizon. The structure varies from granular to sub-angular blocky structure. Organic carbon varied from 0.2 to 2.0 %, indicating low to high. CEC varied from 11.8 to 22.4 cmol/kg, indicating moderate to high. These soil properties justify considering the horizon as the Ochric epipedon of the USDA classification system (Soil Survey staff, 2008). In B-horizon, the soil colour varies from light brown (7.5YR 6/3), yellowish brown (10YR 6/4) to pinkish grey (7.5YR 6/2), with yellowish red (5YR 4/8) or yellowish brown (5YR 4/8) mottles. This is indication of reducing conditions (Schwertmann, 1991). The texture of the B-horizon varies from sandy clay loam, sandy clay to clay. The soil structure varies from sub-angular blocky to angular blocky structure. The organic carbon varied from 0.8 to 1.5 %, indicating low to high. CEC varied from 13.7 to 24.4 cmol/kg, indicating moderate to high. These soil properties justify considering the horizon as cambic B- horizon of the USDA classification system and World Reference Base (Soil Survey Staff, 2008; WRB, 2006). About 60 % of the soils developed from recent alluvial parent material belong to the I**nceptisols** Soil Order of the USDA soil classification system, while the remaining 40 % may belong to the Utisols and or Entisols.

CONCLUSION

The study revealed that Ochric epipedon is the dominant diagnostic surface horizon in soils of Akwa Ibom State. This is because it can be found in all the parent materials. In the sub-surface horizon, argillic and / or kandic horizon is found in soils developed from sandstone /shale and coastal plain sand parent materials. Cambic horizon is found in soil developed from recent alluvial parent material and quaternary fluvio-marine beach ridge sand parent material. The study also showed that Utisols, Inceptisols and Entisols are the widespread soil order of USDA soil classification in the state. This correlated with Acrisols, Cambisols, Gleysols, Fluvisols and Arenosols of FAO/ WRB. Vertisols could also be found but in restricted areas.

REFERENCES

Asadu, G.L.A; Nnaji G.U. and Ezeaku P.I. 2012.Conceptual issues in pedology. University of Nigeria Press Limited, Enugu State, Nigeria. 11-86

Dent, D. and Young A. 1981. Soil survey and land evaluation. George Allen and Unwin, London. 278

AO 2006. Guidelines for Soil Descriptions, 3rd edition. FAO Rome.

Gee, G. W. and Bauder, J. W. 1986. Particle size analysis. In: Methods of Soil Analysis, Par1-Physical and Mineralogical Methods, SSSA Book Seria 5, Madison, Wisconsin, USA. 383-412.

Ibanga, J.I. 2006. Soil studies: the pedological approach.Maesot printing and computers, Calabar-Nigeria. 32-40

Nelson, D. M. and Sommers, L. E. 1996. Total Carbon, Organic Carbon and Organic Matter. In: .Spark, D. L (eds.). Methods of Soil Analysis Part 3- Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. 961-1010.

Petters, S. W.; Usoro, E. J.; Udo, E. J.; Obot, U. W. and Obot S. N. 1989. Akwa Ibom State. Physical Background, Soils and Landuse and Ecological Problems.Technical Report of the Taskforce on Soils and Landuse. Govt. Printer, Uyo. 602.

Schwertmann, U. 1991. Solubility and dissolution of iron oxides. *Journal of Plant and soil*, Vol. 130, Issue 1:1-25.

Sumner, M. E. and Miller, W. P. 1996. Cation Exchange Capacity and Exchangeable Coefficients. In: Spark, D. L. (eds.). Methods of Soil Analysis Part 3-Chemical Methods, SSSA Book Series 5, Madison, Wisconsin, USA. 1201-1230.

Soil Survey Staff. 2008. Soil Survey Manual.Soil conservation Service.U.S. Department of Agriculture Handbook 18.U.S. Govt. Printing Office, Washington, D.C. 871.

Usoro, E. J. and P .A. Akpan (2010). Akwa Ibom State: A Geographical Perspective. Immaculate Publication Limited, Enugu: 23-51

World Reference Base for Soil Resources 2014. International soil classification system for naming soils and creating legends for soil maps. Food and Agriculture Organization of the United Nations Rome.

Table 1: The characteristics of pedogenic horizons developed from sandstone /shale parent material (Odoro Ikpe)

Horizon designation	**Location**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap	Odoro Ikpe	0-13	Very dark brown (10YR 3/3)	Loamy sand	Granular	90	3	7	1.97	12.0	Ochric Epipedon	**Ultisols**
AB		13-35	Dark reddish brown (10YR 4/6)	Loamy sasnd	Granular	88	3	9	0.66	10.0		
Bt_1		35-80	Strong Brown (7.5YR 4/6)	Sandy Loam	Sub-angular blocky	84	2	14	0.60	12.0	Argillic Horizon	
Bt_2		80-157	Yellowish Red (5YR 4/6)	Sandy clay loam	Angular blocky	70	2	28	0.55	8.0	Argillic Horizon	
BC		157-184	Yellowish red (2.5 YR 4/8)	Sandy Clay loam	Angular blocky	63	2	35	0.50	10.0		

Table 2: Characteristics of pedogenic horizons developed from sandstone /shale parent material (Ibam Edet)

Horizon designation	**Location IbamEdet**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap		0-13	Dark grayish brown (10YR 4/3)	Loamy sand	Granular	90	3	7	0.68	17.3	Ochric Epipedon	**Ultisols**
AB		13-37	Dark brown (10YR 4/3)	Sandy loam	Sub-angular blocky	84	2	14	0.44	12.2		
Bt_1		37-86	Dark brown (10YR 4/6)	Sandy clay loam	Sub-angular blocky	70	2	28	0.29	10.5	Argillic horizon	
Bt_2		86-142	Yellowish red (5YR 4/6)	Sandy clay	Angular blocky	60	4	36	0.27	9.6		
BC		142-200	Yellowish red (5YR 5/6)	Sandy clay	Angular blocky	59	1	38	0.20	10.0		

Table 3: **Characteristics of pedogenic horizons developed from sandstone /shale parent material (Oniong Ono)**

Horizon designation	**Location**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap	Oniong Ono	0-14	Dark brown (7.5YR 4/8)	Loamy sand	Granular	81	7	12	1.49	10.66	Ochric Epiepedon	**Ultisols**
AB		1-35	Reddish yellow (7.5YR 6/8)	Sandy loam	Sub-angular Blocky	78	5	17	0.83	9.06		
Bt_1		35-86	Reddish yellow (7.5 YR 7/8)	Sandy clay loam	Sub-angular blocky	71	3	26	0.73	12.26	Argillic horizon	
Bt_2		86-150	Light reddish brown (5YR 6/4)	Sandy clay loam	Angular blocky	70	2	28	0.55	11.73		
BC		150-200	Reddish yellow (5YR 5/6)	Sandy clay	Angular blocky	60	2	38	0.50	11.73		

Table 4: Characteristics of pedogenic horizons developed from coastal plain sand parent material (MbiakpaIbakasi)

Horizon designation	**Location** **Mbiakpa Ibakasi**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution** **Sand (%)**	**Silt (%)**	**Clay (%)**	**Organic Carbon (%)**	**CEC** **Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
Ap		0-12	Dark brown (7.5YR 3/3)	Loamy sand	Granular	89	4	7	1.53	12.8	Ochric epipedon	**Ultisols**
AB		12-35	Dark brown (7.5YR 6/6)	Sandy loam	Sub-angular blocky	80	2	18	1.09	10.0		
Bt_1		35-67	Reddish yellow (7.5YR 6/6)	Sandy clay loam	Sub-angular blocky	70	2	28	0.89	9.5	Argillic horizon	
Bt_2		67-135	Reddish (7.5YR 6/8)	Sandy clay loam	Angular blocky	64	2	34	0.86	11.5		
BC		135-180	Reddish yellow (7.5YR 6/8)	Sandy clay	Angular block	60	2	38	0.81	10.4		

Table 5: Characteristics of pedogenic horizons developed from coastal plain sand parent material (Mbiabong Ikot Etim)

Horizon designation	**Location IbamEdet**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap		0-12	Dark brown (10YR 3/3)	Loamy sand	Granular	90	3	7	2.2	15.9	Ochric epipedon	**Ultisols**
AB		12-25	Strong brown (7.5YR 4/6)	Sandy loam	Sub-angular blocky	86	3	11	1.1	11.2		
Bt_1		25-64	Yellowish red (5YR 5/8)	Sandy clay loam	Sub-angular blocky	66	2	32	0.9	9.6	Argillic horizon	
Bt_2		64-125	Yellowish red (5YR 5/6)	Sandy clay loam	Angular blocky	62	1	37	0.8	15.0		
BC		125-184	Yellowish red (5YR 5/6)	Sandy clay	Angular blocky	58	2	40	0.6	15.0		

Table 6: Characteristics of pedogenic horizons developed from coastal plain sand parent material (Ikot Udobia)

Horizon designation	**Location IkotUdobia**	**Depth (cm)**	**Colour**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap		0-17	Dark brown (7.5YR 3/3)	Sand	Granular	94	1.8	4.2	2.04	7.9	Ochric epipedon	**Ultisols**
AB		17-35	Dark brown (7.5YR 4/4)	Sand	Granular	86.0	5.8	8.2	1.6	7.3		
Bt		35-100	Strong brown (7.5YR 5/6)	Loamy sand	Sub-angular blocky	82.0	5.8	12.8	0.8	6.7	Argillic horizon	
BC		100-180	Reddish brown (7.5YR 6/8)	Loamy sand	Sub-angular blocky	84.0	1.8	4.23	0.4	6.3		

Table 7:Characteristics of pedogenic horizons developed from fluvio-marine beach ridge sand parent material (Ibaka)

Horizon designation	**Location**	**Depth (cm)**	**Colour (moist)**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**		**Cmol/kg**		
Ap	Ibaka	0-20	Very pale brown (10YR 7/3)	Sandy	Crumb	93.25	1.94	4.80	1.1	3.8	Ochric epipedon	**Entisols**
BA		20-46	Dark yellowish brown (10YR 4/6)	Sandy	Sub-angular Blocky	95.14	0.06	4.62	1.2	4.5		
B		46-87	Yellowish brown (10YR 5/6)	Sandy	Sub-angular Blocky	95.14	0.05	4.80	1.0	3.8		
C_1		87-136	Yellowish brown (10YR 5/8)	Sandy	Sub-angular Blocky	95.32	0.06	4.62	1.1	3.7		
C_2		136-200	Brownish yellow (10YR 6/8)	sandy	Sub-angular Blocky	84.98	0.06	4.80	1.1	3.5		

Table 8:Characteristics of pedogenic horizons developed from fluvio-marine beach ridge sand parent material (Okoro Ete)

Horizon designation	Location	Depth (cm)	Colour	Texture	Structure	Particle Size Distribution			Organic Carbon (%)	CEC Cmol/kg	Diagnotic Horizon	USDA Soil Order
						Sand (%)	Silt (%)	Clay (%)				
Ap	Okoro Ete	0-16	Brown (10YR 4/3)	Sandy	Crumb	93.23	1.94	4.8	1.1	3.9	Ochric epipedon	**Entisols**
AB		16-50	Yellowish brown (10YR 5/6)	Sandy	Sub-angular Blocky	91.25	3.94	4.8	1.0	5.1		
B		50-110	Yellowish brown (10YR 5/8)	Sandy	Sub-angular Blocky	89.44	5.84	4.62	1.0	4.0		
BC		110-150	Brownish yellow (10YR 6/8)	Sandy	Sub-angular Blocky	91.44	3.94	4.62	1.0	4.0		
C		150-200	Brownish yellow (10YR 6/8)	sandy	Sub-angular Blocky	97.74	0.05	4.8	1.0	3.6		

Table 9:Characteristics of pedogenic horizons developed from fluvio-marine beach ridge sand parent material (UtaEwa)

Horizon designation	Location	Depth (cm)	Colour (Moist)	Texture	Structure	Particle Size Distribution			Organic Carbon (%)	CEC Cmol/kg	Diagnotic Horizon	USDA Soil Order
						Sand (%)	Silt (%)	Clay (%)				
Ap_1	Uta Ewa	0-12	Dark brown (10YR 3/3)	Sandy	Crumb	95.32	0.06	4.62	1.2	3.1	Ochric epipedon	**Entisols**
Ap_2		12-30	Brown (10YR 4/3)	Sandy	Sub-angular blocky	91.44	0.06	4.62	1.2	4.6		
AB		30-48	Dark yellowish brown (10YR 4/4)	Sandy	Sub-angular blocky	89.44	5.94	4.62	1.0	4.0		
C		48-80	Brown (10YR 4/3)	sandy	Sub-angular blocky	93.26	1.94	4.8	1.2	3.5		

Table 10: Characteristics of pedogenic horizons developed from recent alluvial parent material (Itie Ikpe)

Horizon designation	**Depth (cm)**	**Colour (Moist)**	**Mottles**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap	0-13	Black (5YR 2/1)	Dark red (2.5YR 2/1)	Loamy sand	Granular	83	10	8	2.5	10.7	Ochric epipedon	**Inceptiso;s**
AB	13-56	Yellowish red (5YR 5/6)	Dark red (2.5YR 2/1)	Sandy loam	Sub-angular Blocky	80	6	14	1.2	14.9		
B	56--86	Reddish grey (5YR 2/3)	Reddish yellow (7.5YR 7/8)	Sandy loam	Sub-angular Blocky	78	5	17	1.1	13.3	Cambic Horizon	
BC	86-160	Light brownish grey (10YR 6/2)	Dark red (2.5YR 2/1)	Sandy loam	Angular blocky	75	4	19	1.0	11.2		

Table 11: Characteristics of pedogenic horizons developed from recent alluvial parent material (Mbiabet Ikot Efa)

Horizon designation	**Depth (cm)**	**Colour (Moist)**	**Mottles**	**Texture**	**Structure**	**Particle Size Distribution**			**Organic Carbon (%)**	**CEC Cmol/kg**	**Diagnotic Horizon**	**USDA Soil Order**
						Sand (%)	**Silt (%)**	**Clay (%)**				
Ap	0-15	Brown (7.5YR 5/2)	Yellowish red (5YR 4/8)	Sandy loam	Granular	70	16	14	1.5	11.7	Ochricepipedon	**Inceptisols**
B	15-30	Pinkish grey (7.5YR 6/2)	Strong brown (7.5YR 6/2)	Sandy loam	Sub-angular Blocky	68	14	16	1.4	11.2	Cambic horizon	
BC	30-70	Pinkish grey (7.5YR 6/2)	Strong brown (7.5YR 6/2)	Sandy loam	Angular blocky	66	16	18	1.9	14.4		

Table 12: Characteristics of pedogenic horizons developed from recent alluvial parent material (Obot Itu)

Horizon designation	Depth (cm)	Colour (Moist)	Mottles	Texture	Structure	Particle Size Distribution			Organic Carbon (%)	CEC Cmol/kg	Diagnotic Horizon	USDA Soil Order
						Sand (%)	Silt (%)	Clay (%)				
Ap	0-20	Brown (10YR 5/3)	Nil	Sandy clay loam	Sub-angular blocky	59.8	13.4	26.8	2.6	11.2	Ochric epipedon	**Inceptisols**
AB	20-40	Pale brown (10YR 6/3)	Yellowish red (5YR 5/6)	Clay	Sub-angular blocky	31.8	19.4	38.8	0.7	12.3		
B_1	40-70	Pale brown (10YR 6/3)	Yellowish red (5YR 5/6)	Clay	Sub-angular blocky	19.8	29.4	50.8	0.9	7.2	Argillic horizon	
B_2	70-100	Pale brown (10YR 6/3)	Yellowish red (5YR 5/6)	Clay	Sub-angular blocky	15.8	17.4	66.8	0.7	5.0		