SOIL AGGREGATES AND SELECTED SOIL WATER CHARACTERISTICS OF SOILS FORMED OVER COASTAL PLAIN SANDS IN A HUMID ENVIRONMENT.

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ABSTRACT
The study was conducted to investigate soil aggregates in relations to selected attributes of soil moisture in soils developed over Coastal Plain Sands in Owerri area of Southeastern Nigeria. A free survey technique was used to target flood-prone areas of Ihiagwa and Emeabiam. Core samples as well as bulk samples were collected at two depths for the study. Standard procedures were used in the determination of the selected properties in the laboratory. Results showed that sand-sized particles dominated both sites with sand ranging from 860 to 910 g/kg (Ihiagwa), and 780 to 800 g/kg (Emeabiam). Soil textures were found to be loamy sand (Ihiagwa) and sandy loam (Emeabiam). Bulk density of soils varied, and ranged from 1.22 to 1:35 Mg/m³ (Ihiagwa) and 1.19 to 1.22 Mg/m³ (Emeabiam). Total porosity was 53.96% at 0-10 cm depth and 52.83% at 10-20cm depth (Ihiagwa) while 55.0% and 53.96% were recorded at 0-10 cm and 10 - 20 cm, respectively for Emeabian soils. Mean weight diameter of aggregates of these soils indicated that Ihiagwa soil ranged from 1.22mm (10-20 cm depth) to 1.26mm for 0-10cm depth while Emeabiam soils were 2.56mm(10-20 cm depth) to 2.74 mm(0-10cm depth). Saturated hydraulic conductivity differed at all depths the measured ranging from 5.85 x 10^{-3} to 9.25x10^{-3} cm/sec (Ihiagwa) and 5.91 X10^{-3} to 9.85 x 10^{-3} cm/sec (Emeabiam). The Water Holding Capacity ranged from 0.44 to 0.50 cm³ /cm³ (Ihiagwa) and O.46 to 0.52 cm³/cm³ (Emeabiam),

Keywords: Aggregate, Texture, Soil Moisture, River bank, Humid tropics

INTRODUCTION
Nature of soil aggregates in the determination of soil moisture characteristics and most soils processes is relevant in agriculture and environmental health. Gruber and Peng (2022) reported soil water-plant-atmosphere interactions which Rousseva et al (2017) stated can be used to predict some agronomic and environmental problems. Soil properties such as structure, bulk density, total porosity and particle sizes interact with soil organic matter to affect soil moisture behavior (Indonia *et al*, 2020).

The proportion and nature of soil aggregates tend to exert high influence of soil-water behavior. Nweke and Nnabude (2014) aggregate size distribution and stability significantly related to the amount of soil water and its characteristics. Soil moisture characteristics affect nutrient content of soils, regulates soil temperature, governs the pace of photosynthesis and of great implication on the metabolic activities of microorganisms in the soil. In addition to this, soil moisture dictates the rate of pedogenic activities especially translocatory processes taking place in the pedosphere.

As soil aggregates and aggregate stability play a role in regulation of soil water movement, this is highly determined by soil organic matter , (Verchot *et al.*,2011), total porosity (Kakaire *et al.*, 2015) and particle size distribution (Kamalu and Orji, 2018) which in turn governs movement of water, air and nutrients into soils (Inodria *et al.*, 2020)

However, population pressure has impacted on these soils affecting aggregate stability (Azuka and Obi, 2012) due to loss of organic matter and compaction (Onweremadu *et al.*, 2007) and land use practices (Shittu and Amusan, 2015).

Earlier, Nweke and Nnabude (2014) reported variability in aggregate fractions as related to aggregate stability in soils of cultivated and fallow landscape. Because of incidence of flood hazard which has become widespread in the area, it becomes expedient to investigate ability of soil water to pass through pore spaces which differs according to aggregate characteristics like size. It is assumed that soil aggregate sizes regulate movement of moisture as different peds create varying sizes and shapes of pore spaces. It follows that aggregate stability influences rate of infiltration, macro and micro porosity, water retention and hydraulic conductivity. The major aim of the study was to evaluate aggregate sizes of soils formed over coastal plain sand and how it affects moisture characteristics.

Admist changing climatic variables and weightened demographic pressure, arable crop production becomes very important, and this could be sustained by managing soil water characteristics especially the soil aggregates as they relate to hydraulic conductivity and water-holding capacity. Aggregate stability of soils is a valuable factor that can be used in the management of soil moisture in the choice of climate-smart land use practice for arable crop production.

The main objective of the study was to investigate soil aggregate and selected soil moisture characteristics in soils formed over coastal plain sands for crop production.

MATERIALS AND METHODS

The study was conducted in Owerri area in Imo State Nigeria, lying between Latitudes 4°40' And 7°05'N and longitudes 6°40'and 8°15'E. Ihiagwa and Emeabiam soils are derived from coastal plain sands (Benin-formation). The area has a lowland geomorphology. It has a humid tropical climate with an annual rainfall of about 2500mm. The area has a bimodal rainfall pattern with peaks in July and September as a dry spell occurs in August popularly referred to as August break. The annual temperature ranges from 26 to 31°C with high relative humidity during rainy season. It has a tropical rainforest which is arranged in tiers (Onweremadu and Okolie, 2017). River otamiri traverses Ihiagwa and Emeabiam causing seasonal floods at the bank of the river which extends to human habitations/settlements. Agriculture is major socioeconomic activity of the area, with slash-and-burn practiced during land clearing. Soil fertility regeneration is by bush fallowing and soils are further enriched by sediments carried by the river during rainy season.

Brief description of the sampling sites

Ihiagwa: Ihiagwa is a community in Owerri area of Imo state Nigeria, lying on latitude 5°23'57''N and longitude 7° 0' 39''E with area of 40km^2. It has an elevation 56 meters above sea level. The site is a degraded secondary forest, and samples were collected proximal to Otamiri River. The site is within the Federal University of Technology Owerri premises. Soil colour was somewhat grayish due to seasonal flooding. Soils were granular with loose consistency. Faunal activities were minimal with very few. There were several exposed roots indicating pronounced river bank erosion. Shrubs were showing stuntedness and yellowness in the colouration of the leaves. Few man-made artificial hill were seen indicating disturbance of the area

Emeabiam: Emeabiam is a community in owerri area of Imo state, Nigeria, lying on Latitude 5°20' 2.62''N, and Longitude6°59' 30.84''E and on an elevation of 22m. Above sea level. It occupies an area of 70km^2 and lies very close to the Otamiri River. Its vegetation was lush and contained a variety of plant species arranged in storeys. It has thicker and denser vegetation and the forest floor was characterized by leaf litter at varying stages of decompositions. Roots of a variety of plant species were observed. Soil colour was dark gray. Soil peds were a mixture of crumby and granular in nature. It has almost flat topography of about 2 percent slope.

Field Studies

A free survey technique was used to target flood-prone areas at the bank of Otamiri River in Imo state Nigeria. Core samplers were used to collect soil sample from pre-determined depths of 0-10cm and 10-20cm and undisturbed sites. Each core measured 7cm by 5.0cm internal diameter. Five replicates of core were taken of 20 core samples for the study. The undisturbed core soil samples were used to obtain gravimetric moisture (), saturated hydraulic conductivity soil water holding capacity and bulk density. Total porosity was calculated based on the assumed relationship with average particle density (2.65Mg/m^3) using the equation

TP = 1 - $\frac{BD}{PD}$ multiplied by 100%

Where TP = total porosity

BD = bulk density

PD = particle density (2.65Mg/m^3)

Bulk soil samples were collected by auger sampling at predetermined depths of 0 – 10cm, 10- 20cm and 20 – 30cm and used for the determination of particle size distribution, soil organic matter, cation exchange capacity, exchangeable sodium percentage and aggregate size distribution.

Laboratory studies

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Bulk density was estimated by core procedure (Grossman and Reinsch, 2002). Soil organic carbon was determined by Walkley and Black, (Nelson and Sommers, 1982). Aggregate size distribution was estimated by the procedure outlined by Nweke and Nnabude (2004)

MWD = $\sum_{i}^{ii} = x_1 w_1$

Where MWD = mean weight diameter

ẍ = mean diameter of sieve

W1 = weight of soil

Hydraulic conductivity was determined by a procedure of constant head as described by Azuka and Obi (2012).

Ks = $\frac{Q^1 L}{\Delta HAT}$

Where Ks = saturated hydraulic conductivity (cm/sec)

Q1 = equilibrium of water passing through the soil column (cm2)

L = length of soil column (cm)

A = cross-sectional area through which the flow takes place (cm^2)

ΔH = hydraulic head gradient

T = time (sec)

H = matric head (cm)

F= flux density of water (cm/sec)

Water holding capacity was determined on mass basis (gravimetric method)

θM =$\frac{Mw}{Ms}$

where θM = gravimetric moisture (g(g)

Mw = mass of water (g)

Ms = mass of soil (g)

RESULTS AND DISCUSSION

Morphology of Soils

Morphological properties of the soils are shown on Table 1. Ihiagwa soils were weak in grade of structure with very fine to fine sizes of granular peds. Emeabiam soils were moderate in grade with very fine to fine crumbs at both depths. Similar results were recorded in field studies of other humid tropic soils of Nigeria (Ibanga, 2016). Loose consistence of soil of Ihiagwa implies poor resistance to damage by external natural forces inherent in the area, suggesting inability of soils to hold roots of plants including crops. With weak granular structures, effective foothold to crops is lacking and poor soil moisture retention being sandier than Emeabiam soils. Similar reports confirmed weak soil structures and soil consistence of soil in Taraba State of Nigeria (Imadojemu *et al.*, 2019) and in the Niger Delta region of Nigeria (Kamalu and Nwonuala 2016). Few roots were observed in Ihiagwa soils possibly due to weak granular structures which collapse at least pressure forming smaller particles that clog the pore spaces, thereby making root penetration difficult. There is possibility of poorer aeration as spaces are occupied by smaller particles creating fewer pore space for oxygen circulation. Emebiam soil had more roots which could be due to stronger grade of soil structure and better aggregation and higher mean weight diameter.

Results indicated that soils were sandy irrespective of location. Ihiagwa soils were sandier having loamy sand at 0-15cm depth and sand at 10-20cm depth unlike Emeabiam showing sandy loam at both depths Silt-clay ratio showed that Emeabiam soils were older than Ihiagwa soils (Table 2). Sandiness of soil emanated from the sandy nature of parents materials which is coastal plain sands. Earlier, Onweremadu and Okoli (2017) reported that most soils of Owerri area are sandy resulting from coastal plain sands and pedogenic processes which include washing and sorting process as well as movement of silt and clay-sized particles occasioned by longer duration, intensity and amount of rainfall in the agroecosystem.

Table 1: Morphology of soils

Site	Depth Cm	Colour (moist)	Texture	Structure			Consistence (moist)	Roots
				Grade	Class	Type		
Ihiagwa	0-10	GB(10Yr 5/2)	LS	1,	Vf	gr	L	Few
	10-20	YB(10Yr 5/4)	S	1,	F	gr	fr	Rare
Emeabiam	0-10	DG (10Yr 4/1)	SL	2,	Vf	cr	fr	Many
	10-20	G (10Yr 5/1)	SL	2,	F	cr	fi	Many

Texture: LS = Loamy sand, S = sand, SL = Sandy loam
Structure: 1 = week, 2 = moderate, vf = very fine, f = fine, gr = granular, cr = crumb
Colour: GB = grayish brown, YB = yellowish brown, DG = dark grey, G = grey
Consistence: L = loose, Fr = friable, Fi = firm

Table 2 showed that bulk density of Ihiagwa soils were 1.22Mg/m^3 at 0-10cm depth and 1.25Mg/M^3 at 0-10cm depth and 1.25Mg/M^3 and 1.22Mg/M^3 at 0 - 10cm and 10-20cm depths, respectively. Impliedly, total porosities at the depths were 55.09% and 53.96%, respectively. While bulk densities do not suggest restriction of root movement being less that 1.6Mg/M^3, total porosities being in the range 30-70% are ideal for aeration for plant roots (Landon, 1991).

Soil organic matter in ihiagwa soils were low (16.8 g/kg at 0-10 cm depth and 8.2g/kg at 10-20cm depth) which according to Snakin *et al* (1996) indicates high degradation of soils at 0-10cm depth and very high degradation at 10-20 cm depth. In Emeabiam soils, soil organic matter was 34.6g/kg (0-10 cm depth) and 22.5g/kg (10-20 cm depth) which in the same measure indicates none degradation for surface soils of Emeabiam and moderate degradation for the immediate lower layer (10 -20cm depth).

Low organic matter content could be attributed to sandiness of site particularly Ihiagwa in addition to bush burning and intensive mineralization of organic materials due to isohyperthemic temperature of the area. This is in line with earlier by Wapa *et al.* (2013) which reported sandiness as contributory factor to low organic matter content of soils of Sudano-Sahelian savanna of Northeastern Nigeria.

Mean weight diameter of aggregates of these soils are shown on Table 1, with Ihiagwa soil ranging from 1.22mm (10-20 cm depth) to 1.26mm for 0-10cm depth, suggesting the higher content of soil organic matter on the surface layer (016.8g/kg depth) to have increased the aggregation in the 0-10cm depth compared with 8-2g/kg soil organic matter recorded at 10-20 cm depth. Similar results were obtained in Emeabiam, where 2.74mm diameter aggregates were observed at 0-10 cm depth with higher soil organic matter of 34.6g/kg compared with 2.56mm diameter aggregate at 10-20 cm depth. Verchot *et al.* (2011) observed higher and more stable aggregates in soils with more organic matter. Macro aggregates are created in the presence of more soil organic matter by the particle sizes in line with Poineir *et al.*(2009) who posited that two particle sizes gives coverage to soil organic matter in aggregates thus greater aggregate stability.

Table 2: Selected soil properties

Site	Depth	Sand	Silt	Clay	SCR	MWD	BD	TP	CEC	SOM	TC
	Cm	g/kg				(mm)	Mg/M^3	%	Cmol/kg	g/kg	
Ihiagwa	0-10	860`	50	90	0.55	1.26	1.22	53.96	6.6	16.8	LS
	10-20	910	50	40	0.80	1.22	1.25	52.83	5.0	8.2	S
Emeabiam	0-10	800	60	140	0.42	2.74	1.19	55.0	10.4	34.6	SL
	10-20	780	70	10	0.46	2.56	1.22	53.96	5.8	22.5	SL

SCR = silt-clay ratio, MWD = mean weight diameter, BD = bulk density, TP = total porosity, CEC = cation exchange capacity, ESP = exchangeable sodium percentage, SOM = soil organic matter, TC = textural class

Table 3 shows results of saturated hydraulic conductivity in soils of Ihiagwa and Emeabiam values of hydraulic conductivity were higher in Emeabiam soils at all depths when compared with Ihiagwa soils. At 0-5cm depth, Ksa was 9.85 x 10^{-3}cm/sec at Emeabiam with SOM value of 34.6g/kg compared with I (sec of 9.25 x 10^{-3}cm/sec at the same depth for Ihiagwa with 16.8/kg SOM. These values compared with lower values of 6.1 x 10^{-3}cm/sec obtained in hydromorphic surface soils of Ezilo in similar environment (Obi, 2003; Asawalam, 2022). However, amount of soil moisture depends on the forces governing the soilsphere which include force of gravity and capillary attraction amidst surface tension, force of root suction, attraction of soil air for water and attraction of salts for water(Dupriez and De-Leenar,1997)..

The Ksat decreased with depth particularly in Emebiam soils suggesting impedance at lower layers which could be due to more clay content as posited by Igwe and Nwokocha (2006) stating that soil texture controls stability of aggregates and ability to conduct soil moisture. However, land use history particularly the role of tillage might influence conductivity of soil water (Opara, 2009).

Type of aggregates as influenced by SOM and clay could be implicated in these soils affecting movement of materials into the soil system while micro aggregates highly influenced by clays do promote capillary rise (Dupriez and D-Leener, 1992, Adesodun and Adekonojo, 2011).

Results of waterholding capacity of both soils are shown on Table 2. Ihiagwa and Emeabiam soils indicated more soil moisture content at 0 -5 cm depth and 15 – 20 cm depth. Within these depths, soil moisture was less at 5-10 cm and 10 – 15 cm depths in both soils. Increased soil moisture at 0 – 5cm depth could be attributed to higher SOM as Ihiagwa soil had 16.8 g/kg SOM and Emeabiam soil recorded 34.6 g/kg SOM. Generally, Emeabiam soils had more WHC ranging from 0.46 cm^3/cm^3 to 0.52cm^3/cm^3 while Ihiagwa soils ranged from 0.44cm^3/cm^3 to 0.50 cm^3/cm^3. Nature of particle size distribution differed as Ihiagwa soils had more Sand-sized particles than Emeabiam soils. Curell (2011) reported low waterholding capacity in soils dominated by sand-sized particles, which could also be responsible for low organic matter content of Ihiagwa soils in line with reports of Mehra *et al.* (2018) that a lot of soil organic matter is lost readily transportability of soil materials over sandy soils

Table 3: Saturated hydraulic conductivity and soil moisture

Site	Depth cm	Ksat (cm/sec)	WHC (cm^3/cm^3)
Ihiagwa	0-5	9.25 x 10^{-3}	0.46
	5-10	7.17 x 10^{-3}	0.44
	10-15	6.27 x 10^{-3}	0.48
	15-20	5.85 x 10^{-3}	0.50
Emeabiam	0-5	9.85 x 10^{-3}	0.52
	5-10	8.22 x 10^{-3}	0.46
	10-15	7.20 x 10^{-3}	0.49
	15-20	5.91 x 10^{-3}	0.51

Ksat = saturated hydraulic conductivity
WHC = water holding capacity

CONCLUSION

Ihiagwa soil indicated weak granular soil structure at the epipedon compared with moderate grade of soil structure exhibited by Emebiam soils at the topmost layer. Mean weight Diamer showed grater aggregation in soils of Emebiam. Emebiam soils retained more water compared with soils of Ihiagwa and movement of water was higher in the soils of Emeabiam.

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