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Morpho-Physical Properties and Related Management Implications of Some Inceptisols in Two Ecological Zones of Southern Nigeria

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Abstract

The morphological and physical properties of some inceptisols derived from unconsolidated parent materials at Igbotako in Ondo State and Akwete in Abia State were evaluated in terms of their agricultural relevance. Profile pits were dug and soil properties such as colour, consistency, texture, structure, silt/clay ratio and total porosity evaluated. The soil was classified in USDA Soil Taxonomy as Aquic Entrudept at Igbotako and Fluvaquentic Dystrudept at Akwete. The results indicate that soils at Igbotako were shallow when compared to that of Akwete and that the fluctuation of the water tables was due to their very proximity to the streams near the locations. The profiles were poorly drained. Generally, the two soils are young with no clear evidence of diagnostic horizons. The dominant hues at Igbotako and Akwete were 10YR and 5Y respectively. Soils at Igbotako were structurally weak, fine and crumb when compared with the weak, loose and subangula blocky at Akwete. On both areas, the dominant soil fraction was sand, and the clay contents were low while the texture was sand to sandy loam at Igbotako and only sand at Akwete. However, Igbotako profile was more porous than that of Akwete. Massive structure was encountered at 165 cm soil depth as well as evidence of lithologic discontinuity seen at Akwete profile. In order to maximize the production potential of these Inceptisols, good management practices that will increase the organic matter content, encourage minimal tillage and proper residue management as well as proper drainage measure were discussed and recommended.

Keywords: Akwete, Hue, Igbotako, Lithologic Discontinuity, Residue Management, Silt/Clay ratio.

1.0. Introduction

Inceptisols are those immature soils that have weakly expressed profile features than mature soils and retaining close resemblance to parent materials (Buol, Hole & McCracken, 1973).

They have features that show pedological immaturity. Most Inceptisols are good for agricultural purpose. Brady (2002) however, considered the soil as prone to slow drainage due to its morphophysical properties.

Morpho-physical properties of the soils are of paramount importance in understanding how the soils could be used. Soil morphology is studied from the *in situ* evaluation of the soil profile while the physical properties are measured by laboratory techniques. For agricultural purpose, physical properties of the soils are not easily modified in the plantation. It is even harder to alter them than the chemical properties (Brady, 2002; Malgwi, Ojanuga, Chude, Kparmwang & Raji, 2000). Different workers (Esu, 1999; Orimoloye, Ugwa, & Idoko, 2010; Kamalu, Ugwa and Omenihu, 2014), have associated yield decline to poor physical properties and these may include low soil depth, changes in water holding capacity and relatively light texture soils. Enwezor, Udo, & Sobulo (1981) and Orimoloye (2011) had reported that most soils of southern Nigeria are inherently low in soil fertility, very susceptible to erosion and acidic with poor physical structure.

The production of crops has suffered a decline in recent years arising from soil factors and poor agricultural practices. Therefore, suitable management practices and agricultural planning can be achieved by knowing the physical limitation of the soils. For instance, tree crops do well in soils that are well drained, no impermeable horizons within 100 cm soil depth and ability to retain water and plant nutrients. For the soil to provide such functions, it should be related to its soil morphological and physical characteristics.

Although the morpho-physical properties of soils influence tree crop yield (Planter's Bulletin 1977), there is paucity of information in the study locations especially in areas of sustainable land use and soil structure for optimum yield. However, much soil studies have been focused on soil fertility and suitability of the land for a particular crop. Therefore, the main objective of this paper is to characterize the morphological and physical properties of the Inceptisols of some states in southern Nigeria while the specific objectives are to examine their potential to crop production as well as assess their related management implications.

2.0. Materials and Methods

2.1. Study Areas

The study was carried out in two ecological zones of Southern Nigeria, namely: Igbotako (6^0 35' to 6^0 36'N, 4^0 37' to 4^0 38'E) in Southwest Nigeria and Akwete in Southeast Nigeria (4^0 53' to 4^0 55'N, 7^0 19' to 7^0 21'E). Ojanuga and Chude (2005) classified the ecological zones as very humid Lagos – Benin – Asaba lowlands and very humid Onitsha – Enugu – Abakaliki lowland and scrapland, respectively. Generally, the areas are characterized by hot humid tropical climate with a mean annual temperature of 23 and 26 ^oC for Igbotako and Akwete respectively. The rainfall of the two locations is influenced by two major air masses. The southwest air mass is moisture laden from the Atlantic Ocean while the northeast air mass is from the Sahara desert. The rainy season is from the middle of March to early November of the year with a short spell within August. The mean annual rainfall is about 1920 mm in Igbotako and 2,170 mm in Akwete. Soil leaching is high from the month of April to October when the rainfall exceeds evapotraspiration and moisture storage capacity is lower than the rainfall amount (Ojanuga, 2006). The relative humidity is very high being more than 70%.

Igbotako is underlain by sedimentary rock of southwestern Nigeria constituting the easternmost segment of the extensive Dahomey basin with enormous quantities of water bodies (Omosuyi, Ojo & Olorunfemi, 2008). Igbotako is a transitional zone between the sedimentary and the basement complex rocks with some weathered metamorphic rock outcrops (Ugwa, Obazuaya & Ahana, 2016a). Akwete is underlain by a variety of Cretaceous and Tertiary sediments with sandstones being the dominate rocks. Both areas are relatively flat to very gentle undulating plain with altitudes of 84 and 30 meters above sea level for Igbotako and Akwete respectively (Figure 1).

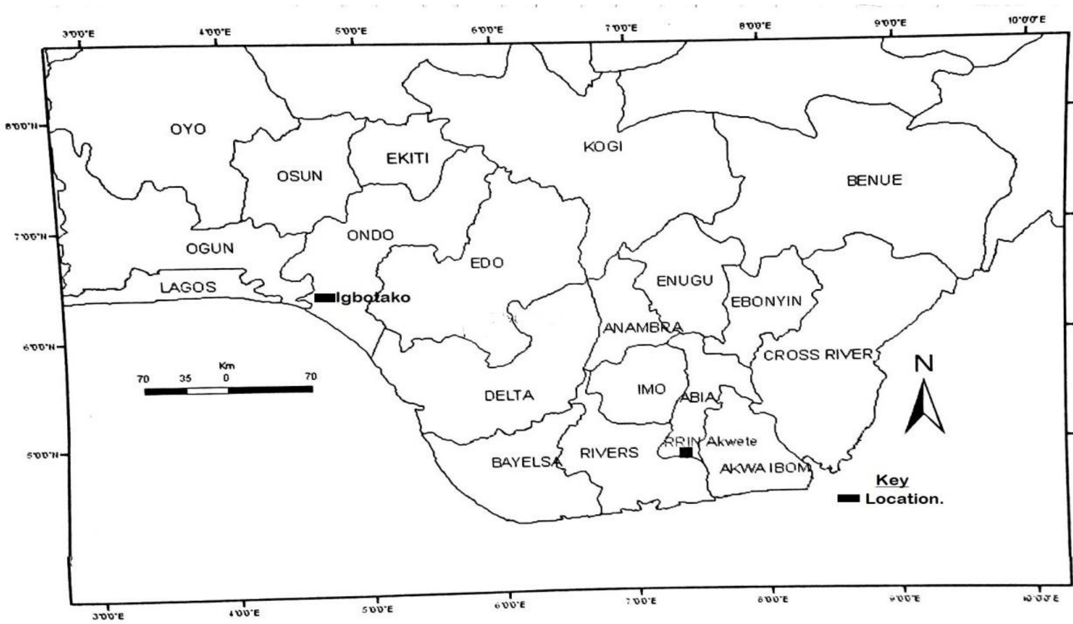

Fig. 1: Map of Southern Nigeria showing the study locations.

The natural vegetation of the locations shows that the areas which were high forest have been replaced by rubber plantations. A few other perennials found along the border areas are African walnut (*Tetracarpidium conophorum*), kola (*Cola nitida*) and mango (*Mangifera indica*). At Igbotako, bamboo trees (*Dracaena sanderina*) and raphia palms (*Raphia* spp) grow luxuriantly along the Gbagba stream. Two main permanent crops rubber (*Hevea brasilensis*) and oil palm (*Elaeis guinensis*) occupy prominent positions in the land-use of Akwete study area. Aquatic weeds are distributed near the southern water bodies of the area.

2.2. Field Studies

The available soil survey reports for Igbotako Ugwa, Obazuaya & Ahana, (2016a) and Akwete Kamalu, Ugwa & Omenihu, (2014) were inspected in order to get dependable soil details. Pedon that correlated with inceptisols was then dug in the two ecological zones and geo – referenced using Garmin Global Positioning System (GPS) handset to coordinate the reference point. Ugwa *et al.,* (2016a) has classified the Igbotako site as Aquic Entrudept (USDA Soil Taxonomy), Gleyic Fluvisol (Eutric) in World Reference Base for Soil resources (WRB) and Adio series (local classification). The area covered 7.2 ha. The Inceptisol at Akwete was classified by Ugwa, Orimoloye & Kamalu (2006) as Fluvaquentic Dystrudept (USDA Soil Taxonmy), Gleyic Cambisol (WRB) and Calabar series (local classification) occupying 48.3 ha. Morphological characterization was carried out according to FAO (2006) guidelines.

2.3. Laboratory Analysis

Soil samples gotten from the genetic horizons of each of the pedons were air–dried, crushed and sieved through a 2 mm sieve for laboratory analyses. The soil samples were analyzed using standard laboratory procedures. Particle size analysis was carried out using the Bouyoucous hydrometer method (Gee and Or, 2002). Bulk density was determined in triplicates by the core method using core sample (216 cm^3) as described by Grossman and Reinsch (2002). The total porosity was calculated from the relationship of particle density to bulk density using the formula:

$$P = 1 - \left({D_b}/{D_p} \right) \times 100 \quad (1)$$

where: P = total porosity
D_b = bulk density
D_p = particle density.
The average D_p of mineral soils is assumed to be 2.65 Mg m^{-3}

2.4. Statistical Analysis

Data collected were analyzed using simple descriptive statistics. T-test was used for comparing means of soil properties while the relationships between the soil properties within each of the areas were subjected to Pearson Correlation Coefficient. All statistical analyses were carried out using Genstat, (2008).

3.0. Results and Discussion

3.1 Morphological Properties

Table 1 shows the morphological properties of the pedons at Igbotako and Akwete. The soil at Igbotako occurs on footslope (0–2%) and gradually grades into the existing Gbagba stream. The drainage system has a poorly uniform pattern and parts of the area near the stream are susceptible to erosion. Similarly, the soils at Akwete occur at the lower slope (3–6%) close to the stream (Mmiri Ohando) and are moderately to poorly drained with slight erosional surfaces. Thus, the drainage pattern is similar to that earlier described by Ugwa, Umweni, & Bakara, (2016b) to be poorly drained valley bottom soils in Iyanomo near Benin City. Adequate drainage enhances soil aeration and assists larger roots growth and development thereby promoting more nutrient absorption. A striking feature of these areas is that the soils lack distinct horizons as well as low solum at Igbotako (71 cm). At Akwete, the solum is deep with 2CC occurring at 200 cm. The areas show evidence of recent deposition.

Table 1: Morphological Properties of the Soil.

Profile no	Horizon	Depth (cm)	Colour (moist)	Structure	Consistency (moist)	Texture (field)	Roots	Mottles	Boundary	Other features
Igbotako: 6⁰ 35', 13'N, 4⁰ 37', 55"E (Lower slope 0 – 2 %)										
IG 4	Ap	0 – 15	2.5 YR 4/2	1,f,cr	fr	SL	vf,m	-	s,c	Stoniness, small, seasonal ant holes, seasonal flooding.
	Bw 1	15 – 27	10 YR 5/4	1,m,sbk	fr	SL	vf,m	-	w ,c	Few charcoal, few medium pores
	Bw 2	27 – 47	10 YR 5/3	1,m,sbk	f	SCL	vfe, vf	fe,m	w ,c	Medium moderate cutans on ped faces
	Bw 3	47 – 71	10 YR 6/8	1,msbk	f	SCL	vfe	m	-	-
Akwete: 4⁰ 39' 63'N, 7⁰ 54' 16'N (Middle slope 3 – 6 %)										
AK 2	AC	0 – 17	5 Y 4/2	1,s,sbk,fr	fr	S	fe	-	s, c	Abundant micropores and biological activities
	Cg1	17 – 34	5 Y 5/2	1,m,fr	fr	S	fe	-	s,c	-do-
	Cg2	34 – 52	5 Y 6/2	1,s,fr	fr	S	fe	fe	s,c	-do-
	Cg3	52 – 70	5 Y 7/2	1,s,fr	fr	S	fe	fe	s,c	Few biological activities
	2CC1	70 – 108	5 Y 4/4	2,m,	l	LS	v,fe	cm	s,c	-do-
	2CC2	108-165	5 Y 6/6	2,s,	l	S	-	m	s,l	Concretion gravel few pores
	2CC3	165-200	5 Y 6/6	2,m,s	l	S	-	fe	-	Gravel concretion few pores

Key:
Structure -1= weak, 2 = moderate, m = medium, c = coarse, cr = crumb, f = fine, sbk = sub angular blocky.
Consistency - f = firm, fr = friable, l=loose
Texture -LS = loamy sand, SL = sandy loam, SCL = sandy clay loam, S=sand.
Boundary - S = smooth, d = diffuse, g = gradual, c = clear, w= wavy, sh=sharp
Roots – f = fine, vfe = very few, vf = very fine, m = many, co = common
Mottles - f = fine, fe = few, m=many.

Physiography, soil depth, drainage and erodability class fall within grading the sites as marginally suitable for rubber cultivation (Ugwa, *et al.,* 2016a). Fluctuation of underground water table is due to its proximity to the stream. The fluctuation is low in rainy season but high in dry season. This gives rise to mottles and gleying especially at Akwete site as a result of redoxmorphism. There was no active gleization and plinthile or paraplinthite observed. Down the profiles at Akwete the soils contain common quartz stones as observed by Kamalu *et al.* (2014).

The epipedons have average depth of 15 and 17 cm at Igbotako and Akwete respectively. There seems to be a basic similarity in the two sites. Orimoloye and Akinbola (2013) observed that there tends to be a soil – slope association occurring on landform as a result of the influence of topography on pedogenesis. Thus, young soils occurred at lower slopes near the stream. The different soil series at the sites have uniform climate and support similar vegetation. It is therefore, inferred that the differences among the Inceptisols (Igbotako being Aquic

Entrudept while Akwete is Fluvoaquentic Dystrudept) should be from the texture of initial deposits on which the soils were formed. The presence of cocoyam corms shows evidence of cultivation (Ap).

Soil development often gives rise to changes in colour due to formation of minerals of iron oxide due to weathering. The colour may be related to specific properties of the soils. According to Ugwa *et al.,* (2016b), the coating of iron oxides often gives rise to yellow, brown or red colouration in the soil matrix and these may provide information on some soil properties. Again, soils developed on different parent materials have vary colours. The soil colour at Igbotako ranges from weak red (2.5YR 4/2 moist) to yellowish brown (10YR 5/4 moist) in the topsoil to brownish yellow (10YR 6/8 moist) in the subsoil. The implication is that the dominant hue is 10YR (moist) and also portrays imperfect drainage.

The soil becomes more yellow as values and chroma increase, perhaps, due to long term high temperature during horizonation. These do not agree with the report of Verma and Jayakuma (2012) that observed a yellow coloration as values due to short term heating of the soils. The colour values in both sites increase from topsoil to subsoils i.e from 4 to a maxima of 6 and 7 for Igbotako and Akwete respectively indicating that the colour is slightly less dark. Morphological feature such as low chroma (Table 1) is an indicative of soil wetness (FAO, 2006). The colour of the soils at Akwete changes form olive grey (5Y 4/2 moist) in topsoil to olive yellow (5Y 6/6 moist) at the subsoil. This is different from the results of the poorly drained Inceptisols of dark grey (10YR 4/1 moist) at the epipedon and light yellow brown (10YR 6/4 moist) at the endopedon at Zaria, Nigeria by Malgwi *et al.,* (2000).

The consistency (moist) of the soil at Igbotako is friable to firm. This may be due to weak cohesion or adhesive forces acting on the soils mass at the upper horizons. According to Esu (1999), this type of consistency is important in soil cultivation. Friability of the soil is essential for tillage operation. At Akwete, the soil consistency (moist) is friable to loose. It is loose because of the dominant sand texture of the endopedon. Generally, this consistency may suggest a speedy permeability for the soils. This phenomenon points to the accessibility of the area for irrigation during the dry spells. While there are few stones and small ant holes at the soils at Igbotako, those of Akwete contain abundant micropores, gravels and hardpans at the lower depths. Brady (2002) asserted that the breakdown of minerals and plant residues are indicative that fauna and flora pedoturbation are active in the soils.

The soil boundaries at Igbotako ranges from smooth and clear to wavy and clear while that of Akwete are generally clear and smooth except between 34 – 70 cm depth that is sharp and wavy and according to Esu, Uko and Aki (2015), it may be the low organic matter content of the soil. Also, the smooth and clear boundary at Akwete especially from 70 cm depth shows a zone of transition rather than sharp lines as reported by Kamalu *et al.,* (2014). One notable feature about the horizon boundaries at the study areas is that they are three and six at Igbotako and Akwete respectively; the horizon thickness increases from epipedon to endopedon. It varies from 12 to 24 cm at Igbotako to 17 and 57 cm at Akwete. The differentiation of horizons within the pedons was made on soil colour and textural variations similar to that of Orimoloye, Ugwa & Idoko (2010)**,** implying that the soils are not old.

3.2. Soil structure and its Development

Soils at Igbotako are structurally weak, fine and crumb over, weak, medium subangular under moist field condition when compared with weak subangular structure over moderate loose to massive structure that is encountered from 165 cm depth at Akwete. Therefore, the structures of the two areas vary within depth. The result of these structures are different from similar inceptisol on a levee slope in Yenogua (Bayelsa State) which is moderate, coarse sub-angular overlie moderate, and fine subagular structure (Ayolagha, 2001). The soils of the study areas are not hard. The friable structure is due to its moist condition between individual aggregates in the topsoil which is in agreement with the report of Brady (2002). It is therefore, optimum for tillage operation. The innate, weak and single grains at Akwete bestow the area high erodibility potentials. This is the different between the soils. The single weak grains at Akwete might breakup under heavy rainfall. The kaolinite nature of the clay of the area might be responsible for the degree of the aggregation. Mbagwu and Auerswald (1999) noted that constant use of the land often affect structural stability more than soil properties do. The soil can be said to be faintly pedal by having some indistinct peds. The structural development is implicated in the cementing of fluctuation particles into secondary unit. The clay fraction is low (Table 2) and this negatively affect the binding of soil aggregates. Organic matter possibly incorporated to the ferric and ammonium ions present in the colloidal complex may undergo reversible reaction and this may be a factor to production of unstable aggregates. The weak and fragile nature of these areas, as a binding agent for the peds, may increase the water holding capacity.

3.3 Textural Variations

Table 2 shows some of the physical properties of the study site. The particle size distribution was such that sand was almost uniform within soil depth except at Akwete where it decreased after 70 cm depth. This may be due to the presence of gravel and hard pan layer. The soils are generally sandy having over 700 and 900 gkg^{-1} content in each of the horizons at Igbotako and Akwete respectively**.** The sand is 712 gkg^{-1} throughout the solum with the exception of Bw_2 that has 732 gkg^{-1} at Igbotako. At Akwete, the sand content ranges between 970 gkg^{-1} in the epipedon and 940 gkg^{-1} in the endopedon. There seems to be a general depositional mechanism in the sola with similar erosion and periodic flooding of the environment. The texture can be described as sandy loam at Igbotako and sand at Akwete because of the predominance of sand fraction. This is similar to the findings of Onyekanne, Akamigbo, and Nnaji (2012) that the soils of the coastal plain sand are coarse grained than that of the basement rocks and these textures according to Babalola and Obi (1981) are devoid of cementing agents such as organic and inorganic colloids. Soils at Akwete are more sandy than that of Igbotako and this may also be due to geological formation; Akwete being in coastal plain sands and Igbotako in the transitional zone between the basement complex and coastal plain sands.

Table 2: Physical characteristics of soils of the study area.

Profile No	Location	Soil classification	Horizon	Depth (cm)	Sand	Silt (gkg^{-1})	Clay	Silt/ clay ratio	Texture	Bulk density (Mg m^{-3})	Total porosity (%)
IG 4	**Igbotako**	Aquic	Ap	0 – 15	712	220	68	1.00	SL	3.24	62.26
	6° 35', 36'N,	Eutrudept	Bw_1	15 – 27	712	160	128	1.24	SL	1.25	53.20
	4° 37', 4° 55'E		Bw_2	27 – 47	732	100	168	1.24	SL	0.67	53.20
			Bw_3	47 – 71	712	100	188	1.25	SL	1.66	52.83
AK 2	**Akwete**	Aquic	AC	0 – 17	970	18	12	1.32	S	1.50	50.19
	4° 39' 63'N,	Dystrudept	Cg_1	17 – 34	980	18	2	1.29	S	9.00	51.32
	7° 19' 7° 54'E.		Cg_2	34 – 52	980	18	2	1.38	S	9.0	47.93
			Cg_3	52 – 70	980	18	2	1.44	S	9.0	45.66
			$2CC_1$	70 – 108	930	18	52	1.48	S	0.35	44.15
			$2CC_2$	108 – 165	940	8	52	1.42	S	0.15	46.42
			$2CC_3$	165 – 200	940	8	52	1.67	S	0.15	36.45

Key: SL=sandy loam; SCL= Sand clay loam

The silt content decreases with soil depth and the decrease is more at Akwete. The silt is more at soils in Igbotako (≤ 220 g kg^{-1}) than in Akwete (≤ 18 g kg^{-1}). This trend distinguishes it from soils of southwestern Nigeria which are characteristic of higher silt content (Orimiloye**,** 2011). The very low silt content at Akwete again confers the sandy texture to the profile and the silt must have undergone transformation into clays to have been low in all the horizons as noted by similar studies by Ugwa *et al.,* (2016b). Ofem and Esu (2015) were of the opinion that the silt might have been eroded to have been so depleted in the soils. Silt is essential micro-sand (Buol, *et al.,* 1973). These reflect the dominance of quartz in the soil parent material than that of Igbotako.

The irregular distribution of silt at Igbotako may be due to the stratification of the fluvial parent material. This opinion is supported by Esu and Ojanuga (1986) who worked on the natural levees of River Kaduna and observed the different seasons of deposition of sediments. Clay on the other hand, increases with soil depth from 68 to 188 g kg^{-1} at Igbotako and between 2 and 12 to 52 gkg^{-1} at Akwete showing the existence of clay budge. Malgwi, Ojanuga, Kparmwang & Raji (2000) attributed the low clay content in the surface horizon to sorting of soil material by biological activities or surface erosion by runoff while Esu,Uko & Aki (2015) were of the view that the relative high amount of clay content in the subsoil is as a result of pedogenic processes involving eluviation and illuviation of clay particles. A characteristic of the soils shows that Akwete has a very low clay content (2 gkg^{-1}) at the upper horizons implying that the soils have low charges that absorb ions and water and therefore, reduces aggregation of soil particles giving rise to surface erosion. This is also in consonance with the report of Babalola and Obi (1981) that soils with high clay content have large specific surface areas that lead to interaction between water and soil particles. The soil particles in this study occur in the order of sand > silt > clay and sand > clay > silt in the upper and lower horizons respectively.

Correlation studies of some soil properties at Igbotako and Akwete are presented in Tables 3 and 4 respectively. At Igbotako, the correlation studies show two pairs of significant values. There is a negative (r = -0.987*) relationship between silt and clay.

Table 3: Correlation matrix of some soil properties at Igbotako.

Soil properties	Sand	Silt	Clay	Silt/Clay	Bulk density	Porosity
Sand	1.000					
Silt	-0.522	1.000				
Clay	0.378	-0.987*	1.000			
Silt/Clay	0.315	-0.879	0.895	1.000		
Bulk density	-0.877	0.098	0.059	-0.026	1.000	
Porosity	-0.320	0.884	-0.899	-1.000*	0.027	1.000

*Significant at 0.05 level of probability.

Ogban and Edoho (2011) reported the direct influence of silt and clay fractions on the formation of large soil aggregates. However, the clay size particles are relatively low in content (Table 2), hence its contribution may also have been equally low. Silt/clay ratio and porosity are also negatively and significantly correlated (r = -1.000*). The pores of sandy loam at Igbotako are more favourable for water movement than those of clay texture. Sandy loam has its solid particles that tend to be organized in porous grains or granules that result to higher total pore spaces (Babalola & Obi, 1981; Brady, 2002). It is surprising, however, that there is no significant difference obtained between sand and bulk density. This may be attributed to the young nature of Igbotako soil.

Four pairs are of significant value at Akwete, sand was negatively and significantly correlated with clay (r = -0.989*). There is, therefore, indirect effect of sand and clay sized particles on formation of soil aggregates. The content of clay sized particles is low (Table 2), hence, the contribution of sand sized particles may have been high. Bulk density was positively and significantly correlated with sand (r = 0.833*) but negatively and significantly correlated with clay (r = -0.855*). There is an inverse relationship between sand and clay fractions in the soil at Akwete. There are lesser sand and more clay in the endopedon. Ogban and Edoho (2011) reported that the bulk density was higher in the endopedon as a result of compaction caused by weight of the overlying soils. Just like the soils at Igbotako, the relationship between silt/clay ratio and porosity was negative and highly significant (r = -1.000). This is also as a result of the inverse relationship between silt and clay contents in the epipedon and endopedon respectively. The parent material may directly influence the texture and structure of the sandy nature of Akwete which is generally non-cohensive and of single grains.

Table 4: Correlation matrix of some soil properties at Akwete.

Soil Properties	Sand	Silt	Clay	Silt/Clay	Bulk density	Porosity
Sand	1.000					
Silt	0.611	1.000				
Clay	-0.989*	-0.773	1.000			
Silt/Clay	-0.641	-0.634	0.680	1.000		
Bulk density	0.833*	0.603	-0.885*	-0.494	1.000	
Porosity	0.635	0.638	-0.675	-1.000*	0.493	1.000

*Significant at 0.05 level of probability.

There is significant difference in the soil profile of the two locations for sand, silt and clay (Table 5). Akwete soil profile has more sand content (960 gkg^{-1}) than that of Igbotako while Igbotako has more fine particles (silt = 145 and clay = 138 gkg^{-1}) than the soil profile of Akwete. This may explain the transitional zone of Igbotako location.

Table 5: T-test for comparing means of soil properties of Igbotako and Akwete

Soil properties	Locations		T- statistics	Pr > t
	Igbotako	Akwete		
Sand (g kg^{-1})	717.00	960.00	24.746	0.0001***
Silt (g kg^{-1})	145.00	15.14	4.512	0.0200***
Clay (g kg^{-1})	138.00	24.86	4.016	0.0174*
Silt/Clay ratio	1.40	4.16	1.508	0.1724 NS
Bulk density (Mg m^{-3})	1.18	1.43	3.189	0.0168*
Porosity (%)	55.37	46.02	3.169	0.0165*

Level of significance: * $P < 0.05$, *** $P < 0.001$, NS = Non significant.

3.4 Stage of the Soils' Development

One of the most commonly used weathering ratio, silt / clay, which was employed to assess the stage of development of the soils shows that at Igbotako, the ratio ranged between 0.53 to 3.24. It was further observed that silt/clay ratio was higher in the upper horizons than in the lower horizons. Thus, the value decreases down the profile unlike the clay fraction that increases along with the soil depth indicating evidence of clay accumulation. The horizon having lowest value of silt/clay ratio also occurred in horizon with the highest quantity of clay as also observed by Ugwa, Umweni & Bakara (2016b). Similar trend was observed at Akwete while the silt / clay ratio ranged between 0.15 and 9.00.

Ayolagha (2001) reported that old parent materials usually have silt / clay ratio < 0.15 while the index > 0.15 was indicative of young parent material and value of = 0.15 is indicative of moderately weathered soils. Again, Ikemefuna (2010) rating the soil degradation rate and vulnerability potential of soils reported that if the silt/clay ratio is 5, it implies none, 3 is moderate, 2 is high while 1 is very high. Generally, soils at Igbotako have lower value of the index than that of Akwete. This is surprising since the pedon at Igbotako is very close to the active Gbagba stream coupled with many shallow hydro-geological units (Omosuyi *et al.,* 2008). The soil is poorly drained occasioned by periodic fluctuation of water table. The soils at Igbotako can be said to be moderate at the epipedon and high at the endopedon in so far as soil degradation rate and soil vulnerability potential are concerned. However, Akwete soils can be termed as not being degradable and not being much vulnerable to surface erosion hazards at the epipedon but having very high potentials of degradation and vulnerability at the endopedon. It is therefore essential to minimize these limitations by choosing appropriate crops and good management practices. Cover crops, application of organic manures as well as minimum tillage are some of such practices. Generally, the two soils are young with no clear evidence of diagnostic horizons and with low weatherable minerals. There was no significant ($P > 0.05$) difference in the soils of the two locations for silt/clay ratio (Table 5). This observation may be an indication that the soils were the most recent deposits and consequently be regarded as young soils.

Morphophysical and pedogenic studies in the sites reveal some parent material congruity. The need to evaluate the uniformity of altered parent materials that give rise to soil horizons is essential in soil genesis (Ibia & Omueti, 1987). Looking at most of the morphological parameters at Igbotako, there tends to be lack of lithogenic discontinuity. The hue of the soil colour is 2.5 YR over 10 YR. The texture of the soils is sandy loam throughout the profile and of weak structure. The evenness in the sand fraction distribution support parent material congruity and same applies to the clay-size particles (Tables 1 and 2).

The pedon at Akwete has a 38 cm thick buried A-horizon from 70 cm depth. The chroma is 2 perhaps, due to the presence of iron hydroxides. The sand fraction was almost constant with soil depth except between 70 – 108 cm depth where it decreased and rose at 165 cm to constancy. Also, the clay particles decreased with depth to its minimum of 2 gkg^{-1} (70 cm), then increased at this point to its maximum of 52 gkg^{-1} (70 – 200 cm depth). These soil fractions do not support the uniformity of parent materials (Elless, Rabenhorst and James, 1996). The pattern of their distributions shows three-layers of demarcations. The clear smooth soil boundaries as well as the sharp difference in soil structure (Table 1) in the adjacent horizons suggests genetic discontinuity in the pedon (Ojanuga, Lee and Folster, 1976; Kamalu *et al.,* 2014). The soils must have been formed at different times and with different parent materials. The hue colour changed from 5Y at the topsoil to abruptly 10YR and then reverted to 5Y from the 108 cm depth. This trend also shows evidence of lithologic discontinuity. The pedisediments or pedorelics at the lower profile (70 – 200 cm) of the Fluvoaquentic Dystrudept at Akwete are gravels and according to Ojanuga *et al.,* (1976), its origin is related to the cyclic erosional processes or inherited from soil parent material. Hardpans observed at the subsoils and the high water tables are constraints to agricultural practices.

3.5 Bulk Density and Total Porosity

The data on bulk density and total porosity are shown in Tables 2. Value of bulk density estimates ranges between 1.00 and 1.32 Mg m^{-3} and between 1.25 and 1.67, Mg m^{-3} in the topsoils and subsoils of Igbotako and Akwete respectively. These shows that bulk density increases with soil depth. The high bulk density at Akwete subsoils may be as a result of soil compaction occasioned by agricultural activities, low organic matter content and /or clay content. The general signature of the bulk density in the studied soils is < 1.50 Mg m^{-3} except that of $2Cc_3$ horizon at Akwete that has massive structure, hardpan and gravels with bulk density of 1.67 Mg m^{-3}. The entire soils have no problem of very high bulk density and according to Babalola and Obi (1981) may not be a mechanical impediment to root penetration. The Akwete pedon that has bulk density of 1.67 Mg m^{-3} may experience poor soil health due to slow nutrient movement and poor aeration. Malgwi *et al.,* (2000) reported that bulk density > 1.6 Mg m^{-3} may not be desirable for good plant growth. Therefore, practices that will increase organic matter content, encourage minimum tillage and the usage of designated routes in the area are essential in reducing the high bulk density. Fasina, Omotosho, Shittu and Adenikinju, (2007) suggested using chain saw to fell trees as well as proper crop residue management.

It is observed that there was significant difference ($p < 0.05$) in the soil profile of Igbotako and Akwete for bulk density and porosity (Table 5). However, while Akwete profile had significantly ($p < 0.05$) higher bulk density than Igbotako, the latter was more porous than the former. Porosity varies from 52.83 and 62.26 % at topsoils and subsoils of Igbotako while it is 36.45 and 50.19%, respectively at Akwete. This shows that soils at Igbotako are more favorable to good aeration and free water movements. Orimiloye (2011) reported similar values at Akwete while Ugwa *et al.,* (2016a) reported same at Igbotako. Such porosity of about 50% is best for crop production while those < 40 % are unsatisfactory (Essoka & Esu, 2001). The total porosity values decrease with increase in soil depth showing an inverse relationship with bulk density.

4.0. Conclusion

Morphological and physical characteristics of some soils at Igbotako and Akwete show that they were formed from sandstones and coastal plain sands respectively and are classified as Aquic Entrudept at Igbotako and Fluroaquentic Dystrudept at Akwete. Sand was the dominant size particle in all the profiles and texture was sand to sandy loam with weak, medium to loose sub-angular blocky structure. The study revealed that there were differences in the site of the two locations for sand, silt, clay, bulk density and porosity but none was for silt / clay ratio. Based on their genesis, the soils were relatively young. The differences in drainage status of the soils were related to their morpho-physical properties. The soils vary considerably and consequently will influence their agricultural potentials. At present the soils are considered satisfactory for tree crop husbandry while their poor structure and periodic flooding need judicious soil management practices to ensure production of other crops.

Tree crop cultivation is suggested as an economic viable land reclamation and soil improvement strategy for the sandy and structural degraded soils. Erosion and soil wetness are major limitations of the locations. Although much soil characterization and fertility trials have been done in the past, a lot still remains in order to optimize the use of these soils for agricultural purposes. Such areas of study include crop residue management, soil genesis, land use planning and farming system research.

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