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Physical properties of three geomorphological swampland soils in Ndokwa West, Delta State, Nigeria

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Abstract

A pedological study was carried out and three representative soil pedons were delineated, described, and assessed in the three locations studied based on the morphological properties. The results showed that sand fractions in Abbi (60.00 to 89.30%) were higher and significantly differ from Onicha Ukwuani (40.60-90.10%) and Ndemili (36.30–90.20%). Clay fraction was higher in Ndemili (4.00 to 56.60%) compare to Onicha Ukwuani (40.30 to 45.30%) and Abbi (4.40 to 44.30%). The bulk densities (low to moderate) varied across locations with Abbi (1.2-1.60gcm^{-3}), Onicha Ukwuani (1.30-1.55gcm^{-3}) and Ndemili ranged from 1.31-1.70 gcm^{-3}. The soil texture varied from sand, sandy loam, loam, clay loam, and sandy clay loam. The total porosity ranged from 13.30 - 47.80% (Abbi), 27.30 - 47.80% (Onicha Ukwuani), and 20.70 - 43.50% in Ndemili. Data collected was analyzed and there was a significant difference at <0.05 in the sand, silt, and clay and the highest mean value of sand (74.6%) was observed in Abbi, Silt (14.2%) in Onicha Ukwuani and clay (28.9%) in Ndemili. The research showed that the soils are compacted to well aggregate; thus, they are suitable for crop production but can be enhanced by soil tillage, use of plant residues, and fertilizers application.

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Introduction

Swamplands are intra-zonal soils formed due to localized drainage conditions (extreme wetness); they are inundated and poorly drained with characteristics associated with wetness and organic soils (Histosols) (Brady and Weil, 2015). The swamplands are described by gleying features caused by the continued existence of groundwater (Alama *et al.,* 2019). Swamps are developed in areas characterized by low wave energy regimes such as rivers and estuaries where they deposit sediments such as organic material (Okoji, 2002).

Because swamplands are one of the intermediaries between terrestrial and aquatic ecosystems, describing the hydrologic and physical characteristics of their soils is necessary not only for appreciating these ecosystems but also placing them in the context of broader landscape-level processes, such as food security export to aquatic ecosystems. Exploring differences in soil characteristics can also reveal predictive relationships that provide insight into the processes that cause spatial patterns (Nave *et al.,* 2017). The swampland soils are derived from coastal marine deposits with complex features of hydrology and soil processes could be reasons for differences in soil properties. In swamp landscapes, hydrology is a direct driver of variability in soil characteristics. Hydrology also imparts on swamps through its interactions with the soil characteristics and their parent materials (Ye *et al.,* 2012).

According to Wang *et al.* (2017), there are reports of variability in the soil's physical features in swampland which ranged from sand to clay or fine silt loam; often characterized by mottling, dark grey colours, or peaty accumulation. Swampland soils, therefore, have peculiar landforms and their general morphology and characteristics may be influenced by factors such as topographic locations and parent material and more significantly the presence of water in such amounts that can cause anaerobic conditions (Okoji, 2002). Variability in physical characteristics is related to topographic heterogeneity (Weill *et al.,* 2010), and changes in soil properties can affect soil moisture content, vegetation response, and land use rate (Ceddia *et al.,* 2009, O'geen, 2012). Another important indicator of topography is terrain slope, which has a clear effect on erosion rate (Weill *et al.,* 2010, Quan *et al.,* 2011) and thus affects soil pH.

Environmental influences are more influential in locations with greater topographic variation; climate, soil types, and geology are all expected to affect land-use change (Opral *et al.,* 2013; Ayele *et al.,* 2016). This will impact significantly soil qualities such as soil texture and fertility (Quesada *et al.,* 2019). These important indicators related to the swampland environment testify to variability, poor management practices, and nutrient depletion in such an ecosystem that poses limitations to land uses. Research made on inundated (swamp) soils in some parts of Nigeria (Okoji, 2002; Adewolu, 2009 and Ghabo, 2009) shows that soils are dynamic natural bodies (Brady and Weil, 2015) and could differ from one location to another depending on the prevailing conditions. As a result, investigating the swampland soils of Ndokwa West to determine variability regarding physical properties and problems associated with successful utilization, and steps to enhance the soil properties.

Material and methods

Study Area

This study was conducted in Ndokwa West, Delta State, Nigeria. The areas studied are located in the Northern Delta; lies between latitudes 4°30' and 5°30' N and longitudes 7°30'and 8°30' E. in the rain forest zone with a mean annual rainfall of over 2500mm. The areas have relatively high-temperature values with the mean annual temperature ranging from 26-27 C. The annual precipitation is 1,175mm and occurs between March and October (Aviation Ministry, 2019). The soils are derived from alluvial and colluvial deposits. The Experiment was carried out in three locations namely: Abbi (longitude 6° 6N and latitude 6° 42 E), Onicha Ukwuani (longitude 6° 48 and latitude 5°45 N), and Ndemili (longitude 6° 41E and latitude 5° 75N) (Ministry of Land and Survey, 2000).

Soil survey and laboratory analysis

A detailed (1:10,000) survey was carried out and four (4) profile pits each was delineated at the three physiographical locations. Each pedogenetic horizon (4) at each location represents the swampland soils. Profiles pits measured 2m (long), 1.5m (wide), and 1.4m (deep) were dug and samples taken were air-dried, sieved (<2mm) and used for laboratory analysis. The particle size distribution was assessed by the hydrometer method of Bouyoucous (1951) using Calgon as a dispersing agent. The bulk density was calculated from the mass of oven-dry soil and the volume of the core (Baruah and Barthakur, 1997). The average soil particle density (Pd) (2.65g cm-3) was used for estimating total porosity.

Statistical analysis

Data collected were analyzed and means showing significant differences were separated using LSD at P<0.05 (SAS 2012).

Results and discussion

Particle size distribution

The result showed that sand fraction ranges from 60.00 to 89.30% (Abbi), silt fraction also ranges from 12.0–19.8% while clay fraction also ranges from 4.30 to 44.30% (Table 1). The sand fraction also ranged from 40.60 to 90.10% (Onicha Ukwuani), the silt fraction also ranges from 3.60 – 29.80%, while the clay fraction ranges from 40.30 to 45.30% in Onicha Ukwuani pedons (Table 2). Consequently, the sand fraction ranges from 36.30–90.20% (Ndemili), silt fraction ranges from 20.0 to 24.00%, and clay fraction ranges from 4.00 to 20.50% in Ndemili (Table 3). The sand fraction decreases with an increase in depth while clay increases with an increase in soil depth. The processes which may have aided this trend could be either a combination of deposition, vertical/lateral clay dissolution or surface erosion (Chukwu, 2013) and activities such as timber lumbering grazing, tillage, trafficking, drainage, liming and manuring activities. These factors have an impact on soil's physical properties through the effects on soil structure, particularly at the surface horizon (Brady and Weil, 2015).

Higher values of clay were observed in Abbi (4.30 to 44.30)% and Onicha Ukwuani (40.30 to 45.30%) compare to Ndemili (4.00 to 20.50%) and increases with an increase in depth of profile across pedons. The clay increase with depth may be ascribed to either clay translocation and surface erosion due to runoff or a combination of these properties (Yitbarek *et al.,* 2016), and irregular distribution and stratification of clay in swamp soils, which perhaps, suggested different periods of depositions of sediments (Ayolagha, 2001). The general increase in the values of clay with depth in the B horizon could be credited to the vertical movement of water and the accumulation of clay. A similar trend was also reported by Kebede *et al.* (2017) and was ascribed to pedogenetic processes such as translocation of clay through the processes of lessivage and illuviation.

Table 1. Physical properties of swampland soils on Abbi.

Horizon	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	TC	B/d (gcm^{-3})	P/d (gcm^{-3})	Porosity (%)
Pedon 1				Abbi West				
Ai	0 – 20	89.20	6.00	4.80	S	1.20	2.30	47.80
Ap	20 – 40	80.80	5.80	13.40	LS	1.30	2.31	43.70
AB	40 – 60	70.80	10.00	19.20	SL	1.40	2.20	56.40
Bt1	60 – 80	70.60	13.00	16.40	SL	1.50	2.21	32.10
Bt2	80 – 100	60.00	18.50	21.50	SCL	1.60	2.20	31.80
Bt3	100 – 120	60.00	15.50	24.60	SCL	1.60	2.18	28.90
Bc	120 – 140	60.00	19.80	20.20	SCL	1.60	2.05	22.00
Pedon 2				Abbi North				
Ai	0 – 20	87.80	5.40	6.80	S	1.20	2.19	45.20
Ap	20 – 40	86.20	5.30	8.50	LS	1.30	2.23	41.70
BA	40 – 60	86.00	5.00	9.00	LS	1.40	2.25	37.70
Bt1	60 – 80	70.80	4.50	24.70	SCL	1.50	2.30	34.80
Bt2	80 – 100	70.00	6.80	23.00	SCL	1.50	2.30	34.80
Bt3	100 – 120	60.40	5.20	34.40	SCL	1.60	2.31	30.70
BC	120 – 140	50.80	4.90	44.30	SC	1.75	2.28	23.20

Horizon	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	TC	B/d (gcm^{-3})	P/d (gcm^{-3})	Porosity (%)
Pedon 3				Abbi South				
A1	0 - 20	89.30	6.30	4.40	S	1.15	2.20	47.70
Ap	20 - 40	82.20	6.00	11.80	LS	1.30	2.30	43.50
AB	40 - 60	80.10	5.60	14.30	SL	1.40	2.31	39.40
Bt1	60 - 80	75.80	4.80	19.40	SL	1.60	2.25	28.90
Bt2	80 - 100	71.60	3.80	24.60	SCL	1.70	2.26	24.80
Bt3	100 - 120	69.50	2.60	27.90	SCL	1.75	2.20	20.50
BC	120 - 140	65.60	3.80	30.6	SCL	1.72	2.23	22.90
Pedon 4				Abbi East				
A1	0 - 20	86.20	10.20	7.60	LS	1.30	2.00	35.00
Ap	20 - 40	82.40	6.50	11.40	LS	1.40	2.09	33.00
E	40 - 60	80.80	4.20	15.00	SL	1.30	1.89	31.20
EB	60 - 80	80.40	2.80	16.80	SL	1.30	1.60	18.70
Bt1	80 - 100	80.00	2.40	17.60	SL	1.30	1.50	13.30
Bt2	100 - 120	70.80	2.00	27.20	SCL	1.20	1.40	14.30
Bt3	120 - 140	70.00	1.20	28.80	SCL	1.20	1.40	14.30

Bd= Bulk density, P/d= Particle density, TC=Textural Class; S= Sand; LS= Loamy Sand, SL=Sandy Loam, SCL=Sandy Clay Loam, CL= Clay loam, L= Loam, SC=Sandy clay

Bulk Density

The bulk density ranged from 1.2-1.60gcm^{-3} (Abbi), 1.30-1.55gcm^{-3} (Onicha Ukwuani) and 1.31-1.70 gcm^{-3} in Ndemili. Lower values of bulk density were observed in the surface horizon with an increase in profile depth. A similar trend was observed by Raji (1995) and Blanco-Moure (2012) who reported that tillage can decrease bulk density, but the aggregates formed are usually unstable and can lead to hard surface caps.

The bulk density varied with an increase in depths across locations and was ascribed to the processes of soil formation and low OM in the sub-surface horizon. Chaudhari *et al.* (2013) reported an increase in bulk density with profile depth and was credited to low organic matter. However, bulk density of 1.4gcm^{-3} or higher is capable of restricting plant root or root penetration. According to Hazelton and Murphy (2007) plants perform best in Bd below 1.44gcm^{-3} for clay and 1.60gcm^{-3} for sandy soils.

Table 2. Physical properties of swampland soils in Onicha Ukwuani.

Horizon	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	TC	B/d (gcm^{-3})	P/d (gcm^{-3})	Porosity (%)
Pedon 1				Onicha Ukwuani West				
Qe	0 – 20	82.20	6.30	11.50	LS	1.30	2.20	40.90
Ap	20 – 40	65.80	6.00	28.20	SCL	1.40	2.30	39.10
BA	40 – 60	65.60	5.30	29.10	SCL	1.50	2.24	33.00
Bt1	60 – 80	55.20	15.0	29.80	SCL	1.50	2.20	32.40
Bt2	80 - 100	60.00	4.40	39.80	SC	1.50	2.22	28.90
BC1	100 - 120	56.20	4.30	39.50	SC	1.55	2.25	29.90
BC2	120 - 140	50.80	3.90	45.50	SC	1.55	2.20	29.50
Pedon 2				Onicha Ukwuani North				
A1	0 – 20	90.1	5.6	4.3	S	1.15	2.00	42.50
Ap	20 – 40	88.5	6.1	5.4	S	1.20	2.10	42.30
AB	40 – 60	60.3	20.5	19.2	SL	1.40	2.20	36.40
Bt1	60 – 80	30.4	40.5	29.1	CL	1.50	2.21	32.10
sBt2	80 - 100	36.6	35.6	27.8	CL	1.60	2.22	27.90
Bt3	100 - 120	40.0	20.5	39.5	CL	1.60	2.20	27.70
BC	120 - 140	40.6	29.8	30.4	CL	1.60	2.21	7.60
Pedon 3				Onicha Ukwuani South				
Qe	0 – 20	89.5	5.80	6.70	S	1.20	2.30	47.80
Ap	20 – 40	80.6	5.80	13.60	LS	1.40	2.20	36.40
AB	40 – 60	80.2	5.20	14.60	SL	1.50	2.30	33.30
B1	60 – 80	76.8	4.70	18.50	SL	1.30	2.30	34.80
Bt1	80 - 100	62.0	4.20	33.80	SCL	1.40	2.10	33.20
Bt2	100 - 120	60.6	4.60	34.80	SCL	1.50	2.20	33.20
Bt3	120 - 140	60.0	3.60	36.40	SC	1.50	2.20	32.10

Horizon	Depth(cm)	Sand (%)	Silt (%)	Clay (%)	TC	B/d (gcm^{-3})	P/d (gcm^{-3})	Porosity (%)
Pedon 4				Onicha Ukwuani East				
Ap	0 – 20	87.50	5.60	6.90	LS	1.20	2.20	45.50
BA	20 – 40	80.70	4.70	14.60	SL	1.30	2.20	43.40
AB	40 – 60	48.60	31.00	20.40	L	1.50	2.20	33.00
B	60 – 80	48.20	30.80	21.00	L	1.60	2.20	28.20
Bt	80 - 100	42.30	30.50	27.20	CL	1.60	2.20	27.30
Bt1	100 - 120	40.00	30.00	30.00	CL	1.60	2.20	28.30
Bt2	120 - 140	40.00	28.60	31.400	CL	1.50	2.20	32.70

Bd= Bulk density, P/d= Particle density, TC=Textural Class; S= Sand; LS= Loamy Sand, SL=Sandy Loam, SCL=Sandy Clay Loam, CL= Clay loam, L= Loam, SC=Sandy clay

Particle density

The result of the study showed that particle density ranged from 2.05 to 2.31gcm^{-3} (Abbi), 2.00 to 2.30gcm^{-3} (Onicha Ukwuani), and 2.10 and 2.90gcm^{-3} (Ndemili). This is a suggestion that the soils in swampland are mostly composed of quartz, feldspars, sesquioxide, and other colloidal silicate clays. However, Brady and Weil (2015) and Ayologha (2001) reported that particle densities ranging from 2.30 - 2.70gcm^{-3} are dominated by quartz, feldspars, and other minerals in soils.

Total Porosity

The result of the total porosity varied from one location to another and ranged from 35.00 to 47.80% (Abbi), 27.30 to 47.80% (Onicha Ukwuani), and 20.70 to 43.50% in Ndemili. The total porosity across the pedogenetic horizons decreased with an increase in profile depth. This could be ascribed to water movement, parent material, and soil processes. Brady and Weil (2015) reported that the value of total porosity varies wildly among soils and ranges from as low as 25% in compacted soils to more than 60% in well-aggregated soils because of their proportionate soil aggregate size, aeration, and water holding capacity. The soil porosity observed falls within the range and followed the same trend which implies that the soils at the subsurface horizons are compacted and well aggregated at the surface horizon as such are capable of supporting plant growth (Alaoui *et al.,* 2011).

Table 3. Physical properties of swampland soils in Ndemili.

Horizon	Depth(cm)	% sand	% Silt	% Clay	TC	B/d gcm^{-3}	P/d gcm^{-3}	Porosity%
Pedon 1				Ndemili West				
Ap	0 - 20	88.60	5.80	5.60	S	1.31	2.30	43.50
B	20 - 40	46.20	20.20	33.60	SCL	1.32	2.10	37.10
Bt1	40 - 60	48.50	19.80	31.70	SCL	1.50	2.30	34.50
Bt2	60 - 80	50.00	19.60	30.40	SCL	1.60	2.20	27.30
Bt3	80 - 100	52.50	15.00	32.50	SCL	1.70	2.30	24.40
BC1	100 - 120	42.00	21.80	36.20	CL	1.60	2.20	28.30
BC2	120 - 140	36.30	24.00	39.70	CL	1.90	2.21	14.00
Pedon 2				Ndemili North				
Ap	0 - 20	90.10	2.50	7.40	S	1.30	2.30	43.50
B	20 - 40	48.20	21.80	30.00	SCL	1.40	2.30	56.40
Bt1	40 - 60	48.00	20.60	31.40	SCL	1.50	2.34	35.90
Bt2	60 - 80	70.60	3.20	26.20	SCL	1.00	2.35	31.90
Bt3	80 - 100	70.00	2.60	27.40	SCL	1.80	2.90	37.90
BC1	100 - 120	62.20	1.60	36.20	SC	1.90	3.00	36.60
BC2	120 - 140	46.00	10.20	42.80	SC	1.80	2.20	10.20
Pedon 3				Ndemili South				
Qi	0 – 20	89.60	5.60	4.80	S	1.40	2.10	33.30
A	20 – 40	86.20	4.80	9.00	LS	1.40	2.20	36.40
AE	40 – 60	70.80	4.50	24.70	SCL	1.50	2.30	34.80
Bt1	60 – 80	70.20	3.80	26.00	SCL	1.60	2.40	33.30
Bt2	80 - 100	60.20	2.20	37.00	SC	1.80	2.30	20.70
BC1	100 - 120	56.40	1.80	41.80	SC	1.70	2.20	22.70

Horizon	Depth(cm)	% sand	% Silt	% Clay	TC	B/d gcm-3	P/d gcm-3	Porosity%
BC2	120 - 140	50.00	2.00	48.00	SC	1.50	2.20	31.0
Pedon 4				Ndemili East				
A	0 – 20	90.20	5.80	4.00	S	1.40	2.10	33.30
AB	20 – 40	80.60	5.60	13.80	SL	1.40	2.20	36.40
BA	40 – 60	70.80	6.00	23.20	SCL	1.50	2.30	34.80
Bt1	60 – 80	52.80	23.80	29.00	SCL	1.60	2.40	33.30
Bt2	80 - 100	52.50	21.20	31.30	SCL	1.80	2.30	20.70
Bt3	100 - 120	50.00	2.00	48.00	SC	1.70	2.20	22.70
BC2	120 - 140	40.80	2.60	56.60	C	1.50	2.20	31.50

Bd= Bulk density, P/d= Particle density, TC=Textural Class; S= Sand; LS= Loamy Sand, SL=Sandy Loam, SCL=Sandy Clay Loam, CL= Clay loam, L= Loam, SC=Sandy clay

In all of the pedons assessed, the total porosity in Abbi and Onicha Ukwuani soil was higher (47%) compared to Ndemili soils. poorly structured horizons with low total porosity can, however, be due to a lack of pore space. Low porosity, in swampland according to Kowal (1970) could be ascribed to structural development and poor stability of soil aggregates, which disintegrates due to soil compaction. It's worth noting that a high Exchangeable Salt Percentage (ESP) will cause the clay to swell, disperse, and pore space blockage, resulting in low porosity and bulk density in the sub-surface horizon. (Shamberg *et al.,* 1981).

Table 4. Effect of location on soil physical properties in Ndokwa west.

Locations	Sand	Silt	Clay	Bd	Pd	Porosity
Abbi	74.6	6.7	18.9	1.4	2.1	32.1
Onicha Ukwuani	61.4	14.2	24.6	1.4	2.2	34.3
Ndemili	61.4	10.0	28.9	1.6	2.3	31.7
LSD(0.05)	5.1	3.5	3.3	0.1	0.1	4.7

Bd= Bulk density, Pd= Particle density, LSD= List Significant Difference

Conclusion

The research showed that the soils are permanently reduced or submerged and have influenced the physical properties. The result showed variations across locations and sand fractions were significantly higher in Abbi compared to Onicha Ukwuani and Ndemili. The soil porosity showed that the soils are compacted to well aggregate. Higher clay contents were also observed in Ndemili followed by Onicha Ukwuani and Abbi. Thus, the soils are suitable for crop production and can be enhanced by soil tillage, use of plant residues and fertilizers.

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