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Original Research Article

Variability in Soil Properties as Influenced by Different Land Use Types in an Ultisols of the Tropical Region, Delta State, Nigeria

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Abstract

The study was conducted in the 2010 – 2012 cropping seasons in a typical ultisols of the tropics. The aim was to assess variability in soil properties as influenced by three land use types namely: oil palm plantation, maize and yam cultivated lands. The study consisted of both field and laboratory studies. The field study was made up of a land use that was carefully surveyed, mapped into 20 × 30 m^2 and plotted into 5 homogenous units of 0.25 ha. Soil samples were randomly augered by grid survey at 5 m equidistant points and surface 0-15 cm samples collected using screw auger for laboratory analysis of the particle size distribution and some chemical characteristics of the soils in the different land use types. Variation in properties within land use types was measured by estimating the coefficient of variance. The results of the study showed that particle size distribution varied from sand in the oil palm land use type to sandy loam in the maize and yam land use types. The variant ratio tests were 84.4%, for sand, 0.51% for silt and 27.4% for clay, and were less variable. The soil pH ranged from strongly acid (5.25) to moderate acid (5.65) and less variable (CV% = <15%). The variant ratio test was statistically not significant (10.7%). The organic carbon (35.7%), total nitrogen (34.5%) and available phosphorus (27.2%) variant ratio tests were non-significant and less variable. The exchangeable bases, exchange acidity and ECEC were also non significant and less variable. The results indicated clearly that variability could occur within soil units and therefore called for caution in assessing uniformity of soil properties within soil areas under cultivation.

Keywords: sand; silt; clay; organic carbon; total nitrogen; available phosphorus; soil pH.

INTRODUCTION

Many Tropical Ultisols are derived from the Pre-Cambrian basement complex. These soils consist of variable migmatized undifferentiated genesis, schist and quartzites (Akinbola et al., 2010). Characteristically, Ultisols are neither stable nor resistance to human induced activities and vary considerably in their physical, chemical and mineralogical properties. These properties are related to their geological history, intensity of different soil forming processes, geomorphological features and parent material (Asadu et al., 2013).

High degree of variability in the tropics has long been recognized and this has made it difficult for most tropical soils to be mapped and predict accurately their management and productive potentials (Wilding and Dress, 1983; Ogunkunle, 2003). Soil variability could either be spatial or temporal. Spatial variability is a variation in soil properties which occurs with distance, while temporal variability is a seasonal variation in certain soil properties that display continuous variation depending on the activities on them (Akinbola et al., 2010).

Spatial variability could be attributed to changes in macro and micro flora and fauna (Dahiya et al., 1984; Lal, 2000). Stolt et al. (1993) also added that spatial variability is universal to all soils and could be induced by differences in weathering rates, lithology, topographic differences and hydrological characteristics of the soil. Temporal variability on the other hand, could arise from changes in soil properties such as bulk density, hydraulic conductivity, thermal conductivity, infiltration rate, water table depth, CO_2 accumulation, soil texture and even ground water quality (Cassel, 1983).

Effiom et al. (2010) have also reported that variability in soil properties could result in some part of a cultivated field receiving sufficient inputs with the other part receiving excess of it. They further adduced that high degree of variability in plant stands and low average productivity of most tropical ultisols have been reported as one moves from fertile valley bottom to generally infertile upland soils. In a similar view, Brouwer et al. (1993) have opined that in the tropics, soil variability has traditionally been identified as a problem that can induce within-field crop growth differences which can reduce farmer's yield expectancy and complicate the interpretation of agronomic experiment.

In recent years, variations in soil properties have been a subject of tropical research. This is because, soil variability has been found to significantly influence soil management and crop production. It is therefore the objective of this study to assess variation in soil properties in relation to

land use types. The result of the study could be of immense importance in agro-technology transfer.

MATERIALS AND METHODS

Description of the study area

The study was conducted in the surrounding environment of Anwai that are involved in crop production as a means of livelihood. The crops mainly produced in the environment are maize, yam, cassava, cocoyam, sweet potatoes, vegetables and small oil palm holdings. The study areas fall within the coordinates (06° 14`N and 06° 49`E), and lie significantly in the tropical rainforest zone with over 1,565 mm of rainfall per annum. The rainfall characteristic is bimodal in nature with peaks in July and September and punctured annually with a short break in August otherwise referred to as "August Break". The mean annual temperature and relative humidity ranged between 27 – 28 °C and 62 – 65%. The geology is made up of coarse-grained pegmatites derived from basement complex that gave rise to more coarse-textured acid soils than base (Egbuchua, 2012). The landscape is generally undulating with pockets of rolling topography. Land use is typically based on rain-fed agriculture and crops mainly cultivated are tuber and root crops, pulses, cereals, grains. Pockets of small holding of oil palm abound in the entire environment. An Isohyperthemic temperature and udic moisture regime typify the general area.

Field work

Three distinct land use types namely oil palm plantation, maize and yam were selected for the study. The land use types occur within a distance of 100 m to each other on the same mapping unit. In each land use type, a land area of 20 × 30 m^2 that is almost homogenous was selected. This was further divided into 5 units of 0.25 ha. Within each land area, soil samples were randomly augered by grid survey at 5m equidistance points. Bulk samples consisting of (10) surface (0-15 cm) soil samples were collected from each land use type to give a total of 30 surface samples replicated 3 times. A total of 90 soil samples were processed for laboratory investigation.

Sample preparation

The augered soil samples were air-dried in an ambient room temperature of 25 °C for 3 days. Thereafter they were ground with an agape-mortar and sieved to separate the fine earth fractions from coarse fragments. Some portions of the sieved samples were further passed through 0.5 mm mesh sieve for organic and total nitrogen determination. Soil samples were analyzed for the following characteristics paramount to crop growth.

Laboratory analytical procedures

The particle size distribution was estimated by Bouyoucous hydrometer method. The analysis involved the measurement of the percentage of the mineral separates, namely, sand, silt and clay. The procedure has two aspects: dispersion of the soil and fractionation into particle size classes. Dispersion was achieved by stirring the soil sample with a sodium hexametaphosphate (Calgon) solution. The determination of the content of silt and clay was achieved by sedimentation-hydrometer method, while the sand fraction was determined by sieving. Soil pH was measured in distilled water in a ratio of 1:1 with dry soil. The values for the pH were measured potentiometrically using a digital pH meter. Organic carbon was determined by wet digestion method in which the soil was digested in an excess of chromic acid with titration of the unused oxidant. Total nitrogen was determined by the macro-Kjeldahl method. The method involved the conversion of organic N into NH_4-N by digesting in concentrated NH_4SO_4 containing potassium sulphate and distilling as NH_3 gas into a boric acid solution trap.

Available phosphorus was extracted with acid fluoride using the Bray P-1 method. Phosphorus in each extract was determined colorimetrically by the molybdenum blue method which is based on the premise that addition of an acid molybdate to an orthophosphate solution leads to the formation of a heteropoly phosphomolybdate compound which on reduction with stannous chloride, produces a characteristics molybdenum blue colour.

Exchangeable cations were determined by the displacement of the ions from the soil colloids using 1N NH_4OAC (pH 7.0). The potassium and sodium content in the extract were determined by flame-photo meter while Calcium and magnesium were determined by Atomic absorption spectrophotometer. Exchange acidity was determined by the potassium chloride (IN KCl) extraction method. Effective cation exchange capacity (ECEC) was calculated as the sum of all base forming cations plus exchange acidity. All the analyses were done following the guideline of Canadian Society of Soil Science (Carter, 1993).

Statistical analysis

The variability of soil properties within land use types was measured by estimating the coefficient of variation, which was calculated as:

$$CV(\%) = \frac{Sd}{\overline{x}} \times 100$$

Where Sd = Sample standard deviation

$\overline{X}$ = Sample mean

Both F and T-test were employed to test for significance differences of soil properties and land use types.

RESULTS AND DISCUSSION

Particle size distribution

The particle size distribution and some chemical properties of the three land use types are shown in Table 1. The oil palm plantation showed sand, silt and clay contents of 900 g kg^{-1}, 30 g kg^{-1} and 70 g kg^{-1}. Maize land use type has a 760 g kg^{-1}; 160 g kg^{-1} and 80 g kg^{-1} of sand, silt and clay contents. Finally, yam land use type had 780 g kg^{-1}; 160 g kg^{-1} and 80 g kg^{-1} contents of sand, silt and clay, respectively. By textural classification according to Soil Survey Staff (2006), the oil palm plantation was sandy in texture whereas the maize and yam land use types were sandy loam in texture, respectively. The content of sand in the maize and yam land use types were closely related (760 g kg^{-1} and 780 g kg^{-1}), whereas the oil palm plantation had a higher sand fraction of 900 g kg^{-1}. In all the land use types, sand seemed to be the dominant soil fraction and they all were highly permeable and well aerated. Generally, the soils were coarse-textured and this could be attributed to the nature of parent materials (Egbuchua, 2012).

Chemical properties

Generally, the soils were acidic in nature (pH values of 5.25, 5.60 and 5.65) and varied from strong to moderate acid. The acidic nature could be attributed to the humid nature of the environment which is characterized by intense rainfall and its associated erosion and leaching effects. This phenomenon, however, affects soil reaction as most basic cations are removed by leaching thereby leaving behind the hydrogen and aluminum ions that can cause soil acidity. Aluminum ions cause acidity by hydrolysis reaction while hydrogen is by direct dissociation (Brady and Weil, 2007). Organic carbon content was significantly higher in oil palm plantation than in maize and yam land use types. The mean value for oil palm was 8.35 g kg^{-1}, which is rated moderate (FMNAR, 1996). Maize and yam had mean values of 7.25 g kg^{-1} and 7.35 g kg^{-1} which is rated low (FMANR, 1996). The moderate to low content of organic carbon could be attributed to plant residues accumulation associated with oil palm plantation and nutrient depletion arising from continuous cultivation, erosion and leaching effects associated with maize and yam land use types. Isirimah et al. (2003) asserted that organic matter is important in many tropical soils for many characteristics such as fertility status improvement. Asadu et al. (2013) opined that organic matter is largely responsible for both storage and release of nutrient ions in tropical soils especially in the ultisols that are dominated by low activity clay.

Total nitrogen was also significantly higher in oil palm than in maize and yam land use types. The mean values were 1.35 g kg^{-1}, 0.23 g kg^{-1} and 0.15 g kg^{-1} (Table 2). The moderate status of total nitrogen (1.35 g kg^{-1}) in the oil palm plantation has to do with the content of soil organic matter. According to Agboola et al. (1997) soil organic matter is responsible for over 70% of soil total nitrogen. On the other hand, low nitrogen content in relation to maize and yam land use types were largely caused by crop uptake, erosion effects, excessive mineralization in the study area and non return of crop residues after harvest (Agboola et al., 1997). The content of available phosphorus in the land use types was generally

Table 1. Particle size distribution and some chemical properties according to land use types in the study area

Soil Properties	Land Use types		
	Oil palm	Maize	Yam
Sand (g kg^{-1})	900	760	780
Silt (g kg^{-1})	30	160	140
Clay (g kg^{-1})	70	80	80
Textural Class	S	SL	SL
Soil pH (H_2O)	5.25	5.60	5.65
Organic carbon (g kg^{-1})	8.35	7.25	7.35
Total nitrogen (g kg^{-1})	1.35	0.23	0.15
Available phosphorus (mg kg^{-1})	6.35	6.25	4.35
Exchangeable bases (cmol kg^{-1})			
Ca	3.24	2.54	2.48
Mg	0.74	0.52	0.45
K	0.15	0.12	0.08
Na	0.03	0.03	0.03
Exchange acidity (cmol kg^{-1})	3.54	2.45	2.35
Effective Cation Exchange Capacity (ECEC) (cmol kg^{-1})	7.70	6.60	3.90

Key: S = Sandy; SL = Sandyloam

Table 2. Variations in soil properties within land use types. Means, Standard deviation and coefficient of variance (CV%)

Soil properties	Replicates	Oil palm	Maize	Yam
Sand (g kg^{-1})	1	32.25	25.3	25.50
	2	32.00	24.7	25.50
	3	25.75	27.0	27.00
	Mean ± SD	30.00 ± 3.68	25.67 ±1.19	26.00 ± 0.87
	CV%	12.28	4.65	3.33
Silt (g kg^{-1})	1	1.05	5.32	5.35
	2	1.03	5.32	5.25
	3	0.90	5.36	3.40
	Mean ± SD	0.99 ± 0.08	5.33 ± 0.02	4.67 ± 1.09
	CV	8.19	4.33	23.5
Clay (g kg^{-1})	1	2.50	2.70	2.75
	2	2.35	2.75	2.70
	3	2.15	2.55	2.55
	Mean ± SD	2.33 ± 0.18	2.67 ± 0.10	2.67 ± 0.10
	CV%	7.53	3.90	3.90
Soil pH (H_2O)	1	5.25	5.55	5.60
	2	5.15	5.60	5.55
	3	5.30	5.65	5.70
	Mean ± SD	5.23 ± 0.08	5.60 ± 0.05	5.62 ± 0.08
	CV%	1.46	0.89	1.36
Soil Organic Carbon (g kg^{-1})	1	8.30	7.25	7.35
	2	8.35	7.20	7.30
	3	8.40	7.30	7.30
	Mean ± SD	8.35 ± 0.05	7.25 ± 0.05	7.32± 0.03
	CV%	0.60	0.69	0.40
Total nitrogen (g kg^{-1})	1	1.35	0.23	0.15
	2	1.30	0.20	0.13
	3	1.40	0.25	0.17
	Mean ± SD	1.35 ± 0.05	0.23 ± 0.03	0.15 ± 0.02
	CV%	3.70	11.1	13.33
Available phosphorus (mg kg^{-1})	1	6.37	6.23	5.34
	2	6.33	6.25	5.38
	3	6.35	6.27	5.60
	Mean ± SD	6.35 ± 0.02	6.25 ± 0.02	5.44 ± 0.14
	CV%	0.31	0.31	2.57
Exchangeable Ca (cmol kg^{-1})	1	3.20	2.54	2.46
	2	3.24	2.52	2.48
	3	3.28	2.56	2.50
	Mean ± SD	3.24 ± 0.04	2.54 ± 0.02	2.40 ± 0.02
	CV%	12.35	0.79	0.81
Exchangeable Mg (cmol kg^{-1})	1	0.74	0.52	0.45
	2	0.76	0.50	0.43
	3	0.72	0.54	0.47
	Mean ± SD	0.74 ± 0.02	0.52 ± 0.02	0.45 ± 0.02
	CV%	2.70	3.85	4.44
Exchangeable K (cmol kg^{-1})	1	0.15	0.12	0.08
	2	0.13	0.10	010
	3	0.17	0.14	0.06
	Mean ± SD	0.15 ± 0.02	0.12 ± 0.02	0.08 ± 0.02
	CV%	13.33	16.66	25.0
Exchangeable Na (cmol kg^{-1})	1	0.05	0.03	0.03
	2	0.03	0.02	0.05
	3	0.02	0.05	0.02
	Mean ± SD	0.03	0.03	0.03
	CV%	50.92	50.92	50.92
Exchange acidity (cmol kg^{-1})	1	3.50	2.45	2.35
	2	3.58	2.50	2.30
	3	3.54	2.40	2.40
	Mean ± SD	3.54 ± 0.04	2.45 ± 0.05	2.35 ± 0.05
	CV%	1.13	2.04	2.13
CEC (cmol kg^{-1})	1	7.65	6.65	3.85
	2	7.75	6.55	3.95
	3	7.70	6.60	3.90
	Mean ± SD	7.70 ± 0.05	6.60 ± 0.05	3.90 ± 0.05
	CV%	0.65	0.77	1.28

low (< 8 mg kg^{-1}) FMNAR (1996). This is a reflection of low values of reserved phosphate minerals in the soil and its parent material (Akamigho and Asadu, 1983). Again, the acid natures of the soils and phosphorus fixation by sesquioxides have also been adduced as factors of low phosphorus content of the soils (Brady and Weil, 2007).

Total exchangeable bases (Ca, Mg, K and Na) across the land use types were seemingly low. This could be attributed to the dominance of low activity clay, low organic carbon content; the nature of parent material, intense weathering, erosion and leaching effects in the humid region which cause loss of colloidal matters (Isirimah et al., 2003 and Egbuchua, 2007). The low content of exchangeable sodium (> 0.3) is an indication that sodicity would not be a problem if proper soils and water management are observed.

The exchange acidity was high in all the land use types. The mean values ranged from 2.35 cmol kg^{-1} to 3.54 cmol kg^{-1} (Table 2). These values which are considerable high FMNAR (1996) would have stemmed up from the leaching of basic cations by rainfall and the low pH values of the soil (Brady and Weil, 2007).

The effective cation exchange capacity (ECEC) of the soils was significantly ($P \leq 0.05$) low and below 8 cmol kg^{-1} in all cases. This could be as a result of low activity clays of the soils in favour of kaolinite formation. This will certainly have a pronounced influence on the production capacity of the soils.

Variation in soil properties

Variation in soil properties within land use types was estimated by coefficient of variation (CV%) (Table 2). The results showed that the particle size distribution (sand, silt and clay) of the study area were least variable (CV% < 15%) irrespective of land use types. The coefficient of variation obtained for total sand 12.28%, 4.65% and 3.33% in the three land use types indicate that the whole area seemed to be homogenous with respect to sand content. This is a reflection of the nature of the parent materials from which the soils have been formed. The observed differences in particle size distribution could be attributed to biological action, erosion affects and micro-relief of the environment. These findings agreed to a larger extent with the works of Ogunkunle (2003) and Fasina et al. (2006).

Soil chemical properties

These are properties that are ephemeral and closely related to management practices. When these properties are grouped by coefficient of variation (CV%) according to Wilding and Dress (1983), they are found to be the least variable (CV% < 15%). The variance ratio test (Table 3) showed that they are statistically non-significant. The level of variability observed in the chemical properties could be due to cultivation techniques employed in the areas such as, fertilizer application, bush burning effects and other management practices.

Zebarth et al. (2002) have reported that human induced changes in soil can fundamentally alter the pattern of soil distribution in a landscape. The changes in the means and variance of the chemical properties clearly showed that the soils in the study area could be susceptible to agricultural uses.

Influences of land use type on soil properties

The non-significant differences (Table 3) within land use types on soil chemical properties can be vividly explained from the work of Beckett and Webster (1971) who opined that variability in these properties are largely affected by management practices. The awesome implication is that crop production may be affected by nutrient depletion. This is indeed a serious management problem. What this implies is that, soils under different land use types must be managed differently and cannot be taken as uniform entity for agricultural experimentation and production.

Table 3. Variance ratio test of soil properties for the whole land use types

Soil Property	F-value
Sand (%)	84.4 NS
Silt (%)	0.51**
Clay (%)	27.4 NS
pH (H_20)	10.7 NS
Organic carbon (g kg^{-1})	35.7 NS
Total nitrogen (g kg^{-1})	34.5 NS
Available phosphorus (mg kg^{-1})	27.2 NS
Exchangeable Cations (cmol kg^{-1})	
Ca^{++}	38.7 NS
Mg^{++}	42.3 NS
K^{+}	27.2 NS
Na^{+}	41.3 NS
Exchange acidity (cmol kg^{-1})	20.4 NS
ECEC (cmol kg^{-1})	34.3 NS

CONCLUSION

Variations in soil properties have been a subject of modern soil research in recent years due to the increasing need for information on soil as a means to produce food. The results of the study clearly showed that variability exist in particle size distribution and other determined chemical properties of the study area. The variabilities encountered in this study even when the whole soil units seemed to be homogenous in micro-relief and vegetational attributes could be attributed to factors of management practices within the land use type which can alter the pattern of soil distribution in the landscape.

The results of the study confirmed the high values of within series variation in soil properties. It also emphasizes the need

for caution in assuming uniformity of soil properties within areas under cultivation.

REFERENCES

Agboola A.A. Eneji A.E., Aiyelari-Eriola A. (1997): Marginal lands, Water quality and Agricultural land pollutants in Nigeria. Proceedings of the 23rd Annual Conference of Soil Science Society of Nigeria. 2nd – 5th March, 1997.

Akamigbo F.O.R., Asadu C.L.A. (1983): The influence of parent materials on the soils of south eastern Nigeria. East Africa Agricultural and Forest Journal 48: 81-91.

Akinbola G.E., Ojo U.A., Adigun M. O. (2010): Variability of properties of some pedons on basement complex of South Western Nigeria. Proceedings of the 34th Annual Conference of the Soil Science Society of Nigeria 22nd – 26th March, 2010, Ibadan, Nigeria.

Asadu C.L.A., Obasi S. C., Dixon, A. G. O. (2013): Soil Nutrient variations in a cleared forest land continuously cultivated for seven years in Eastern Nigeria. Proceedings of the Soil Science Society of Nigeria. 12th – 16th March, 2012, University of Nigeria, Nsukka, Nigeria.

Beckett P.H.T., Webster R. (1971): Soil variability. Soil and Fertilizers 34: 1-15.

Brady A.C., Weil, R.R. (2007): The Nature and Properties of Soils (13th ed.) Pearson Prentice-Hall Education Inc. 976 p.

Brouwer J., Fussel L.K., Hermann L. (1993): Soil and Crop growth Micro-variability. Ecosystem and Environment 45: 229-238.

Carter M.R. (1993): Soil samples and methods of analysis. Canadian Society of Soil Science. Lewis Publishers, London. 823p.

Cassel D.K. (1983): Spatial and Temporal variability of soil physical properties following tillage of a Norfolk loamy sand soil. Soil Science Society of America Journal 47: 196-201.

Dahiya S., Richter J., Malik, R.S. (1984): Spatial variability: A review. International Journal of Tropical Agriculture 11: 1-102.

Effiom O., Ayuk, E., Thomas E. (2010): Variability in soil properties along an Udalf toposequence in the humid zone, Nigeria. Kasetsart Journal of Natural Science 44: 564-573.

Egbuchua C.N. (2007): Pedological characterization of some wetland soils. Ph.D. Thesis, Delta State, University, Abraka, Nigeria.

Egbuchua C.N. (2012): Pedological characteristics of some alluvial soils in Delta State. Nigerian Journal of Soil and Environmental Research 9: 65-70.

Fasina A.S., Omolayo F.O., Ajayi O.S., Falodun A.A. (2006): Influence of land use on soil properties in three mapping units in South Western, Nigeria. Implications for sustainable soil management. Proceedings of the 31st Annual Conference of the soil Science Society of Nigeria 13th – 17th November, 2006 ABU, Zaria, Nigeria.

FMNAR-Federal Ministry of Agriculture and Natural Resources (1996): Literature Review of soil fertility investigation in Nigeria (In 5 volumes), Federal Ministry of Agriculture, Lagos 281 p.

Isirimah H.O., Dickson A.A., Igwe C. (2003): Introduction to Soil Chemistry and Biology for Agriculture and Biotechnology. Port Harcourt, Nigeria, p. 7-140.

Lal R. (2000): Physical management of Soils of the tropics. Priorities of the 21st Century, Soil Science 165: 191-207.

Ogunkunle A.O. (2003): Spatial variability of some chemical properties in two Ultisols mapping units in Southern Nigeria. Soil Survey and Land Evaluation 6: 26-32.

Soil Survey Staff (2006): Soil Survey Manual (Complete Print friendly version) USDA National Resource Conservation Service, USA.

Stolt M.H., Baker J., Simpson T.W. (1993): Soil landscape relationship, soil variability and parent material uniformity. Soil Science Society of America Journal 57: 414-421.

Wilding L.P., Dress L.R. (1983): Spatial variability. A pedologist viewpoint. ASA Special publication 34: 1-12.

Zebarth R.H, Ress H., Walsh J., Pennock D.J. (2002): Soil variation within a humid clay podzolic landscape under intensive cultivation. Geoderma 11: 19-33.

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