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Original Research Article

Fertility Status of Selected Eroded and Non-Eroded Soil in Urualla Imo State, Southeastern Nigeria

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Abstract

This study was carried out to evaluate the fertility status of eroded and non-eroded soils of Urualla area of Imo State. A total of 12 composite soil samples were collected, comprising of 6 from eroded and 6 from non-eroded, at depth of 0-20, 20-40 and 40-60 cm. Two mini Pedons were sunk in the eroded and two in the non-eroded site. The soil samples were analyzed for some selected physico-chemical properties and fertility status of the soils using standard procedures and 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 higher sand particle in the non-eroded sites (835.20g/kg) relative to the eroded sites (801.90g/kg). Clay particle was more prominent in the eroded sites (174.80g/kg) compared to the non-eroded site (128.10g/kg). Bulk density was higher in the non-eroded soils (0.4 -0.93 gcm-3) relative to the eroded soils (0.46-1.96 gcm-3) while moisture content was higher in the non-eroded site (mean=16.40%) than the eroded site (mean=15.19 %). The results of the chemical properties showed that the pH of the both sites is slightly acidic. Soils of eroded site had more organic carbon than those of the non-eroded site. Mean values of 2.4g/kg and 4.0g/kg were observed for the eroded and non-eroded soils, respectively. Higher values of available phosphorus were observed in the non-eroded site (mean=5.26mg/kg) compared to the eroded site (mean=2.60mg/kg).The results obtained for exchangeable bases showed slightly differences among the eroded and non-eroded sites with higher values observed in eroded site. The results of the fertility status of the eroded and non-eroded soils using elemental ratios showed that the C/N ratio of the non-eroded site (3.08) was slightly higher than the eroded site (2.00). The Ca/Mg ratio was higher in the non-eroded site than the eroded site. On mean value basis, K/Mg ratio of the non-eroded soils (0.98) was slightly higher than the eroded soils (0.61). The results of the T-test analysis revealed that there was significant positive difference in clay, total porosity, Ca, available phosphorus, BD, BS, ECEC, TEB, Ca/Mg ratio, K/Mg ratio and C/N ratio but significant negative difference in TEA and total porosity. 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 organic manures on soils of the eroded and non-eroded sites should be done.

Keywords: soil fertility, eroded and non-eroded soils, Ultisol, southeastern Nigeria

Introduction

Erosion is one of the major environmental hazards currently ravaging the southeastern part of Nigeria, especially Imo-state. Nigeria is presently facing severe soil erosion problems which manifest in the form of both sheet and gully erosions. These problems can be attributed to natural and human causes. Presently, over 6,000km^2 of the country's land is affected by erosion while about 3,400km^2 is highly vulnerable. Erosion has a devastating effect on many peoples' lives and destroys essential infrastructure for economic development and poverty alleviation. Specifically, gully erosion has severely contributed to environmental problems in Nigeria causing damage estimated at over $100 million annually (mostly in south-Eastern Nigeria). This has consequently undermined socio-economic growth and thus constitutes a threat to the Federal Government of Nigeria's "Vision 2030"(Asiegbu,2021).

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, many 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 aluminum 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 is the ability of soil to sustain agricultural plant growth, thereby providing plant habitat and result in sustained and consistent yields of high quality. Fertile soil supply essential plant nutrients and water in adequate amounts and proportions for plant growth and reproduction; and the absence of toxic substances which may inhibit plant growth.

Soil fertility also 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; Nkwopara et al., 2021). 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.

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. 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 topo-sequence 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 Urualla 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 Urualla 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 eroded and non-eroded soils of Urualla, Imo State Southeastern Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted in Urualla, Ideato North, Imo state (South-East Nigeria) which lies between Latitude 5^{o} 51^{I} 0” N and Longitude 7^{o} 6^{I} 0” E. Soils of the area are derived from Coastal Plain Sands. The study area is in Imo State, Southeastern Nigeria which lies between Latitudes 4^{o} 40^{I} 1”and 8^{o} 15^{I} 1” N and Longitudes 6^{o} 40^{I} 1” and 8^{o} 15^{I} 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^{o}C, 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 a major socio-economic activity in the study area. Agricultural crops mostly cultivated in the study area include yam (*Dioscoreaspp*) cassava (*Manihotspp*), oil palm (*Elaiesguineensis*) and maize (*Zea mays*).

Field Studies

A reconnaissance visit was carried out in the sampling sites. Two mini-pedons on eroded and two on non-eroded, of about 60 cm depth was 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 is used for the study. Soil samples were taken using hand trowel, from the lowest depth to the topmost depth of each of the eroded site 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

The particle size analysis was carried out using Bouyoucous hydrometer method as described by (Gee and Or, 2002). Textural triangle will be used to establish textural classes.

Bulk density was obtained using the core sampling method (Grossman and Reinsch, 2002).

Total Porosity (TP) was determined from bulk density using the equation $TP = \left(1 - \frac{bd}{pd}\right) \times 100\%$ (Vomocil, 1965).

Where TP = Total Porosity

Bd = Bulk Density

Pd = Particle Density (2.65g/cm^3)

Moisture content was determined gravimetrically. It will be calculated thus:

$$\%MC = \frac{w2 - w3}{w3 - w1} \times \frac{100}{1}$$

Where

W_1 = Weight of moisture

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 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). Total Exchangeable Bases 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). Total Exchangeable Acidity was determined by leaching the soil with IN KCl and titrating with 0.05N NaOH (Mclean, 1982).Effective Cation Exchange Capacity is also determined by summing all the basic and acidic cations. ECEC= TEA + TEB.

Percentage Base Saturation was calculated as follows:

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

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

Data Analyses

Data obtained from laboratory analyses were presented in Tables. The 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

Table 4.1 shows the physical properties of the eroded and non-eroded soil. The results of the particle size distribution indicated higher sand particle in the non-eroded sites (835.20g/kg) relative to the eroded sites (801.90g/kg). However, it was observed that clay particle was more prominent in the eroded sites compared to the non-eroded sites, with the eroded and non-eroded having mean values of 174.80g/kg and 128.10g/kg respectively. This result agrees with Nkwopara et al., (2019) on eroded and non-erode soils of Orsu area in Imo state . Texture varied from sandy clay loam to sandy loam and from sandy loam to loamy sand and then back to sandy loam in the eroded sites and sandy loam to loamy sand and from loamy sand to sandy loam and then back to loamy sand in non-eroded sites. These findings on particles 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 Nandi 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 Nandi 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 4.1). It ranged from 0.4 -0.93 gcm-3 in the eroded site and 0.46-1.96 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.

Higher soil porosity was observed in the eroded site than the non-eroded soils. Mean values of 73.05% and 63.71% were recorded in the eroded and non-eroded soils, respectively (Table 4.1). The higher porosity observed in the eroded site indicates better aggregation, higher infiltration and percolation rate

Table-4.1: Physical Properties of the Eroded and Non-Eroded site

ERODED SOILS							
Sample	**Sand g/Kg**	**Silt g/Kg**	**Clay g/Kg**	**TC**	**BD**	**TP %**	**MC %**
PT_1 (0-20)	755.20	40	204.80	SCL	0.70	73.64	8.32
PT_1 (20-40)	775.20	0	224.80	SCL	0.83	68.50	4.10
PT_1 (40-60)	795.20	40	164.80	SL	0.92	65.44	50.87
PT_2 (0-20)	795.20	40	164.80	SL	0.50	81.01	15.13
PT_2 (20-40)	855.20	0	144.80	LS	0.40	84.81	9.60
PT_2 (40-60)	835.20	20	144.80	SL	0.93	64.92	3.15
Mean	**801.90**	**23.3**	**174.80**		**0.71**	**73.05**	**15.19**
NON-ERODED SOILS							
PT_1 NE(0-20)	815.20	60	124.80	SL	0.52	80.48	3.13
PT_1 NE(20-40)	855.20	40	104.80	LS	0.46	82.64	5.57
PT_1 NE (40-60)	835.20	40	124.80	LS	0.69	74.14	60.43
PT_2 NE (0-20)	795.20	20	184.80	SL	1.49	43.86	2.61
PT_2 NE (20-40)	855.20	40	104.80	LS	1.66	37.30	1.79
PT_2 NE (40-60)	855.20	20	124.80	LS	0.96	63.85	24.86
Mean	**835.20**	**36.7**	**128.10**		**0.96**	**63.71**	**16.40**
LSD(0.05)	**3.43**	**2.54**	**5.08**		**0.73**	**27.52**	**13.28**
CV	**2.8**	**57.1**	**22.6**		**58.6**	**27.1**	**56.7**
Key: PT1= Eroded Site I, PT1 NE = Non-Eroded Site I, PT2 = Eroded Site II, PT2 NE = Non-Eroded Site II							

in that site. The results of moisture content showed that it was higher in the non-eroded site. It was in the range of 3.15-50.87% in the eroded site and 1.79-60.43% in the non-eroded site (Table 4.1). 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 4.2). 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 Non-Eroded Soils

The results of the chemical properties of the eroded and non-eroded soils are presented in Table 4.2. The pH of the soils varied slightly. It varied from 6.20-6.60 with a mean of 6.37 in the eroded site while in the non-eroded site, it varied from 6.20-6.43 with a mean of 6.30. These values fall on slightly acidic soil (FAO, 2004). Similar pH results have been reported for some soils of Southeastern Nigeria (Nkwopara et al., 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 et al., 2017; Onwudike et al., 2019).

Soils of eroded site had more organic carbon than those of the non-eroded site. Mean values of 2.4g/kg and 4.0g/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*. (2007) in their study of some eroded and non-eroded soils of Southeastern Nigeria. The result also showed that the percentage organic carbon increased down the profile pit in the two sites

Table-4.2: Chemical Properties of Eroded and Non-Eroded Site

Sample	pH	OC g/Kg	OM g/Kg	TN g/Kg	AvP (Mg/Kg)	Ca	Mg	Na	K	TEB	TEA	ECEC	BS %	H^+ %	Al %
						→ Cmol kg^{-1} ← Exchangeable Bases									
ERODED SOILS															
PT_1 (0-20)	6.35	3.0	5.2	1.24	3.36	5.62	1.87	1.73	3.59	12.81	0.25	13.06	98.09	0.25	__
PT_1 (20-40)	6.20	1.2	2.1	1.19	1.82	2.26	1.03	0.43	0.22	3.94	0.65	4.59	85.84	0.46	0.19
PT_1 (40-60)	6.60	1.6	2.8	0.87	0.98	1.82	0.94	1.08	0.31	4.15	0.63	4.78	86.82	0.43	0.20
PT_2 (0-20)	6.22	3.8	6.5	1.35	1.61	3.06	1.98	0.83	0.34	6.21	0.61	6.82	91.06	0.49	0.12
PT_2 (20-40)	6.43	2.2	3.8	1.27	3.64	1.45	0.85	0.85	0.32	3.47	0.61	4.08	85.05	0.44	0.17
PT_2 (40-60)	6.43	2.4	4.1	1.09	4.20	1.06	0.52	1.28	0.33	3.19	0.66	3.85	82.86	0.48	0.18
Mean	6.37	2.4	4.1	1.17	2.60	2.55	1.20	1.03	0.85	5.63	0.57	6.20	88.28	0.43	0.17
NON-ERODED SOILS															
PT_1 NE(0-20)	6.30	6.2	10.7	1.47	5.81	1.95	0.75	2.20	0.66	5.56	0.53	6.09	91.30	0.42	0.11
PT_1 NE(20-40)	6.26	3.6	6.2	1.27	5.88	2.18	1.20	0.72	0.69	4.79	0.56	5.35	89.53	0.38	0.18
PT_1 NE (40-60)	6.36	3.0	5.2	1.03	5.32	2.15	0.84	1.18	0.58	4.75	0.49	5.24	90.65	0.41	0.08
PT_2 NE (0-20)	6.26	5.4	9.3	1.40	6.79	2.37	1.07	1.00	1.27	5.71	0.65	6.36	89.78	0.46	0.19
PT_2 NE (20-40)	6.20	3.2	5.5	1.35	2.80	2.08	1.15	1.46	1.98	6.67	0.57	7.24	92.13	0.42	0.15
PT_2 NE (40-60)	6.43	2.8	4.8	1.20	4.97	2.75	1.08	1.24	0.89	5.96	0.84	6.8	87.65	0.63	0.21
Mean	6.30	4.0	6.9	1.29	5.26	2.25	1.02	1.30	1.01	5.57	0.61	6.18	90.17	0.45	0.15
LSD(0.05)	0.14	0.11	0.18	0.01	2.44	1.92	0.72	0.25	1.67	3.98	0.17	3.88	5.3	0.11	0.08
CV	1.5	22.1	22	3.8	41.8	54.1	43.6	14.6	12.8	47.8	19.6	42.2	4	16.8	38.2

Key: PT_1= Eroded Site I, PT_1 NE = Non-Eroded Site I, PT_2 = Eroded Site II, PT_2 NE = Non-Eroded Site II

A comparison of organic matter levels in the two sites revealed that the soil organic matter was higher in the eroded site than the non-eroded site (Table 4.2). Mean values were 4.1g/kg and 6.9g/kg in the eroded and non-eroded sites, respectively. The lower values recorded in the eroded site could be due to leaching effect and run-off of water to the non-eroded site. It has been reported that soil organic matter loss has been associated with increase in severity of soil erosion (Kosmas *et al*., 2001).

The findings also showed that the organic matter was generally low in the two sites (FAO, 2004) and could be attributed to high temperature, leaching and high amount of rainfall which have accelerate 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 0.87%-1.35g/kg with a mean of 1.17g/kg, while that of non-eroded site ranged from 1.03%-1.47g/kg with mean values of 1.29g/kg. 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).

Available phosphorus followed similar distribution trend with total nitrogen as higher values were observed in the non-eroded site (2.80 -6.79mg/kg) compared to the eroded site (0.98-4.20mg/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 slightly differences among the mean of eroded (5.63) and non-eroded (5.57) sites. On mean value basis, exchangeable Ca in eroded site (2.55 $cmolkg^{-1}$) and non-eroded site (2.25 $cmolkg^{-1}$) is the same but ranges from (1.06-5.62$cmolkg^{-1}$) for eroded and (1.95-2.75$cmolkg^{-1}$), exchangeable Mg also was higher in the eroded site (1.20 $cmolkg^{-1}$) than the non-eroded site (1.02 $cmolkg^{-1}$), exchangeable Na was higher in the non-eroded site (1.30 cmolkg-1) compared to the eroded site (1.03 $cmolkg^{-1}$), While exchangeable K is higher in the non-eroded site then eroded site and was in the range of 0.58-1.98 cmolkg-1 and 0.22-3.59 $cmolkg^{-1}$, 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 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 0.25-0.66 cmolkg^{-1} while in the non-eroded site, it was in the range of 0.49-0.84 cmolkg^{-1}. Generally, the values of total exchangeable acidity increased with depth in both eroded and non-eroded sites. Total exchangeable base is slightly higher in eroded site having mean of 5.63 cmolkg-1 then non-eroded site having 5.57 cmolkg^{-1} (Table 4.2).

Soils of the eroded site (6.20 cmolkg^{-1}) had more ECEC than those of the non-eroded site (6.18 cmolkg^{-1}). The ECEC values recorded in the both sites were higher 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 non-eroded site (90.17%), it's higher compared to the eroded site (88.28%) and it's mean ranges from (82.86-98.09%) for eroded site and (87.65-92.13%) for non-eroded site. 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).

Finally, the H^+ content in both eroded and non-eroded soil is low resulting to the neutrality of the soil. The eroded soil ranges 0.25-0.49% and non-eroded ranges 0.38-0.63%.

Fertility Ratio of Eroded and Non-Eroded Soils

Table 4.3 shows the fertility status of the eroded and the non-eroded soils using elemental ratios.

The C/N ratio of the eroded site (2.00) and the non-eroded site (3.08) differed 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 the both sites. However, based on the assertions of USDA NRCS (2011), it can be inferred that soils of the eroded are more fertile than soils of non-eroded site and could be due to losses of N from the eroded site.

The results of Ca/mg ratio showed mean values of 2.07 and 2.26 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 the 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 the both sites indicates possible Ca deficiency and P inhibition (Udo *et al*., 2009). The results also showed irregular pattern of distribution of Ca/Mg in the profiles of the two sites. On mean value basis, K/Mg ratio of the non-eroded soils (0.98) was higher than the eroded soils (0.61). In most of the profiles of the eroded and non-eroded sites, the K/Mg ratio increased with soil depth 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. Similarly, asserted that K: Mg ratio below 1:1 is adequate for the most arable.

Table-4.3: Fertility ratio of eroded and non-eroded soils

Location	C/N	Ca/Mg	K/Mg
PT1 ERODED(0-20cm)	2.42	3.00	1.92
PT1 ERODED(20-40cm)	1.01	2.19	0.21
PT1 ERODED(40-60cm)	1.84	1.94	0.33
PT2 ERODED(0-20cm)	2.81	1.55	0.17
PT2 ERODED(20-40cm)	1.73	1.71	0.38
PT2 ERODED(40-60cm)	2.2	2.04	0.63
MEAN	2.00	2.07	0.61
PT1 NON ERODED(0-20cm)	4.21	2.60	0.88
PT1 NON ERODED(20-40cm)	2.83	1.82	0.58
PT1 NON ERODED(40-60cm)	2.91	2.56	0.69
PT2 NON ERODED(0-20cm)	3.85	2.21	1.19
PT2 NON ERODED(20-40cm)	2.37	1.81	1.72
PT2 NON ERODED(40-60cm)	2.33	2.55	0.82
MEAN	3.08	2.26	0.98
LSD(0.05)	0.69	0.509	0.863
CV	18.20	0.34	73.30

Key: C/N – Carbon Nitrogen Ratio, Ca/Mg – Calcium Magnesium Ratio, K/Mg – Potassium Magnesium Ratio.

and vegetable crops. Thus, on the basis of K/Mg ratio, both the eroded and non-eroded soils were considered fertile. (Table 4.3).

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 4.4. For the physical properties of the soils, the analysis showed that the erosion menace significantly and positively affected the clay particles and total porosity of the soils (Table 4.4), evident in the significant positive difference observed. The implication of this finding is that increase in the severity of soil erosion will result to clay particles dominating the particle size distribution of the soils which will result to significant increase in total porosity of the soils making the prone to erosion.

Meanwhile, to compare the chemical properties of the eroded and non-eroded soils showed that Calcium and Total Exchangeable Acidity differed significantly and positively. The results imply that increase in severity of soil erosion will result in increase in Calcium and Total Exchangeable Acidity of soils of the area (Table 4.4).

Table-4.4: t – Test result showing the Comparisons among Soils of Eroded and Non-Eroded Sites

Soil Property	Eroded soil	Non eroded soil	t – Test	Remark
Sand	80.19	83.52	0.027	NS
Silt	2.33	3.67	0.118	NS
Clay	17.48	12.81	0.032	S
Bulk density	0.71	0.96	0.209	NS
Total Porosity	73.05	63.71	0.211	S
MC	15.19	16.40	0.413	NS
pH	6.37	6.30	0.127	NS
OC	0.24	0.40	0.005	NS
OM	0.41	0.69	0.005	NS
TN	0.12	0.13	0.004	NS
AP	2.60	5.26	0.019	NS
Ca	2.55	2.25	0.353	S
Mg	1.20	1.02	0.269	NS
Na	1.03	1.30	0.021	NS
K	0.85	1.01	0.408	NS
H	0.71	0.76	0.247	NS
Al	0.24	0.22	0.417	NS
TEB	5.63	5.63	0.487	NS
TEA	0.78	0.03	0.214	S
ECEC	6.58	6.58	0.499	NS
BS	82.08	84.67	0.177	NS
Cd	0.001	0.004	0.041	NS
dPd	0.005	0.005	0.239	NS

Key: NS – Non significant, S – Significant

Relationship between Fertility Ratio and Soil Properties of Eroded and Non-Eroded

The relationship between fertility ratio and soil properties of eroded and non-eroded soils using t-test analysis (Table 4.5) showed that when available phosphorus, organic matter and total nitrogen percentage increases in the soil, C/N ratio increases as well. C/N ratio is significant in composting because microorganisms need a good balance of C/N (ranging from 25-35)) in order to remain active. High C/N ratios can lead to prolonged composting duration and low C/N ratios enhance nitrogen loss. Bulk density, base saturation, ECEC and total exchangeable base increases too as K/Mg ratio increases as the same time but total exchangeable acidity and total porosity, as it increases the K/Mg reduces in the soil. K/Mg ratio can be indicative of how available the potassium and magnesium are in the soil. The ratio is within the range of (-0.52 - 0.76), which shows that when it is less than 0.25, magnesium over powers the potassium in the soil making it harder for plant root to uptake potassium and when it is greater than 0.35, plant may have trouble accessing magnesium. Also as ECEC and total exchangeable base increases Ca/Mg and K/Mg ratios increase too.

Table-4.5: Relationship between Fertility Ratio and Soil Properties

Soil property	C/N	K/Mg	Ca/Mg
Available Phosphorus	0.7061**	0.2745	0.3646
BD	0.0515	0.522*	-0.0106
BS	0.4193	0.7192*	0.492
Clay	-0.3428	-0.0574	0.2213
ECEC	0.1856	0.7616**	0.5649*
Mg	0.0166	0.2426	0.0029
Moisture content	-0.1096	-0.279	0.1461
OM	0.9683**	0.3278	0.2031
Sand	0.0453	-0.1048	-0.3612
TEA	-0.1848	-0.5257*	-0.4143
TEB	0.1074	0.858**	0.7473**
TN%	0.5587*	0.3303	-0.0261
Total Porosity	-0.0478	-0.5205*	0.0147
pH	-0.2463	-0.2034	0.1154

***and ** = significant at 0.05 and 0.01 probability levels respectively**

Key: C/N – Carbon Nitrogen Ratio, Ca/Mg – Calcium Magnesium Ratio, K/Mg – Potassium Magnesium Ratio

Conclusion

The study shows that there were difference in the physico-chemical properties and fertility status of the eroded and non-eroded soils of Urualla area of Imo State. Thus, erosion affects soil properties and fertility status. Specifically, water erosion menace resulted to decrease in organic matter, total nitrogen, exchangeable bases, soil pH, sand content and bulk density of the soils but increased soil porosity, exchangeable acidity. 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 the both soils, it can be inferred that soils of the non-eroded site were of better fertility than soils of the water eroded site.

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