RESEARCH ARTICLE

ASSESSMENT OF SOME PHYSICAL PROPERTIES OF SOIL ALONG AN EROSION PRONE WATERSHED, OWERRI-IMO STATE NIGERIA

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ABSTRACT

Nworie River watershed in Owerri Imo State, Southeast Nigeria is an Urban watershed that should provide agricultural resources to the inhabitants of the area; however, the watershed has been under ecological threat as result of some activities of people within the area leading to soil degradation in the form of gully erosion. The study area was divided into Upstream, Midstream and downstream after which 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 erosion prone area and this served as the control. Soil data collected were subjected to statistical analysis; Variation of soil properties at various sampling points were ranked according to standard procedures. Soils of the watershed were found to be acidic. The results of some physical soil properties for soil quality evaluation were matched with FAO standard to assess the degree of degradation. Soil texture of the watershed was sandy and can be classified as an Ultisol. The watershed had low variation of SCR with mean values of 0.20, 0.10 and 0.26 obtained respectively at the upstream, midstream and downstream. Bulk density was high and ranged from 1.81g/cm³ to 2.22g/cm³ at the Upstream, 1.78g/cm³ to 2.71g/cm³ at the Midstream and 2.22 g/cm³ to 2.36g/cm³ at the downstream indicating moderately to highly degraded. Bulk density significantly and positively correlated with sand at P=0.01 respectively at the Upstream and Midstream. The mean values of moisture content of the watershed at the upstream, midstream and downstream were 1.02%, 0.69% and 3.62%. Hydraulic conductivity of the soil ranged from 2.65cm/hr to 8.12cm/hr Upstream, 0.90cm/hr to 8.20cm/hr Midstream and 2.68cm/hr to 3.25cm/hr downstream indicating moderately slow to moderately rapid soil. Aggregate stability of the watershed was low with mean values of 0.32, 0.38, 0.40 at upstream, midstream and downstream respectively. Erosion within the watershed was more pronounced at the upstream and midstream compared to the downstream hence the need for appropriate conservation measures and practices within the watershed is paramount.

KEYWORDS

agricultural resources, Soils, erosion prone, watershed.

1. INTRODUCTION

Land degradation is an integral part of environmental change which leads to loss of valuable resources. It represents a downward trend in the environmental resource such that their level of use in human society decreases at an increasing rate (FAO, 1994). It is a massive global environmental problem (FAO/UNEP, 1995, Scherr 1999). 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. Land degradation is one of the leading critical environmental issues facing Nigeria. It is of varying types and the degrees are generally un-evenly distributed ranging from less devastating such as sheet erosion and mild gullies to highly dangerous ones such as loss of soil bio-physical characteristics.

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 reduction in total and biomass carbon as well as 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 micro-organisms 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 large human population depends almost entirely on land resources for their sustenance hence increasing the demand for land utilization through their activities. Currently, over 6000km² of the country's land are affected by erosion (NEWMAP, 2014).

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According to a study the major kind of land degradation experienced in southeastern Nigeria is soil erosion considering the low-lying nature of the land that exposes the surface areas to flooding and erosion (Urama, 2005). Igwe reported the major causes of land degradation in Central Eastern Nigeria to be Soil erosion (due to high rainfall), deforestation, fragile nature of soil and farming activities (Igwe, 2003). According to a study soils in the Southeast Nigeria constitute Sandy loose Surface and this makes it vulnerable to attack by floods (Ezemonye et al., 2012).

Erosion by water is a morphological process that involves three distinct actions of soil detachment, soil movement, and deposition. It reduces cropland productivity and contributes to the pollution of adjacent watercourses. However, this has become a critical environmental issue in Imo State owing to the fragility and nature of the soils. Again, some activities of man through forest deforestation, illegal construction, sand excavation as well as urbanization contribute to serious degradation of land in Owerri and this has a direct effect on Nworie river watershed that ordinarily would provide economic and agricultural resources to the inhabitants. Nworie River watershed in Owerri, Imo- State is an urban watershed that should provide rich, economic and agricultural resources to the inhabitants. However, the watershed is faced with serious ecological stress due to intense land use conversion and modification; therefore, the main objective of this study was to evaluate the soil physical properties along the watershed prone to erosion while the specific objectives were to;

- investigate some physical properties of soils along nworie river watershed prone to erosion and their relationship to land degradation.
- establish the degree of physical degradation in nworie River watershed using standard indicators.
- compare some physical soil properties of the watershed with standards.

2. MATERIALS AND METHODS

2.1 Study Area

Owerri the capital of Imo State Nigeria has a population of about 1,401,873 (Owerri-Wikipedia ,2016). It is approximately 100sq/km in area. Owerri is bordered by the Otamiri River to the east and Nworie river to the west (Acholonu, 2008). Owerri has maximum and minimum temperatures of 33^oc and 23^oc respectively. The study area (Nworie river watershed) lies within latitude 5^o29' to 5^o49'N and longitude 07^o01' to 7^o25'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 undulating slope. Nworie river watershed has an annual rainfall of 2500mm. Soils of the study area are coastal plain sands of Benin formation (figure 2). Nworie river is about 8km in its total length. Nworie river had its source at Ubomiri in Egbada; 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 broad leaf weeds like *Panicum Maximum* (Guinea grass), *Pennisetum Purpureum* (Elephant grass), *Axonopus Compressus* (Carpenter grass), *Elusine Indica* (Goose grass), *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 major occupation of the inhabitants of the area while Sand mining and excavation are the major activities within the study area. Cassava and yam are the major 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 many untreated wastes thus leading to various forms of degradation such as erosion especially gully erosion as seen in figure 3.

Figure 1: Location map showing the Nworie River Watershed (Source: Onyekuru et al., 2014)

Figure 2: Geological Map of Imo State Showing the Study Area

Figure 3: Gully Erosion in Nworie River Watershed

2.2 Field Studies/Soil Sampling

Prior to 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 gullies was scrapped with a shovel to create a new surface from where soil samples were collected; soil samples were collected from down to 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 co-ordinates 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.

Table 1: GPS Values of the Studied Areas

LOCATION	CO-ORDINATES	ELEVATION
PROFILE	5.52543°N, 7.01021°E	55m
UPSTREAM GULLY 1	5.52533°N, 7.01053°E	60m
UPSTREAM GULLY 2	5.52224°N, 7.01393°E	52m
MIDSTREAM GULLY 1	5.51975°N, 7.01543°E	54m
MIDSTREAM GULLY 2	5.51683°N, 7.01997°E	52m
DOWNSTREAM GULLY	5.49078°N, 7.0258°E	51m

Source: Handheld GPS Receiver (Garmin Model 72h)

2.3 Laboratory Analysis

- Particle size Distribution: The hydrometer method as described by was used to determine the particle size distribution of the samples, while the soil textures were determined using the USDA Textural triangle (Gee and Or 2002).
- Bulk Density: The bulk density was determined by core method as described by (Grossman and Reinsch, 2002)
- Soil Total Porosity: This was calculated from the bulk density as shown in this equation:

$$\text{Total porosity (\%)} = \frac{1 - \text{Bd}}{\text{pd}} \times 100 \quad (1)$$

Where Bd=Bulk density

Pd=particle density (2.65g/cm³)

v. Saturated Hydraulic conductivity(k_{sat}): This was determined by method of (Young, 2001)

vi. Aggregate stability: Soil Aggregate stability was determined using wet sieving method of (Kemper and Rosenau, 1986)

vii. Gravimetric Moisture Content: Moisture content of the soil was determined by oven drying at a temperature of 105°C and percentage of moisture in soil calculated mathematically as follows:

$$GMC = \frac{W_2 - W_3}{W_3 - W_1} \times 100 \quad (2)$$

Where W_1 =Weight of the can

W_2 =Weight of wet sample+can

W_3 =Weight of oven dried sample+can

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 as well as the indicators guide for evaluating analytical data (FAO, 2004; FAO, 1979). 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%.

Table 2: Indicators and Criteria for Physical, Chemical and Biological Land Degradation Assessment

Indicator	Degree of Degradation			
	1	2	3	4
Soil bulk density (g/cm ⁻³)	<1.5	1.5 – 2.5	2.5-5	<5
Permeability (cm/hr)	<1.25	1.25 – 5	5 – 10	>20
Content of nitrogen Element (multiple decrease) N (%)	>0.13	0.10 – 0.13	0.08 – 0.10	<0.08
Content of phosphorus Element (cmolkg ⁻¹)	>8	7 – 8	6 – 7	<6
K content (cmolkg ⁻²)	>0.16	0.14 – 0.16	0.12 – 0.14	<0.12
Content of ESP (increase by % of (CEC)	<10	10 – 25	25 – 50	>50
Content of Base saturation (decrease of saturation in more than 50%)	<2.5	2.5 – 5	5 – 10	>10
Excess salts (salinization) (increase in Conductivity mmhos/cm/vr	<2	2 – 3	3 – 5	>5
Content of humus in the soil	>2.5	2- 2.5	1.0 – 2	<1.0

Source: FAO (1979)

Note: Class 1: None to Slightly Degraded. Class 3: Highly Degraded
Class 2: Moderately Degraded. Class 4: Very Highly Degraded

2.5 Data Analysis

Descriptive statistics such as 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 where $C_v \leq 15\%$ = low variation, $C_v \geq 15 \leq 35\%$ = moderate variation, $C_v \geq 35\%$ = high variation (Wilding et al., 1994). Level of significance was determined using Fishers least significance difference at $p=0.05$

3. RESULTS AND DISCUSSION

3.1 Morphological Features of the Watershed

The entire Nworie river watershed is extensively eroded with several gullies at various stages of development, growth and stabilization (Table 3). Among the types of erosion in the watershed are riverbank erosion, rill & inter rill erosion, as well as gully erosion (figures 4,5 and 6). With respect to gully erosion, Upstream and Midstream had more gullies than the downstream. Soils of the study area were Sandy and well drained; this can be attributed to the nature of the parent's material. Grade of soil structure in the watershed indicates that structureless to weak soil structures predominates in the degraded area while moderate to strong structure dominated the undegraded area. The watershed is covered by depleted rainforest vegetation. Building construction and sand mining/excavation (figure 7) were the major activities within the watershed. Heaps of solid waste e.g food waste, plastic, metals, polyethylene bags varying in different sizes and contents were observed at different sections of the watershed as seen in figure 8.

Table 3: Features of Studied Gullies in the Watershed

Gully	Gully location	Length (m)	Width (m)	Depth (m)	status
1	Upstream	70	0.81	1.35	Active
2	Upstream	60	0.60	0.50	Developing
3	Midstream	29	0.90	0.86	Developing
4	Midstream	44	1.84	0.80	Active
5	Downstream	60	1.50	1.00	Active

Source: Field Studies

Figure 4: RiverBank Erosion **Figure 5: Rill and inter rill Erosion in the watershed** **Figure 6: Gully Erosion in the Watershed** **Figure 7: Sand mining in the Watershed** **Figure 8: Waste dumpsite**

3.2 Texture

The results of the textural analysis of soils from the study area are shown in Table 4. The results showed that upstream had a percentage mean values of 82.2, 3.03 and 14.80 respectively for sand, silt and clay contents.

Midstream had percentage mean values of 90.5, 0.90 and 8.65 for sand, silt and clay contents while downstream had percentage mean values of 85.2, 3.10 and 11.70 for sand, silt and clay contents. Clay content was significantly lower in the upstream than in the control at 5% probability level. Sand content in the midstream was significantly higher than in the control while Clay content was significantly lower than in the control at 5% probability level. Generally, midstream had higher sand content than the upstream and downstream and this could be attributed to the higher rate of deposition and lower transportability of sand at the midstream. Sand had low variation ($cv \leq 15$) in the control, upstream, midstream and downstream. Silt had high variation ($cv \geq 35$) in the upstream, midstream and downstream whereas it varied moderately in the control. Clay had moderate variation ($15\% \leq 35\%$) in the upstream, low variation ($cv \leq 15\%$) in the control while high variation ($cv \geq 35\%$) in both the upstream and downstream. There were significant differences at 5% probability level in the texture of the degraded gully area when compared with the control. Silt and Clay were significantly higher in undegraded area than the degraded area; this could be attributed to the topography, deposition of high volume of silt-clay due to high rainfall as well as land use types as reported by (Onweremadu et al., 2009). Soil texture of the watershed ranged from sandy to sandy Loam; Oguike and Mbagwu (2003) reported similar results for coastal plain soil of Owerri. The sandiness of the watershed was more a reflection of the parent material from where the soils were derived and can be classified as an ultisol according to USDA soil classification system.

3.3 Silt Clay Ratio (SCR)

The results show that upstream, midstream and downstream had mean SCR values of 0.20, 0.10 and 0.26 respectively while the control had a mean SCR value of 0.17. There was no significant difference in SCR of the degraded watershed and the control. Silt clay ratio indicates the weathering stage of the soil. It is also helpful in the classification of tropical soils. The lower the SCR the more weathered the soils are. There was low variation ($cv \leq 15\%$) of SCR in all the studied areas. Clay fraction had moderate variation ($15\% \leq 35\%$) at the upstream, high variation ($cv \geq 35\%$) at the midstream and downstream. The low variations of SCR observed in the watershed reflects parent material that is at a more advanced stage of weathering which could be attributed to the excessive rainfall in the area as well as the temperature of the watershed.

3.4 Bulk Density

From the results obtained; the control had a mean BD value of 2.07 g/cm³ while soils at the upstream, midstream and downstream had BD mean values of 2.08g/cm³, 2.27g/cm³ and 2.29 g/cm³ respectively. Soil bulk density obtained in the midstream and downstream were significantly higher than that of the control at 5% probability level. Generally, Soil bulk density of the watershed was high. Higher bulk density decreases the pore volume as a result of soil compaction and trampling by humans coupled with a decline of the soil organic carbon content at the upper horizon. (Yimer et al., 2008). Compaction influences crop yield and reduces the vegetative cover available to protect soil from erosion. According to FAO criteria for land degradation assessment which had between 1.5 g/cm³ to 2.5 g/cm³ range as moderately degraded and 2.5 g/cm³ to 5 g/cm³ as highly degraded (FAO, 1979). The bulk density of the watershed revealed moderately degraded too highly degraded. At both the upstream and downstream soil bulk density had low variation ($cv \leq 15\%$) while the midstream had moderate variation ($15\% \leq 35\%$). Soil bulk density of the degraded area was significantly higher at 5% probability level when compared with the control.

3.5 Total Porosity

The results show that control had a mean TP value of 21.63% while the upstream, midstream and downstream respectively had TP mean values of 21.41%, 15.38% and 13.58%. The soil total porosity means values obtained in the midstream and downstream were significantly lower than the control at 5% probability level. Soil total porosity is the ratio of the volume of soil pores to the total soil volume. However, soil bulk density indirectly provides a measure of the soil porosity. The higher the bulk density the lower the soil total porosity. From the results, it was found that the total porosity of soils of the watershed was low. The control, upstream and downstream had moderate variation ($15\% \leq 35\%$) of soil total porosity while midstream had high variation of soil total porosity ($cv \geq 35\%$).

3.6 Hydraulic Conductivity (Ksat)

Table 4 shows the results of hydraulic conductivity of the watershed. At the control, a mean Ksat value of 4.90cm/hr was obtained while the upstream, midstream and downstream respectively had mean Ksat values of 4.31 cm/hr, 3.94 cm/hr, 2.97 cm/hr. Generally, hydraulic conductivity of soil in the upstream, midstream and downstream were significantly lower than in the control at 5% probability level. Hydraulic conductivity of the watershed was in the range of 0.90 cm/hr to 8.20 cm/hr which according to FAO, 2004 was moderately slow to moderately rapid. The control, upstream and midstream had high variation ($cv \geq 35\%$) while the downstream had low variation ($cv \leq 15\%$). There was a significant difference at 5% probability level when soil hydraulic conductivity of the degraded area was compared with the control.

3.7 Moisture Content

Table 4 shows the results of moisture content determination of the watershed. From the results obtained, the control had a mean moisture content of 1.58% while the upstream, midstream and downstream had mean moisture content values of 1.02%, 0.69%, 3.62% respectively. Moisture content was significantly lower in the midstream than in the control at 5% probability level and significantly higher in the downstream than in the control at 5% probability level. According to a study upstream had moderate soil moisture variation ($15\% \leq 35\%$), midstream had low variation ($cv \leq 15\%$) and downstream had high soil moisture variation ($cv \geq 35\%$) (Wilding et al., 1994). There was no significant difference in Soil moisture content of the degraded area when compared with the control.

3.8 Aggregate Stability

The results show that the control, upstream, midstream and downstream had aggregate stability mean values of 0.32, 0.38, 0.40 and 0.45 respectively. From the results obtained, it was observed that soil aggregate stability of the watershed was low and this could be attributed to low soil

organic matter content as well as sandiness of soils of the watershed. There was a significant difference at 5% probability level when aggregate stability of the degraded area was compared with the control. The difference could be attributed to be lack of binding agents to the erosive runoff in the degraded area. According to a study, a level of soil organic carbon of 2.0 to 2.5% is considered necessary to maintain good aggregate stability and aggregate stability is considered to deteriorate rapidly when SOC falls below 1.2% to 1.5% (Kay et al., 1999). Again, the relative importance of soil organic matter in maintaining aggregate stability varies with texture. In sandy soil, SOM is the most important factor. In clayey soils; cation balance can be the most important effect and in loamy soil both cation balance and soil organic matter are important (Oades, 1993). Upstream and control had low variation ($cv \leq 15\%$) of aggregate stability while midstream and downstream had moderate variation ($15\% \leq 35\%$).

3.9 Relationship Between Bulk Density, Texture and Total Porosity of Soils of the Watershed

Significant and Positive correlation of soil bulk density with sand at the control, midstream and downstream was obtained in this study ($r=0.7459^{**}, 0.8779^{**}, 0.5383^{*}$), density correlated negatively with sand and clay at the upstream and midstream respectively ($r=-0.2054, -0.8610^{**}$). Equally, negative and significant correlation of bulk density with total porosity in the studied areas was obtained ($r=-0.9984^{**}, -1.000^{**}, -0.9935^{**}, -0.9935^{**}$). According to correlation exist between texture and bulk density and this was observed in this study (Bernoux et al., 1998). The effect of sand content on soil bulk density was found to be higher than that of other soil properties; clayey soils tend to have lower bulk densities and higher porosities than sandy soils. Onwudike reported that a relationship existed among soil physico-chemical properties which positively or negatively interfered with nutrient availability (Onwudike, 2015). The positive correlation between bulk density, texture and total porosity as obtained in this study were in line with the findings of (Pravin et al., 2013).

Table 4: Physical Properties of Soils of the studied area

Location	Gully depth (cm)	Bulk density (g/cm) ³	Total porosity (%)	K _{sat} (cm/hr)	Moisture Content (%)	Aggregate Stability	Sand (%)	Silt (%)	clay (%)	Textural Class	SCR
control	137										
A _p horizon	0-24	2.13	19.22	3.20	1.50	0.30	81.2	2.00	16.80	SL	0.12
AB _{horizon}	24-44	2.11	20.37	3.20	1.86	0.34	89.2	4.00	20.80	SS	0.19
B _{horizon}	44-137	1.98	25.30	8.20	1.37	0.33	75.2	4.00	20.80	SCL	0.19
mean		2.07	21.63	4.90	1.58	0.32	81.87	3.33	19.47		0.17
Upstream											
G 1	135										
A _p horizon	0-11	1.81	31.69	8.12	1.24	0.36	85.2	2.10	12.80	LS	0.16
AB _{horizon}	11-16	2.22	16.23	3.30	1.17	0.37	83.2	4.00	12.80	LS	0.19
B _{horizon}	16-135	2.11	20.37	3.15	0.86	0.36	75.2	4.00	20.80	SCL	0.19
G 2	50	2.19	17.35	2.65	0.82	0.44	85.2	2.00	12.80	LS	0.16
AP _{horizon}	0-50	2.08	21.41	4.31	1.02	0.38	82.2	3.03	14.80	0.20	
Midstream											
G 1	86										
A _p horizon	0-14	1.78	32.83	8.20	0.68	0.40	83.2	2.00	14.80	SL	0.14
AB _{horizon}	14-86	2.32	12.46	3.25	0.78	0.42	92.2	1.20	6.60	SS	0.18
G2	80	2.71	2.26	0.90	0.57	0.32	93.2	0.20	6.60	SS	0.03
AP _{horizon}	0-20										
AB _{horizon}	20-80	2.28	13.96	3.40	0.71	0.46	93.2	0.20	6.60	SS	0.03
mean		2.27	15.38	3.94	0.69	0.40	90.5	0.90	8.65	0.10	
Downstream											
G1	100										
A _p horizon	0-52	2.36	10.94	3.25	5.64	0.52	93.2	0.2	6.60	SS	0.03
AB _{horizon}	52-100	2.22	16.22	2.68	1.60	0.38	77.2	6.00	16.80	SL	0.3
mean		2.29	13.58	2.97	3.62	0.45	85.2	3.10	11.70	0.26	

Note: SL=Sandyloam, SS=sandysoil, SCL=sandyclayloam, G1=Gully 1,

Table 5: Variability Among Some Soil Physical Properties of the Studied Area.

Location	Bulk density(g/cm) ³	Total porosity (%)	Hydraulic conductivity (cm/hr)	Moisture content (%)	Aggregate stability	San %	Silt %	Clay %
Control								
Mean	2.07	21.63	4.90	1.58	0.32	81.9	3.33	19.5
Sd	0.08	3.23	2.89	0.25	0.02	7.02	1.15	2.31
Cv(%)	4.00	15.00	59.00	16.00	6.25	9.00	35.00	12.00
Ranking	L.V	M.V	H.V	M.V	L.V	L.V	M.V	L.V
Upstream								
Mean	2.08	21.41	4.31	1.02	0.38	82.2	3.03	14.80
Sd	0.19	7.07	2.56	0.21	0.04	4.76	1.13	4.00
Cv(%)	9.13	33.02	59.39	21.00	11.00	6.00	37.29	27.03
Ranking	L.V	M.V	H.V	M.V	L.V	L.V	H.V	M.V
Midstream								
Mean	2.27	15.38	3.94	0.69	0.40	90.5	0.90	8.65
Sd	0.38	12.74	3.06	0.09	0.06	4.86	0.87	4.10
Cv(%)	17.00	83.00	78.00	13.04	15.00	5.37	97.00	47.39
Ranking	M.V	H.V	H.V	L.V	M.V	L.V	H.V	H.V
Downstream								
Mean	2.29	13.58	2.97	3.62	0.45	85.20	3.10	11.70
Sd	0.09	3.73	0.40	2.86	0.09	11.31	4.10	7.21
Cv(%)	4.00	27.47	13.47	79.00	20.00	13.27	132.3	62.00
Ranking	L.V	M.V	L.V	H.V	M.V	L.V	H.V	H.V

Note : *= significant, ns = not significant

Table 6: Comparison of Control and Upstream Location using T- test

Soil Property	Control	Upstream	T – test value
Bulk density	2.07	2.08	0.47 ^{ns}
Total porosity	21.63	21.41	0.48 ^{ns}
K sat	4.86	4.31	0.39*
Moisture content	1.58	1.02	0.01*
Aggregate stability	0.32	0.38	0.03 ^{ns}
Sand	81.87	82.2	0.47 ^{ns}
Silt	3.33	3.03	0.37 ^{ns}
Clay	18.80	14.8	0.14*
Silt/ clay ratio	0.18	0.18	0.24 ^{ns}

Note : *= significant , ns = not significant

Table 7: Comparison of Control and Midstream Location Using T- test

Soil Property	Control	Midstream	T-test value
Bulk density	2.07	2.27	0.20*
Total porosity	21.63	15.38	0.23*
K sat	4.86	3.94	0.35*
Moisture content	1.58	0.69	0.001*
Aggregate stability	0.32	0.40	0.04*
Sand	81.87	90.45	0.06*
Silt	3.33	0.90	0.01*
Clay	18.80	8.65	0.02*
Silt/ clay ratio	0.18	0.09	0.10 ^{ns}

Note : *= significant , ns = not significant

Table 8: Comparison of Control and Downstream Location Using T- test

Soil Property	Control	Downstream	T – Test value
Bulk density	2.07	2.29	0.03*
Total porosity	21.63	13.58	0.04*
K sat	4.86	2.97	0.22*
Moisture content	1.58	3.62	0.14*
Aggregate stability	0.32	0.45	0.05*
Sand	81.87	85.2	0.35*
Silt	3.33	3.10	0.46 ^{ns}
Clay	18.80	11.70	0.16*
Silt/ clay ratio	0.18	0.19	0.42 ^{ns}

Note : *= significant, ns = not significant

4. CONCLUSION

The investigated soil physical properties of the watershed showed different levels of degradation that ranged from moderately degraded (MD) to highly degraded (HD). The acidity of the soils of the watershed was more a reflection of the parent's material as well as the resultant effect of the leached basic cations caused by erosion. Therefore, soil conservation practices and measures should be put in place within the watershed to avoid further deterioration of the watershed.

RECOMMENDATIONS

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

- 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 a lot of deforestation have 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 productive capacity of soils of the watershed.
- iii. Periodic dredging of Nworie River is recommended, this would ensure that river obstructions are removed and in turn clears the water ways thereby increasing its carrying capacity. The excavated materials could equally be used to build up the riverbanks to curtail the erosion of the banks of the river.
- iv. Environmental Laws should be enacted and if already enacted should be enforced on individuals mining and excavating sand in negligence to outlined guidelines and procedures. Defaulters should be sanctioned
- v. For easy control and management, the watershed should be divided in sub-catchments.

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