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Distribution of soil quality indicators in Fadama soils of Anambra State Southeast, Nigeria

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ABSTRACT

Fadama soils are low lying flood plain soils found along river bank areas of Anambra state prone to flooding. The present study investigated the distribution of soil quality indicators in Fadama soils in Anambra State. Soil sample for the study were collected from 7 different locations across the state which were Ubahuekwem, Ogbakuba, Igbakwu, Ezi-Anam, Ogboji, Ugbenu and Ufuma. Sixty (60) samples were randomly collected from rice farms in each of the location to form a composite. These samples were analyzed for physical, chemical, heavy metal content and structural stability etc. Result findings showed the soils are acidic (pH 3.75-5.88). Organic matter content of the soils varied 1.59-4.29%. There was high concentration of P in aggregate sizes of the soils relative to OC and N concentration. Positive significant ($P<0.05$ and $P<0.01$) relationship existed between structural stability and most chemical soil indicators such as N, OC, OM, P and Na. Calcium (Ca), magnesium (Mg) and effective cation exchange capacity (ECEC) showed a highly negative relationship with sand respectively. Soil quality for the different location suggest that Igbakwu and Ezi-Anam were most suitable when considering chemical indicators and Ezi-Anam and Ogbakuba for structural stability of the soils. From the result findings the Fadama soils in Anambra state will require nutrient management to optimize crop production in the areas studied.

Keywords: Fadama, soil quality indicators, Land use management, Flooding, Erosion.

1. INTRODUCTION

Soil - an integral part of the earth ecosystem is a natural filter, habitat for diverse soil organisms, animal and man; a natural medium for crop production, hence a living entity with chemical, biochemical interactions and physical qualities that define its health status. Thus SSSA, (2008) and FAO, (2015) reiterated that, soil is unconsolidated organic material on the surface of the earth that supports plant growth, regulates nutrients and hydrological cycles and habitat for diverse range of soil organisms. For Lal, (2015) soil plays a major role in C cycling, serving as both source and sink for atmospheric CO2. In all, soil is a major foundation for agricultural activities to ensure food security for increasing population. Without healthy and quality soil however, increased food production will not be adequately achieved and hunger will become more prevalent.

The health status and quality of soil vary greatly and are dependent on a wide range of factors, like human activities, weather, location, topography, management practices etc. Thus, to assess soil quality, fertility status, biological activity, structure etc. certain set of indicators are to be measured to help farmers make decisions on land use and management practices. According to FAO, (2006) soil quality indicators are categorized into physical, chemical and biological indicators. The physical indicators can relate to soil depth, water infiltration, structural stability, bulk density, porosity, compaction, texture etc., while chemical indicators relate to soil pH, OM content, availability of P, cation exchange capacity (CEC), salinity, presence of radioactive substances and heavy metals as well as organic compounds.

These indicators as argued by Mairura et al., (2007), control or influence soil – plant – organism interactions or atmosphere, nutrient availability, mobility of contaminants, water and nutrient uptake by plant and organisms. In Nigeria, Fadama is a Hausa language (Hausa is tribe located in the northern part of Nigeria) and a name designated for wet land soils. Bello, (2006) noted that over four (4) million hectares of such lands identified and classified as Fadama soils which are scattered along the river systems of Nigeria and are capable of supporting intensive cultivation and grazing. Described these lands as the 'kidney of the landscape' because to him these lands function as the downstream receivers of water and waste from both natural and human sources. While some other authors like Ojanuga et al., (2003) described wet land as the lands where water table is at or near or above the land surface; long enough to promote the formation of hydric soils or to support the growth of hydrophytes.

Wet land soils contribute ideally to crop production, food security, soil fertility, water quality, conservation of biodiversity etc. Many of the contributions were documented (Zedler and Kercher, 2005; Chen et al., 2019; Mandal et al., 2021). Fadama soils characterized by their high-water content and nutrient-rich composition are critical resource for crop production activities and rural livelihoods for farmers especially poor resource farmers in a low lying and flood plain areas. It is pertinent to note that Fadama soils (wetland soils) due to the high ground water table and frequent water accumulation expose the soils to sodicity and salinity problems which are harmful to soil, its habitats and crop productivity. Hence, this is subject to reduction in value, human exploitation through urbanization, climatic changes and other environmental challenges.

These challenges can impact on their distribution, capacity, efficient productivity and management. Climate for instance can cause changes in water distribution and availability. While urbanization can lead to soil degradation and loss of fertility. All affect soil productivity and food security. Regarding these challenges Fadama soils prevalent in areas with high water tables and frequent flooding as observed in Anambra State, become topic of significant interest and important study on the distribution of soil quality indicators in these soils and their structural stability for effective agricultural activities. The objective of the present study therefore is to assess the distribution of soil quality indicators in aggregate sizes and micronutrient status of the soils and to relate the aggregate stability of the soils to chemical and micro-minerals of the soils.

2. MATERIALS AND METHODS

Site Description

The study was carried out within Anambra state, Nigeria. The towns where the soil samples were collected include; Ubahuekem, Igbakwu, Ufuma. Ogboji, Ugbenu, Ezi-Anam and Ogbakuba. The study area is situated between Latitudes 5° 32I and 6°45IN and Longitude 6°43I and 7° 22IE (Ezenwaji et al., 2014). According to Ifeka and Akinbobola, (2015), the towns listed above in Anambra experience warm humid tropical climate, with average rainfall between 1520-2020 mm/annum. The rainfall pattern is characterized by a dry season (November to March), with dry continental North-East winds dominating during this period and a long-wet season which occur normally from April to October, and dominated by the moist maritime south-west winds (Nzoiwu et al., 2017). Also, according to Ezenwaji et al., (2014) the climate shows that annual mean minimum temperature is 23 °C while the annual mean maximum temperature is 32 °C. Ogbakuba has more wetlands than the other locations. It is located in the south western part of Anambra State (Ekenta et al., 2015).

Soil Sampling

Soil samples were collected with soil Auger at 0-20cm depth from seven locations, which were (Ubahuekem, Igbakwu, Ufuma. Ogboji, Ugbenu, Ezianam and Ogbakuba) in Anambra state. Sixty (60) samples were randomly collected from rice farms in each of the location to form a composite. The soil samples collected were used to determine the variability in soil physical and chemical properties. The soils collected were put in polythene bags to prevent contamination as well as minimize moisture loss, they were further transported to the laboratory for analysis. These samples were used for the determination of soil physical and chemical parameters.

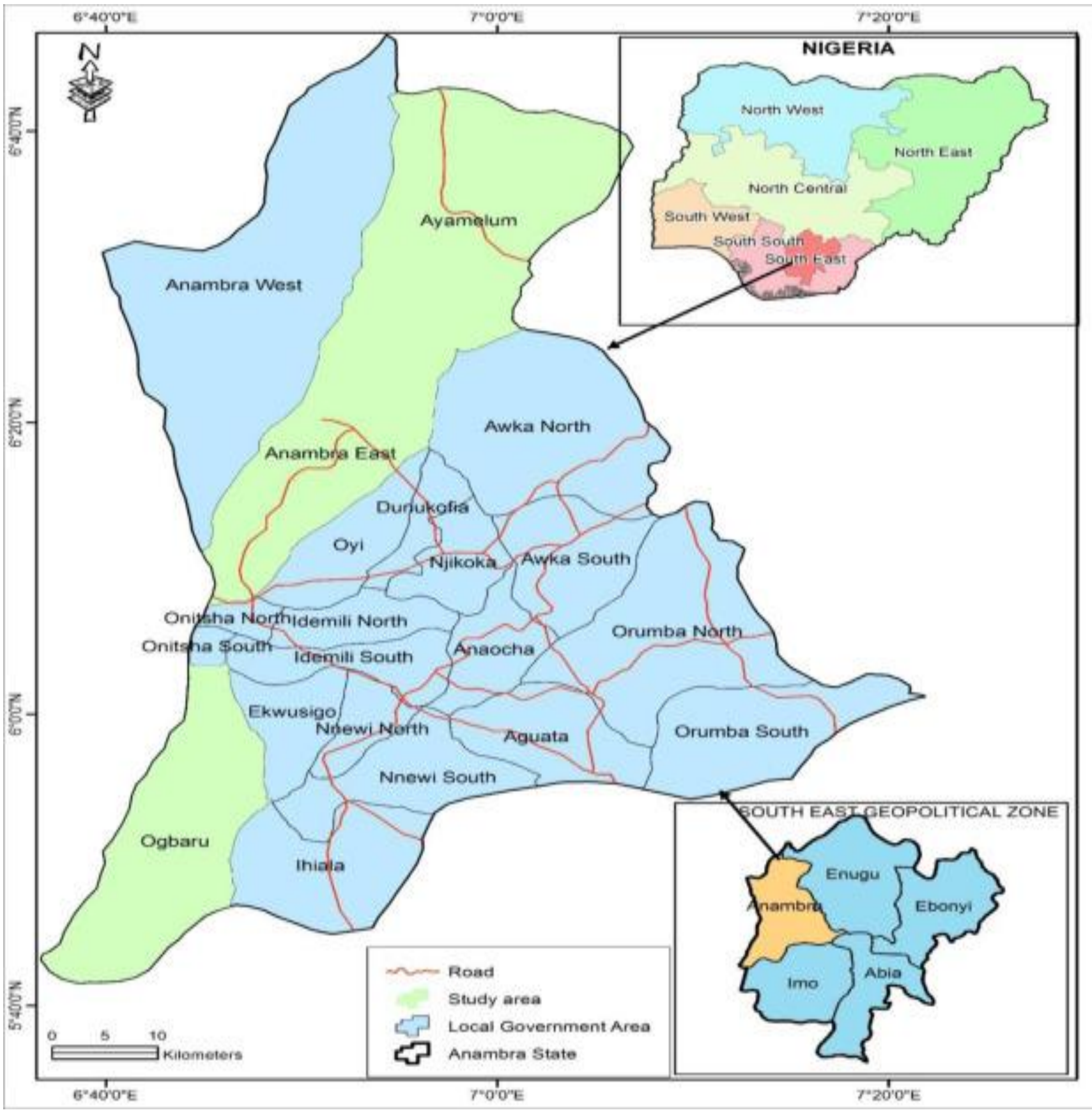


Figure 1 Map of Anambra showing study locations.
Source: Modified from divagis.org

Laboratory Methods

Soil physical analyses

Mean-weight diameter of wet aggregates (MWDW)

The method of Kemper, (1965) was used to determine the mean-weight diameter of wet aggregates. In accordance with the procedure, 40g of soil was pre-soaked for 5 minutes on the topmost sieves of diameters 2, 1, 0.5 and 0.25 mm, then vertically oscillated for 20 times at the rate of 1 oscillation per second. The resistant aggregates were oven-dried and their masses recorded. The mean weight diameter of wet aggregates (MWDW) was computed thus,

$MWDW = \sum_{i=1}^{n} xiwi$ ---------------- (equation 1)

Where;

MWDW = Mean weight diameter of wet Aggregates (mm)

$\sum$ = Summation

n = number of observations of ith

xi = the sum of the product of the mean diameter of each size fraction

wi = proportion of the total sample weight wi of each size fraction

State of aggregation, Degree of aggregation, and Soil Dispersibility

The wet and dry sieving method was used to determine the soil aggregate stability as described by Yoder, (1936);

$$\text{State of Aggregation} = \frac{\text{wt. of water stable aggregates} - \text{wt. of sand}}{\text{Wt. of sample}} \times \frac{100}{1} \quad \text{--------(2)}$$

$$\text{Degree of aggregation} = \frac{\text{wt. of water stable aggregates} - \text{wt. of sand}}{\text{Wt. of sample - weight of sand}} \times \frac{100}{1} \quad \text{------------(3)}$$

Where;

wt. = Weight

Soil dispersibility was determined by a method similar to Middleton (1930), dispersion ratio.

$$\text{Soil dispersibility} = \frac{\text{(clay)}}{\text{(clay + silt)}} \times \frac{100}{1} \quad \text{-------------------- (4)}$$

Water stable aggregates

Method modified by Kemper and Rosenau, (1986), was used to determine the mean weight diameter (MWD). Mean weight diameter of wet-sieved aggregates. 50 g of the 5.00 mm aggregates were placed on the topmost of a stack of sieves with descending mesh size (2, 1, 0.5, and 0.25 mm) from top to bottom. The samples were first immersed in distilled water and then sieved by moving the sieve set vertically. The soil retained by each sieve was dried at 60 °C for 24 hours, weighed and corrected for sand/gravel particles to obtain the proportion of water-stable aggregates

Aggregates size distribution (W/W)

For the determination of aggregate size distribution, the weight ratio of aggregates of each sieve to the total weight of aggregates was calculated.

$$\text{Dispersion ratio (DR)} = \frac{\text{Silt (\%) + Clay (\%) (water)}}{\text{Silt (\%) + Clay (\%) (calgon)}} \quad \text{------------------- (5)}$$

Soil chemical parameters

Soil pH: Soil pH was determined by using a pH meter in a soil solution ration of 1:2.5.

Exchangeable bases: Exchangeable bases were determined from the soil samples through normal ammonium acetate solution. Calcium (Ca) and magnesium (Mg) were determined by the EDTA titration method, while sodium (Na) and potassium (K) were determined using flame photometer (Black et al., 1965).

Total nitrogen: Total nitrogen was analyzed using the procedures as described by (Adepetu, 1990).

Organic carbon: Organic carbon was determined by using the Walkley and Black, (1934) methods as described by (Nelson and Sommers 1982). The Bray 1 method as described by was used for extractable phosphorus.

Effective Cation Exchange Capacity (ECEC): The cation exchangeable capacity (CEC) was determined by ammonium acetate saturation method.

Percentage Base Saturation (PBS) was calculated by dividing the sum of the charge equivalents of the base cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) by the CEC of the soil and multiplying by 100.

$$\% BS = \frac{TEB}{CEC} \times 100 \quad \text{----------- (6)}$$

Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percent (ESP)

ESP and SAR was calculated using the equation;

$$SAR = \frac{Na^+}{[(Ca^{2+} + Mg^{2+}) / 2]^{0.5}} \quad \text{------------------ (7)}$$

While ESP was calculated as;

$$ESP = \frac{Ex.\ Na}{CEC} \times 100 \quad \text{-------------------- (8)}$$

Where;

ESP = Exchangeable sodium percentage (%)

Ex. Na = Measured exchangeable Na^+ $cmolkg^{-1}$

CEC = Cation exchange capacity $cmolkg^{-1}$

Heavy metals Determination

Manganese (Mn) was determined by spectrophotometric method, using Morpholine Dithiocarbomate as described by (Madhavi and Saraswath, 2013). Iron (Fe) was determined by spectrophotometric method using atomic adsorption as described by (Kopacek et al., 2001).

Soil Chemical Quality Assessment

Soil chemical quality assessment was determined by using the soil management framework (SMAF) technique as described by (Andrews et al., 2004). The technique was based on the guidelines that soil quality can be assessed by a combination of different properties of the soil; thus, no single indicator can represent the condition of the soil. The laboratory analysis results were combined into a quantitative index using the soil management assessment framework (SMAF). The combination was based on the critical values of the indicators and soil function (Andrew et al., 2004).

The soil chemical quality indicators such as soil pH, organic carbon, total nitrogen, available phosphorous, exchangeable bases, manganese and Iron, sodium adsorption ratio, exchangeable sodium percent (Ca, Mg, K, Na, CEC and EC, Mn, Fe, SAR and ESP) was given relative weights and the entire weights added up to 100%. Standard scoring functions as described by Wymore, (1993) was used to combine the different indicators in order to convert numerical or subjective ratings to unit less values on a scale of 0-1. The scoring was assigned according to the critical values of the indicators while weights was done according to the level of importance of the indicator to crop production. Following the scoring of the indicator, the values obtained was multiplied by the appropriate weights and a matrix was produced as below.

$$Q = n / \sum IW$$

Where

Q = Soil chemical quality for crop production x

I = Indicator

W = Relative weight

n = nth indicator

Therefore, soil chemical indicators with their relative weight assigned will be as follows; soil pH (0.10), organic matter (0.20), exchangeable cations like Ca (0.10). Mg (0.10), K (0.10), Na (0.00), N (0.10), P (0.10) and CEC (0.00).

Statistical Analysis

Data collected from the site was subjected to descriptive statistics and correlation analysis using the statistical package SPSS. Multiple correlation was used to find the relationship between the tested parameters and soil quality indicators. Descriptive statistics was used to understand trends and patterns for individual properties for different locations and different properties for individual locations. Pearson's correlation(r) was performed to identify the relationships between physical properties, chemical properties, stability status of the soil, and concentrations of heavy metals and their pollution potentials. The correlation matrix of the relationships was done at 1% and 5% level of significance.

3. RESULTS AND DISCUSSION

Concentration of C, N and P in aggregate sizes of soils of different location

The OC, N and P concentrations of the aggregate fractions of the soils of the 7 locations are given in (Table 1). The concentration of the parameters of the aggregate sizes varied among the soils of the 7 locations. The result of OC showed that lowest concentration of OC (0.02%) for the soils in 5-2 mm fraction was obtained from Ogbakuba, while Ufuma, Ogboji and Ezi-Anam recorded zero (0) OC concentration. The OC concentration in 2-1 mm fraction indicated higher concentration in Ubahuekwem soils followed by Ogbakuba and the least in Ezi-Anam soils. The concentration of OC in 0.5-0.25mm fractions showed relatively higher concentration compared to other fractions of the seven soils. Higher concentration of 1.69% OC was recorded in Ubahuekwem soils next in rank was Ezi-Anam soils, while the same value of 1.554% OC was recorded in Ufuma and Ugbenu soils respectively.

Higher concentration of OC in < 0.25mm fraction was recorded from Ufuma soils relative to other soils and the least value (0.84%) obtained from Igbakwu soils. For each of the soil location, the result of OC showed increased value as the aggregate sizes decreased though the increase did not follow a particular order. The increased concentration of OC observed in smaller fractions compared to larger fractions could suggest that cultivation has caused destruction of the largest aggregates leading to loss of OC. This may be responsible for the zero (0) value recorded in larger aggregates of Ufuma, Ogboji and Ezi-Anam soils. The zero (0) value could as well be attributed to the loss of OC in water solution by wet-sieving process through the disintegration of OM binding agents.

The low OC concentration observed in the soils could be associated with cultivation that increase rapid disintegration of OM binding agents. The protective effect of clay on OM or dissolution of OM and moving out with water solution might be the reason for a higher, concentration of OC recorded in some of the fractions compared to the others. The OC concentration equally varied with the location of the soils, and when considered on the average, there was an increase in OC content as the aggregate sizes decreased. The macro-aggregate >250mm had greater OC than micro-aggregates 250mm (Buyanovsky et al., 1994; Nweke and Nnabude, 2014). The total N concentration in the aggregate sizes of the soils and location was observed to be very low compared to the recorded values of OC and P in the fractions.

In aggregate size 5-2mm, zero (0) concentration of N was recorded from Ubahukwem, Ogboji and Ugbenu, while the least value of 0.01% N was recorded in 1 – 0.5mm fraction from Ogbakuba soils. Igbakwu and Ufuma, as well as Ogboji and Ezi-Anam recorded 0.042% N, and 0.028% N in 2-1mm aggregates respectively. While in 1-05mm Igbakwu and Ogboji recorded 0.07% N respectively. There was higher N concentration in 0.5-0.25mm relative to other size fractions, a higher value (0.090 % N) was obtained from Igbakwu and Ezi-Anam relative to other soil locations and least value (0.044%N) from Ogbakuba. The N concentration in <0.25mm fractions showed least value (0.042%N) in Ubahukwen relative to other soil locations. In contrast Igbakwu and Ezi-Anam (0.084% N), Ogboji and Ugbenu (0.07% N) recorded the same value respectively.

On the average higher concentration of N was observed in 1-0.5mm relative to other fractions and in Ezi-Anam compared with other locations. This probably may be due to the Om content in the fractions and in the soils, this suggests that Ezi-Anam soils are less weathered than the other soils and that may have influenced the higher total N value observed in Ezi-Anam soils. Additionally, Ezi-Anam has the highest silt and clay content compared to the other soils. The two (sit and clay) particle fractions generally have a higher surface area to volume ration and as such can increase the adsorption and retention of N on soil surfaces of Ezi Anam soils compared with the other soils. The value of N increased as the aggregate fractions decreased. The percentage increase in total N content in 0.5-0.25mm relative to 5-2 mm and 2-1.0mm fractions were 233.33% and 150% respectively.

The total N obtained from Ufuma soils was small compared to what was recorded in other soils. This may simply suggest that the Ufuma soils are more weathered and show the ultimate effects of leaching than the other soils. The low variation of total N observed in these soils may have been due to their hydromorphic nature. And this inhibits aerobic micro-organism activities, hence lowering the decomposition of readily decomposable organic compounds and release of N in the soil. Similarly, N according to Sharpley et al., (2009) is mainly in the form of $NH4+$ and $NO3-$ in soil and therefore can adsorb on to soil particles and be held in the soil CEC. The available P concentration in the aggregate sizes of the 7 locations showed a higher value compared to OC and N concentrations. The order of P concentration by fractions is 0.5-0.25mm > 1.0-0.5mm> <0.25mm > 2-1mm > 5-2mm and by location is Ezianam > Igbakwu > Ogbakuba > Ufuma > Ogboji > Ugbenu.

The observed variation in available P could be attributed to the mineralogical composition that differed in their attack during weathering, as well as silt and clay contents (Table 3, 6) of the soils. Clay absorb many nutrients and has effect on their decomposition process. In line with the present study, Sharpley et al., (2009) reported a higher concentration of available P in 0.5 – 0.25mm fraction compared to other fractions. Soil particles smaller than 0.5mm have a higher adsorption capacity for available P due to the presence of active surface sites such as Al and Fe oxides. Unlike the OC and N concentrations, all fractions of the soils contain P. This scenario can lead to an increased nutrient uptake and improved root development (Vance et al., 2003; Lynch and Brown, 2001).

Table 1 Concentration of C, N and P in aggregate sizes of the different soil locations

Location	Aggregate. Size	C concentration	N concentration	P concentration
UBAHUEKWEM	5-2mm	0.16	0	7.5
	2-1mm	1.16	0.056	5.4
	1-0.5mm	1.74	0.098	28.6
	0.5-0.25mm	1.69	0.09	27.5
	< 0.25mm	1.20	0.042	25.5
Mean		1.19	0.057	18.9
IGBAKWU	5-2mm	0.14	0.101	4.8
	2-1mm	0.34	0.042	11.2
	1-0.5mm	1.13	0.07	31.4
	0.5-0.25mm	1.30	0.154	35.6
	< 0.25mm	0.84	0.084	27.6
Mean		0.75	0.090	22.12
UFUMA	5-2mm	0	0.101	11.2
	2-1mm	0.54	0.042	4.2
	1-0.5mm	1.26	0.084	20.4
	0.5-0.25mm	1.54	0.07	17.4
	< 0.25mm	1.27	0.085	15.6
Mean		0.922	0.076	13.76
OGBOJI	5-2mm	0	0	3.0
	2-1mm	0.48	0.028	5.2
	1-0.5mm	1.24	0.07	13.8
	0.5-0.25mm	1.22	0.056	16.8
	< 0.25mm	1.12	0.07	14.9
Mean		0.812	0.045	10.74
UGBENU	5-2mm	0.114	0	3.6
	2-1mm	0.56	0.014	3.0
	1-0.5mm	0.69	0.098	9.7

	0.5-0.25mm	1.54	0.14	12.2
	< 0.25mm	1.04	0.07	13.1
Mean		0.789	0.064	8.32
EZI-ANAM	5-2mm	0	0.028	1.4
	2-1mm	0.29	0.028	8.8
	1-0.5mm	1.42	0.21	33.7
	0.5-0.25mm	1.57	0.098	36.4
	< 0.25mm	0.96	0.084	37.4
Mean		0.848	0.090	23.54
OGBAKUBA	5-2mm	0.12	0.014	4.3
	2-1mm	0.67	0.056	6.0
	1-0.5mm	0.56	0.01	29.8
	0.5-0.25mm	1.39	0.075	33.1
	< 0.25mm	0.88	0.064	30.9
Mean		0.724	0.044	20.82

Correlation matrix of C, N and P in the aggregate sizes of the soils of seven locations.

The correlation result presented in Table 2 indicated highly significant (P <0.01) positive relationship between carbon (C), nitrogen (N) and phosphorous (P) content of the soils. This is in line with the work of Brenda et al., (2024), Oliver et al., (2024), Azuka and Igue, (2020) that reported significant positive relationship between C, N and P and even with some other soil properties. The significant positive relationship between the parameters can be associated to the OM content (Table 3) of the soils. Organic matter influences positive soil aggregation, hence the positive correlation coefficient. The amount of OM in soil greatly influence stability of soil aggregates in water, Nweke, (2015), hence measures of good soil structure.

From Table 1, it was also observed that P concentration was higher than C and N concentrations. According Elser et al., (2007) the scenario is against recommended ratios of 1 unit of P to 106 units of C to 10 units of N. This simply suggests that the uptake of OC and N can be limited. The excess of P can interact with other soil minerals to form insoluble compounds that are not easily available to the plants. In their studies found out that excess P application in Fadama soils without sufficient N and C led to the accumulation of P. Their studies equally found out that the imbalance of nutrients also led to increased soil acidity which further exacerbate the adverse effects on soil that invariably affect plant health.

Table 2 Correlation between C, N and P concentrations in the aggregate sizes of the soils

	Carbon	Nitrogen	Phosphorus
Carbon	-	-	-
Nitrogen	.917*	-	-
Phosphorus	.942**	.928**	-

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

Distribution of Soil chemical properties of the soils.

The chemical properties of the soils in Table 3 showed that base saturation (BS) value of the soils ranged from 58.30% - 95.90%. Ogbukuba had the highest (95.90%) base saturation and Ubahukwen with the least base saturation (58.30%). The result may be associated to their clay content, and this may cause imbalance in nutrient availability of the soils. The lower value obtained from Ubahukwen and Igbakwu compared to the other soils could be due to loss of some cations from cation exchange complex of the two soils or the presence of low activity clays such as kaolinite and Fe-oxy-hydroxides. The pH of the soils measured in water was generally acidic. But among the soils, Ogboji soils showed strongly acidic with pH level 3.75.

This pH level (3.75) may cause less nutrient availability and poor soil structure, as evident in its OM content (Table 3) and structural stability status (Table 6). The Moderately and strongly acidic nature of the soils could be attributed to the intense rainfall that the study area often experiences in association to extensive leaching of basic cations due to coarse texture of the soils that result from high weathering. The amount of Ca and Mg which are the dominant exchangeable bases (Table 3) in soil solution of the soils might have also influenced the result obtained. Because an increase or decrease in pH is associated with an increase or decrease in the amount of Ca and Mg in the soil solution. Generally, in Fadama soils rice plant can thrive well in pH range of 4.5-9.0.

The availability of P content of the soils ranged from 12.20-38.40 mgkg-1, which is higher in Igbakwu soils and least (12.20mgkg-1) in Ugbenu soils. The available P scenario of the soils could be associated with some factors, such as the pH level of the soils, OM content, P desorption and sorption by Fe and Al phosphate, as well as the type and nature of P-fertilizer used for rice production in these soils. All these in part might have contributed to the available P value obtained in these soils. The TN, OC and OM content of the soils varied among the soil locations. OM is the source of N in the soil. The low levels of N and OC content of the soils may be attributed to high productivity and reduced decomposition associated with Fadama soils.

The two parameters apart from Ubahukwem with 2.49 OC% are below their critical level for crop production (Greenland et al., 1975; Greenland et al., 1992). The value obtained ranged among the soils from 0.09 – 0.22% N and from 0.95 – 2.49% OC respectively. The OM content recorded for the soils were low except for the Om content of Ezi-Anam soils that recorded 4.29%. The OM value obtained from Igbakwu, Ufuma and Ogboji were relatively alike. Soil OM is an important soil parameter that stores soil nutrients and prevents them from leaching and other environmental challenges. Apart from the EziAnam soils, the recorded value of OM in all other soils was below the critical level of 3% specified in FAO, (1979), suggesting that crop production cannot be adequately sustained under continuous land use without proper and appropriate soil amendment in these soils.

The result situation concerning OC, N and OM content of the soils may have resulted probably from decomposable quantity of OM present in the soils, rate of materials in transportation, deposition and mineralization at the various physiographic position as well as other anthropogenic activities. Another critical possibility of low OC/OM and N content is that in flooded soils, organic matter degradation is retarded, probably due to the lower C assimilation rate of anaerobic bacteria, where facultative and obligate anaerobes make use of NO3-, SO42-, Fe3+, Mn4+ etc. dissimilation product of OM. In contrast, in their respiration they use CO2 and H+ as electron acceptor. The result scenario is in line with the work of Nsor and Adesenmuyi, (2016) in soils of southeastern, Nigeria.

The exchangeable bases (Ca, Mg, K, Na) result showed variations among the soils studied. The Ca 2-12.60 cmolkg-1, while Mg ranged very low to medium value, 1.40-6.60 cmolkg-1. Ubahukwem and Ogboji (3.0 cmokg-1), Igbakwu and Ezianam (5.0 cmolkg-1), Ufuma and Ugbenu (1.40cmolkg-1) recorded the same value of Mg respectively. The dominance of Ca could be attributed to Ca being the least lost from the soil exchange complex. The order, of loss is Ca < Mg < Na < K. The higher concentration observed in Ogbakuba for Ca, and Mg could be associated to parent materials of the soil, abundant biological activities as well as plant and animal residues at the top soil. Kiflu and Beyene, (2013) asserted that parent materials plays a significant role in determining its Ca and Mg concentration.

The K content of the soils was very low and below critical level. The presence of K in soil is enhanced by the solvent actions of carbonic acids, humus, and acid clays. Among the soils Igbakwu recorded highest exchangeable Na value of 9.29 cmoikg-1. The exceptional increase in Na might be an indication of high susceptibility of Igbakwu soils to disaggregation of soil particles relative to other soil locations. However, the result of ESP and SAR recorded in Table 4 showed the opposite result to Na value, indicate that Na+ may not have played its dispersive role in Igbakwu soils. The result scenario obtained in these soils for the exchangeable bases (Ca, Ng, K, Na) could be attributed to the parent material from which the soils are formed, the porous nature of the soils, the high weathering and rainfall intensity that result to leaching losses, and low SOC.

Soils with low OC lack the capacity to hold cations in the exchange sites. The exchangeable acidity (EA) are generally low in the soil studied. Thus, indicate absence of the possibility of Al-toxicity that might be detrimental in rice production in the Fadama soils studied. The recorded value was highest in Ogbakuba and least in Ezi-Anam. The EA maintains an inverse relationship with pH, this is likely why Ezi-Anam one of the most acidic soils (Tables 3) has the highest exchangeable acidity. The ECEC of the studied soil varied low to moderate value (5.93-22.78 cmolkg-1), with Igbakwu recording the highest value and Ufuma the least value. The ECEC measures the soil's capacity to hold positively charged ions.

It is very significant as it impacts soil structure stability, nutrient accessibility, soil hydrogen content (pH) and reaction of soil to fertilizer and other ameliorants (Dan et al., 2018). This is likely to be due to cation exchange capacity (CEC) being a property of the colloidal fraction of soil derived mainly from the clay and OM fractions. According to soils with ECEC value above 4cmolkg-1 could withstand heavy leaching. The soil quality result of the studied soils is relatively alike with least value in Ubahukwen soils. From the recorded result it showed that soil quality increases as phosphorous and sodium contents of the soils increased. Phosphorous is known to improve nutrient availability, OM decomposition and encouraged robust root growth.

Adequate amount of Na promotes soils aggregation and improve soil structure and prevent dispersion of clay in certain soils. The result in Table 3 showed good soil quality, though of different degrees and range between 30.78%-30.25%. The changes in the indicators assessed signaled the changes in soil quality according to (Brejda and Moorman, 2001). While Andrews and Carroll, (2001) suggested that dynamic of soil quality (SQ) assessment could be viewed as one of the components needed to quantify agroecosystem sustainability.

Table 3 Distribution of soil chemical properties

LOCATION	BS (%)	pH (H2O)	P (mg/kg)	TN (%)	OC (%)	OM (%)	Ca (Cmol/kg)	Mg (Cmol/kg)	K (Cmol/kg)	Na (Cmol/kg)	EA (Cmol/kg)	ECEC (Cmol/kg)	SQ (%)
UBAHUE KWEM	58.30	5.88	28.45	0.15	1.59	2.73	2.00	3.00	0.14	0.80	0.14	9.12	20.78
IGBAKWU	59.24	4.20	38.40	0.10	0.95	1.62	8.20	5.00	0.15	9.29	0.15	22.78	30.25
UFUMA	85.14	4.55	21.98	0.11	0.97	1.66	3.40	1.40	0.11	0.88	0.11	5.93	25.10
OGBOJI	71.00	3.75	16.65	0.09	0.98	1.68	4.40	3.00	0.12	2.66	0.12	10.78	29.70
UGBENU	73.05	4.07	12.20	0.13	1.27	2.18	3.00	1.40	0.12	1.72	0.12	6.39	26.90
EZIANAM	81.50	4.20	36.35	0.22	2.50	4.27	8.20	5.00	0.19	3.08	0.18	16.65	30.00
OGBAKUBA	95.90	5.61	31.55	0.100	1.14	1.96	12.60	6.60	0.12	0.84	0.10	20.25	23.40

BS = Base saturation, P = Phosphorous, TN = Total nitrogen, OC = Organic carbon, OM = Organic matter, Mg = Magnesium, K: potassium, Na: Sodium, EA: Exchangeable acidity, ECEC: Effective cation exchange capacity, SQ: Soil quality.

Distribution of micronutrient and pollution potential of the soils.

The results in Table 4 showed Ezi-Anam soils to be high in Mn and Fe relative to other soils value. In contrast Ufuma soils recorded the least value of 2.83mgkg-1 Mn and 2.28mgkg-1 Fe. The availability of Mn and Fe in the soils are mainly affected by soil pH, OM and exchangeable bases like Ca and Mg (Table 3). Exchangeable sodium percent (ESP) was recorded highest in Ugbenu and Ufuma soils, its value was 1.95% and 1.83% respectively, they also recorded the highest (0.05molL-1) value of SAR. Sodium hazard is expressed in terms of sodium adsorption ratio (SAR). When Na replaces adsorbed Ca and Mg in exchange site it becomes detrimental to soil structure causing impermeable and compact problems that are not ideal for crop root growth and development. Even with the flooding nature of the soils the average SAR value was generally low, below 13molL-1 considered the threshold for soil to have adverse effect on soil structure (Liz et al., 2020).

Table 4 Distribution of heavy metals and pollution potentials

LOCATION	Mn (mgkg-1)	Fe (mgkg-1)	ESP (%)	SAR (molL-1)
UBAHUEKWEM	5.99	3.83	1.48	0.03
IGBAKWU	5.94	3.07	0.65	0.02
UFUMA	2.83	2.28	1.83	0.05
OGBOJI	4.81	3.15	1.13	0.03
UGBENU	6.14	4.68	1.95	0.05
EZIANAM	20.09	10.92	1.10	0.03
OGBAKUBA	5.52	3.02	0.50	0.01

Variability in size distribution of different soil locations.

The variability in the size distribution of the soils in Table 5 showed Ubahukwem to have recorded 185.1% compared to the value recorded by the other soils. This indicate that it has a diverse range of aggregate sizes that made it more structurally stable and less prone to erosion and soil dispersibility. Though it has less OM content, less Ca and Mg, which would affect the structure stability of the soils. The large difference in aggregate size distribution among the studied soils demonstrates the sensitivity of the wet sieving procedure in detecting differences in aggregation among soils. Also, the differences in particle size distribution among the seven (7) soils are wide and therefore may have explain the differences in aggregate size distribution of the soils. Observed similar variation in the size distribution of four contrasting soils of two different land use systems.

The stability of the sandy loam soils is likely to be due to the presence of a high number of aggregates between 2-1mm and 1-0.5 which are highly water stable. Water stable aggregates act as building blocks that hold soil particles together, enhance soil porosity and allow for better water infiltration and drainage to reduce the risk of erosion and support structural stability. The Table 5 result indicated that 5-2mm aggregate to be absent in soils of Ubehukwem, Ezi-Anam and Ogbakuba, but have large amount of 2-1mm and 1-0.5mm. These soils with no 5-2mm aggregate would likely have reduced water infiltration and drainage. However, Ezi-Anam and Ogbakuba soils are observed to have the highest structural stability among the soils by their SA and DA values (Table 6), which might have been influenced by their silt + clay content.

Table 5 Variability in size distribution of soils of different locations (%w/w)

LOCATION	5-2mm	2-1mm	1-0.5mm	0.5-0.25mm	<0.25mm	Variability
UBAHUEKWEM	0	41	24.2	14.4	16.1	185.1
IGBAKWU	1.4	33.8	21.9	10.6	14.8	99.63
UFUMA	0.58	24	36.4	8.8	8.4	141.2
OGBOJI	4.2	33.7	22.9	7.0	10.2	109.94
UGBENU	3.3	38.6	16.0	7.9	18.4	124.6
EZI-ANAM	0	37	16.7	19.8	22.6	141.77
OGBAKUBA	0	20.3	28.4	16.4	16.4	74.3

Structural Stability of the Soils

The result in Table 6 shows the particle size distribution and structural stability of the studied soils. Sand content among the different locations varied from 29.6% to 85.60%. The result revealed that the soils of the study sites were dominated by sand. This implies that the soils could display poor nutrient-holding capacity due to the relatively large pore spaces between sand particles (Pearson, 2019). Among all the studied locations, Ubahuekwem has 85.6%, which is the highest sand content. None of the soils in all the investigated land uses were severely impacted, as the value of sand were < 90%, which is the threshold value for severe impacts according to US (EPA, 2012).

The sandy nature of the soils could be attributed to parent material and climate as earlier reported by Iloeje, (1981) and Osujieke et al., (2017) on soils of southeastern Nigeria or erosion (Lal, 2001). The high percentage of silt + clay proportion may be due to sediment deposition (Iloeje, 1981). The textural class of the soils varied from sandy loam, silt loam to clay. Dispersion ratio which is the ability of clay and silt to be dispersed by water ranged from 23.02% (Ufuma), indicating the most stable structure and lowest erosion risk to 58.55% (Igbakwu). This suggests potential influence of tilling practice on soil compaction. High DR as recorded in Igbakwu soil might simply suggests high susceptibility to erosion. Basga et al., (2018) noted that high DR disorganize soil structure and facilitate mobilization of fine soil fractions that increase soil susceptibility to erosion.

Soil dispersibility ranged from 37.46% to 79.44%, lowest at Ogbakuba and highest at Ogboji. Soils with high soil dispersibility are easily dispersed which can cause erosion and poor soil structural stability. This is likely the reason Ogboji has the least structural stability. Water stable aggregate ranged 73.5g to 91.15g with Ezi-Anam soils having the highest water stable aggregate and an aggregate size distribution of 2.57%. This may likely be due to the high organic matter content, calcium and magnesium levels, and a high silt + clay proportion (Table 3, 6). Mean weight diameter, state of aggregation and degree of aggregation are found to be highest in Ezi-Anam (1.29mm, 36.64%, 43%) respectively as recorded in (Table 6).

The high MWD indicates that the soil has larger and more stable aggregates which may help to resist erosion. The state of aggregation also indicates that the soil's particles are bound together in stable aggregate, and the relatively high degree of aggregation indicates a strong bond between soil particles within aggregate. These properties all contribute to the high structural stability of Ezi-

Anam soils. Results in Table 6 further showed that the sandy loam soils of Ogboji and Ufuma had the least water stable aggregate of 73.50g and 74.93g respectively. The highest value of aggregate size distribution was seen in the silt loam soils of Ezi-Anam and Ogbakuba, which were 2.57g and 2.05 respectively. This may be due to the silt content of the soils.

Table 6 Structural stability status of the soils

LOCATION	SAND (%)	SILT (%)	CLAY (%)	TC	DR (%)	SD (%)	WSA (g)	ASD (%)	MWD (mm)	SA %	DA%
UBAHUEKWEM	85.60	3.90	10.50	Sandy loam	38.99	72.92	82.10	1.98	0.73	28.20	27.75
IGBAKWU	31.60	27.40	41.00	Clay soil	58.55	59.94	77.00	1.94	1.18	25.24	29.14
UFUMA	81.10	6.40	12.50	Sandy loam	23.02	66.14	74.93	1.94	0.84	25.15	28.94
OGBOJI	78.60	4.40	17.00	Sandy loam	25.97	79.44	73.50	1.72	1.10	21.00	24.27
UGBENU	62.60	22.40	15.00	Sandy loam	26.62	40.11	77.95	1.96	0.86	23.76	43.33
EZIANAM	29.60	37.40	33.00	Silt loam	35.90	46.88	91.15	2.57	1.29	36.64	43.00
OGBAKUBA	38.60	38.40	23.00	Silt loam	52.60	37.46	75.55	2.05	1.02	32.84	35.74

TC= Textural class, DR = Dispersion ratio, SD = Soil dispersibility, WSA= Water stable aggregates, ASD = Aggregate size distribution, MWD = Mean wet diameter, SA= State of aggregation, DA= Degree of aggregation

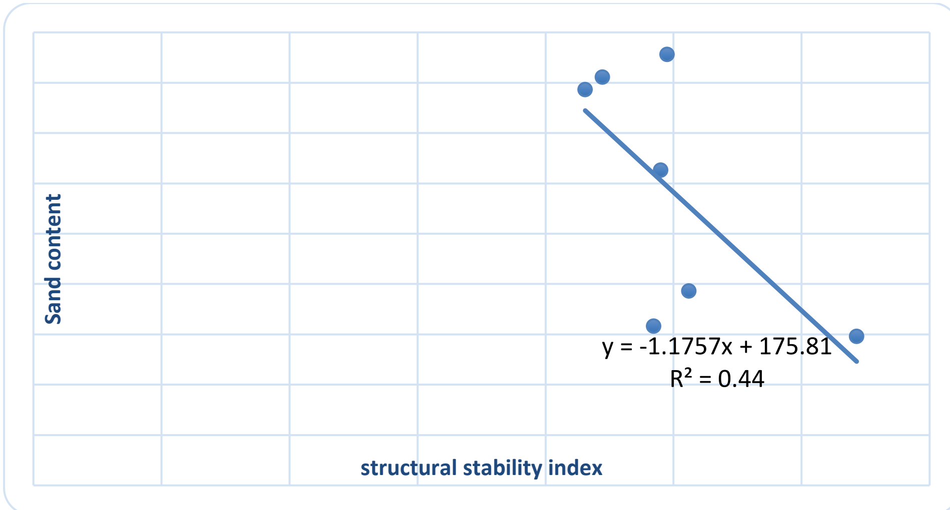
Relationship between structural stability and sand content, OM and silt content of the soils.

Figures 1, 2 and 3 showed the relationships between structural stability and the following soil properties; sand content, organic matter, and silt content. Structural stability is noticed to have a highly positive relationship with a medium negative relationship with sand content ($r = -0.663$, $P < 0.05$), organic matter ($r = 0.925$, $P < 0.05$) and a medium positive relationship with silt content ($r = 0.702$, $P < 0.05$). The negative relationship between structural stability and sand content may likely be due to the ease with which sand particles are lost to erosion caused by their large sizes and low cohesion. Organic matter plays a significant role in structural stability including binding soil particles to improve soil aggregation, preventing erosion by reducing susceptibility of soil to erosion. The relationship between structural stability and silt content involves providing cementing and binding agents to enhance structural stability.

Relationship between chemical properties and structural stability indices

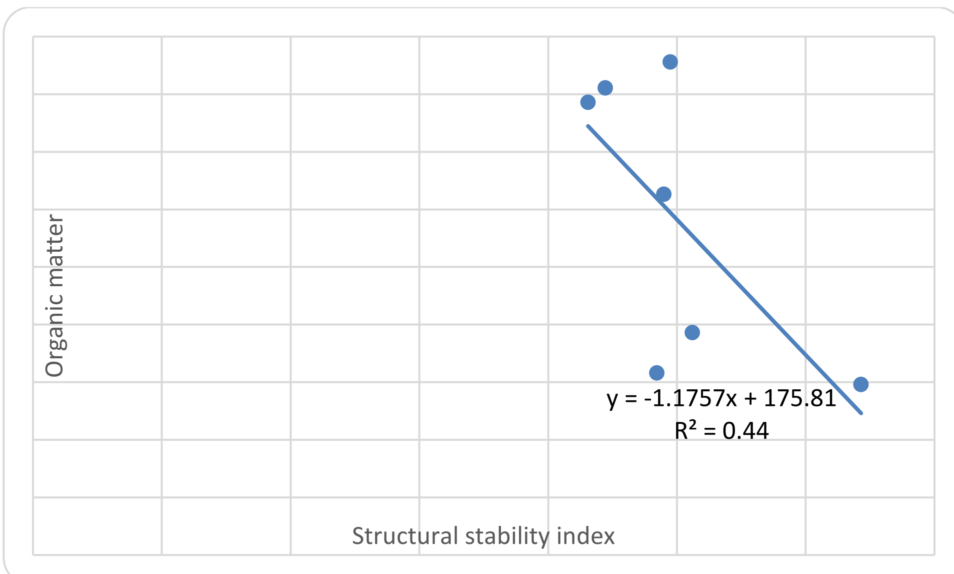
The relationship between the structural stability of the soils and the chemical properties analyzed is shown in (Table 7). A significant positive relationship is shown by nitrogen, organic carbon, organic matter and potassium with structural stability. The positive relationship between structural stability and the chemical properties is likely to be due to the interactions of the chemical properties within the soils. Nitrogen availability often is associated with high organic matter content, and during the decomposition process of organic matter, there is a release of organic carbon, this organic carbon acts as a binding agent and holds soil particles together improving soil structural stability.

Plant roots and its exudates which contribute to soil aggregation and stability of soil structure is highly dependent on nitrogen and potassium availability (Six et al., 2000). A significant negative relationship is shown by Ca, Mg and ECEC with sand. This negative relationship could likely be due to the differences in particle size and textural class of the soils. Sandy soils usually have lower Ca and Mg contents, as both properties are predominant in soils with finer particles. Sandy soils can also not hold and exchange cations, leading to a reduced ECEC content. Silt showed a highly positive significant ($P < 0.01$) relationship with Ca. This relationship is likely due to the high surface area and adsorption sites of silt particles that interact with ions, including calcium ions.



r = -0.66

Figure 1 Relationship between structural stability and sand content



r = 0.925

Figure 2 Relationship between structural stability and organic matter

Clay showed a highly positive significant relationship with EA and ECEC. This may be due to the large surface area of clay particles that provide more sites for the retention and exchange of cations, leading to higher EA and ECEC. Dispersion ratio (DR) showed a highly positive significant ($P<0.01$) relationship with P, Mg, and ECEC, due to the possibility of a high content of exchangeable cations. WSA has a significant positive ($P<0.05$) relationship with N, OC, OM, K and Na. Nitrogen promotes microbial decomposition of organic matter, while organic matter and organic carbon act as cementing agents that bind soil particles together. The cations, sodium and potassium help particles stick together and form stable aggregates acting as bridges. Therefore, as these properties increase, there is a concurrent increase in water stable aggregates.

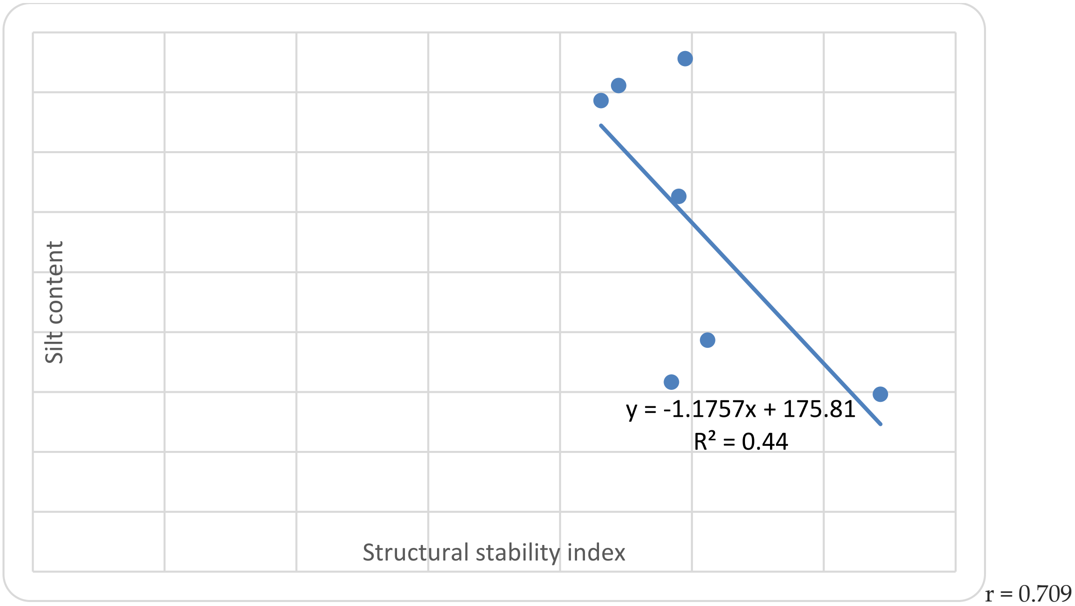


Figure 3 Relationship between structural stability and silt content

A similar relationship is seen in variability in aggregate sizes, except it has no significant relationship with Na. The significant (P<0.05) positive relationship between aggregate size distribution (ASD) and the chemical properties N, OC, OM and K is likely to be due to their interactions. They collectively contribute to the formation and maintenance of stable soil aggregates to improve overall soil health. SA has a positive significant (P<0.05) relationship with OC. This positive relationship may be due to the role of organic matter in soil structure formation and stability. Organic carbon may act as a binding agent helping to bind soil particles, it may also act as a bridge between soil particles making the aggregate more resistant to physical harms. Therefore, as organic matter increases, there is an increase in the state of aggregation.

Table 7 Correlation between chemical properties and structural stability status of the soil

	BS	pH	P	N	OC	OM	Ca	Mg	K	EA	Na	ECEC
AGG.STAB	0.217	0.063	0.570	0.861*	0.923**	0.925**	0.418	0.492	.863*	0.042	0.752	0.387
SAND	-0.243	0.138	-0.692	-0.239	-0.341	-0.554	-0.827*	-0.774*	-0.617	-0.558	-0.477	-0.851*
SILT	0.455	0.010	0.554	0.277	0.393	0.597	.842*	0.742	0.495	0.271	0.315	0.722
CLAY	-0.083	-0.310	0.751	0.146	0.210	0.397	0.660	0.677	0.669	0.841*	0.607	0.870*
DR	-0.116	0.382	.792*	-0.174	-0.053	-0.077	0.714	0.825*	0.283	0.579	0.163	0.901**
SD	-0.555	-0.088	-0.157	-0.216	-0.278	-0.462	-0.578	-0.385	-0.154	0.069	0.004	-0.322
WSA	-0.061	0.063	0.477	0.972**	0.979**	0.861*	0.070	0.231	0.885**	0.006	0.853*	0.145
ASD	0.306	0.060	0.556	0.882**	0.908**	.929**	0.374	0.405	0.819*	-0.018	0.717	0.301
MWD	0.123	-0.513	0.536	0.253	0.355	0.605	0.627	0.623	0.708	0.597	0.633	0.713
SA	0.454	0.417	0.675	0.673	0.767*	0.736	0.601	0.657	0.648	-0.146	0.471	0.464
DA	0.389	-0.114	0.028	0.580	0.593	0.728	0.264	0.126	0.389	-0.139	0.298	0.060

*Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Relationship between chemical properties, heavy metals and pollution potentials

The result presented in Table 8 showed the relationship between chemical properties, heavy metals, and pollution potentials. Mn showed a highly positive significant (P<0.01) relationship with N, OC, OM, K and Na. This is likely to be due to the role of manganese in enhancing nitrogen assimilation and uptake, the release of manganese into the soil during the decomposition of organic matter and the role of manganese in improving potassium utilization. The same positive significant (P<0.01) relationship was observed with Fe.

This may be due to the role of iron levels in optimal nitrogen utilization and uptake, organic matter contents that help to make iron more soluble and available to the soil. ESP and SAR showed a highly negative significant ($P<0.01$) relationship with Ca, Mg and ECEC. This relationship may be because when ESP and SAR are high, the concentration of sodium is higher compared to other cations; like magnesium and calcium. These cations were replaced by sodium in the soil exchange sites which aid in the reduction of the ECEC and an increase in osmotic pressure that is hazardous to plant roots and soil microbes.

Table 8 Correlation between chemical properties, heavy metals and pollution potentials

	BS	pH	P	N	OC	OM	Ca	Mg	K	EA	Na	ECEC
Mn	0.119	-0.181	0.467	.888**	0.936**	0.969**	0.287	0.373	0.924**	0.106	0.858*	0.301
Fe	0.111	-0.220	0.330	0.921**	0.949**	0.976**	0.166	0.236	0.873*	0.018	0.826*	0.157
ESP	-0.133	-0.170	-0.711	0.213	0.026	-0.059	0-.863*	-0.944**	-0.315	-0.476	-0.158	-0.943**
SAR	-0.079	-0.390	-0.685	0.184	-0.019	0.002	0-.792*	-0.937**	-0.267	-0.321	-0.101	-0.870*

*. Correlation is significant at the 0.05 level. **. Correlation is significant at the 0.01 level.

Relationship between structural stability, heavy metals and pollution potentials

The relationships between structural stability, heavy metals and pollution potentials is shown in (Table 9). Manganese and Iron have highly positive significant ($P<0.01$) relationship with water stable aggregates ($r = 0.925$, $r = 0.928$), and aggregate size distribution ($r = 0.925$, $r = 0.906$). This relationship could be attributed to the actions of manganese oxides (MnO2) as binding agent on soil particles, and promotion of lime in soil. It also acts as binding agent, creating bridges between soil particles, strengthening aggregate stability and improving structural stability. Similar relationship observed with Fe can be attributed to the role of iron in forming cementing agent.

Also, iron's interaction with organic matter through complexation, forming iron-organic complexes that enhance aggregate stability and improve structural stability. A negative significant ($P<0.05$) relationship was observed between ESP and SAR with DR. The result may likely be due to the adverse effect of sodium on soil structure. Sodium (Na) level is relatively high in the studied soils, it may form looser attachments to clay particles. Thus, the binding force is weakened, making the soils more susceptible to dispersion. Also, as DR increases, soil particles may become less stable. Dispersibility tends to increase, and sodium ions are released from the exchange sites of the soil, causing a decrease in SAR.

Table 9 Correlation between structural stability, heavy metals and pollution potentials

	Sand	Silt	Clay	DR	SD	WSA	ASD	MWD	SA	DA
Mn	-0.578	0.568	0.487	0.059	-0.348	.925**	0.925**	0.650	0.746	0.620
Fe	-0.487	0.504	0.376	-0.074	-0.357	.928**	0.906**	0.560	0.688	0.678
ESP	0.677	-0.572	-0.695	-.832*	0.164	0.011	-0.135	-0.641	-0.389	0.138
SAR	0.558	-0.499	-0.537	-.842*	0.139	-0.023	-0.113	-0.467	-0.430	0.160

* Correlation is significant at the 0.05 level. ** Correlation is significant at the 0.01 level.

4. CONCLUSION

The present study examined the distributions of physical and chemical soil quality indicators in seven (7) Fadama soils locations in Anambra state namely; Ubehuekwem, Igbakwu, Ufuma, Ogboji, Ugbenu, Ezi-Anam and Ogbakuba. Data generated from the study showed a high content of sand among the soils that invariably showed the extent of weathering of the soils. The soils had a high concentration of P in all the aggregate sizes considered compared to C and N. This indicator was found most abundant in smaller soil particles 0.5-0.0.25mm and below fraction. In 5-2mm aggregate size, C and N was absent in Ubahuekwu, Ufuma, Ogboji, Ugbenu and Ezi-Anam soils respectively.

The correlation matrix showed highly significant ($P<0.01$) positive relationships between carbon, phosphorous and nitrogen content of the soils. Ezi-Anam soils had the highest content of Mn and Fe, 20.09mgkg-1 and 10.92mgkg-1 respectively. While the ESP and SAR result of the soils were relatively alike. Though, the pollution potentials are within acceptable limit, the soils should be monitored as well as chemical fertilizer in use before they become a problem. Ezi-Anam soils proved to have highest quality of the soils studied, with the highest water stable aggregate (91.15%), highest value of aggregates size (2.57%) highest concentration of nitrogen and carbon, highest degree and state of aggregation and consequently, a high soil quality percentage (29.86%).

Igbakwu topped the soil quality rating with 30.25% with a very high content of phosphorous, nitrogen and carbon; however it has the highest dispersion ratio of the soils (58.55%) and has a very low state of aggregation and degree of aggregation which makes it prone to erosion and flooding, that is already a problem for Fadama soils. Fadama soils are low land soil which despite having agricultural potentials are prone to flooding. This present evaluation is therefore, critical for decision making for profitable and sustainable agriculture in these Fadama soils studied. So, nutrient management plans should be adopted by paying attention to the ratio of N and C. This should include measures to immobilize most of the P content of the soils, reduce the application of P fertilizers, increase the application of N rich fertilizers and use of organic wastes to improve the organic matter content of the soils.

Since Fadama soils are mainly used for rice production in the areas, planting leguminous or heavy feeder crops during off season can help balance nutrients in the soil by reducing the buildup of nutrient like P, increase N and such other nutrient that may have been depleted in the soil by leaching losses. The groundwater quality needs to be regularly monitored by relevant agencies and stakeholders to identify potential issues and take appropriate action to manage the situation. Adoption of the aforementioned measures will help improve the stability and texture of these soils, thereby having significant positive impact on soil quality and enhance maximum food production.

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Author Contributions

Nweke Ikechukwu Aloysius: The head of the team, initiator of the research work and the author of the paper. Uwaoma Cynthia Chioma was involved in field data collection that involve series of travel to the field site that was not located in one area. Also, in literature review and in travelling to Abia and Awka to collect the laboratory results as well as in the statistical analysis of the data generated. Nwankwo Jessica Ezinne assisted in laboratory analysis and literature review.

Informed consent

Not applicable.

Conflicts of interests

The authors declare that there are no conflicts of interests.

Ethical approval

Not applicable.

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Data and materials availability

All data associated with this study are present in the paper.

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