

*Full Length Research Paper*

## **Fertility status of soils under selected land use types in Orlu, Imo State, Southeastern Nigeria**

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The study evaluated the fertility status of some land use types in Orlu area of Imo State using elemental ratio. Soil samples were collected from three land use types namely; plantain plantation, oil palm plantation and cassava. A total of 18 samples were collected. Six soil samples were randomly collected from each land use at depths of 0 - 15 cm and 15 - 30 cm. Routine analyses were conducted and Ca/Mg and K/Mg were used to determine the fertility status of the soils. The result of physical properties indicated that mean sand content of the soils ranged from 820.1 - 910.1 g/kg. The mean silt content of the soils ranged from 13.3 – 56.7 g/kg while the clay content ranged from 76.5 – 136.5 mg/kg. Bulk density was highest under oil palm (1.43 g/cm<sup>3</sup>) and lowest under cassava (1.10 g/cm<sup>3</sup>). The results of the chemical properties showed that mean pH varied from 5.0 – 5.7. Soil organic carbon was highest under plantain (16.9 g/kg) and lowest under oil palm (9.3 g/kg). Ca/Mg ratio was highest under plantain (1.78) and lowest under cassava (1.20). The K/Mg was highest under oil palm (0.14) and lowest under plantain (0.02). Ca/Mg ratio of the soils indicates possible Ca deficiency and phosphorus inhibition. The K/Mg ratio of the soils shows non inhibition of the uptake of magnesium Ca/Mg ratio varied highly under plantain and cassava but had medium variation under palm oil. There was significant negative relationship between K/Mg and Mg, ECEC, Ca, base saturation (BS) and available phosphorus (-0.85, - 0.85, - 0.86, -0.77, and -0.47) respectively.

**Key words;** Elemental ratio, soil fertility, land use, Imo state, southeastern Nigeria

### **INTRODUCTION**

Soil is the most important resource for agricultural production (Khalif, 2010), hence soil fertility depletion in smallholder farms has been cited as the fundamental biophysical root cause for the declining per capita food production in Africa (Sanchez et al., 1996). Fertile soil is the foundation of sustainable agricultural system (Pimentel and Warneke 1989).

Changes in land use and soil management can have a marked effect on the soil organic matter. Several studies

have shown that deforestation and cultivation of virgin tropical soils often lead to depletion of nutrients (N, P and S) present as part of complex organic polymer. Bernoux et al. (1998) indicated that long practice of deforestation and/or replacement of natural forests by agro ecosystem and uncontrolled overgrazing have been the major cause of soil erosion and climate change. Since harvested trees are not replaced and thus, expose the soil, about 1.9 to 3.5 billion tons of fertile soils are washed away annually

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into rivers and lakes due to deforestation alone (Lakew et al., 2000).

Soil fertility and plant nutrition are two closely related subjects that emphasized the forms and availability of nutrients in soils, their movement to and their uptake by roots, and the utilization of nutrients within plants (Foth and Ellis, 1997). Without maintaining soil fertility, one cannot talk about increment of agricultural production in feeding the alarmingly increasing population. Therefore, to get optimum sustained-long lasting and self-sufficient crop production, soil fertility has to be maintained.

Soil fertility quality at field scale is mainly influenced by differences in fertilization, cropping system and farming practices (Liu et al., 2010). The distribution and availability of phosphorus in soil is determined by management practices such as level of soil organic matter, vegetation cover and nutrient recycling in the ecosystem as well as the different land use types (Megistu et al., 2017).

Soil fertility status has been measured using different methods. Common one among them is the use of elemental ratio (Li et al., 2016; Landon 1991), which is an important parameter used in determining soil fertility. Ca : Mg ratio is usually in the range between 3:1 – 7:1 (Johnstone, 2011). Ca: Mg values lower than 3:1 indicate unfertile soils (Landon, 1991) and may result to deficiency of calcium as well as phosphorus inhibition (Udo et al., 2009). K:Mg ratio greater than 2:1 may inhibit the uptake of magnesium, which is common in acid soils, and may be an indication that the soil is unfertile.

Little information is currently available to farmers and extension workers with regards to soil fertility and nutrient management in Orlu area of Imo State. Hence, this research work was carried out to determine the fertility status of soils under selected land use types in Umudioka, Orlu, Imo State using elemental ratio.

## MATERIALS AND METHODS

### Study area

The study was carried out in Orlu area. Soil of the study area derives from the coastal plain sands, Benin formation (Orajaka, 1975). The area lies between latitude 4° 40' and 8° 15' N and longitude 6° 40' and 8° 15' E (Federal Department of Agricultural Land Resources, 1985). Imo State lies in humid tropical rainforest with a mean monthly temperature of about 27°C and mean annual rainfall of about 2400 mm. The rainfall pattern is bimodal with peaks in the month of July and September with a short dry spell in the month of August known as August break (Onweremadu et al., 2007). Agriculture is the major socio-economic activity in the study area where cassava (*Manihot* spp), oil palm (*Elaeis guineensis*), maize (*Zea mays*) and plantain (*Musa* spp) are grown.

### Field study

A reconnaissance visit was made to the study area and sample sites of the three land use types; cassava, oil palm and plantain, Orlu area. In each land use, samples were collected at depths of 0 -

15 cm and 15 – 30 cm, and the sampling was replicated three times. A total of 18 samples were collected. Core sample were used to collect soil sample for bulk density determination. The soil samples collected were bagged, labeled and taken to the laboratory for air drying, crushing and sieving using 2-mm sized sieve and stored for laboratory analyses.

### Laboratory analyses

Routine laboratory analyses were conducted on soil sample using standard procedures. The particle size distribution was determined by the Bouyoucos hydrometer method (Bouyoucos, 1962; Van Reeuwijk, 1992). Bulk density was determined by the method described by Grossman and Reinsch (2002) and calculated using the formulae

$$pb = \frac{ms}{vs}$$

where  $P_b$  = bulk density,  $ms$  = mass of oven dry soil,  $vs$  = volume of core sampler obtained using the relation  $v = \pi r^2 h$ , where  $r$  and  $h$  are radius and height of the core sampler.

Total porosity was computed from the values of bulk density and particle density (Brady and Weil, (2002) as

$$Tp = \left(1 - \frac{pb}{ps}\right) \times \frac{100}{1}$$

Where  $T_p$  = total porosity,  $p_b$  = bulk density,  $p_s$  = particle density assumed to be 2.65 g/cm for tropical soils. Moisture content was determined by Gravimetric method (Obi, 1990) and was computed as follows;

$$\% MC = \frac{w_2 - w_3}{w_3 - w_1} \times \frac{100}{1}$$

$W_1$  = Weight of moisture can

$W_2$  = Weight of air-dried soil + moisture can

$W_3$  = Weight of oven-dry soil + moisture can.

Soil pH was determined in 1:2.5 (soil: liquid ratio) potentiometrically using a glass electrode (Van Reeuwijk, 1992). Organic carbon was carried out by wet oxidation method as described by Walkley and Black (1934). Organic matter was then estimated by multiplying the organic carbon with a value of 1.724 (Van Bemmelen factor). Total nitrogen was estimated using the micro kjeldahl method as described by Black (1965). Available phosphorus was determined using Bray II solution (Mclean, 1965). Exchangeable bases were extracted using 1N  $NH_4OAC$  neutral solution (Thomas, 1982); exchangeable calcium and magnesium in the extract were analyzed using atomic absorption spectrophotometer while sodium and potassium were analyzed by flame photometer (Chapman, 1965; Rowell, 1994). Exchangeable acidity was extracted by leaching the soil sample with potassium chloride solution and titrating with sodium hydroxide as described by Mclean (1965). The effective cation exchange capacity (ECEC) was determined by the addition of all the exchangeable acidity and exchangeable bases.

$ECEC$  = Exchangeable acidity + Exchangeable bases.

Base saturation was computed using the formulae

$$\%BS = \frac{TEB}{ECEC} \times \frac{100}{1}$$

Ca: Mg ratio was estimated by dividing the value of exchangeable

**Table 1.** Physical properties of the studied land use types.

Land use type	Depth (cm)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)	Textural class	Silt:clay ratio	Bulk density (g/cm <sup>3</sup> )	Total porosity (%)	Moisture content (%)
Plantain	0-15	956.8	40	3.2	SL	12.5	1.23	52.0	14.3
	0-15	856.8	0	143.2	SL	-	1.30	49.2	14.5
	0-15	916.8	0	83.2	SL	-	1.09	57.4	15.6
	Mean	910.1	13.3	76.5		0.17	1.21	52.9	14.8
	15-30	836.8	50	113.2	S	0.44	1.43	44.1	14.0
	15-30	816.8	60	123.2	SL	0.48	1.36	46.9	14.0
	15-30	896.8	60	43.2	SL	1.39	1.28	50.0	13.7
	Mean	850.1	56.7	93.2		0.61	1.36	47.0	13.9
Oil palm	0-15	876.8	20	103.2	SL	0.19	1.1	57.0	11.0
	0-15	876.8	20	103.2	SL	0.19	1.15	55.1	9.7
	0-15	856.8	80	63.2	SL	1.27	1.13	55.9	8.5
	Mean	870.1	40	89.9		0.45	1.13	56.0	9.7
	15-30	856.8	40	103.2	SL	0.39	1.28	50.0	12.2
	15-30	876.8	40	83.2	SL	0.48	1.52	40.6	13.5
	15-30	866.8	40	93.2	SL	0.43	1.49	41.8	14.4
	Mean	866.8	40	93.2		0.43	1.43	44.1	13.3
Cassava	0-15	876.8	0	123.2	SL	-	1.10	57.0	11.9
	0-15	876.8	20	103.2	LS	0.19	1.18	53.1	10.3
	0-15	836.8	60	103.2	SL	0.58	1.03	59.8	12.5
	Mean	863.5	26.7	109.9		0.24	1.10	56.6	11.6
	15-30	796.8	40	163.2	LS	0.25	1.44	43.8	12.2
	15-30	806.8	50	143.2	SL	0.35	1.52	40.6	14.2
	15-30	856.8	40	103.2	S	0.36	1.23	52.0	15.2
	Mean	820.1	43.3	136.5		0.32	1.40	45.4	13.9

SL = Sandy loam, S = Sand, LS = Loamy sand.

Calcium with the value of exchangeable Magnesium. K:Mg ratio was estimated by dividing the value of exchangeable potassium with value of exchangeable magnesium whereas C:N ratio was obtained by dividing the value of organic carbon with value of total Nitrogen.

### Statistical analysis

The variability of soil properties was measured by estimating coefficient of variation (CV). The coefficient of variation was ranked according to the procedure of Wilding (1985) where CV < 15% = low variation, CV >15 < 35% = moderate variation, CV > 35% = high variation. Correlation analysis was done to detect the functional relationships between soil properties and fertility indices.

## RESULTS

### Physical properties of the soils of the studied land use types

Results of the physical properties of the soils of the studied land use types are shown in Table 1. The results showed that the mean sand content of the soil at plantain,

oil palm and cassava ranged from 820.1 – 910.1 g/kg. The mean silt content of the soil ranged from 13 – 56 g/kg while the clay content ranged from 76.5 – 136.5 g/kg. From the results, the highest average sand content (910.1 g/kg) was observed under plantain and the lowest (820.1 g/kg) was recorded in cassava. Highest average clay content 136.5 g/kg was recorded under cassava and the lowest (76.5 g/kg) was recorded under plantain. The clay content increased with depth under all land use types.

Bulk density of the soils under plantain, oil palm and cassava were moderate, ranging from 1.03 – 1.52 g/cm<sup>3</sup>. The highest mean (1.43 g/cm<sup>3</sup>) value of bulk density was recorded under oil palm at 15- 30 cm and the lowest mean (1.10 g/cm<sup>3</sup>) value of bulk density was recorded under cassava at 0 -15 cm depth. Total porosity of the soil under plantain, oil palm and cassava ranged from 40.6 – 59.8%. The highest mean (59.8%) value of total porosity was obtained under cassava and the lowest (40.6%) under oil palm and cassava. While the highest occurred on 0 – 15 cm depth, the lowest occurred on 15 – 30 cm depth.

**Table 2.** Chemical properties of the studied land use types.

Land use types	Depth (cm)	pH H <sub>2</sub> O	OC (g/kg)	TN (g/kg)	C/N	AVP (mg/kg)	Ca (mol mm <sup>-1</sup> )	Mg	K	Na (Cmol/kg)	Al	H	TEA	TEB	ECEC	BS (%)
Plantain	0-15	5.9	16.6	1.4	11.6	11.1	3.4	1.3	0.1	0.09	0	0.4	0.4	4.8	5.2	93.0
	0-15	5.3	15.8	1.4	11.5	9.5	5.5	4.5	0.1	0.09	0	0.4	0.4	10.2	10.6	96.2
	0-15	5.5	16.2	1.4	11.6	8.5	3.4	2.3	0.1	0.1	0	0.8	0.8	5.8	6.6	87.9
	Mean	5.5	16.2	1.4	11.6	9.7	4.1	2.7	0.1	0.09	0	0.5	0.5	6.9	7.5	92.4
	15-30	5.6	18.1	1.6	11.6	13.9	5.1	4.3	0.1	0.04	0	0.4	0.4	9.5	9.9	96.3
	15-30	5.9	15.7	1.4	11.6	8.9	5.8	4.4	0.1	0.05	0	0.2	0.2	10.4	10.6	98.1
	15-30	5.4	17.0	1.5	11.6	11.8	5.7	4.5	0.1	0.05	0.08	1.2	1.3	10.3	11.7	88.7
	Mean	5.7	16.9	1.5	11.6	11.5	5.6	4.4	0.1	0.05	0.03	0.6	0.6	10.1	10.7	94.4
Oil palm	0-15	5.1	0.40	0.0	10.5	2.0	4.7	3.2	0.2	0.06	0	0.4	0.4	8.1	8.5	95.3
	0-15	5.3	19.0	1.6	11.6	2.0	6.6	3.8	0.2	0.06	0	0.4	0.4	10.5	11.0	96.0
	0-15	5.5	18.2	15.7	1.2	2.1	3.0	1.9	0.2	0.06	0	3.0	3.0	5.1	8.1	62.7
	Mean	5.3	12.5	5.8	7.7	2.0	4.8	3.0	0.2	0.06	0	1.3	1.3	7.9	9.2	84.7
	15-30	6.0	9.2	0.8	11.1	8.1	1.3	1.2	0.2	0.03	0	1.1	1.1	2.7	3.8	70.5
	15-30	5.1	9.3	0.8	11.4	3.8	1.0	0.9	0.2	0.04	0	1.0	1.0	2.1	3.1	67.4
	15-30	5.1	9.5	0.8	11.6	2.2	1.4	1.1	0.1	0.04	0	1.7	1.7	2.7	4.4	61.9
	Mean	5.4	9.3	0.8	11.4	4.7	1.2	1.1	0.2	0.04	0	1.3	1.3	2.5	3.8	66.6
Cassava	0-15	4.9	11.4	1.0	11.6	4.3	1.2	1.0	0.1	0.1	0.56	0.8	0.4	2.1	3.7	63.4
	0-15	4.9	13.0	1.1	11.6	3.4	2.7	1.0	0.1	0.1	0	0.6	0.6	3.9	4.5	86.9
	0-15	5.1	9.2	0.8	11.5	4.7	4.4	4.3	0.1	0.12	0	1.0	1.0	8.9	9.9	89.7
	Mean	5.0	11.2	1.0	11.6	4.1	2.8	2.1	0.1	0.11	0.19	0.8	0.7	5.1	6.1	80
	15-30	5.9	14.2	1.2	11.6	1.1	2.6	2.1	0.2	0.03	0.76	0.2	1.0	4.8	6.6	72.8
	15-30	5.0	15.0	1.3	11.6	1.2	1.3	1.0	0.1	0.04	0	0.8	0.8	2.4	3.2	73.9
	15-30	5.2	14.8	1.3	11.6	1.2	1.1	1.1	0.1	0.04	1	0.9	2.0	2.3	4.2	54.5
	Mean	5.4	14.7	1.3	11.6	1.1	1.7	1.4	0.1	0.04	0.59	0.7	1.3	3.2	4.7	67.1

OC = Organic carbon, TN = Total nitrogen, C/N = Carbon-nitrogen ratio, AVP = Available phosphorus, TEA = Total exchangeable acidity, TEB = Total exchangeable bases, ECEC = Effective cation exchange capacity, BS = Base saturation.

### Chemical properties of the soils of the studied land use types

Results of the chemical properties of the soils of the studied land use types are shown in Table 2.

The soil pH in H<sub>2</sub>O of the soils under plantain, oil palm and cassava ranged from 4.9 – 6.0. The highest mean (5.7) value was recorded under plantain while the lowest mean (5.0) value was recorded under cassava. It was observed that pH

increased with soil depth.

The value of the organic carbon under different uses ranged from 0.4 – 18.4 g/kg. The highest mean value (16.9 g/kg) was recorded under plantain while the lowest mean value (9.3 g/kg)

**Table 3.** Fertility status of the studied land use types.

Land use type	Depth (cm)	Ca/Mg	K/Mg
Plantain	0 -15	2.63	0.06
	0 -15	1.22	0.02
	0 -15	1.49	0.04
	Mean	1.78	0.04
	15-30	1.18	0.02
	15-30	1.33	0.02
	15 -30	1.25	0.02
	Mean	1.26	0.02
Oil palm	0 -15	1.47	0.05
	0 -15	1.72	0.04
	0 -15	1.58	0.08
	Mean	1.59	0.06
	15 -30	1.08	0.13
	15-30	1.04	0.16
	15-30	1.30	0.13
	Mean	1.14	0.14
Cassava	0 -15	1.22	0.08
	0 -15	2.62	0.08
	0 -15	1.02	0.02
	Mean	1.62	0.06
	15 -30	1.23	0.07
	15-30	1.31	0.09
	15-30	1.07	0.08
	Mean	1.20	0.08

was recorded under oil palm. Total Nitrogen of the soils ranged from 0.0 – 15.7 g/kg. The highest and lowest total nitrogen value occurred under oil palm. Total nitrogen followed a similar trend as soil organic carbon. The C/N ratio of the soils ranged from 7.7 – 11.6. The mean available phosphorus under plantain, oil palm and cassava ranged from 1.1 – 11.5 mg/kg. The highest was recorded under plantain (11.5 mg/kg) and the lowest (1.1 mg/kg) under cassava. The mean value for exchangeable calcium (Ca), magnesium (Mg), potassium (K) and Sodium (Na) ranged from 1.2 – 5.6 cmol/kg, 1.1 – 4.4 cmol/kg, 0.1 - 0.2 cmol/kg and 0.04 – 0.11 cmol/kg respectively. The highest mean value for Ca and Mg occurred under plantain (5.6 and 4.4 cmol/kg) respectively at 15 -30 cm depth. The lowest mean value for Ca and Mg occurred under oil palm (1.2 and 1.1 cmol/kg) respectively at 15 – 30 cm depth; the highest mean value for K was obtained under oil palm (0.2 cmol/kg) at both 0 -15 cm and 15 – 30 cm while the lowest occurred under plantain (0.1 cmol/kg) at 15 – 30 cm depth. Average ECEC of the soils under different land uses ranged from 3.8 – 10.7 cmol/kg.

#### Fertility status of soils of the studied land use type

The results of the fertility status of the studied land use

types using elemental ratio are shown in Table 3. The highest mean value of Ca: Mg ratio (1.78) occurred under plantain while the lowest (1.20) occurred under cassava. The mean Ca: Mg ratio ranged from 1.20 – 1.78. The mean K: Mg ratio ranged from 0.02 – 0.14. The highest mean value of K: Mg ratio (0.14) occurred under oil palm while the lowest occurred under plantain.

#### Variability among some soil physical-chemical properties and fertility indices of the studied land use types

Results of the spatial variability among soil physical-chemical properties of the studied land use types are shown in Table 4. Sand content had low variation in all land use types. The total porosity had low variation in the three land use types 9.12%, 14.53% and 14.63% for plantain, oil palm and cassava respectively. The bulk density also recorded low variation under plantain and oil palm (9.09% and 14.57%) while it recorded medium variation in cassava (15.40%). Moisture content had low variation under plantain and cassava (4.81% and 13.61%) and medium variation under oil palm (19.38%). The pH in water had low variation in all the land use types. Organic carbon and total nitrogen had low

**Table 4.** Variability among selected physicochemical properties and fertility indices of studied land use types.

Land use type	Sand (g/kg)	Bulk Density (g/cm <sub>3</sub> )	Total Porosity (%)	Moisture Content (%)	pH (H <sub>2</sub> O)	Organic Carbon (g/kg)	Total Nitrogen (g/kg)	Available Phosphorus (mg/kg)	Base Saturation (%)	Ca/Mg
Plantain	6.00	9.09	9.11	4.81	4.73	5.49	5.50	19.42	4.60	36.41
Oil palm	1.13	14.57	13.53	19.38	6.48	62.84	84.30	72.25	20.90	19.93
Cassava	4.10	15.40	14.63	13.61	7.23	17.6	17.51	64.22	18.31	42.65

variation (5.49% and 5.50%) under plantain, medium variation (17.60% and 17.51%) under cassava and high variation (62.84% and 84.3%) under oil palm. Available P had medium variation (19.42%) under plantain and high variation (72.25% and 64.22%) under oil palm and cassava respectively. The base saturation had low variation (4.60%) under plantain and medium variation (20.90% and 18.31%) under oil palm and cassava respectively. The Ca:Mg had high variation except for oil palm where it had medium (19.90%).

#### Relationship among selected soil properties and fertility indices in the studied land use types

Results of the relationship among selected soil properties and the fertility indices in the studied land uses are shown in Table 5. Result showed that available phosphorus had a significant negative correlation with K: Mg ratio ( $r = -0.485$ ,  $p \leq 0.05$ ). Base saturation, exchangeable Ca, ECEC and exchangeable Mg had a significant negative correlation with K: Mg ratio ( $r = -0.768$ ,  $-0.856$ ,  $-0.845$ ,  $-0.849$ ;  $p \leq 0.01$ ) respectively.

## DISCUSSION

#### Physical properties of the soils of the studied land use types

In all the land use types, sand content decreased

with depth and could be as a result of transported eroded materials. Soils are predominantly sandy, with the sandy nature a reflection of the parent material from which they were formed. This is in line with findings by Enwezor et al. (1990) and Uzoho (2005). Clay and silt content increased with increase in soil depth and could be due to illuviation and argillation in the lower depths (Brady and Weil, 2008). When studying the eroded and non-eroded soils in Orlu area of Imo State, Nkwopara et al. (2019) attributed the observation to increased clay migration to the subsurface horizons. This was in conformity with the findings of Eshett et al. (1989), Mengistu et al. (2017) and Aririguzo et al. (2019) for soils underlain by false bedded sand stone and coastal plain sands respectively. Generally, it was observed that bulk density increased with soil depth. This could be as a result of reduction in organic matter with increase depth. From the result, the soils are well aggregated having bulk density less than 1.4 g/cm<sup>3</sup> except soil under oil palm at 15 - 30 cm depth. This is in line with the findings of White (1997) who stated that the values of bulk density that ranged from 1.0 – 1.4 g/cm<sup>3</sup> indicate aggregate soil. The total porosity under the different land use types decreased with depth and could be due to reduction in organic matter with increased depth. Brady and Weil (2002) stated that the decreasing organic matter and increase in clay that occur with depth in many profiles are associated with the shift from macro pores to micro pores. Soils having this property

lack absorption capacity for basic nutrient and water retention (Oguike and Mbagwu, 2009).

#### Chemical properties of the soils of the studied land use types

The pH increase with soil depth could be attributed to the leaching of cations from the surface. The soils were moderately to strongly acidic (FAO, 2004). Similar results have been reported for some soils of southeastern Nigeria (Nkwopara et al., 2017, 2019) due to the inhabitation materials that give rise to the chemical composition of the organic matter. The high amount of rainfall in the area and the coarse texture of the soils lead to leaching of some basic cations and dominance of acidic cations on the exchange complex of the soil (Nkwopara et al., 2017). The optimum pH for most agricultural crops falls between 6.0 and 7.0, because nutrients are more available at pH of 6.5 (Wong et al., 2001). The values of organic carbon when compared with critical value of 15 – 20 g/kg for tropical soils (Enwezor et al., 1990), showed that the soil under oil palm and cassava fell below critical level and only the soil under plantain (16.2 -16.9 g/kg) have values above the critical level. The general low levels could be attributed to management practices involving burning, and to continuous farming as well as reduction in the fallow period (Akinrinde and Obigbesan, 2000). Total nitrogen for all land uses except oil palm was below 1.5

**Table 5.** Relationship among selected soil properties and fertility indices.

Soil property	Ca/Mg	K/Mg
Al	-0.265	0.122
Available phosphorus	0.061	-0.485*
Base saturation	0.317	-0.768**
Ca	0.113	-0.856**
Effective cation exchange capacity	-0.101	-0.845**
Hydrogen ion	-0.132	0.378
Mg	-0.228	-0.849**
Organic carbon	0.206	-0.357
pH (H <sub>2</sub> O)	0.043	-0.189
Total nitrogen	0.101	0.054

\*, \*\* = Significant at 0.05 and 0.01 levels of probability.

g/kg, which is the critical value for tropical soils (Enwezor et al., 1990) and indicates high nitrogen deficiencies. It has been observed that the main cause of nitrogen deficiency in tropical soils is intense leaching and erosion due to high tropical rainfall (White and Reddy, 1999; Isrimah et al., 2003). The low nitrogen level signifies responses to Nitrogen fertilization. The C/N ratio relates to soil organic matter decomposition and nitrogen mineralization. Lower C:N indicates higher mineralization and decomposition. It has been reported that nitrogen mineralization occur at C/N ratio below 30:1 (Catherine et al., 1992). However, Ma et al. (1999) observed N mineralization in soils with higher C/N ratios and thus concluded a no relationship between C/N ratio and N mineralization. The available phosphorus in all land uses were below critical value (15 mg/kg) according to rating of Landon (1991). However, soils under plantain had high available phosphorus when compared to other land uses. Critical values of soil nutrients have been reported by various researchers. For instance, Adeoye and Agboola (1985) reported critical values of 2.0, 0.4 and 0.20 cmol/kg for Ca, Mg and K respectively. When compared with values obtained for the three different land use types, it shows that Ca and Mg were above the critical level not deficient in the soil while K was below the critical level. This suggests that K fertilization will be responded to by the crops. Compared with critical K values of 0.16 and 0.20 cmol/kg (White and Reedy, 1999; Isirimah et al., 2003) and 0.10 cmol/kg (Ekpete, 1972), all the soils studied showed great deficiencies. When compared with 0.15 – 0.42 cmol/kg critical Mg values suggested by Lombin (1994), Mg deficiency may not be a problem for the soils studied. Low values of Ca, Mg, and K have been reported for most Nigerian soils (Akinrinde and Obigbesan, 2000) and could be attributed to leaching losses by the high tropical rain as well as low content in the parent rock. Soil ECEC has been classified as low (< 6 cmol/kg), medium (6 – 12 cmol/kg) and high (> 12 cmol/kg). On the basis of the classification, all the soils

studied have low to medium ECEC due to the dominance of kaolinite clays in the fine earth fractions (Ojanuga and Awojuala, 1981). Most researchers have observed that CEC of tropical soils is related to their organic matter content (Aluko and Oguntala, 1997; Noma et al., 2005).

#### Fertility status of soils of the studied land use type

For fertile soils, the Ca:Mg ratio is usually in the range of 3:1 – 7:1 (Johnstone, 2011). Ca: Mg values less than 3:1 are typical of unfertile soils (Landon, 1991). Higher Ca: Mg value indicates high fertility. Considering the mean values recorded in the studied land use types, the soils are of low fertility status. The Ca: Mg ratio of less than 3:1 in the soils indicated possible Ca deficiency and P inhibition (Udo et al., 2009). The results also indicate that Ca: Mg ratio decreased with depth. This is contrary to finding by Nkwopara et al. (2019) who stated that Ca:Mg showed irregular pattern of distribution in eroded and non- eroded soils in Orsu area of Imo state. The reason for this is not yet understood. Except soil under plantain, the K: Mg ratio increased with depth. Nkwopara et al. (2019) stated that K: Mg ratio in most profile of eroded and non-eroded soils of Orsu area of Imo State increased with soil depth. K: Mg ratio greater than 2:1 may inhibit uptake of Mg, which is very common in acid soils, and is an indicator of soil infertility. The ideal K: Mg ratio is 0.2 – 0.3 (Udo et al., 2009). Considering the mean values recorded in the studied land use types, the soils of the land use types are of low fertility status. These findings are in agreement with Mbah (2006), Onweremadu (2007), and Onwudike et al. (2016) who concluded that Southeastern Nigeria soils are low in fertility level. This poor fertility status is due to high rainfall in the area which increases soil erosion and leaching of plant nutrient elements. The dominant nature of sand fraction as the result of the parent material (coastal plain sands) contributes to soil acidity and low nutrient element in the

soil.

### Variability among some soil physical-chemical properties and fertility indices of the studied land use types

Low variation in sand content could be attributed to the same parent material (coastal plain sands) that dominated the three land uses as well as the homogeneity of underlain geology and climate. This finding agrees with the works of Onweremadu et al (2011), Ahukaemere et al. (2012), Aririguzo et al. (2019) of soils under the same agro ecology. The results of bulk density and total porosity, agree with Aririguzo et al. (2019) on soils under forested and pasture land use. The result of the moisture content could be due to different vegetation cover in the various land use which has different tendencies of holding soil. The result of pH agrees with Aririguzo et al. (2019) on soils under forested and pasture land use.

### Relationship among selected soil properties and fertility indices in the studied land use types

The significant negative correlation between some soil properties like available phosphorus, base saturation, exchangeable Ca, ECEC and exchangeable Mg with K: Mg ratio implies that as these soil properties increase the K: Mg ratio decreases.

### Conclusions

The soils of the land use are well aggregated except soils under oil palm at 15 - 30 cm depth. The soils were moderately to strongly acidic. On the basis of the classification, all the soils studied have low to medium ECEC. The Ca: Mg ratio and K:Mg ratio of the soils show that the soils are infertile. The results also showed that Ca: Mg ratio decreased with depth. The soils of the land use types are of low fertility status, and the sand content and total porosity had low variation in all land use types. Available phosphorus, base saturation, exchangeable Ca, ECEC and exchangeable Mg had a significant negative correlation with K: Mg ratio which means that the increase of these soil properties leads to decrease of K: Mg ratio and vice versa. It is recommended that agronomic practice such as organic farming that will help in improving the soil fertility of the soils be employed.

### CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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