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PHYSICAL PROPERTIES OF SOIL IN RELATION TO SATURATED HYDRAULIC CONDUCTIVITY OF SOILS UNDER SELECTED LAND USE PRACTICES IN AKWA IBOM STATE

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ABSTRACT: *This study assessed the effects of land use types on selected physical properties of soil in Akwa Ibom State, south-south Nigeria. Four land use types, intensive cultivated land (ICL), natural forest (NF), oil palm plantation (OPP) and gmelina plantation (GP), were considered. Each land use was represented by three profile pits which were sampled according to genetic horizons for laboratory analysis. Data generated were analyzed statistically using descriptive and regression analyses. The results showed that ICL had the highest bulk density (Bd) (1.7g/cm^3) followed by NF and OPP (1.6g/cm^3) while GP had the least (1.5g/cm^3), OPP had the highest total porosity (Tp) (43.7%) followed by GP (42.6%), NF (41.1%) while ICL had the least (36.2%), ICL and NF had the highest water stable aggregates (WSA) (12.9%) followed by OPP (8.3%) while GP had the least (4.3%). However, OPP had the highest saturated hydraulic conductivity (Ksat) (8.4cm/h) followed by NF (8.2cm/h) while ICL and GP had the least (4.3cm/h). Result further showed that Ksat was significantly correlated with clay with r^2 value of 0.53 (p< 0.01). Across the four land use types, Ksat was moderately rapid. Irrespective of land use type, soils were dominated by sand-sized fraction which generally decreased with depth, reflecting the influence of the parent material(coastal plain sands). This study shows that the land use types were similar in their effects on Ksat but there were no significant differences.*

KEYWORDS: Land use practices, Saturated hydraulic conductivity, Soil properties, Sandstone parent material.

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INTRODUCTION

The inherent quality of Nigerian soils is generally low, hence they are easily degraded, in terms of physical, chemical and biological properties, as soon as the land is opened up for cultivation and other kinds of uses. In Nigeria, there have been indiscriminate deforestation and intensive utilization of land for all purposes irrespective of the agricultural qualities of the soils or the environmental impact of these uses (Ogunkunle, 2011; Ahukaemere et al., 2012).

Soil is the basis of agriculture and natural plant communities. Soil is at the root of food shortage, food insecurity or undernourishment which has assumed global dimension in the last three decades (Ogunkunle, 2015). Frequent changes in land use predisposes it to several environmental problems amongst which include desertification, acidification, eutrophication, greenhouse effect which causes climate change and biodiversity loss (Heiman & Reichstein, 2008). The reduction in the capacity of the land to provide ecosystem goods and services over a period of time is known as land degradation and it is a global problem affecting an estimated 1.5 billion people and a quarter of land area in all agro-ecological zones around the world (Lal et al., 2012). Food and Agriculture Organization (FAO, 1984) observed that about 20% of the world's agricultural lands have been irreversibly damaged due to accelerated land degradation and continuous intensive cultivation (land use), leading to a reduction of about 15-30% of their productivity. Helen (2000) stated that land degradation has a serious implication on food insecurity, health, safety hazards and depressed viability of the earth for food production. Land degradation has majorly affected soil physical properties such as, hydraulic conductivity, bulk density, infiltration, organic matter content, porosity and aggregate stability resulting in soil compaction and erosion (Tukahirwa, 2003).

Hydraulic conductivity is important in understanding the flow of water through a porous medium such as soil. It is the single most important soil water transport property which refers to the readiness with which a liquid such as water flows through a solid such as soil in response to a given potential gradient (Brady & Weil, 2002).

Soil hydraulic properties such as water retention capacity, saturated hydraulic conductivity, infiltration rate, sorptivity and transmissivity are affected differently by land use practices, due to the accompanying changes in soil's intrinsic properties. Selby (1972) reported that the conversion of land from forest to pasture resulted in significant changes in the infiltration characteristics of the soil surface layer in central North Island, New Zealand, because the open structure of the forest soil had been destroyed by grazing. According to Lal (1990), hydraulic conductivity data have been used in the drainage of agricultural land and soils with a strong texture contrast between topsoil and subsoil. These soils may have a sharp reduction in hydraulic conductivity with depth. In this case, drainage of water is impeded and water logging can be a problem

Most soils in Southeastern Nigeria are formed from coastal plain sand parent material that is characterized by high rainfall and temperature. These soils are fragile, highly leached, acidic and subjected to water erosion (Udoh et al., 2013). This calls for a serious attention in managing and ensuring sustainable agricultural productivity and environmental quality. There is a need for information relating to soil conditions, their current status, changes due to land use types and the best agronomic practices and conservation measures to ensure sustainable and optimal land utilization. Detailed soil survey, land evaluation and land use planning will be involved (Azagaku, 2005). There have been indiscriminate land use practices in Akwa Ibom state,

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Southeastern Nigeria, that has given rise to serious ecological problems and degradation of land resources. Efforts to address these information necessary for proper land use planning to guarantee sustainable agricultural development and environmental quality is important. Therefore, the aim of this study was to evaluate the effect of selected land use practices on soil properties and to determine the relationship between some soil properties with saturated hydraulic conductivity in Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Description of Study Area

This study was conducted randomly from selected land use types in Akwa Ibom State, Southeastern Nigeria. The state lies within latitudes 4^0 32' and 5^0 53' N and longitudes 7^0 25' and 8^0 15' E. The climate is characterized by two seasons: wet season (April-October) and dry season (November-March). Total annual rainfall ranges from 2000mm to 3000mm. Temperatures are uniformly high throughout the year with slight variation between 26^0 C and 29^0C. Relative humidity is also high averaging about 75%. Revival deposited sands and clays cover 80% of Akwa Ibom State and constitute the Benin formation otherwise known as the coastal plain sands. The sand mass rises gently from the southern areas and eastern (Cross river) base levels to hilly topography in the north of the state, The soils are derived from the sandy parent materials which are highly weathered and dominated by low activity clays (Ogban, 1998). The native vegetation has however been almost completely replaced by palm trees of various densities of coverage and shrubs such as Chromolaena odorata (Siam weed) and various grass undergrowth.

Land Use Types and Sampling Location

Table 1: Showing the different land use types and their sampling locations

Land use	**Locations**
ICL	(i) IKOT OKU UBARA EDIENE, ABAK L.G.A (01) (ii) NTAK INYANG, ITU L.G.A. (02) (iii) IKOT OBIO ASANGA, NSIT IBOM L.G.A (03)
NF	(i) OBOYO IKOT ITA, NSIT IBOM L.G.A (04) (ii) UKANA IKOT NTUEN, ESSIEN UDIEM L.G.A.(05) (iii) OBOT ITU, ITU L.G.A.(06)
OPP	(i) WEST ITAM, ITU L.GA. (07) (ii) AFIAHA ABIA, NSIT IBOM L.G.A(08) (iii) IKOT OKU UBO, ABAK L.G.A. (09)
GP	(i) EDIENE, ABAK L.G.A. (10) (ii) AFIAHA OFFIONG, NSIT IBOM L.G.A.(11) (iii) OKU, IBOKU-ITU L.G.A.(12)

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Table 1 shows a total of 12 soil profile pits. The soil profile pits were demarcated and described according to genetic horizons. Bulk samples were collected from the horizons for laboratory physical analysis. Core samples were also collected with a cylinder measuring 7.2cm height and 6.8cm internal diameter for the determination of bulk density and saturated hydraulic conductivity.

Soil Sampling and Sample Preparation

Four land use types namely intensive cultivated land (ICL), natural forest (NF), oil palm plantation (OPP) and gmelina plantation (GP) were selected for the study. In each land use type, three representative profile pits measuring 2m x 1m and about 1.8m depth were dug, namely: intensive cultivated land (01,02,03), natural forest (04,05,06), oil palm plantation (07,08,09) and gmelina plantation (10,11,12) described according to FAO (2006) guidelines for profile description.

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Laboratory Analysis

Particle Size Distribution

Particle size distribution was determined by Bouyoucos hydrometer method as modified by Gee and Or (2002), after dispersing the soil particles with sodium hexametaphosphate ($NaPO_3$).

Bulk Density (Bd)

Bulk density was determined using the undisturbed core sample by the method of Black and Hartge (1986). The soil was oven dried at 105^0c to a constant weight. The weight of oven dried soil was recorded and total volume calculated from the height and radius of the soil; afterward the bulk density was calculated as follows;

$$\text{Bulk density} = \frac{\text{mass of oven dried soil(g)}}{\text{volume of bulk soil (cm}^3\text{)}}$$

Total Porosity (Tp)

It was calculated with core samples using the method of flint and flint(2002) as:

%Total porosity= volume of water at 0kpa /volume of bulk soil x 100/1

Saturated Hydraulic Conductivity (Ksat)

Saturated hydraulic conductivity (Ksat) was determined by constant head core technique (Reynolds et al., 2002). Volume of water draining out will be measured over time period until flow becomes constant, at which time the flow rate will be determined by the equation:

$$Ksat = \underline{Q / AT \ X \ L / \Delta H}$$

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Where Q is the volume of water collected (cm^3), A is the area of core (cm^2), T is time elapse (S), L is length of core (cm), and ΔH is the change in hydraulic head differences(cm).

Water Stable Aggregates (WSA)

A single sieve method was used in determining water stable aggregate. 4g of 2mm air-dried aggregates were weighed into a 0.25mm sieve. The sample was prewetted by capillarity, and then raised and lowered 20 times per minutes for 3 minutes in a can. Sample retained on the sieve was dispersed with 100ml sodium hexametaphosphate in a can until only sand particles larger than the sieve size remained. The first can in which the dry aggregates samples was oscillated and the second can containing the dispersal solution were oven-dried to determined the dry weight of material in such can. The can containing the dispersing solution 0.2g was subtracted to account for the weight of the dispersing agent. The stable fraction is equal to the soil contained in the dispersing solution can, divided by the sum of the weights in both cans.

Mathematically, it is expressed as

% SA = (weight retained) (weight of sand) /(total sample weight)-(weight of sand).

Where SA is stable aggregates.

EXPERIMENTAL DESIGN AND DATA ANALYSIS

The data obtained were subjected to descriptive analysis to compare the effect of land use practices and regression analysis to assess the relationship between saturated hydraulic conductivity and some soil properties.

RESULTS AND DISCUSSION

Soil Physical Properties under Different Land Use Practices

Some properties of soils under the different land use types such as intensive cultivated land (ICL), natural forest (NF), oil palm plantation (OPP) and gmelina plantation (GP) are presented in Table 1. Particle size distribution shows that all the profiles had high sand content ranging from 83.8 – 92.2% and generally decreased with depth. Silt fraction, which was the least compared to sand and clay, ranged from 1.5 – 5.9% and was irregularly distributed with depth. On the other hand, clay content generally increased down the profile ranging from 5.5 – 12.2%. There was characteristically evidence of clay illuviation, leading to the formation of argillic (Bt) horizons (Soil Survey Staff, 2010) in almost all the profiles, irrespective of the land use practices. This result is in line with earlier observations that soils derived from coastal plain sands are characteristically coarse textured, highly weathered associated with clay illuviation and susceptible to leaching (Enwezor et al., 1990; Uzoho, 2005; Onweremadu, 2007; Udoh et al., 2013).

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Table 2: Selected physical properties of soils under different land practices

SOIL PROPERTY	LAND USE	MAX	MINI	TC	MEAN	Sd	% CV
SAND (%)	ICL	92.2	85.2	LS	88.2	3.6	4.0
	NF	89.0	88.0	LS	88.4	0.5	0.6
	OPP	90.9	83.8	LS	87.7	3.7	4.1
	GP	87.8	84.6	LS	86.5	1.7	1.9
SILT (%)	ICL	1.6	1.5	LS	4.2	2.4	57.2
	NF	3.3	3.0	LS	3.2	0.2	5.4
	OPP	4.3	2.6	LS	3.6	0.9	25.0
	GP	5.9	5.5	LS	5.6	0.2	4.1
CLAY(%)	ICL	8.6	6.3	LS	7.6	1.2	15.5
	NF	9.1	7.8	LS	8.4	0.7	7.7
	OPP	12.2	6.5	LS	8.7	3.1	35.2
	GP	5.9	5.5	LS	5.6	0.2	4.1
Bd (%)	ICL	1.8	1.6	LS	1.7	0.1	6.7
	NF	1.6	1.5	LS	1.6	0.1	3.7
	OPP	1.7	1.5	LS	1.6	0.1	6.3
	GP	1.6	1.4	LS	1.5	0.1	20.0
Tp (%)	ICL	40.8	33.6	LS	36.2	4.0	11.1
	NF	45.1	38.4	LS	41.1	3.6	8.7
	OPP	48.4	37.7	LS	43.7	5.5	12.5
	GP	45.5	38.5	LS	42.6	3.7	8.6
WSA (%)							
	ICL	15.4	8.9	LS	12.9	3.5	27.2
	NF	16.6	10.6	LS	12.9	3.2	24.9
	OPP	10.0	6.3	LS	8.3	1.9	22.5
	GP	4.7	3.9	LS	4.3	0.4	9.3
Ksat (cm/h)	ICL	4.6	3.9	LS	4.3	0.4	8.4
	NF	10.3	7.0	LS	8.2	1.9	22.7
	OPP	14.0	3.6	LS	8.4	5.3	62.8
	GP	4.7	3.9	LS	4.3	0.4	9.3

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The result in Table 2 further shows that Bd in the various land use practices ranged from 1.4 – 1.8 g cm-3. The highest bulk densities of 1.7 gcm-3 was obtained in ICL, followed by 1.6g cm-3 in NF and OPP while 1.5 g cm-3 was obtained for GP and was the least. In each land use practice, Bd increased irregularly with soil depth – inversely with organic matter but directly with clay content. High values of Bd obtained for ICL, NF and OPP, compared to GP, could be attributed to low organic matter content, high compaction due to vehicular traffic and other human activities such as building construction, as well as raindrop impact due to lack of vegetative cover (Mbagwu, 2009; Isirimah et al., 2003). Soil porosity ranged from 33.6 – 48.4%. Expectedly, the highest values of 43.7, 42.6% and 41.1%, were obtained in OPP, GP and NF and 36.2% for ICL, which was the least. The higher total porosity values suggest better aeration and microbial activities (Oti, 2007; Anikwe, 2010) and inversely related to Bd (Table 2). Similarly, WSA ranged from 3.9 – 16.6%. The highest values of 12.9% were obtained in ICL and NF, followed by 8.3% for OPP, and 4.3% for GP which was the least. High soil moisture content in ICL and NF could be attributed to the high organic carbon content, since soil moisture content is linearly related to organic matter content (Ndukwu et al., 2010; Anikwe, 2010). Ksat ranged from 3.6 – 14.0cm/h. The highest values of 8.4cm/h were obtained in OPP, followed by 8.2cm/h for NF while 4.3cm/h for ICL and GP, and were the least. The high values of Ksat in OPP and NF could be associated with the nature of the soil which is sand. Sandy soils consist of macro pores. Brady and Weil (2002) reported that Ksat requires macro pores in conducting water. According to soil survey staff (1993), the soils in this area are moderately rapid.

Table 3: Relationship Between Saturated Hydraulic Conductivity (Ks) And Selected Soil Properties

REGRESSION	B	r^2	P value
Ksat Vs Sand	**-0.193**	**0.037**	**0.548**
Ksat Vs Silt	**-0.375**	**0.141**	**0.229**
Ksat Vs Clay	**0.728**	**0.530**	**0.007******
Ksat Vs Bd	**0.091**	**0.008**	**0.779**
Ksat Vs Tp	**-0.151**	**0.023**	**0.639**
Ksat Vs WSA	**0.083**	**0.007**	**0.798**

Where b = Coefficient of determination

r^2 = R Square

*** * =** Significant at both 1% and 5% level

The result of analysis of regression shows that Ksat was significantly correlated with clay with r^2 value of 0.53(p<0.01) presented in Table 3. This study shows that the land use types were similar in their effects on Ksat and they do not have a significant effect on saturated hydraulic conductivity of these soils and this might be attributed to the high fraction of sand content associated in this area of study. Generally, the land-uses have high sand particles compared to other fine earth fractions. This could be attributed to parent materials, climate, and land-use. These factors influence pedogenesis and properties of soils (Wang et al., 2001; Osujieke et al.,

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2017). It is also in agreement with the findings of Enwezor (1990) and Onweremadu et al. (2011) who found that the sandy nature of the soils reflects the parent material from which they were formed, which is coastal plain sand.

CONCLUSION AND RECOMMENDATION

Soils in this location were dominated by sand-fraction consisting of macropores that favored a high rate of water flow. Mulching, vegetative cover, contour and soil conservation practices are improved and best management practices that enhance flow of water through soils.

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