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ELECTRICAL CONDUCTIVITY, BASIC CATIONS AND ORGANIC MATTER CONTENT OF SOILS UNDER DIFFERENT LAND USE PRACTICES IN AKWA IBOM STATE

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ABSTRACT: *Variation in electrical conductivity, basic cations and organic matter content of soils can be influenced by land use practices, and these parameters may be affected by another. The study was conducted to ascertain the electrical conductivity (EC), basic cations and organic matter content of soils under varying land use types and to assess the relationship between electrical conductivity and the other parameters. The land use types were intensively cultivated farmland (ICF), natural forest (NF), oil palm plantation (OPP) and gmelina plantation (GP). Stratified random sampling technic was used in the collection of soil samples from the land use types. Three (3) replicates of bulk soil were collected for each land use giving a total of twelve (12) observational units. Soil samples were prepared and analyzed in a laboratory and data generated were subjected to analysis of variance, regression analysis and descriptive statistics. There was significant ($P \leq 0.05$) variation in the measured parameter among soils of the land use types. Soils under ICF, OPP, and GP had similar electrical conductivity of 0.08 (dS/m), while NF had 0.10 (dS/m). Organic matter (OM) content of 13.3 g/kg, 19.0 g/kg, 15.3 g/kg and 18.7 g/kg were observed under ICF, NF, OPP and GP, respectively. Exchangeable calcium at ICL was 2.33 cmol/kg; at NF it was 2.50 cmol/kg; at OPP, it was 2.40cmol/kg, and 1.93cmol/kg at GP. Exchangeable magnesium (Mg) was highest (1.07 cmol/kg) at ICL but lowest (0.93cmol/kg) at GP. Similarly, ICF had highest (1.73cmol/kg) and NF had lowest (0.04 cmol/kg) for exchangeable sodium. Calcium and magnesium had significant ($P \leq 0.05$) positive relationships with electrical conductivity, while organic matter and sodium had negative but non-significant relationship with electrical conductivity. The soils do not have salt problem and may not be prone to salinity in the future, meanwhile, organic matter input should be increased at the soil under intensively cultivated farmland.*

KEYWORDS: Land use practices, Hydraulic conductivity, Basic cations, Organic matter, Salt.

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INTRODUCTION

Changes in land use systems affect biomass production and soil organic carbon which directly influences soil physicochemical and biological properties, such as soil water retention and availability, nutrient cycling, gas flux, plant root growth and soil conservation indices (Gregorich et al., 1994). Sustainable land-use practice is a rapidly growing field aiming at producing food security, nutrition security, bio-safety and environmental health (Aluko, 2000). The increase in population growth in the humid rainforest zone of Nigeria has led to increasing pressure in land through intensive crop cultivation, resulting in soil degradation (Opara et al., 2007, Amanze et al., 2022), nutrient imbalance (Oti, 2002) and unavailability of plants nutrients (Onweremadu, 2007). These conditions are heightened by bush fires, deforestation, inappropriate tillage techniques and other conflictive land use practices (Lai et al., 1990; Okoror et al., 2021). Some of these activities promote leaching of basic cations (Ca^{2+},Mg^{2+},Na^{+} and K^{+}) and leaving a preponderance of acidic cations (H^{+} and Al^{+3}) and consequent fixation of available phosphorus (Barzegar, 2003).

Land use practices, especially those resulting in compaction from equipment or livestock use can also lead to decrease in soil productivity by reducing the availability of organic matter and increasing run-off (Amanze et al., 2023). Brady and Weil (1999) observed that soil organic matter is a complex and varied mixture of organic substances that provides much of the cation exchange and water holding capacities of surface soils while Edem (2007) and Okoror et al. (2022) reported that organic matter helps to maintain a high proportion of macro pores which stabilizes soil structure and control certain influence on some physical and chemical properties of the soil including soil electrical conductivity an basic cations.

Soil electrical conductivity (EC) measures the ability of soil water to carry electrical current. It is a measure of soil salinity which directly influences crop production and development in a soil. When ions (Salts) are present, the EC of soil solution increases but if no salts are present, then the EC is low, indicating that the soil solution does not conduct electricity well. Salts are influenced by various factors such as rainfall amount and timing, internal soil drainage and irrigation practices (Patni et al., 1998). Electrical conductivity is an electrolytic process that takes place principally through water-filled pores. Cations (Ca^{2+}, Mg^{2+},K^{+},Na^{+} and NH_4^{+}) and anions (SO_4^{2-},Cl^{-}, NO_3^{-} and HCO_3^{-}) from salts dissolved in soil water carry electrical charges and conduct the electrical current and the concentration of these ions determines the electrical conductivity of soils (Corwin et al., 2005). Increased water retention capacity of soils increases the ability of the soil to conduct electrical currents, that is, other properties being similar, the wetter the soil, the higher the EC (Doolittle et al., 1994); hence, electrical conductivity is influenced by the amount and type of soluble salts in solution, porosity, soil texture (clay content and mineralogy), soil moisture, and soil temperature. High levels of precipitation can flush soluble salts out of the soil and reduce EC while in arid soils (with low levels of precipitation), soluble salts are more likely to accumulate in soil profiles resulting in high EC (Smith et al., 1996).

In soil management, high EC has been associated with high levels of nitrate and other selected soil nutrients (P, K, Ca, Mg, Mn, Zn and Cu). The addition of organic matter such as manures and compost increases EC by adding cations and anions and improving the water-holding capacity of the soil (Corwin et al., 2005). Soils with high EC resulting from a high concentration of sodium generally have poor structure and drainage, and sodium becomes toxic to plants (Smith et al., 1996). In arid climates, plant residues and mulch help to retain water

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and thus allow seasonal precipitation and irrigation to be more effective in leaching salts from the surface (Adviento-Borbe et al., 2006). Hence, this study was conducted to ascertain electrical conductivity (EC), basic cations and organic matter content of soils under intensive cultivated farmland (ICF), natural forest (NF), oil palm plantation (OPP) and *gmelina* plantation (GP) in Akwa Ibom State, Nigeria.

MATERIALS AND METHODS

Description of Study Area

This study was conducted in Akwa Ibom State, Nigeria. It lies within latitudes 4^0 32′N 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 relatively uniform throughout the year with slight variation between 26^0C and 29^0C. Relative humidity is high, averaging about 75%. The geology of the place shows that the parent material is of the Benin formation otherwise known as the Coastal Plain Sands. The soils are highly weathered and dominated by low activity clays (Ogban, 1998). The native vegetation has however almost completely replaced palm trees of various densities of coverage and shrubs such as *Chromolaenaodorata* (Siam weed) and various grass undergrowth.

Land Use Types, Soil Sampling and Sample Preparation

This study was conducted in four land use types, namely: intensively cultivated farmland (ICF), natural forest (NF), oil palm plantation (OPP) and gmelina plantation (GP). Soil sampling was done through stratified random sampling technique in which three (3) locations representing three (3) replicates were used for each land use type. Five auger samples of soils were randomly collected in each location and bulked to obtain a representative sample. The sampling locations for ICF were Ikot Oku; Ntak Inyang, and Ikot Obio Asanga. The sampling locations for NF were Ikot Ntuen, Essien Udiem, and Obot Itu. Sampling locations for OPP were West Itam, Afiaha Abia**,** and Ikot Oku Ubo. Sampling locations for GP were Ediene, Afaha Offiong, and Oku. The samples were prepared and sent for laboratory analyses.

Laboratory Analysis

Soils samples were analyzed using the standard procedures for laboratory analyses. Organic matter was determined using the wet oxidation method of Walkley and Black Electrical conductivity (EC) was measured in the extract obtained by 1:2.5 soil-water suspensions using a conductivity bridge. Exchangeable cations (Ca, Mg and Na) were extracted from the soil with 1N NH_4OAC solution. Na was measured with the flame Analyzer while Mg and Ca were determined by Ethylene diamine tetra-acetic (EDTA) titration method.

Experimental Design and Data Analysis

The experiment was laid out in a randomized complete block design consisting of four (4) land use types and three (3) replicates to give a total of twelve (12) observational units. Data obtained was subjected to analysis of variance (ANOVA) and regression analysis using SPSS version 20.

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RESULTS AND DISCUSSION

Variation among Soil Properties across the Land Use Practices

Table 1 shows the range, mean and percentage coefficient of variation among the soil properties measured across the land use practices while Table 2 shows the separation of mean values of the soil properties across the land use practices. Table 1 shows that there is variation in soil properties across each land use soil while Table 2 reveals that there was significant ($P \leq 0.05$) variation of the soil properties among the land use practices, and the soils are generally low in EC. Electrical conductivity (EC) at each land use practice was low and ranged from 0.04(dS/m) to 0.10 (dS/m) at the other land use types except at NF where it remained 0.10 dS/m across the land. The highest EC (0.10 dS/m) obtained at NF varied significantly from the EC at ICL, OPP and GP which had the least EC of 0.08(dS/m). This observation is in agreement with Smith (1996) that the optimal EC values for plants growth is usually between 0.8-1.8(ds/m) and should not exceed 2.5(ds/m) while Dahnke (1988) reported that EC of the range 0-1.2dS/m is common at loamy fine sand to loam and that they are non-saline soils. The highest EC at NF may be attributed to the effective ground cover by the forest trees against rainfall impact which reduced the incidence of leaching of soluble ions and resulted in their accumulation in the soil. This corroborates the report of Smith (1996) that the accumulation of soluble salts of calcium, magnesium, potassium, nitrates and sulfates contributed to increased electrical conductivity of soils. Also, the increased accumulation of organic matter at the NF which upon decomposition and mineralization released ionic substances may have contributed to the increased EC at NF; consequently, the reduced EC observed at some regions within the other land use types relative to NR may be attributed to low organic matter return and increased leaching of soluble salts at such (Smith at al., 1996). The general low EC at the soils could be predicted on the increased amount and intensity of rainfall within the study area which may have translated to increased leaching of soluble ions (Patni et al., 1998).

The highest variation of organic matter content across each land use was observed at the ICF with arrange of 1.0 g/kg to 30.0 g/kg and % CV of 122.78%, while the least variation was observed at OPP with a range of 17.0 – 14.0 g/kg and % CV of 9.8% as shown in Table 1. The highest OM (19.0 g/kg) was obtained at NF which differed significantly ($P \leq 0.05$) from that of the other land use except GP, while ICF had the lowest OM (13.3 g/kg) which was not significantly different from OPP as shown in Table 2. Across the land use types, the content of organic matter in the soils were considered low when matched with the critical levels of organic matter as reported in Udo et al. (2009). This assertion is in conformity with the findings of Aban and Oriji (2019) who related that the range of values of organic carbon varied widely across soils of varying parent materials such that OM content of soils on Coastal Plain Sands ranges from 4.1 to 11.2g/kg and Sandstones ranges from 4.1 to 10.7g/kg. The high OM at NF may be attributed to the accumulation of litters from fallen leaves, dead tree trunks and tree roots which when decomposed add to the organic matter content of the soil while the low OM at ICF was probably a result of increased loss of organic matter due to continuous tillage of the soil that exposed it to increased oxidation (Amanze et al., 2023).

The greatest variation in exchangeable calcium and magnesium across each land use was observed at ICF and ranged from 1.6 - 3.0cmol/kg with % CV of 30.10 % for Ca, and 0.60 - 1.30 cmol/kg with % CV of 36.10% for Mg. However, the least variation in Ca and Mg was observed at GP with a range of 1.8 – 2.0 cmol/kg and % CV of 5.97% for Ca and a range of 0.9 – 1.0 cmol/kg with % CV of 6.18%.The highest mean Ca (2.50cmol/kg) and mean Mg

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(1.07 cmol/kg) were obtained at NF. The Ca concentration at NF was not significantly different ($P \leq 0.05$) from that of the other land use except GP while the Mg concentration at NF was not significantly different from those of the other land use types. Conversely, GP had the lowest mean Ca and Mg concentration of 1.93cmol/kg and 0.93 cmol/kg, respectively. It was observed that across the land use types, exchangeable calcium was moderate while exchangeable Mg was low, and this was based on the established critical level reported in Landon (1991). The high exchangeable calcium and magnesium at NF could be predicted on its increased OM content which upon decomposition may have released Ca and Mg into the soil. Also, the possible improved nutrient holding capacity of the soil by the aggregation effect of OM content of the soil may have contributed to the retention of Ca and Mg in the soil against loss by leaching. This agrees with the report of Amanze et al. (2017) that organic carbon improved the availability of basic cations including Ca and Mg by improving the water and nutrient holding capacity of the soil. The decreased concentration of Ca and Mg at GP may have resulted from the possible increased leaching of basic cations and low organic matter turnover resulting from the sparse distribution of the plants which reduced canopy cover and exposed the soil to increased impact of rainfall (Gregorich et al., 1994).

The greatest variation in exchangeable Na across each land use type was observed at OPP and GF with a range of 0.04 - 1.8cmol/kg and % CV of 50%. Meanwhile, the least variation of Na was observed at ICF with a range of 1.60 – 1.80 cmol/kg and % CV of 6.70%. The highest mean exchangeable Na concentration of 1.73 cmol/kg was obtained at ICF and it varied significantly ($P \leq 0.05$) from the other land use types. On the other hand, NF had the lowest mean Na concentration of 0.04cmol/kg, and this was not significantly different from the other land use types except ICF. Generally, across the land use types, exchangeable sodium was high as reported in Amalu (1998) that the critical value for exchangeable sodium in tropical soils is 0.02cmol/kg. However, the above values certainly would not constitute a problem for growth and development of most crops (Amalu, 2016). The highest exchangeable sodium in ICF is possibly an indication of continuous plant uptake of exchangeable bases such as K, Ca and Mg which are of great nutritional important to the crops leading to the accumulation of Na at the exchange site of the soil (Amanze et al., 2022); also, the use of pesticides, fertilizers and other soil amendments of high Na content may have led to the accumulation of Na thereby increased its content at the soil under ICF (Onweremadu, 2007; Okoror et al., 2021).

Relationship between Electrical Conductivity and the Other Soil Properties

Table 3 shows that EC had significant ($P \leq 0.05$) positive relationship with Ca and Mg but had negative relationship with OM and Na though not significant ($P \leq 0.05$). The total variability (R^2) in EC contributed by OM was 3.9% and for any unit increase in OM, EC decreased by 19.90%. This indicated that OM had very low influence on the EC of the soils studied. The total variability (R^2) in EC due to Ca and Mg was 43.8% and 34.1%, respectively; and for a unit increase in Ca and Mg, EC increased by 66.20% and 58.40%, respectively. This underscores that Ca and Mg had increased influence on EC and contributed greatly to the total available salt content of the soils. Contrariwise, the total variability in EC accounted for by Na was 1.30% and for any unit increase in Na, EC decreased by 11.40%.

The negative relationship observed between EC and Na negates the previous reports that exchangeable Na contributed to the increase in EC (Corwin et al., 2005). However, the contrary observation in this research may be predicated on the negative influence of the high concentration of Na in the soils. Electrical conductivity depends on a number of factors

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including soil structure, texture, moisture content and OM; hence the high concentration of Na at the soils may have increased the degradation of soil structure leading to the loss of OM, and inability of the soils to retain water. This corroborates the report of Doolittle et al. (1994) that decreased water retention capacity of soils decreases the ability of the soil to conduct electrical currents; hence, the wetter the soil, the higher the electrical conductivity. Similarly, the negative relationship between EC and OM content of the soils negates the previous report of Brady and Weil (1999) that OM provides much of the cation exchange and water holding capacities of surface soils thereby increasing electrical conductivity. The contrary finding on this from this study could be associated with the possibility of certain soil OM to increase the dispersivity of soil aggregates thereby degrading the soil structure against water retention and other physicochemical conditions of the soil that would have enhanced EC (Nelson & Oades, 1998). The significant positive relationship of EC with Ca and Mg confirms the report of Corwin et al. (2005) that high EC has been associated with high levels of selected nutrients including Ca and Mg.

CONCLUSION

The study reveals that the soils have low electrical conductivity; hence, they do not have salt problems. The soil parameters measured varied across regions within each land use practice. The soils were low in OM though the highest was obtained at NF while the lowest was observed at ICF. Moreover, the soils had moderate amounts of Ca and Mg with the highest mean value of the two observed at the NF; hence soils under NF had the best quality compared to the other soils studied. The EC of the soils has a negative relationship with OM and Na though not significant, while Ca and Mg significantly enhanced the EC of the soils. Soils at the ICF need increased input of organic matter to improve the OM content.

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Table 1: Summary statistics of soil properties under different land use practices

Soil properties	Land use	Max	Min	Mean	% CV
EC (ds/m)	ICF	0.10	0.04	0.08	50.00
	NF	0.10	0.10	0.10	0.00
	OPP	0.10	0.04	0.08	50.00
	GP	0.10	0.04	0.08	50.00
OM (%)	ICF	3.00	0.10	1.33	112.78
	NF	2.60	1.30	1.90	34.71
	OPP	1.70	1.40	1.53	9.80
	GP	2.90	1.30	1.87	27.81
Ca (cmol/kg)	ICF	3.00	1.6	2.33	30.10
	NF	2.80	1.9	2.47	19.99
	OPP	2.80	1.9	2.40	19.10
	GP	2.00	1.8	1.93	5.97
Mg (cmol/kg)	ICF	1.30	0.60	1.00	36.10
	NF	1.30	0.80	1.07	23.60
	OPP	1.20	0.80	1.03	20.15
	GP	1.00	0.90	0.93	6.18
Na (cmol/kg)	ICF	1.80	1.60	1.73	6.70
	NF	0.04	0.04	0.04	25.00
	OPP	0.10	0.04	0.08	50.00
	GP	0.10	0.04	0.08	50.00

Table 2: Mean values of electrical conductivity, organic matter and basic cations of the soils

Land Use type	EC(dS/m)	OM(g / kg)	Ca(Cmol/kg)	Mg(Cmol/kg)	Na(Cmol/kg)
ICF	**0.08**	**13.30**	**2.33**	**1.00**	**1.73**
NF	**0.10**	**19.00**	**2.50**	**1.07**	**0.04**
OPP	**0.08**	**15.30**	**2.40**	**1.03**	**0.08**
GP	**0.08**	**18.70**	**1.93**	**0.93**	**0.08**
LSD	**0.03**	**4.00**	**0.24**	**0.76**	**0.05**

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Table 3: Relationship between electrical conductivity (dS/m) and selected soil properties

Variables	b	r^2	P value
EC Vs OM	**-0.199**	**0.039**	**0.536**
EC Vs Ca	**0.662**	**0.438**	**0.019***
EC Vs Mg	**0.584**	**0.341**	**0.046***
EC Vs Na	**-0.114**	**0.013**	**0.723**

b = Regression Coefficient, r^2 = Coefficient of determination, * = Significant at 5%

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