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Chemical properties of a watershed prone to erosion along Nworie river banks in Owerri-Imo State, Southeast Nigeria.

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Abstract

The study investigated the soil chemical properties of Nworie river watershed prone to erosion in Owerri- Imo State, Southeast Nigeria. The study area was divided into Upstream, Midstream and downstream. Five Major gullies were used for the study. Soil samples were collected from the walls of the gullies beginning from down to up according to apparent horizon differentiation. Soil profile pit was dug 100m away from the degraded area, and this served as the control. Soil data collected were subjected to statistical analysis. The soils of the watershed were acidic. The results of some chemical properties for soil quality evaluation were matched with the FAO standard to assess the degree of degradation. The soil nitrogen content of the watershed ranged from 0.01% to 0.02%, Potassium ranged from 0.16cmol/kg to 0.31cmol/kg, available phosphorus ranged from 1.64Mg/kg to 6.13Mg/kg, Base Saturation ranged from 61.5% to 81.5%, ESP ranged from 2.37% to 9.42%, while organic matter content ranged from 0.30% to 2.09%. Based on the degree of degradation; the watershed was found to be very highly degraded (VHD) due to the low content of organic matter. Erosion within the watershed was more pronounced at the upstream and midstream compared to the downstream.

Keywords: Chemical properties, watershed, Erosion, Imo State

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1.0 Introduction

Land degradation is defined as a change in one or more properties of land that results in a decline in the quality of that land. It indicates a reduction in the resource potentials of land through the actions of those processes that may force the conditions of the land to become unpleasant and less useful to man. It is estimated that up to 849 million hectares of natural land may be degraded by 2050 should current trends of unsustainable land use continue warns a report by United Nations Environmental Programme.

The principal types of land degradation are physical, chemical, and biological degradation (Lal, 1994). Physical degradation refers to the deterioration of the physical properties of the soil. It includes soil compaction, hard setting, soil erosion, sedimentation and laterization. Significant chemical degradation includes acidification, leaching, salinization, decrease in cation retention capacity and fertility depletion, the build-up of some toxic chemicals and elemental imbalance that are injurious to plant growth also constitute chemical degradation of soil. Biological degradation includes a reduction in total and biomass carbon as well as a decline in land biodiversity. The position here is that all forms of environmental degradation relate to the gradual exchanges between soil minerals and the complex interactions between the fauna and other microorganisms in the soil (Osuji and Nwoye 2007). Soil structure is the most important property that affects all the degradative processes.

Nigeria as a developing country with a large human population depends almost entirely on land resources for their sustenance hence increasing the demand for land utilization through their activities. Igwe (2003) reported the significant causes of land degradation in central-eastern Nigeria to be soil erosion (due to high rainfall), deforestation, fragile nature of soil and farming activities. According to Ezemonye *et al. (2012),* soils in Southeast Nigeria constitute sandy loose surface, and this makes it vulnerable to attack by floods.

Erosion removes topsoil, reduces levels of soil organic matter and contributes to the breakdown of soil structure; it reduces cropland productivity and contributes to the pollution of adjacent watercourses. A watershed in its natural setting is a grooming place for biodiversity, hence a tourism potential; however, careful observation of Nworie River watershed and its surroundings reveals that it is under severe ecological stress due to increasing land-use conversion, modifications and indiscriminate socio-economic exploitation which have all resulted in the severe erosion menace within Owerri metropolis. Therefore, the main objective of this study was to evaluate chemical properties of this watershed prone to erosion along Nworie River Banks in Owerri –Imo State southeast, Nigeria while the specific objectives of this study were to:

- investigate the chemical properties of soils along Nworie River watershed and their relationship to land degradation.
- establish the degree of land degradation in Nworie River watershed using standard indicators.

2.0 Materials and Methods

2.1 Study Area

Owerri, the capital of Imo State Nigeria, has a population of about 1,401,873 (Wikipedia,2016). It is approximately 100sq/km in area. The Otamiri River borders Owerri to the east and Nworie river to the west (Acholonu, 2008). Owerri has maximum and minimum temperatures of 33^0c and 23^0crespectively. The study area (Nworie River watershed) lies within latitude $5^029'$ to 5^049'N and longitude $07^001'$ to 7^025'E standing on an elevation of 77m upstream,55m midstream, and 45m downstream above the sea level; Handheld Global Positioning System (GPS). The watershed has a gentle to the undulating slope. Nworie River watershed has an annual rainfall of 2500mm. Soils of the study area are coastal plain sands of Benin formation (fig.3). Nworie river is about 8km in its total length. Nworie river had its source at Ubomiri in Egbeada; the river joins Otamiri river at Nekede. The river flows through the back of Federal medical centre, Alvan Ikoku College of Education and Holy Ghost College, Owerri. These institutions discharge their untreated waste into the river as recorded by Alinnor and Obiji (2010). The watershed is covered by depleted rainforest vegetation; grasses and broadleaf weeds like *Panicum Maximum (Guinea grass), Pennisetum Purperum(Elephant grass)*, *Axonopus Compressus(Carpet grass), Eleusine indica (Goosegrass)*, *Centrosema pubescens, Calapagonium mucunoides*, *Aspillia africana*, *Andropogon gayanus (Gamba grass)*as well as few forest species, e.g. palm trees, mango trees, cashew tree dominated the vegetation of the watershed. Farming is the principal occupation of the inhabitants of the area, while Sand mining and excavation are the primary activity within the study area. Cassava and yam are the primary root and tuber crops grown in the watershed. Nworie river catchment is approximately 30sq/km (Imo State Ministry of Lands, Survey and Urban Planning, 2010). Nworie River watershed is subject to intensive human activities resulting in the discharge of untreated waste, thus leading to various forms of degradation such as erosion especially gully erosion as seen in Figure 3.

2.2 Field Studies/Soil Sampling:

Before field studies, a reconnaissance visit was made to the study area during which five major gullies (two at the upstream; UG1-**5.52533°N, 7.01053°E UG2-5.52224°N, 7.01393°E**, two at the midstream; MG1-**5.51975°N, 7.01543°E**MG2-**5.51683°N, 7.01997°E**and one at the downstream; DG1-**5.49078°N, 7.0258°E**) were chosen for detailed field studies. The length, width and depth of the gullies were measured and values recorded. Each of the

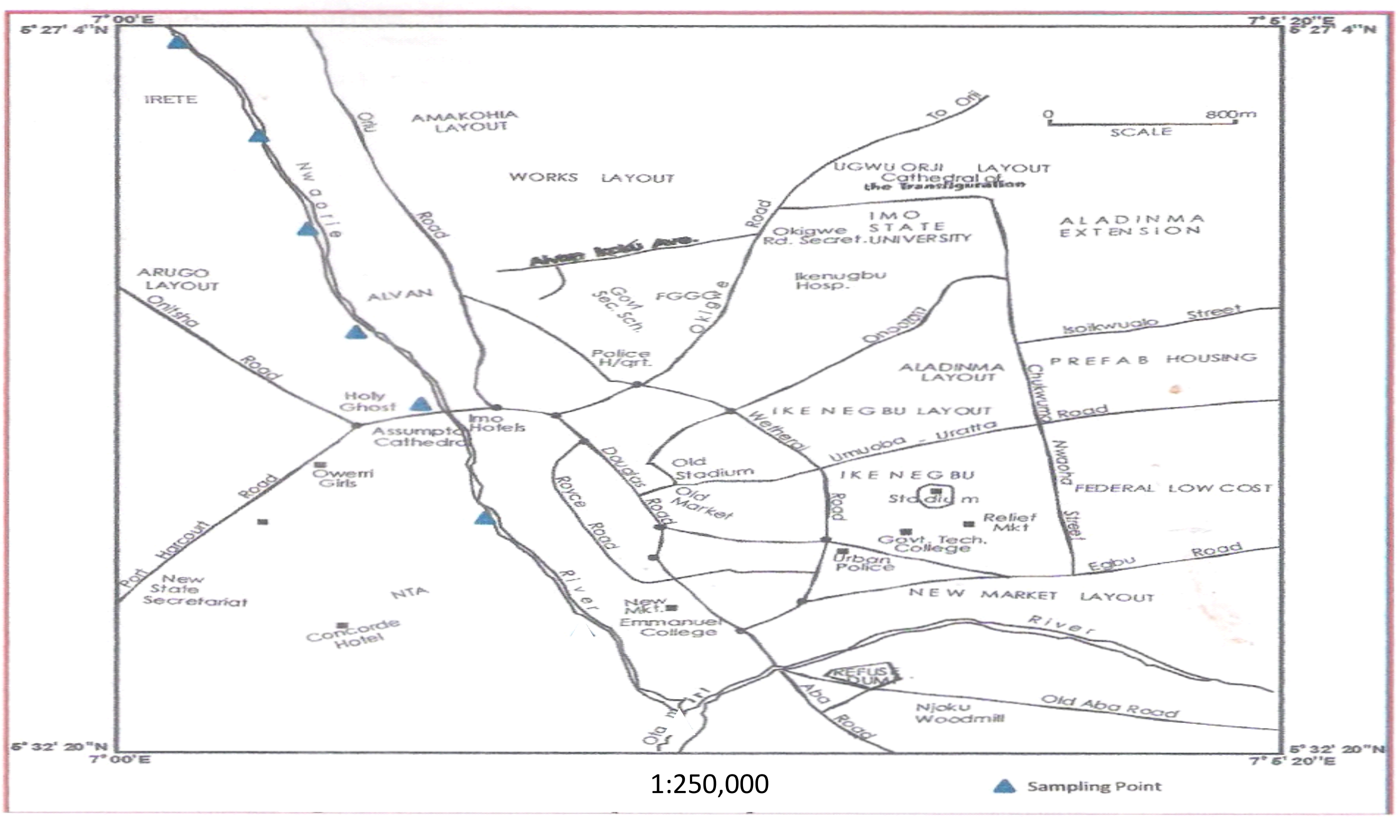
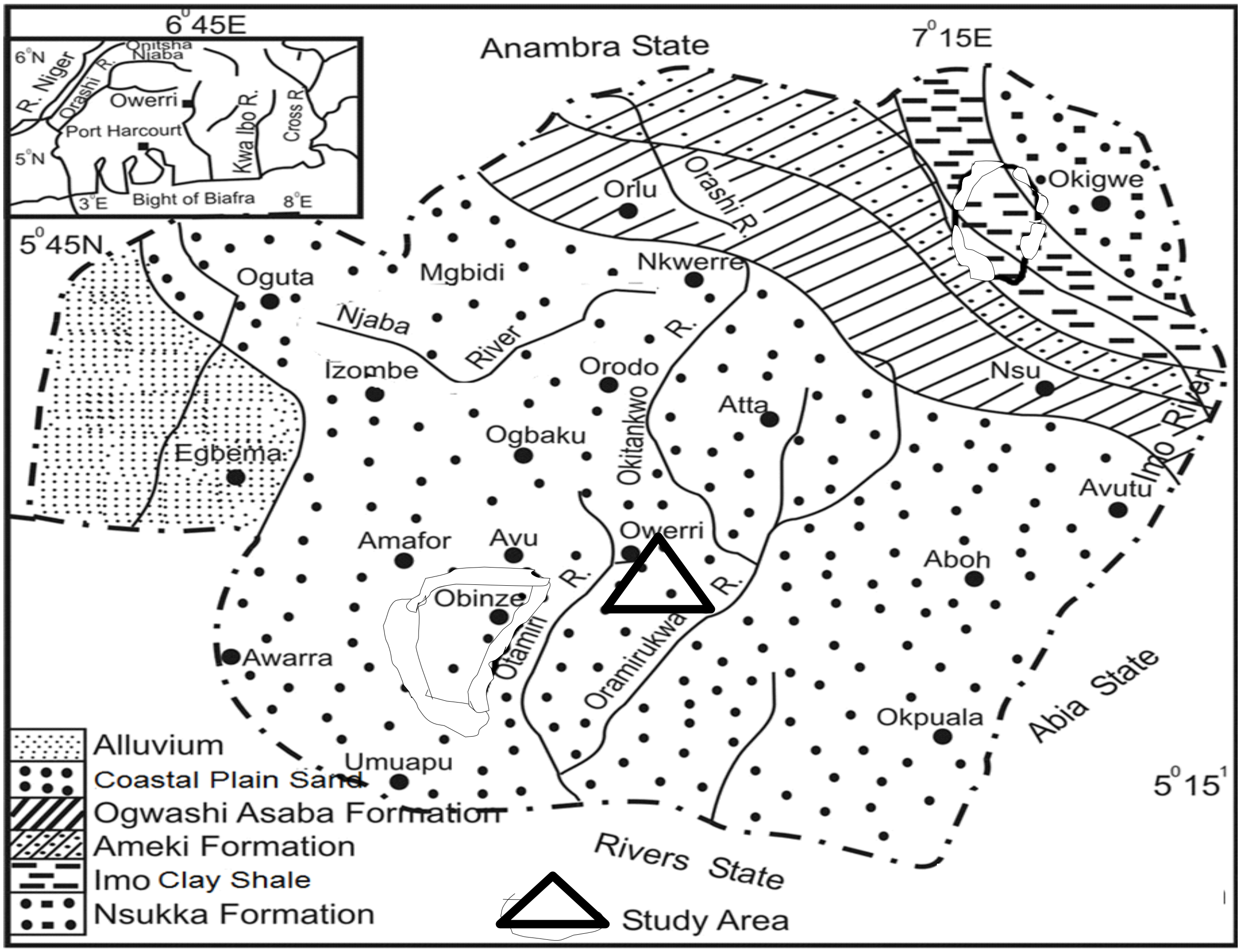


Fig. 1: Location map showing the Nworie River watershed

Source:Onyekuru *et al.,2014*



Geological Map of Imo State showing the Study Area

Fig. 2: Geological Map of Imo State Showing the Study Area

Fig 3: Gully Erosion in Nworie River Watershed

gullies was scrapped with a shovel to create a new surface from where soil samples were collected; soil samples were collected from down up the gully based on apparent horizon differentiation. Soil samples for bulk density were taken with core samplers. A soil profile pit(**5.52543°N, 7.01021°E)** was dug on a non-gully area upstream 100m away from the gully; this served as a control. A handheld global positioning system receiver was used to take the coordinates of each sampled area. A total of 13 soil samples were collected from the sampled areas. Each soil sample was bagged, labelled and taken to the laboratory for air-drying and subsequent storage for analysis.

2.3 Laboratory Analysis

All the soil analysis were carried out in the Soil Science Laboratory unit of Federal College of Land Resources Technology (FERCOLAT) Owerri-Imo state.

i. Soil pH: The soil pH in water was estimated using pH Meter in 1:2:5 ratio of soil to water according to Thomas(1996)
ii. Soil organic carbon (SOC): The wet digestion method (Nelson and Sommers,1996) was used to determine the organic carbon content of the soil samples. Soil organic matter (SOM) was calculated by multiplying the value of SOC by a factor of 1.724. (Van Bemmelen's correction factor)
iii. Total Nitrogen (TN): This was determined by the Kjeldahl digestion method, according to Jackson (1965).
iv. Exchangeable Basic cations (calcium, magnesium, potassium and sodium): These were extracted in 1N, NH_4OAC at pH 7 and this followed by calcium and magnesium determination using Atomic Absorption Spectrophotometer and potassium, sodium determination using a flame photometer.
v. Exchangeable acidic cations: Hydrogen and Aluminum were estimated titrimetrically.
vi. Available phosphorus: Bray II method was used (Olsen and sommer,1982)
vii. Base Saturation: This was calculated on a percentage basis by dividing total exchangeable bases (Ca^{2+}, mg^{+}, K^{+}, Na^{+}) by cation exchange capacity multiplied by 100%.
viii. Cation Exchange Capacity (CEC): This was determined by 1N ammonium acetate extraction method.
ix. Exchangeable Sodium Percentage (ESP): This was calculated by dividing the exchangeable sodium by CEC, as shown in the equation:

$$ESP = \frac{TEB}{CEC} \times 100 \qquad (3)$$

Where TEB=Total Exchangeable Bases
CEC=Cation Exchange Capacity

2.4. Land Degradation Assessment

The levels of degradation of the soils were assessed using the standard indicators and criteria for land degradation assessment by the Food and Agriculture Organization (FAO, 1979) as well as the indicators guide for evaluating analytical data (FAO,2004). Analytical data from each sample was placed in a degradation class by matching the soil characteristics with land degradation indicators. The estimation of the degree of degradation was based on some physical and chemical parameters. The four degrees of degradation used were:

None to slightly degraded soil; where productivity ranges from 75-100%.

Moderately degraded; productivity ranges from 50-70 %.

Highly degraded soil; productivity ranges from 25-50 %

Very highly degraded soil; productivity ranges from 0-25 %.

2.5 Data Analysis

Descriptive statistics using mean, standard deviation and t-test were used to compare the statistical differences between soil properties at various locations. Coefficient of variation was used to determine the variations of soil properties at various sampling points and was ranked according to the procedure of wilding *et al., 1994* where Cv≤15% =low variation, Cv≥15≤35% = moderate variation, Cv≥35% = high variation. Level of significance was determined using Fishers least significance difference at p=0.05

3.0 Results and Discussion

The results of the chemical properties of soils of the area studied are presented in Table 1.

3.1. Soil pH

From table 1, the results obtained showed that the average pH of soils at the control was 5.21 while Upstream, Midstream and downstream had average pH values of 5.09,5.09 and 4.89, respectively. The soils of the watershed were found to be generally acidic. The acidic nature of the area studied partly was more a reflection of the parent material from which the soils were derived. It also suggests high rainfall and consequent leaching of the basic cations as revealed by Onweremadu (2007) and Chikezie *et al.* (2010).

3.2. Cation Exchange Capacity (CEC)

The mean CEC value of 4.1cmol/kg was obtained at the control while the upstream, midstream and downstream had CEC mean values of 4.58cmol/kg, 3.12cmol/kg, and 3.09cmol/kg respectively. When compared with the control, CEC was found to be significantly higher at the upstream and lower at the midstream at 5% probability level. The low CEC observed in this study suggests the inability of the soils to retain nutrients and water, which could be as a result of the parent material and coarse nature of the soil. Soils with low CEC and organic matter are prone to high leaching losses because of few ions retained in exchangeable form. Lombin *et al*. (1991) reported that organic matter content was a significant contributor to CEC of soil; Akamigbo (1999) reported the organic matter to have a significant positive influence on soil pH, cation exchange capacity, colour, base saturation and water holding capacity; however, this was not observed in this study due to minimal organic matter content present.

3.3. Total Nitrogen

Results from this study showed that the mean total nitrogen at the control was 0.09% while upstream, midstream and downstream respectively had a mean TN value of 0.03%,0.05% and 0.03%. The total nitrogen content at the upstream did not differ significantly with that of the control, whereas it was significantly lower at the midstream at 5% probability level. No significant difference was observed when the total nitrogen at the downstream was compared with that of control. The total nitrogen contents in the watershed were low; this could partly be attributed to the predominantly sandy texture of the soil as well as an indication of nutrient loss at the epipedon. The total nitrogen in the soils of the watershed ranged from highly degraded to very highly degraded. Total nitrogen was significantly lower in the degraded area at 5% probability level when compared with the control.

3.4 Available Phosphorus

The results showed that an average value of 4.65mg/kg available phosphorus was obtained at the control while upstream, midstream and downstream had 3.73mg/kg,2.58mg/kg and 2.80mg/kg respectively. At midstream, available phosphorus content was significantly lower at 5% probability level when compared with the control; downstream also followed the same trend. Available phosphorus content of the watershed ranged from 1.64 mg/kg to 6.13mg/kg. Available phosphorus of the studied area was within the critical limits of 15 mg/kg as reviewed by Enwezor *et al.,*1990 for soils of southeastern Nigeria. Available phosphorus was significantly lower in the degraded area when compared with the control at the 5% probability level. The low available phosphorus in the watershed could be due to erosion, leaching and low organic matter content as observed in this study. Phosphorus is the second most critical element influencing plant growth and production throughout the world. Plants take it up from soil solution as orthophosphate anion $H_2PO_4^-$ or HPO_4. Based on the level of degradation; available phosphorus content of soils of the watershed ranged from highly degraded to very highly degraded.

3.5 Exchangeable Sodium Percentage (ESP)

The results of ESP of the area studied is shown in table5**;** from the results, a mean ES value of 3.72% was obtained at the control while upstream, midstream and downstream had to average ES values of 3.12%,5.60% and 2.66% respectively. When compared with the control, ES at the upstream was significantly lower and higher at the midstream at 5% probability level. ESP identifies the degree to which the exchange complex of soil is saturated with Na^+. Low ESP obtained suggests an acidic condition of soils of the watershed. A soil is considered sodic (high level of Na^+) when the ESP is 6 or greater. However, results obtained in this study were less than 6; this showed that the watershed was non-sodic. ESP of soils of the watershed was non to slightly degraded. There was no significant difference in the percentage of ES of the degraded area when compared with the control.

3.6 Base Saturation

The average BS obtained at the control, upstream, midstream and downstream were 74.7%,73.4%,69.4% and 73.4%. When BS at the control was compared with BS at the upstream, midstream and downstream, it was found to be significantly lower at 5% probability level. Soil Base saturation of the watershed ranged from 61.5% to 81.5%. The soils of the watershed were very highly degraded (VHD) in Base saturation, and this could be attributed to low organic matter content of the soil. Base saturation was significantly lower in the degraded area at 5% probability level when compared with the control.

3.7. Total Exchangeable Bases(Ca^{2+},Mg^{2+},k^+ and Na^+)

The results of TEB obtained in this study are shown in table 5**.** At the control, the mean values of calcium (Ca^{2+}), magnesium **(**Mg^{2+}**)**, potassium**(**k^+) and sodium **(**Na^+) at the control were 1.63cmol/kg,1.08cmol/kg,0.25cmol/kg and 0.16cmol/kg, upstream had 1.76cmol/kg,1.21cmol/kg,0.23cmol/kg and 0.14cmol/kg of calcium(Ca^{2+}), magnesium **(**Mg^{2+}**)**, potassium **(**k^+) and sodium **(**Na^+) respectively. Midstream recorded mean values of 1.03cmol/kg,0.75cmol/kg,0.24cmol/kg and 0.16cmol/kg of calcium (Ca^{2+}), magnesium **(**Mg^{2+}**)**, potassium **(**k^+) and sodium **(**Na^+) respectively. At the downstream, there were 1.20cmol/kg,0.83cmol/kg,0.18cmol/kg and 0.08cmol/kg mean values of calcium(Ca^{2+}),magnesium **(**Mg^{2+}**)**,potassium**(**k^+) and sodium**(**Na^+) obtained. Calcium content of the studied area was significantly lower at 5% probability level at the upstream, midstream and downstream when compared with the control respectively. Magnesium, potassium and sodium were significantly lower at the downstream than the control at 5% probability level. Total Exchangeable bases of the watershed ranged from very low to moderate and was dominated by calcium and magnesium ions. Calcium ranged from 0.65cmol/kg to 2.85cmol/kg, Magnesium ranged from 0.40 cmol/kg to 1.65cmol/kg, potassium ranged from 0.16 cmol/kg to 0.31cmol/kg ,sodium ranged from 0.07cmol/kg to 0.22cmol/kg. According to FAO (2004) ,Calcium was low in the watershed; Eshett *et al.(1999)* reported Exchangeable calcium content of soils of Eastern Nigeria to be generally low which could be due to high rainfall (swine,1993).An attempt of classification of exchangeable calcium by FDALR(1985) puts calcium content of < 2 cmol/kg to be very low,2.0 cmol/kg to 5 cmol/kg to be low,5.0 cmol/kg to 10.0 cmol/kg to be moderate. The low TEB obtained suggests low pH, intense leaching and weathering thus low inherent status with regards to the major nutrients as reported by Ernest *et al.*(*2016)* .The degree of soil degradation with respect to potassium(k^+) was 100% non to slightly degraded in the watershed.

3.8 Total Exchangeable Acidity

From the results obtained; the TEA mean values obtained at the control was 1.03 cmol/kg while 1.25cmol/kg,0.95cmol/kg and 0.39cmol/kg mean values obtained respectively at the upstream, midstream and downstream. The Total Exchangeable acidity of the watershed ranged from 0.09 cmol/kg to 1.60 cmol/kg. There was no significant difference in the TEA of the degraded area when compared with the control.

3.9 Soil Organic Carbon and Soil Organic Matter

The results obtained showed that the control had a mean SOC of 0.66% while the upstream, midstream and downstream had average values of 6.34%,0.55%, and 0.33% respectively again the SOM contents of the studied area as obtained were 1.15%,0.68%,0.94%, and 0.58% respectively at the control, upstream, midstream and downstream. The SOC ranged from 0.17% to 1.05% while SOM ranged from 0.30% to 1.82%, as observed in this study. The study showed that SOC and SOM were significantly lower at the upstream than in control at 5% probability level. The low SOM observed could be attributed to the level of erosion at the uppermost soil surface, thereby leaving the soil surface depleted of nutrients. Organic matter is the primary exchange site for the basic nutrient cations in the soil; therefore, measures should be taken to increase the organic matter content of the soil to improve soil quality and reduce soil degradation. The soils of the studied area can be said to be 95% very highly degraded to SOM; this result as obtained agrees with the findings of Agber *et al.,2017* who observed that more than 50% of Nigeria soils are moderate to highly degraded

4.0 Conclusion.

Soils were sampled from the selected gullies at the Upstream, Midstream and Downstream of the river watershed. Analytical data obtained from each sampled area was placed in a degradation class by matching the soil characteristics with standard indicators. The investigated Soil chemical properties of the watershed were found to be low; various degrees of degradation were observed from the upstream to the downstream areas of the watershed. The acidic nature of the soil observed was a reflection of the parents material as well as the resultant effect of the

Table 1: Chemical Properties of Soils of the watershed

Location	Depth (cm)	pH H_{20}	Soc (%)	Som (%)	TN (%)	AvP Mg/kg	Ca^{2+}	Mg^{2+}	K^+ Cmol/	Na^+ kg	AL^{3+}	H^+	TEA	CEC	ESP (%)	BS (%)
Control	137															
$Ap_{horizon}$	0-24	4.47	0.41	0.72	0.04	3.72	1.60	1.20	0.24	0.12	0.60	0.30	0.90	4.06	2.96	77.2
$AB_{horizon}$	24-44	5.63	1.21	2.09	0.20	6.13	2.00	1.20	0.29	0.22	0.80	0.40	1.20	4.91	4.48	75.5
$B_{horizon}$	44-137	5.52	0.37	0.65	0.03	4.09	1.30	0.85	0.22	0.13	0.90	0.10	1.00	3.50	3.71	71.4
Mean		5.21	0.66	1.15	0.09	4.65	1.63	1.08	0.25	0.16	0.77	0.27	1.03	4.16	3.72	74.7
Upstream																
G 1	135															
$Ap_{horizon}$	0-11	4.92	0.35	0.68	0.04	3.56	1.55	1.10	0.21	0.14	1.00	0.60	1.60	4.60	3.04	65.2
$AB_{horizon}$	11-16	5.51	0.31	0.55	0.02	4.56	2.85	1.65	0.31	0.17	1.00	0.60	1.60	6.58	2.58	75.6
$B_{horizon}$	16-135	4.86	0.41	0.72	0.03	3.67	1.25	1.00	0.23	0.14	0.50	0.10	0.60	3.25	4.31	81.5
G 2	50															
$Ap_{horizon}$	0-50	5.07	0.43	0.75	0.04	3.12	1.40	1.10	0.18	0.10	0.80	0.40	1.20	3.90	2.56	71.2
mean		5.09	0.34	0.68	0.03	3.73	1.76	1.21	0.23	0.14	0.83	0.43	1.25	4.58	3.12	73.4
Midstream																
G 1	86															
$AP_{horizon}$	0-14	4.89	0.33	0.58	0.03	3.76	1.20	1.20	0.18	0.08	0.40	0.20	0.60	3.26	2.45	81.5
$AB_{horizon}$	14-86	5.61	1.05	1.82	0.09	2.86	0.65	0.40	0.27	0.21	0.50	0.20	0.70	2.23	9.42	68.6
G 2	80															
$Ap_{horizon}$	0-20	4.90	0.56	0.96	0.04	1.79	1.45	0.85	0.25	0.19	0.90	0.50	1.40	4.14	4.59	66.1
$AB_{horizon}$	20-80	4.97	0.24	0.41	0.02	1.91	0.80	0.55	0.24	0.17	0.70	0.40	1.10	2.86	5.94	61.5
Mean		5.09	0.55	0.94	0.05	2.58	1.03	0.75	0.24	0.16	0.63	0.33	0.95	3.12	5.60	69.4
Downstream																
G 1	100															
$Ap_{horizon}$	0-52	5.12	0.49	0.85	0.04	3.96	1.60	1.00	0.20	0.09	0.70	0.20	0.09	3.79	2.37	76.2
$AB_{horizon}$	52-100	4.65	0.17	0.30	0.01	1.64	0.80	0.65	0.16	0.07	0.40	0.30	0.70	2.38	2.94	70.5
Mean		4.89	0.33	0.58	0.03	2.80	1.20	0.83	0.18	0.08	0.55	0.25	0.39	3.09	2.66	73.4
Degraded		5.02	0.41	0.73	0.04	3.04	1.33	0.93	0.22	0.13	0.67	0.34	0.86	3.60	3.79	72.07
$F\text{-}LSD_{(0.05)}$		0.02*	0.012*	0.008*	0.001*	0.005*	0.122*	0.18^{ns}	0.073^{ns}	0.118^{ns}	0.148^{ns}	0.135^{ns}	0.272^{ns}	0.158*	0.469^{ns}	0.059*

Note: G1 = Gully I G2 Gully2

Table 2: Variation of some soil Chemical Properties at various sampling points..

Location	pH	SOC	SOM	TN	AVP	Ca^{2+}	Mg^{+}	K^{+}	Na^{+}	CEC	ESP	BS	Al^{+}	H^{+}	TEA
Control															
Mean	5.21	0.66	1.15	0.09	4.65	1.63	1.08	0.25	0.16	4.16	3.72	74.7	0.77	0.27	1.03
Sd	0.64	0.47	0.81	0.07	1.30	0.35	0.20	0.04	0.06	0.71	0.76	2.98	0.15	0.15	0.15
Cv(%)	12.28	71.21	70.43	78.00	28.00	21.47	19.00	16.00	38.00	17.07	20.43	4.00	19.48	56.00	15.00
Ranking	LV	HV	HV	HV	MV	MV	MV	MV	HV	MV	MV	LV	MV	HV	MV
Upstream															
Mean	5.09	0.34	0.68	0.03	3.37	1.76	1.21	0.23	0.14	4.58	3.12	73.38	0.83	0.43	1.25
Sd	0.29	0.07	0.09	0.09	0.60	0.74	0.30	0.06	0.03	1.44	0.82	6.90	0.24	0.24	0.47
Cv(%)	6.00	21.00	13.24	300	16.09	42.05	25.00	26.10	21.43	31.44	26.28	9.40	29.00	56.00	38.00
Ranking	LV	LV	MV	LV	HV	MV	MV	MV	MV	MV	MV	LV	MV	HV	HV
Midstream															
Mean	5.09	0.55	0.94	0.05	2.58	1.03	0.75	0.24	0.16	3.12	5.60	53.93	0.63	0.33	0.95
Sd	0.35	0.36	0.63	0.03	0.92	0.37	0.35	0.04	0.06	0.80	2.92	19.84	0.22	0.15	0.37
Cv(%)	7.00	65.45	67.02	60.00	36.00	36.00	47.00	17.00	38.00	26.00	52.14	37.00	35.00	45.45	39.00
Ranking	LV	HV	HV	HV	HV	HV	HV	MV	HV	MV	HV	HV	MV	HV	HV
Downstream															
Mean	4.89	0.33	0.58	0.03	2.80	1.20	0.83	0.18	0.08	3.09	2.66	73.40	0.55	0.25	0.39
Sd	0.33	0.23	0.39	0.01	1.64	0.57	0.25	0.03	0.01	0.99	0.40	4.03	0.21	0.07	0.43
Cv(%)	7.00	70.00	67.24	33.33	59.00	48.00	30.12	17.00	13.00	32.04	15.04	5.49	38.18	28.00	110.3
Ranking	LV	HV	HV	MV	HV	HV	MV	MV	LV	MV	MV	LV	HV	MV	HV

Note: cv=Coefficient of variation ,LV= low variation(0-15), mv=moderate variation(15-35), HV=High variation(>35)

Table 3: Comparison of Control and Upstream Location using t-test

Soil Property	Control	Upstream	t-Test value
		Chemical Properties	
Soil pH	5.21	5.09	0.38^{ns}
Soil organic carbon	0.66	0.38	0.13*
Soil organic matter	1.15	0.68	0.14*
Total nitrogen	0.09	0.03	0.13^{ns}
Available phosphorus	4.65	3.73	1.29^{ns}
Exchangeable Ca	1.63	1.76	0.39^{ns}
Exchangeable Mg	1.08	1.21	0.27^{ns}
Exchangeable K	0.25	0.23	0.33^{ns}
Exchangeable Na	0.16	0.14	0.29^{ns}
Exchangeable Al	0.77	0.83	0.36^{ns}
Exchangeable H	0.27	0.43	0.18^{ns}
Total exchangeable acidity	1.03	1.25	0.24^{ns}
Cation exchange capacity	4.16	4.85	0.33*
Exchangeable sodium percentage	3.72	3.12	0.19*
Base saturation	74.7	73.38	0.39*

Note : *= significant , ns = not significant

Table 4: Comparison of Control and Midstream Location Using t-test

Soil Property	Control	Midstream	t-test value
		Chemical properties	
Soil pH	5.21	5.09	0.39^{ns}
Soil organic carbon	0.66	0.55	0.36^{ns}
Soil organic matter	1.15	0.94	0.36^{ns}
Total nitrogen	0.09	0.05	0.20*
Available phosphorus	4.65	2.58	0.03*
Exchangeable Ca	1.63	1.02	0.04*
Exchangeable Mg	1.08	0.78	0.10*
Exchangeable K	0.25	0.25	0.31^{ns}
Exchangeable Na	0.16	0.16	0.45^{ns}
Exchangeable Al	0.77	0.63	0.19^{ns}
Exchangeable H	0.27	0.33	0.32^{ns}
Total exchangeable acidity	1.03	0.95	0.37^{ns}
Cation exchange capacity	4.16	3.12	0.07*
Exchangeable sodium percentage	3.72	5.60	0.17*
Base saturation	74.7	69.43	0.18*

Table 5: Comparison of Control and Downstream Location Using t-test

Soil Property	Control	Downstream	t-Test value
		Chemical properties	
Soil pH	5.21	4.89	0.29*
Soil organic carbon	0.66	0.33	0.22*
Soil organic matter	1.15	0.58	0.22*
Total nitrogen	0.09	0.03	0.23^{ns}
Available phosphorus	4.65	2.80	0.12*
Exchangeable Ca	1.63	1.20	0.18*
Exchangeable Mg	1.08	0.83	0.01*
Exchangeable K	0.25	0.18	0.05*
Exchangeable Na	0.16	0.08	0.07*
Exchangeable Al	0.77	0.55	0.13*
Exchangeable H	0.27	0.25	0.45^{ns}
Total exchangeable acidity	1.03	0.39	0.04*
Cation exchange capacity	4.16	3.09	0.12*
Exchangeable sodium percentage	3.72	2.66	0.09*
Base saturation	74.7	73.4	0.35*

Note: *= significant , ns = not significant

Table 6: Degrees of degradation of some soil chemical properties of the watershed

Location	Depth (cm)	N (%)	P (mg/kg)	K (cmol/kg)	B.S (%)	ESP (%)	OM (%)
Control	137						
A_P horizon	0-24	HD	VHD	NSD	VHD	NSD	HD
AB horizon	24-44	VHD	HD	NSD	VHD	NSD	VHD
B horizon	44-137	VHD	VHD	NSD	VHD	NSD	VHD
Upstream							
G1	135						
$_P$ horizon	0-11	VHD	VHD	NSD	VHD	NSD	VHD
AB horizon	11-16	VHD	VHD	NSD	VHD	NSD	VHD
B horizon	16-135	VHD	VHD	NSD	VHD	NSD	VHD
G 2	50						
A_P horizon	0-50	VHD	VHD	NSD	VHD	NSD	VHD
Midstream							
G 1	86						
A_P horizon	0-14	VHD	VHD	NSD	VHD	NSD	VHD
AB horizon	14-86	HD	VHD	NSD	VHD	NSD	HD
G2	80						
A_P horizon	0-20	VHD	VHD	NSD	VHD	NSD	VHD
AB horizon	20-80	VHD	VHD	NSD	VHD	NSD	VHD
Downstream							
G1	100						
A_P horizon	0-52	VHD	VHD	NSD	VHD	NSD	VHD
AB horizon	52-100	VHD	VHD	NSD	VHD	NSD	VHD

leached basic cations caused by erosion. With a decline in organic matter content of the watershed, high level of land degradation was expected since organic matter contributes significantly to soil Nitrogen, available phosphorus, Sulphur, Cation Exchange Capacity and Exchangeable cations of which are adversely affected where organic matter lacks.

5.0 Recommendations.

Based on my findings, the following recommendations are made, and these include:

i. Clearing of trees within the watershed as a matter of urgency needs to stop.

ii. Re-introduction of forest condition; a look at the watershed shows that much deforestation has taken place which accelerated the rate at which erosion occurs within the watershed. A planned expansion of tree covers to counteract the various side effects of deforestation and soil erosion would, in turn, adds nutrients to the soil as well increases the productive capacity of soils of the watershed.

iii. For easy control and management, the watershed should be divided into sub-catchments.

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