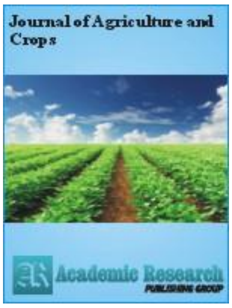

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Variability in the Physico-chemical Properties of Soils of Similar Lithology in Three Land Use Types in Ahiazu Mbaise, Imo State Nigeria

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Abstract: Variability in the physicochemical properties of soils of different land uses form from the same lithology was studied. Soil samples were collected from surface (0 – 20 cm) and subsurface (20 – 40 cm) depths from three land use namely fallow land, continuous cultivated land and mechanic village land. The soils were air dried, sieved with 2 mm sieve and subjected to routine laboratory analysis. Results obtained were subjected to analysis of variance (ANOVA) and significant treatment means were separated using Least Significant Difference (LSD) at 0.05 probability level. Relationship between selected soil properties were determined using correlation analysis. Results showed that the textures of the studied soils were not affected by land use practices. Bulk density increased with increase in depth with fallow land recoding the lowest values of 0.86 g/cm^3 (0.-20 cm depth) and 1.06 g/cm^3 (20 – 40 cm depth). Land use types significantly (P = 0.05) affected soil chemical properties such as soil pH, soil organic carbon, total N, available P and exchangeable cations with the highest values recorded in fallow land, followed by palm plantation and the least was continuous cultivated land. There were slight variations among soil properties in the three land use types studied. Significant positive and negative correlations existed and some soil properties. Good soil management practices such as organic fertilization, zero tillage and mulching is recommended especially in continuous cultivated lands.

Keywords: Land use; Soil degradation; Anthropogenic activities; Food security.

1. Introduction

Soil infertility and land degradation has been considered as some of the major constrain facing agricultural productivity in Southeastern Nigeria. To meet the food requirement of increasing human population in the area, agricultural lands have been subjected to overuse such as continuous cultivation, bush burning and other anthropogenic activities [1].

Among the greatest challenge facing the world today is the development of soil, crop and nutrient management strategies that enhance the plant productivity and quality of soil, water and air [2].

Understanding changes in soil quality due to land use practices has become very essential especially in the era food security has been a global concern [3]. The knowledge of the variations and distribution of soil properties due to land use is vital for refining the effects of agriculture on environmental quality [4]. The effects of cropping systems and management practices on soil properties provide essential information for assessing sustainability and environmental impact [5]. Researchers have reported that change of land use such as long term cultivation, deforestation, overgrazing and mineral fertilization can cause significant variations in soil properties, terrestrial cycles and reduction of output [6, 7]. Ahiazu Mbaise in Imo State is a part of Southeastern Nigeria that is characterized by high human population density and this has resulted to land overuse with different cropping systems to meet the food requirement of the population. However, little information is available on the effect of these land use types on soil properties. The objective of this study therefore was to assess the variability in the physico-chemical properties of soils of similar lithology in three land use types in Ahiazu Mbaise, Imo State Southeastern Nigeria.

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2. Materials and Methods

2.1. The Study Area

The study was carried out at Ahiazu Mbaise Local Government Area of Imo State, Southeastern Nigeria. The area lies between Latitude 5° 14' N and 5° 41' N and Longitude 7' 08°E and 7° 48' E. The area has an average annual rainfall range of 1949 mm – 2251 mm and annual temperature range of 27°C – 30°C with average relative humidity of 78%. The geological material of soil in the study area is an ultisol and classified as Typic Haplustult [8], derived from Coastal Plain Sands (Benin formation) of the Oligocene-Miocene geological era and are characterized by low cation exchange capacity, low organic matter with high leaching of nutrient elements [9]. Tropical rainforest is the dominant vegetation of the area, though with remarkable ecological diversity caused by anthropogenic activities, especially farming and deforestation resulting into depleted vegetation as a result of demographic pressure. More than 50% of people in the area are subsistent farmers. Soil fertility restoration in the area is by bush fallow and application of inorganic and organic fertilizers.

2.2. Soil Sampling and Experimental Design

Three land use practices in three communities in Ahiazu Mbaise Imo State, Southeastern Nigeria were selected. A reconnaissance visit was made to the study locations to locate the sampling sites and to obtain information from the owners about the sites. The communities were Mpam Owerre, Umuchieze and Okpokume Mpam. The three locations have similar lithological property (parent material) which is coastal plain sand and this guided the sampling points. Fallow land (three years fallow), continuous cultivated land and palm plantation farm (15 years old) were studied. In each of the location, four soil samples were collected from each of the land use which had similar history and agronomic practices. The four sampling points acted as replications. Samples were collected at the root zones of 0 – 20 and 20 - 40 cm using soil auger and core samplers for bulk density determination. The five sample points act as replications while the three land use types act as treatments. The samples were collected in a randomized complete block design. The samples were air-dried, sieved using 2mm sieve and then subjected to laboratory analysis using standard methods.

2.3. Laboratory Analysis

Particle Size Analysis (PSA): This was determined using hydrometer method with Sodium hexametaphosphate (Calgon) as dispersal agent according to Gee and Or [10]. Bulk Density (BD) was determined using the core method according to Grossmans and Reinch [11] using the formula which is calculated mathematically as follows:

Bulk density = Mass of oven-dried soil / Volume of core sampler (g/cm^3).

Total Porosity (P_t). This was calculated from bulk density as

$P_t = 1 - (Bd/Pd) \times 100$; where Pd = particle density (2.65)

Moisture content was determined by the gravimetric method calculated mathematically as follows:

$$\% M.C = \frac{W_2 - W_3}{W_3 - W_1} \times 100$$

Where; W_1 = weight of the can, W_2 = weight of wet sample + can, W_3 = weight of oven-dried sample + can.

Soil pH was determined in distilled water (at the ratio of 1:2:5) and in KCl solution according to Mclean [12]. Total Nitrogen was determined calorimetrically using the modified micro-kjedhal digestion method of Bremner and Yeomans [13]. Organic Carbon was determined using the Walkley and Black wet oxidation technique [14]. Available P was determined by extraction with Bray II solution according to Olsen and Sommers [15]. Exchangeable Bases (Ca, Mg, Na and K) were determined extracted using Ammonium acetate solution buffered at pH 7 [16]. The exchangeable Ca and Mg were determined by EDTA complex metric titrations while the exchangeable Na and K was determined using the flame photometer. Exchangeable Acidity (EA was determined by the extraction with 1N KCl and titrated. [12] Effective Cation Exchange Capacity (ECEC) was determined by the summation of all exchangeable bases and exchangeable acidity. Base saturation was obtained mathematically as follows:

% B.S = {(TEB / ECEC) X 100)} where; TEB = Total Exchangeable Bases (Ca, Mg, Na and K), Ca / Mg and Mg/ K ratios were calculated by computation

Data collected were subjected to Analysis of Variance (ANOVA) for a Randomized Complete Block Design (RCBD). Significant means were separated using Least Significant Difference (LSD) at 0.05 probability level. Variability among soil physical and chemical properties were determined using coefficient of variation (CV) and ranked according to Wilding, *et al.* [17] as %CV from 0 – 15 = low variation, 15 – 35 = medium variation and above 35 = high variation.

3. Results and Discussion

3.1. The Physical Properties of Soils in the Study Area

Results of the physical properties of soil in the study locations are presented in Table 1. Results showed that texturally, the soils were mainly sandy loam with high sand fraction in the three land use types. There was no significant effect on the particle sizes of the soil with respect to land use. This observation contradicted the observation of Agoumé and Birang [18] that reported a significant effect on the clay, silt and sand fractions of the soil and attributed the differences to variations in climatic condition. However, Shepherd, *et al.* [19] observed no effect of land-use systems on soil particle size distribution. The high sand fraction in the studied locations could be attributed the parent material dominant in the area which is coastal plain sand since the texture of the soil is highly influenced by the parent material over time [20]. The silt/clay ratio in the three locations ranged from 0.29 – 0.54. This result agreed with Onweremadu [21] who observed similar textural characteristics on coastal plain soils in Owerri under different land uses in Southeastern Nigeria. Also, the humid rainfall characteristics that promote illuviation or leaching of silt and clay particles below the epipedon could contribute to the texture of soils in the area.

There was a increase in the soil bulk density from the top soil to the sub soil in each of the locations. Fallow land recorded the lowest soil bulk density, followed by palm plantation and the least was continuous cultivated land. The high bulk density recorded in continuous cultivated land could be attributed to tillage activities. This is because tillage activities could reduce organic matter accumulation which reduces soil bulk density. Therefore litter falls in the uncultivated farms which after decomposition, increases aggregation and microbial activities could contribute to lower bulk densities in fallow and palm plantation. However, the values of bulk densities were below the critical limit of 1.3g/cm^3 according to Kayombo and Lal [22]. Soil total porosity ranged from 49.8 – 67.4% with the highest in the epipedon of fallow land. Increase in soil bulk density resulted to a decrease in soil total porosity which could be attributed to compaction of soil macro and micro pore spaces.

Table-1. Selected physical properties of soils of the study locations

Land use	**Soil depth**	**Sand**	**Silt**	**Clay**	**Texture**	**Silt/Clay**	**Bulk density**	**Total porosity**
	(cm)	←	**g/kg**	→			**g/cm^3**	**%**
Fallow land	0 – 20	825	49	126	SL	0.39	0.86	67.4
Fallow land	20 – 40	815	42	143	SL	0.29	1.06	59.7
Continuous cultivated land	0 – 20	865	45	90	LS	0.5	1.03	62.1
Continuous cultivated land	20 – 40	822	55	123	SL	0.45	1.16	56.1
Palm plantation	0 – 20	778	56	166	SL	0.34	1.23	53.4
Palm plantation	20 – 40	776	79	145	SL	0.54	1.33	49.8
LSD(0.05)		NS	21.6	62		0.32	0.07	2.63

NS = Not significant

3.2. Soil Chemical Properties

Results of the chemical properties of the studied locations are shown in Table 2. Results showed that the soils were moderately acidic. Comparing the three land uses, fallow land recorded higher values of soil pH, soil organic carbon, total nitrogen, available phosphorus and exchangeable cations. This was followed by palm plantation and the least was continuous cultivated land. Also, most of the nutrient elements were concentrated at the epipedon in the three land use types. The highest soil pH in fallow land could be attributed to litter falls which after decomposition increases soil organic matter and exchangeable bases thereby reducing the accumulation of H and Al ions on soil exchange complex [1]. The highest organic carbon in the fallow land could be due to litter fall and expected increase in soil biodiversity [23]. Woldeamlak and Stroosnijder [24] have observed that conversion of forest vegetation to agricultural land results in a decline of the soil organic carbon content. This could be the reason for the low organic carbon recorded in continuous cultivated land. High total nitrogen and available phosphorus recorded in fallow land could be due to higher soil organisms that help in organic matter decomposition since there is a positive correlation between organic matter and total nitrogen. The low exchangeable bases in these locations could be due to high rainfall which accelerates runoff and leaching of cation down the subsoil. Higher exchangeable bases in the fallow land could be due to the macro and micro climate that hinders the impact of rain drops on soil Brady and Weil [25]. The lowest content of soil organic carbon in continuous cultivated land could be attributed to the rapid decomposition and mineralization of soil organic matter due to nutrient uptake by plants. Similar findings were reported by Agoumé and Birang [18] who recorded the lowest soil organic carbon on crop land as compared with forested land.

Calcium/ Magnesium ratio in the three land use types was low with values ranging from 2.0 – 2.5 when compared with a normal range of 3.1 - 5.1 for productive soils according to Landon [26]. This ratio indicated that the Calcium content in the soil solution is low when compared to the Magnesium content irrespective of the land use type and agronomic practices. Similarly, the Magnesium / Potassium contents were high (> 1.2) when compare with a critical level of 1.2 for productive soils (Landon, 1991) except in continuous cultivated land (20 – 40 cm). High values of Mg / K ratio indicates that Mg^{2+} is likely to be more available to plants relative to K^+ [27].

Table-2. Selected chemical properties of soils of the study locations

Land use	Soil Depth	pH	OC	Total N	C/N	Avail. P	Exch Ca	Mg	K	Na	EA	ECEC	BS	Ca / Mg	Mg/K
	Cm	(H_20)	g/kg	g/kg	Ratio	mg/kg	Cmol/kg						%	ratios	
Fallow land	0 – 20	5.59	14	1.22	11.5	10.9	3.49	1.53	1.24	0.08	0.81	7.17	88.7	2.3	1.3
Fallow land	20 – 40	5.47	13.2	1.14	11.6	9.2	2.86	1.24	1.05	0.03	1.04	6.23	83.1	2.3	1.2
Continuous cultivated land	0 – 20	6.41	9.2	0.8	11.5	28	2.6	1.27	1.11	0.08	1.28	6.34	80.2	2	1.1
Continuous cultivated land	20 – 40	6.58	5.9	0.52	11.3	13.2	2.42	1.2	1.02	0.09	1.39	6.11	77.5	2.1	2
Palm Plantation	0 – 20	6.15	5.5	0.49	11.2	9.6	0.66	0.42	0.82	0.04	1.77	3.72	52.1	2.5	1.6
Palm Plantation	20 – 40	5.47	5.4	0.47	11.7	8.9	0.5	0.26	0.74	0.07	1.85	3.42	48.8	2.2	1.9
LSD(0.05)		0.26	0.11	0.02	NS	21.5	1.03	0.25	0.22	0.03	0.62	1.24	10.8	0.08	0.03

3.3. Variability among the Physico-Chemical Properties in the Study Locations

Variations among soil physico-chemical properties of the three land use types are presented in Tables 3 and 4. There were variations in some soil properties under the three land use types such as silt/clay ratio, available phosphorus, total nitrogen and exchangeable bases. Slight variations existed among soil properties under the two soil depths (Tables 3 and 4). These variations could be due to variations in the management practices such as cultivation and constant anthropogenic activities as in the case of continuous cultivated land as well as differences in macro and micro climate in these land use types. These observations were in concord with the results of Chen and Xu [28] who stated that land use and farming management practices significantly affect the content of soil organic carbon (SOC), total nitrogen, total phosphorus and available phosphorus in the sub- layer of 0-25cm (<0.5) in the Yanging Basin Northwestern Beijingand and attributed the differences to variations in climate and the level of intensive land use.

Relationship between soil physical properties and chemical properties are presented in Table 5. Silt correlated positively with available P (r = 0.6118) and exchangeable acidity and negatively with exchangeable Ca, and Mg base saturation, ECEC and organic carbon. There was significant (p = 0.05) positive correlation between silt /clay ratio and pH. Total porosity correlated negatively with available P and exchangeable acidity and positively with base saturation, exchangeable Ca, K, Mg and Na as well as ECEC. Similar trend followed with bulk density.

Table-3. Variability among the Physical Properties in the Study Locations

Property	Sand g/kg	Silt g/kg	Clay g/kg	Bulk Density g/cm3	Total Porosity %	Silt / Clay
Fallow Land (Depth = 0 – 20 cm)						
% CV	0.7	13.2	1.3	4.8	2.4	17.3
Rank	Low	Low	Low	Low	Low	Medium
Fallow Land (Depth = 20 – 40 cm)						
% CV	0.8	23	9.6	2.9	1.9	33.3
Rank	Low	Medium	Low	Low	Low	High
Continuous Cultivation (Depth = 0 – 20 cm)						
% CV	0.8	23.6	14.2	6.8	4.2	32.7
Rank	Low	Medium	Low	Low	Low	Medium
Continuous Cultivation (Depth = 20 – 40 cm)						
% CV	6.3	20.3	50.2	3.9	3	52.9
Rank	Low	Medium	High	Low	Low	High
Palm plantation (Depth = 0 - 20 cm)						
% CV	3.5	11.9	20.1	2.3	2	42.2
Rank	Low	Low	Medium	Low	Low	High
Palm plantation (Depth = 20 – 40 cm)						
% CV	0.8	25.8	17.1	20.8	0.6	7.2
Rank	Low	Medium	Medium	Medium	Low	Low

Rating: 0 – 15 Low, 16 – 35 = Medium, > 35 = High

Table-4. Variability among the Chemical Properties in the Study Locations

	Ph (H_20)	OC	Total N	Aval. P	Ca	Mg	Exch. K	Na	EA	ECEC	Ca/Mg	BS
		g/kg	g/cm3	mg/kg	Cmol/kg							%
Fallow Land (Depth = 0 - 20 cm)												
% CV	2.9	6.9	14.3	13.3	20.6	7.5	9.5	24	26.6	14.9	15.7	2
Rank	Low	Low	Low	Low	Medium	Low	Low	Medium	Medium	Low	Medium	Low
Fallow Land (Depth = 20 - 40 cm)												
% CV	0.9	0.8	11.9	49.9	22.6	4.7	5.6	66.7	10.2	8.9	18.4	3.5
Rank	Low	Low	Low	High	Medium	Low	Low	High	Low	Low	Medium	Low
Continuous Cultivation (Depth = 0 - 20 cm)												
% CV	0.7	6.9	9.3	9.1	34.3	4.8	9.1	12.5	43.7	20.2	36.9	5.6
Rank	Low	Low	Low	Low	Medium	Low	Low	Low	High	Medium	High	Low
Continuous Cultivation (Depth = 20 - 40 cm)												
% CV	1.0	8.6	13,6	13.7	21.3	11.9	0.0	11.1	33.3	7.4	29	8.2
Rank	Low	Low	Low	Low	Medium	Low	Low	Low	Medium	Low	Medium	Low
Palm plantation (Depth = 0 - 20 cm)												
% CV	3.6	11.7	15.9	19.5	22.5	18.4	21.6	17.7	2.0	7.4	69.8	4.6
Rank	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low	High	Low
Palm plantation (Depth = 20 - 40 cm)												
% CV	2.0	2.7	15.2	51.2	73.0	21.4	24.4	7.9	10.9	10.9	82.9	20.6
Rank	Low	Low	Medium	High	High	Medium	Medium	Low	Low	Low	High	Medium

Rating: 0 – 15 Low, 16 – 35 = Medium, > 35 = High

Table-5. Relationship between Soil physical properties and selected soil chemical properties

Soil Property	Clay	Silt	Silt/Clay	Total Porosity	Bulk density
Avail. Phosphorus	0.0452ns	0.6118**	0.3926ns	-0.5835**	0.5834**
Base Saturation	-0.3161ns	-0.647**	-0.2574ns	0.82822**	-0.8291**
Exch. Ca	-0.38397ns	-0.4988*	-0.1037ns	0.81931**	-0.8194**
Ca/ Mg ratio	0.12204ns	-0.0561ns	-0.1587ns	-0.0133ns	0.0136ns
Exch. Acidity	0.10993ns	0.53589*	0.33714ns	-0.70157**	0.7020**
ECEC	-0.41764ns	-0.5249*	-0.0825ns	0.83416**	-0.8343**
Exch. K	-0.21944ns	-0.6749**	-0.3537ns	0.85541**	-0.8560**
Exch. Mg	-0.34080ns	-0.6418**	-0.1926ns	0.86824**	-0.8686**
Exch. Na	-0.33444ns	0.16759ns	0.25716ns	0.2364ns	-0.2371ns
Organic Carbon	-0.17008ns	-0.4941*	-0.2753ns	0.77339**	-0.7733**
pH (H_20)	-0.41246ns	0.18983ns	0.44028*	-0.1866ns	0.18532ns

*and ** = significant at 0.05 and 0.01 probability levels respectively, ns = not significant

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