EVALUATION OF FERTILITY STATUS OF SELECTED ERODED AND NON-ERODED SOILS IN AN ULTISOL IN A HUMID TROPICAL ENVIRONMENT USING ELEMENTAL RATIO.

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ABSTRACT

This study was carried out to evaluate the fertility status of some water eroded and non-eroded soils of Orsu area of Imo State using elemental ratio. Two mini pedons were sunk in the eroded and non-eroded site each .A total of 12 composite soil samples were collected, comprising of 6 from eroded and 6 from the non-eroded at 0-20, 20-40 and 40-60 cm depths. Routine analyses were conducted and Ca/ Mg and K/Mg were used to determine the fertility status of the soils. Data generated were subjected to t-Test analysis to compare some selected physico-chemical soil properties and fertility status of the eroded and non-eroded soils. The results of physical properties indicated slight higher sand particle in the non-eroded sites (mean= 755.1 g/kg) relative to the eroded sites (mean=749.6 g/kg). Clay particle was more prominent in the eroded sites (197.5 g/kg) compared to the non-eroded site (169.8 g/kg). Bulk density was higher in the non-eroded soils (1.14-1.29 gcm^{-3}) relative to the eroded soils (1.00 -1.20 gcm^{-3}) while moisture content was higher in the non-eroded site (mean=253.3 g/kg) than the eroded site (mean=137.2 g/kg). The results of the chemical properties showed that the pH of both sites varied from strongly acidic to moderately acidic. Soil organic matter was higher in the non-eroded site (12.7 g/kg) than the eroded site (5.4%). Higher values of available phosphorus were observed in the non-eroded site (mean=29.74 mg/kg) compared to the eroded site (mean=27.88 mg/kg).The results obtained for exchangeable bases showed marked differences among the eroded and non-eroded sites with higher values observed mostlsy in non-eroded site. The C/N ratio of the eroded site (10.44) was slightly higher than the non-eroded site (10.17). The results of the fertility status of the eroded and the non-eroded soils using elemental ratios showed that the Ca/Mg ratio was higher in the eroded site (2.02) than the non-eroded site (1.41). Ca/Mg ratio of both sites indicates possible Ca deficiency and phosphorus inhibition. On mean value basis, K/Mg ratio of the non-eroded soils (0.03) was slightly higher than the eroded soils (0.02). The K/Mg ratio of the soils indicates non inhibition of uptake of magnesium. The K/Mg ratio increased with soil depth except eroded site 1. The results of the T-test analysis revealed that there was significant positive difference in Ca/Mg ratio, K/Mg ratio, clay, Na, %BS, and C/N ratio but significant negative difference in moisture content, bulk density, organic carbon, organic matter, total nitrogen and available phosphorus.

Keywords**:** Elemental ratio, Soil fertility, Eroded and non eroded soil, southeastern Nigeria.

INTRODUCTION

Land degradation can be viewed as any change or disturbance to the land perceived to be deleterious or undesirable (Eswaran, 2001). Land degradation is a major threat to agricultural sustainability because it negatively affects soil productivity (Khan *et al.*, 2001). Major causes of land degradation include soil erosion, poor farming practices, overgrazing, urban sprawl and commercial development, land pollution amongst others.

Land degradation is a universal set of which soil degradation is a subset. Since soil is the most stable and most manipulated feature of land, soil degradation contributes most significantly to land degradation. This explains why land degradation studies are mostly approached from the study of soil degradation (Ibrahim and Idoga, 2013).

Soil erosion which has been Identified as major cause of soil degradation in southeastern Nigeria (Oti, 2015) resulting to loss of soil mass from land surfaces while reducing the productivity of all natural ecosystems as well as agricultural, forest, and pasture ecosystems (Troeh, et al., 2004). It has been reported that soil erosion results to degradation of important biological, chemical and physical properties of soils for plant production thus reducing soil fertility with the major consequence being low crop yield (Oti *et al.*, 2007).

Using different soil fertility indices, different researchers working in different environments have reported erosion induced fertility decline. Loss of rooting depth, changes in soil texture and water holding capacity were identified as major negative effects of soil erosion in the temperate environment. However, in the tropics low organic matter levels and nutrient pools, nutrient imbalance and aluminium toxicity were reported to be associated with eroded soils (Oti, 2002). The sustainable exploitation of the water eroded soils is however, currently hindered by the lack of site specific information on the eroded soils, thereby rendering them prone to abuse and mismanagement (Mustapha and Loke, 2005).

Soil fertility means the capacity of soil to supply plant nutrients required by a healthy crop whereas from the perspective of Brady and Weil (2010), soil fertility refers to the quality of soil that enables it to provide essential chemical elements in quantities and proportions for the growth of specified plants.

Various indices have been used to assess the fertility status of soils. Common ones include the use of elemental ratios such as Ca:Mg ratio, K:Mg ratio, C:N ratio etc. (Li et al., 2016; Landon, 1991). The elemental ratio is an important soil quality parameter used in determining soil fertility status. 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) and may result to P inhibition and Ca deficiency (Udo *et al.*, 2009). Udo *et al.* (2009) reported that K:Mg ratio greater than 2:1 may inhibit uptake of Mg and this is very common in acid soils, thus may be an indicator of soil infertility. The USDA Natural resources conservation service (2011) reported that nitrogen will become temporarily deficit (immobilization) in soils with C:N ratio greater than 24 whereas in soils with C:N ratio less than 24, nitrogen will become temporarily surplus, thus C:N ratio of 24 is favorable for optimum crop production.

Soil fertility decline has been associated with soil erosion occurrence (Oti *et al.*, 2007). Several studies on the impact of soil erosion on fertility status using fertility indices of soils have been made (García-Díaz *et al.*, 2017; Li et al., 2016). Oti (2002) observed increase in Ca:Mg ratio with severity of soil erosion. Similarly, Onweremadu (2007) revealed higher Ca:Mg ratio at the eroded sites relative to the control site. Soil erosion occurrence increases C:N ratio of soils (Stacy 2015; Onweremadu et al., 2007). Studies by Stacy (2015) on C:N ratio of a toposequence under active erosion indicated lower C:N ratio at the crest compared to the valley bottom, suggesting that erosive forces remove more nitrogen than carbon in the soil system.

Crop production is a predominant socio-economic activity in Orsu area of Imo State where soils are highly degraded as a result of erosion and erosive forces acting upon the soil surface resulting in washing away of the soil, loss of nutrients and creation of gullies. However, little or no work has been carried out to evaluate the impact of erosion menace on the fertility status of soils of Orsu area. It was against this backdrop that this work was carried out. The objective of this study was to use elemental ratio to determine the fertility status of selected water eroded and non eroded soils of Orsu, Imo State Southeastern Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted at Orsu area located on Latitude 5^0 51^1 $14^{'}$ N and Longitude 6^0 51^1 $14^{'}$ E. Soils of the area are derived from Coastal Plain Sands (Benin formation) (Orajaka, 1975). The study area is in Imo State, Southeastern Nigeria which lies between Latitudes $4^0 40^1$and 8^0 15^1 N and Longitudes 6^0 40^1 and 8^0 15^1 E (Federal Department of Agricultural Land Resources, 1985). Imo State is in the humid tropical rainforest with a mean monthly temperature of about 27^0C, 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, 2007). Agriculture is a major socio-economic activity in the study area. Agricultural crops mostly cultivated in the study area include yam (*Dioscorea spp*) cassava (*Manihot spp*), oil palm (*Elaies guineensis*) and maize (*Zea mays*).

Field Study

Prior to field study, a reconnaissance visit was made to the study area and the sampling sites comprise two eroded (gullied) and two non eroded (non-gullied) locations in the Eziawa Orsu. Two mini-pedons on eroded and two on non eroded, of about 60 cm depth were sunk in each. Composite soil samples were collected from 0-20 cm, 20-40 cm and 40-60cm from the mini- pedons, giving to a total of 12 samples used for the study. Soil samples were taken using hand trowel, from the lowest depth to the topmost depth of each of the profile pits to avoid contamination Also, core samples were used to collect soil samples for bulk density determination. The soil core samples collected were sealed immediately in the field and then bagged using polythene bags, labeled and transported to the laboratory where they were air-dried, crushed, sieved through 2 mm sized sieve and stored ready for laboratory analyses.

Laboratory Analyses

Routine analyses were conducted on soils samples using standard procedures. The sand, silt and clay contents of the soils were determined by hydrometer method using sodium hexameta phosphate (calgon) as dispersing agent (Gee and Or, 2002). Bulk density (g/cm^3) was determined using the method described by Grossman and Reinchm (2002) and calculated using the relation $pb = \frac{Ms}{Vs}$

Where 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 calculated from particle and bulk densities of the soils as follows:

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

Where pb= Bulk density, Ps= Particle density (Assumed to be 2.65 g/cm^3 for tropical soils).

Moisture content was determined by gravimetric method (Obi, 1990). It was calculated as follows;

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

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 to liquid ratio in water and 0.1N KCl using the glass electrode pH meter (Hendershot *et al.*, 1993).Organic carbon was determined by chromic acid wet oxidation method as described by Nelson and Sommers (1982). Organic Matter was then determined by multiplying the organic carbon with a value of 1.724 (Van Bemmelen factor).

Total Nitrogen was determined using the micro Kjeldahl method (Bremner and Mulvaney, 1982).Available phosphorus was determined using Bray II solution (Olsen and Sommers, 1982).These were extracted using neutral IN NH_4OAC neutral solution (Thomas, 1982). After extraction, exchangeable calcium and magnesium were determined by complexometric titration method using ethylene Diamine Tetra Acetic Acid (EDTA), while sodium and potassium were determined by flame photometer method (Jackson, 1962).This was determined by leaching the soil with IN KCl and titrating with 0.05N NaOH (Mclean, 1982).This was determined by summing all the basic and acidic cations ECEC= TEA + EA.

This was calculated as follows:

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

Ca:Mg ratio was determined by dividing the value of exchangeable Calcium with the value of exchangeable Magnesium, K:Mg ratio was determined by dividing value of exchangeable potassium with value of exchangeable magnesium whereas C:N ratio was obtained by dividing value of organic carbon with value of total Nitrogen. Data obtained from laboratory analyses were presented in Tables. Data were subjected to t-Test analysis at 5% level of probability to compare the physico-chemical properties and fertility status of the eroded and non-eroded soils of the study area

RESULTS AND DISCUSSION

Physical properties of the eroded and non-eroded soils

The physical properties of the eroded and non-eroded soils are shown in table 1. The results of the particle size distribution indicated slight higher sand particle in the non-eroded sites (755.1 g/kg) relative to the eroded sites (749.6 g/kg). However, it was observed that clay particle was more prominent in the eroded sites compared to the non-eroded sites, with the former and the latter having mean values of 197.5 g/kg and 169.8 g/kg, respectively. Texture varied from sandy loam to sandy clay in the eroded sites and sandy loam to sandy clay in the non-eroded sites. These findings on particle size distribution suggest that erosion occurring in the study area removes more sand particle than clay particle which does not corroborate with the reports of Nnadi and Luffman (2012) in their study of the properties of eroded and non-eroded soils. Generally, in the non-eroded site with minimal disturbances, sand particle decreased with depth whereas clay particle increased with depth which could be due to illuviation and argillation in the lower depths (Brady and Weil, 2008). In the eroded site, the distribution of sand and clay particles did not follow a definite pattern which is similar to the reports of Nnadi and Luffman (2012).

Expectedly, bulk density was higher in the non-eroded soils compared to the eroded soils, attributable to the higher sand content of non-eroded soils (Table 1). It ranged from 1.0 -1.2 gcm^{-3} in the eroded site and 1.14-1.29 gcm^{-3} in the non-eroded site. It has been observed that increasing sand particle in soils, increases soil bulk density (Salvalia *et al*., 2009). Generally, the bulk densities of the soils were moderate suggesting that root growth would not be impeded by the bulk densities recorded. The values of bulk densities were below the critical limit of 1.3 gcm^{-3} recommended for tuber and cereal crops (Kayombo and Lal, 1984)

Table 1: Physical Properties of the Eroded and Non-Eroded Soils

Sample	Sand g/kg	Silt g/kg	Clay g/kg	TC	BD (gcm^{-3})	TP %	MC g/kg
			ERODED SOILS				
E_1 (0-20)	729.6	27.2	243.2	SL	1.14	57	55
E_1 (20-40)	729.6	27.2	243.2	SL	1.17	56	221
E_1 (40-60)	749.6	33.8	216.6	SL	1.13	58	229
E_2 (0-20)	769.6	13.8	216.6	SC	1.20	55	207
E_2 (20-40)	769.6	167.7	62.7	SC	1.00	63	69.1
E_2 (40-60)	749.6	47.7	202.7	SC	1.11	59	42.5
Mean	**749.6**	**52.9**	**197.5**		**1.13**	**58**	**137.2**
			NON-ERODED SOILS				
NE_1 (0-20)	789.6	47.2	163.2	SC	1.29	52	212
NE_1 (20-40)	789.6	27.2	183.2	SC	1.17	56	327
NE_1 (40-60)	729.6	127.2	143.2	CL	1.15	57	235
NE_2 (0-20)	789.6	67.5	143.2	SL	1.18	56	253
NE_2 (20-40)	702.9	113.9	183.2	SC	1.14	57	261
NE_2 (40-60)	729.6	67.2	203.2	SC	1.18	56	232
Mean	**755.1**	**75.0**	**169.8**		**1.20**	**55.66**	**253.3**

Key: E_1= Eroded Site I, NE_1 = Non-Eroded Site I, E_2 = Eroded Site II, NE_2 = Non-Eroded Site II
TC =Textural class, BD= Bulk density, TP= Total porosity, MC= Moisture content

Higher soil porosity was observed in the eroded site than the non-eroded soils. Mean values of 58% and 55% were recorded in the eroded and non-eroded soils, respectively (Table 1). The higher porosity observed in the eroded site indicates better aggregation, higher infiltration and percolation rate in that site (Wei *et al.*, 2007). The results of moisture content showed that it was higher in the non-eroded site. It was in the range of 42.5-228.5 g/kg in the eroded site and 212-327.5 g/kg in the non-eroded site (Table 1). Rhoton and Tyler (1990) asserted that severely eroded soils tend to have lower moisture content than the non-eroded soils. Higher moisture content observed in the non-eroded site could be due to the higher organic matter content of that site (Table 2). Increase in water holding capacity of soils has been associated with increase in organic matter levels in soils (Havlin *et al.*, 2012).

Chemical Properties of the eroded and the non-eroded soils.

The results of the chemical properties of the eroded and non-eroded soils are presented in Table 2. The pH of the soils varied slightly. It varied from 5.5-5.8 in the eroded site while in the non-eroded site, it varied from 5.4-5.9. These values varied from strongly acidic to moderately acidic (FAO), 2004). Similar pH results have been reported for some soils of Southeastern Nigeria (Nkwopara, 2017). The generally low pH of the eroded and non-eroded soils could be due to the high amount of rainfall in the area and the coarse texture of the soils which might have encouraged the leaching of some basic cations leading to the dominance of acidic cations on the exchange complex of the soils (Nkwopara, 2017).

Soils of the non-eroded site had more organic carbon than those of the eroded site. Mean values of 3.1 g/kg and 7.4 g/kg were observed for the eroded and non-eroded soils, respectively. The results can be considered to be generally low and could be attributed to erosion losses, leaching, intensive cultivation, and rapid mineralization processes in the study area (Nwagbara and Ibe, 2015). Lower values of organic carbon recorded in the eroded site could be due to erosion activity in the site which is similar to the reports of Onweremadu *et al.* (2007b) in their study of some eroded and non-eroded soils of Southeastern Nigeria. The result also showed that the percentage organic carbon decreased down the profile pit in the two sites.

A comparison of organic matter levels in the two sites revealed that the soil organic matter was higher in the non-eroded site than the eroded site (Table 2). Mean values were 5.4 g/kg and 12.7 g/kg in the eroded and non-eroded sites, respectively. The lower values recorded in the eroded site could be due to erosion effects. It has been reported that soil organic matter loss has been associated with increase in severity of soil erosion (Kosmas *et al.,* 2001).

Table 2: Chemical Properties of the Eroded and Non-Eroded Soils

Sample	pH	OC g/kg	C/N	TN g/kg	AvP (mg/kg)	Ca (Exchangeable Bases)	Mg	Na Cmol kg^{-1}	K	TEA	ECEC	BS %
ERODED SOILS												
E_1 (0-20)	5.8	4.8	12.00	0.4	25.13	3.30	1.08	0.06	0.03	1.32	5.77	77.2
E_1 (20-40)	5.5	2.6	8.67	0.3	25.48	0.25	1.42	0.11	0.01	0.88	2.67	67.0
E_1 (40-60)	5.5	2.8	9.33	0.3	37.38	2.25	0.42	0.11	0.01	0.56	3.35	83.3
E_2 (0-20)	5.8	3.4	11.33	0.3	25.34	3.30	1.38	0.05	0.02	0.56	5.31	89.5
E_2 (20-40)	5.8	2.4	12.00	0.3	31.36	2.00	4.83	0.07	0.01	1.72	8.63	80.1
E_2 (40-60)	5.8	2.8	9.33	0.3	22.61	0.50	0.67	0.18	0.04	0.76	2.15	64.7
Mean	**5.7**	**3.1**	**10.44**	**0.3**	**27.88**	**1.93**	**1.63**	**0.09**	**0.02**	**0.96**	**4.65**	**76.96**
NON-ERODED SOILS												
NE_1 (0-20)	5.9	9.0	9.00	1.0	28.07	2.70	1.67	0.05	0.01	1.00	5.42	81.5
NE_1 (20-40)	5.8	8.6	10.75	0.8	26.88	2.70	1.92	0.03	0.01	1.24	5.89	78.9
NE_1 (40-60)	5.4	7.0	10.00	0.7	47.67	0.75	0.58	0.03	0.01	1.16	2.53	54.1
NE_2 (0-20)	5.9	6.4	10.69	0.6	40.18	0.90	1.67	0.03	0.01	1.36	3.96	65.7
NE_2 (20-40)	5.5	4.8	9.60	0.5	28.56	3.50	1.50	0.03	0.06	1.60	6.69	76.1
NE_2 (40-60)	5.6	8.8	11.00	0.8	54.74	0.75	0.58	0.03	0.04	1.64	3.04	46.1
Mean	**5.7**	**7.4**	**10.17**	**0.7**	**29.74**	**1.88**	**1.32**	**0.03**	**0.02**	**1.33**	**4.59**	**67.06**

Key: E_1= Eroded Site I, NE_1 = Non-Eroded Site I, E_2 = Eroded Site II, NE_2 = Non-Eroded Site II

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

The findings also showed that the organic matter was generally very low in the two sites (FAO, 2004) and could be attributed to high temperature, leaching and high amount of rainfall which have accelerated mineralization of organic matter (Nwagbara and Ibe, 2015). Generally, in the sites, organic matter decreased with depth.

The percentage total nitrogen for eroded site ranged from 0.3 g/kg -0.4 g/kg, while that of non-eroded site ranged from 0.5 g/kg-1.0 g/kg with mean values of 0.3% and 0.7 g/kg for eroded and non-eroded soils respectively. The lower values recorded in the eroded site could be due to erosion menace. Most sediments from soil erosion have always been found to be five times richer in nitrogen compared to the original soil (Brady and Weil, 2010), which indicates that soil erosion removes significant quantity of nitrogen from soils. The findings corroborates with the reports of Oti (2002) in the study of some eroded and non-eroded soils of Southeastern Nigeria. Generally, higher values were observed in the upper horizons at the two sites which could be due to higher organic litter content of surface soil (Zhijing *et al.*, 2013). The C/N ratio of the eroded site (10.44) and the non-eroded site (10.17) differed slightly with higher values recorded in the eroded site. C/N ratio of soils less than 24 results in net mineralization of N whereas C/N ratio of soils greater than 24 results in net immobilization of N (USDA-NRCS, 2011). This indicates that irrespective of erosion menace, there is net mineralization of N in both sites. However, based on the assertions of USDA-NRCS (2011), it can be inferred that soils of the non-eroded are more fertile than soils of the eroded site and could be due to losses of N from the eroded site. According to the rating of Hazelton and Murphy (2007), C/N value less than 25 as recorded in the present study indicated that decomposition proceed at the maximum rate possible under hot conditions which is true of the environment of the study.

Available phosphorus followed similar distribution trend with total nitrogen as higher values were observed in the non-eroded site (26.88-54.74 mg/kg) compared to the eroded site (22.61-37.38 mg/kg). However, the values recorded in the two sites were sufficient for optimum crop production (Esu, 1999). The lower P values observed in the eroded site could be associated to the erosion menace. It has been reported that soil erosion occurrence results to losses of available P and most of the eroded available P find their way to nearby streams, causing Eutrophication (Brady and Weil, 2010).

The results obtained for exchangeable bases showed marked differences among the eroded and non-eroded sites. On mean value basis, exchangeable Ca was higher in the eroded site (1.93 $cmolkg^{-1}$) than the non-eroded site (1.88 $cmolkg^{-1}$), exchangeable Mg also was higher in the eroded site (1.63 $cmolkg^{-1}$) than the non-eroded site (1.32 $cmolkg^{-1}$), exchangeable Na was higher in the eroded site (0.09 $cmolkg^{-1}$) compared to the non-eroded site (0.03 $cmolkg^{-1}$), While exchangeable K was higher in the non-eroded and was in the range of 0.01-0.06 $cmolkg^{-1}$ and 0.01-0.04 $cmolkg^{-1}$, for non-eroded and eroded respectively. Most of the values observed in the two sites were below the critical level recommended by FAO (2004) and could be due to high intensity of rainfall in the area which might have resulted in the leaching of basic cations. Total exchangeable acidity was more prominent in the non-eroded site relative to the eroded site. In the eroded site, it ranged from 0.56-1.72 $cmolkg^{-1}$ while in the non-eroded site, it was in the range of 1.00-1.64 $cmolkg^{-1}$. Generally, the values of total exchangeable acidity increased with depth in both eroded and non-eroded sites (Table 2).

Soils of the eroded site (4.65 $cmolkg^{-1}$) had more ECEC than those of the non-eroded site (4.59 $cmolkg^{-1}$). The ECEC values recorded in the both sites were far lower than the critical limit of 6 $cmolkg^{-1}$ recommended by Esu (1999) for arable crop production. The results also showed that the values were higher in the upper depths and could be due to higher organic matter content of that depth. It has been reported that organic matter contributes to ECEC of soils (Das, 2011). The results of the percentage base saturation in both the eroded and non-eroded sites revealed higher values in the eroded site (64.7-89.5%) compared to the non-eroded site (54.1-81.5%). In the two sites, the distribution followed an irregular pattern. The base saturation of the soils of the eroded and non-eroded sites varied from moderate to high which augur well for crop production (FAO, 2004). The low ECEC of less than 10 $cmolkg^{-1}$ and low base saturation suggest the dominance of 1:1 clays and high level of aluminium. Generally, the low soil carbon, total nitrogen and organic matter contents indicates poor soil fertility (Duruigbo *et al.,* 2007).

Fertility Status of the Eroded and Non-Eroded Soils Using Elemental Ratios

Table 3 shows the fertility status of the eroded and the non-eroded soils using elemental ratios.

The results of Ca/mg ratio showed mean values of 2.0 and 1.41 in the eroded and non-eroded sites, respectively. For fertile soils, the Ca/Mg ratio is usually in the range of 3:1-7:1 (Johnstone, 2011). Similarly, Ca:Mg values less than 3:1 are typical of unfertile soils (Landon 1991). Therefore, judging by the mean values recorded in both sites, the soils of the eroded and non-eroded are of low fertility status. The Ca/Mg ratio of less than 3:1 in both sites indicate possible Ca deficiency and P inhibition (Udo *et al.*, 2009). The results also showed irregular pattern of distribution of Ca/Mg ratio in the profiles of the two sites (Table 3).

Table 3: Fertility Status of the Eroded and Non-Eroded Soils, Using Elemental Ratios

Sample	Ca/Mg	K/Mg
ERODED SOILS		
E_1 (0-20)	3.05	0.03
E_1 (20-40)	0.18	0.01
E_1 (40-60)	5.36	0.02
E_2 (0-20)	2.39	0.01
E_2 (20-40)	0.41	0.01
E_2 (40-60)	0.75	0.06
Mean	**2.02**	**0.02**
NON-ERODED SOILS		
NE_1 (0-20)	1.62	0.01
NE_1 (20-40)	1.41	0.01
NE_1 (40-60)	1.29	0.02
NE_2 (0-20)	0.54	0.01
NE_2 (20-40)	2.33	0.04
NE_2 (40-60)	1.29	0.07
Mean	**1.41**	**0.03**

Key: E_1= Eroded Site I, NE_1 = Non-Eroded Site I, E_2 = Eroded Site II, NE_2 = Non-Eroded Site II

On mean value basis, K/Mg ratio of the non-eroded soils (0.03) was slightly higher than the eroded soils (0.02). In most of the profiles of the eroded and non-eroded sites, the K/Mg ratio increased with soil depth (Table 3). Udo *et al.* (2009) had reported that K:Mg ratio greater than 2:1 may inhibit uptake of Mg and this is very common in acid soils, thus may be an indicator of soil infertility and that the ideal K/Mg ratio is 0.2-0.35. Therefore, judging by the mean values recorded in both sites, the soils of the eroded and non-eroded are of low fertility status.

Comparison of the physico-chemical properties and fertility status of the eroded and non-eroded soils using T-test analysis.

The results of the T-test statistical analysis conducted to compare the physico-chemical properties and fertility status of the eroded and non-eroded soils are presented in Tables 4, 5 and 6, and showed that the erosion menace significantly and positively affected the clay particles evident in the significant positive difference observed whereas it significantly and negatively affected moisture content and bulk density of the soils (Table 4). The implication of this findings is that increase in the severity of soil erosion will result to clay particles dominating the particle size distribution of the soils but will result to significant decrease in bulk density and moisture content of the soils.

Table 4:T-test analysis of Physical properties of eroded and non-eroded

Sample	Eroded	Non Eroded	T-test	p value	Remarks
Sand (%)	74.96	76.96	-1.37	0.201	Not significant
Silt (%)	5.29	7.50	-0.79	0.451	Not significant
Clay (%)	22.86	16.99	4.14	0.002	Significant
MC(%)	13.72	25.3	-2.89	0.016	Significant
BD(gcm^{-3})	1.13	1.19	-1.68	0.017	Significant
TP (%)	58	56	1.69	0.122	Not significant

Key: ns = non significant, s = significant
MC = Moisture content, BD = Bulk density, TP – Total porosity

Results showed that organic carbon, organic matter, total nitrogen and available phosphorus differed significantly and negatively. The results imply that increase in severity of soil erosion will result in decrease in organic carbon, organic matter, total nitrogen and available phosphorus of soils of the area. However, significant positive difference in exchangeable Na and percentage base saturation was observed. There was significant positive difference in C/N ratio. Therefore, increasing severity of soil erosion in the site will result to increase in C/N ratio of the soils which probably may result to decrease in the fertility status of the soils (Table 5).

Table 5: T-test analysis of Chemical properties of eroded and non-eroded

Sample	Eroded	Non Eroded	T-test	p value	Remarks
pH(H_20)	5.7	5.7	0.15	0.88	Not significant
OC(%)	0.31	0.74	-5.59	< 0.001	Significant
C/N	10.44	31.12	3.12	< 0.001	Significant
TN(%)	0.03	0.08	-8.22	< 0.001	Significant
AvP(mg/kg)	27.88	37.68	-1.85	0.094	Significant
Ca(cmolkg^{-1})	1.9	1.88	0.07	0.947	Not significant
Mg(cmolkg^{-1})	1.63	1.32	0.45	0.67	Not significant
Na(cmolkg^{-1})	0.09	0.03	2.51	0.052	Significant
K(cmolkg^{-1})	0.02	0.03	-0.73	0.481	Not significant
TEA(cmolkg^{-1})	0.97	1.33	-1.7	0.119	Not significant
ECEC(cmolkg^{-1})	4.65	4.59	0.05	0.962	Not significant
%BS	76.97	67.1	4.14	0.002	Significant

Key: ns = non significant, s = significant
O = Organic carbon**,** Avp = Available phosphorus, TN = Total nitrogen, TEA = Total exchangeable acidity, ECEC = Effective cation exchange capacity, BS = Base saturation.

A comparison of the fertility status of the eroded and non-eroded soils using T-test analysis (Table 6) showed significant positive difference in Ca/Mg ratio and K/Mg ratio . Therefore, increasing severity of soil erosion in the site will result to increase in Ca/Mg ratio and K/mg ratio of the soils which probably may result to decrease in the fertility status of the soils.

Table 6: Selected fertility indices of eroded and non-eroded

Sample	Eroded	Non Eroded	T-test	p value	Remarks
Ca/Mg	2.02	1.41	1.80	0.002	Significant
K/Mg	0.02	0.03	4.10	0.002	Significant

Key: ns = non significant, s = significant

CONCLUSION

Water erosion affects soil properties and fertility status. Specifically, water erosion menace resulted to decrease in organic matter, total nitrogen, exchangeable bases, soil pH and sand content, bulk density of the soils but increased soil porosity, exchangeable acidity, C/N ratio, Ca/Mg ratio and K/Mg ratio. The study indicated that both the eroded and non-eroded soil are of low fertility status and requires improvement. However, based on fertility indices of both soils, it can be inferred that soils of the non-eroded site were of better fertility than soils of the water eroded site.

Further studies on the effect of erosion menace on growth performance and yield of major tropical crops should be conducted in the area in order to account for soil erosion induced crop performances and yield decline. Conclusively, soils of both sites were low in fertility but those of the non-eroded site were considered better in fertility. It was therefore recommended that liming and application of organic manures on soils of the eroded and non-eroded sites be done.

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