ASSESSMENT OF SOIL PROPERTIES AT GULLY EROSION SITES IN MAKURDI, BENUE STATE, NIGERIA

Samaila, Kunden Ishaya and Onu, Veronica

Department of Geography
Nasarawa State University, Keffi, Nasarawa State, Nigeria
Email: ikunden@yahoo.com

ABSTRACT

Gully erosion is a serous environmental problem that has created irretrievable changes in most parts of Nigeria's environment. Despite several measures at addressing this environmental catastrophe erosion is still a problem that has seemed to defy all possible solutions. This study assessed soil properties at gully erosion sites in Makurdi, Benue State, Nigeria. Data for this study were sourced mainly from fieldwork. This involved the collection of soil samples at the gully erosion sites. A total of eleven soil samples at the gully sites and three at control sites were taken. The soils samples were analyzed for physical and chemical properties such as; bulk density and total porosity by core method, Bouyoucos hydrometer method for particle size, moisture content and organic matter were determined after Walkey and Black (1934), pH using a glass-calomel combination electrode, available phosphorous Bray p-1 extracting solution, total nitrogen by macro-kjedal method, base saturation calculated as the sum of exchangeable bases divided by C.E.C, exchangeable acidity by titration method, cation exchangeable capacity, Na^{+}, Ca^{++}, Mg^{++} by Ammonium acetate leaching method, while K^{+} , and micronutrients (Fe, Mn, Zn, and Cu) by atomic absorption spectrophotometer screening. Findings from the study showed that electrical conductivity was between 60umhos to 210umhos, with a mean of 114.55umhos indicating salinity built up in the soil. pH was between 4.55 to 10.18, with a mean of 6.43 showing high variation in distribution, Nitrogen concentration was from.04% to .42%, with a mean of .13% and was low as in most West African Soils, sodium was between .48meq/kg to .53meq/kg, with a mean of .52meq/kg, magnesium 1.28meg/kg to 1.70meq/kg, with a mean of 1.55meq/kg, calcium was 3.38meq/kg to 4.01meq/kg, with a mean of 3.68meq/kg and potassium from .10meq/kg to .39meq/kg, with a mean of .25meq/kg. These major cations were generally low in the soils. Trace elements such as iron, zinc and copper were also low for the soils at the gully sites. A T-test showed the properties of the soils at the gully sites and control sites had no significant difference in distribution at 0.05 confidence level. The study therefore recommends that, there is the need for reclaiming the gully erosion sites to restore them to usable state and also increase in tree planting so as to reduce the threat pose by erosion in the study area.

Keywords: Gully, Anthropogenic, Degradation, Salinity and Processes

INTRODUCTION

Erosion is an environmental menace especially in the humid and sub-humid environments characterised by heavy rainfall and accompanied by severe human assaults on the environment. This has created permanent scares and irretrievable changes on the earth surface that has attracted great concern to environmentalist and agriculturalist. The increase in erosion as a result of anthropogenic activities has further heightened the depletion of soil nutrients culminating therefore in low agricultural productivity. Despite several measures at addressing this environmental catastrophe erosion is still a problem that has seemed to defy all possible solutions. Several documented works have highlighted the causes, processes, occurrence and environmental effects of erosion (Tukur and Ray, 2000). The soil is an important natural resource that supports most of the planet's life, and the major function of soil on man is that, it supports food supply and ensures food security. However, over 65 percent of the soil on the earth is said to have displayed degradation predisposition as a result of soil erosion (International Labour Organisation, ILO, 2007). Soil erosion when unchecked may develop into an extreme stage of gulling, resulting in degraded lands that cannot easily be redeemed for productive agricultural venture. According to Ehiorobo and Izinyo, (2011).Gully erosion is one of the major causes of land degradation in most parts of the world and constitutes a great threat to human survival especially in the developing countries. Many of the gullies have developed as a result of inappropriate land use, inadequate drainage facilities, deforestation, overgrazing and intensification of agriculture. Soil erosion caused by water is the commonest form of land degradation. It is estimated that one sixth of the world's soils are affected by water erosion. Globally, human's impact is around 1,094 million hectares, of which 43% was as a result of deforestation and the removal of natural vegetation, 29% from overgrazing, 24% from improper management of the agricultural land and 4% from over-exploitation of natural vegetation (Walling, et.al,. 2003). On a global scale, the Food and Agriculture Organization (FAO) in Kumar, et.al, (2003) estimated that the loss of productive land through soil erosion globally is about 5-7 million ha/year. Many scholars projected that unless there is an adoption of better land management practices, otherwise, about 140 million hectares of high quality soils in Africa and Asia will be degraded as a result of soil erosion by 2020.

Gesses *et al.*, (2009) were of the opinion that soil erosion constitutes one of the major problems affecting agriculture world wide and identified two main types' namely geologic norm or natural erosion and accelerated erosion. According to Wishmeer and Smith (1987) a more destructive form of land degradation is that associated to anthropogenic processes from human interference with the natural ecosystem, thus culminating in accelerated removal of the surfacial part of the earth creating disequilibrium and irretrievable changes in most landscapes and rendering the soils unproductive for a number of uses including agriculture. Soil degradation is a loss of soil function, it is a serious and most common form of land degradation, and this is because the soil is the basis for survival and production (Blum, 1998). It encompasses physical, chemical and biological deterioration, such as loss of organic matter, decline in soil fertility and structural stability. Erosion causes unfavourable changes in the soils culminating in salinity, acidity or alkalinity, and the built of toxic chemicals at levels to affect the productive capacity of the soils. The impact of raindrops on the soil surface can cause a break down of soil aggregates and disperse the aggregate materials therefore affecting the internal structure of the soil. Lighter aggregate materials such as very fine sand, silt, clay and organic matter can be easily removed reducing the colloidal materials that are necessary for improving the fertility in the soil. Gully erosion exposes the subsoil which usually is devoid of nutrients and reduces the potentials of the soil for a variety of uses (Samaila, 2005). Soil erodibility is an estimate of the ability of soils to resist erosion, based on the physical characteristics of each soil. Generally, soils with faster infiltration rates, higher levels of organic matter and improved soil structure have a greater resistance to erosion, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and clay texture soil (Olori, 2006). Soil erosion is thus an environmental problem that exists in all parts of the globe. It is a problem which is growing stronger in Nigeria as a result of deforestation, desertification, overgrazing, bush burning, heavy rainfall and poor agricultural management. It is equally prevalent in areas affected by large-scale construction, mining activities, urbanization, quarrying and lumbering (Olalusi and Olurunoje, 2004).

MATERIALS AND METHOD

Makurdi is situated within the Benue trough at the lower Benue valley, in the North Central region of Nigeria. It is traversed by River Benue, the second largest river in the country. The area is overlained by early cretaceous sediments which are predominantly sandstones and mudstones of the Rima group, shale and limestone of the Pindiga formation Basic and intermediate intrusions and also alluvium of the quaternary era are mostly found along the river valleys. Makurdi is under the influence of the tropical wet and dry climate, characterised by seasonality and the Aw type of climate according to Koppen classification. The seasonal rainfall comes in form of intense violent convection within short duration, especially at the onset and cessation of the rainy season. This violent rainfall constitutes an active agent of erosion resulting in gullies a common sight in the town. The friable soils mostly sandy loams coupled with intensive deforestation and cultivation have accelerated soil erosion which has developed into gullies creating degraded landscape. Figure 1 shows the study area and the gully sites covered by this study.

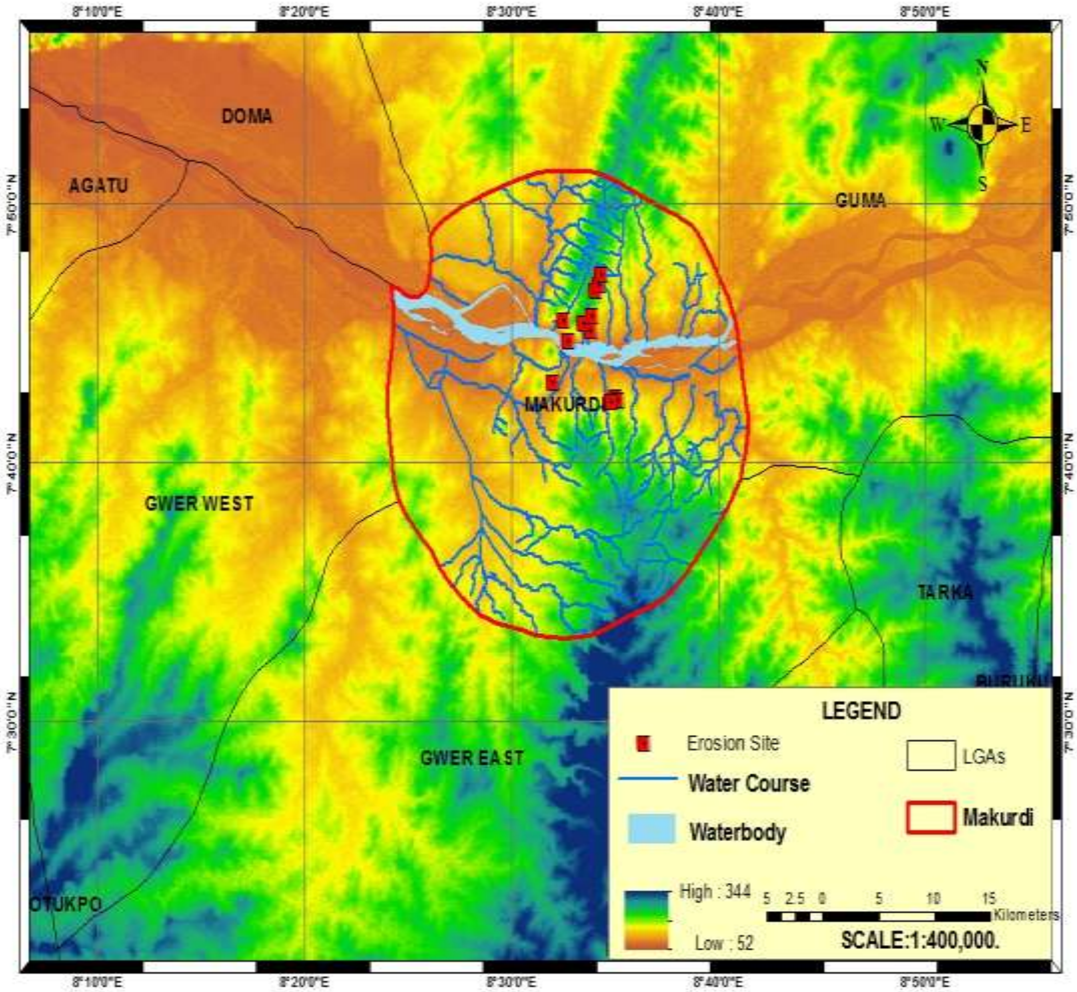

Figure 1: Gully erosion sites covered by the study in Makurdi.
Source: ArcGIS, 2015

Soil samples were taken at eleven gully erosion sites as shown in table 1. The soil samples were taken at 30cm depth of the gully using a soil auger at a depth. The soils were thoroughly mixed and a representative sample collected for each of the gully covered by this study. A one kilogram of soil sample was taken at each sampling point in polythene bags for laboratory analysis and handheld GPS was used to geo-referenced the position at which the sample was taken. Three soil samples were also taken at

100metres distance from the gullies to serve as control points. The soil samples were subjected to laboratory analysis using standard laboratory analytical methods. Properties analysed included; bulk density and total porosity by core method, Bouyoucos hydrometer method for particle size, moisture content and organic matter content were determine after Walkey and Black (1934), pH using a glass-calomel combination electrode, available phosphorous Bray p-1 extracting solution, total nitrogen by macro-kjedal method, base saturation calculated as the sum of exchangeable bases divided by C.E.C, exchangeable acidity by titration method, exchangeable cations, cation exchangeable capacity, Na^{+}, Ca^{++}, Mg^{++} by Ammonium acetate leaching method, while K^{+} , and micronutrients (Fe, Mn, Zn, and Cu) were by atomic absorption spectrophotometer screening.

Table: 1: Gully sites and geographical position in the study area.

Gully Sites	Geographical Position	
	Latitude	Longitude
BIPC quarters	8^{0}33'7.8543"E	7^{0}44'59.2194"N
A.A. Rano	8^{0}33'7.5612"E	7^{0}45'20.7911"N
Kings N/P School	8^{0}34'2.4975"E	7^{0}45'36.7952"N
Federal low cost	8^{0}34'2.1166"E	7^{0}46'43.1470"N
Yagba settlement 1	8^{0} 34' 5.439"E	7^{0} 47' 13. 6074"N
Yagba settlement 2	8^{0} 34' 8.590"E	7^{0} 45' 28.9346"N
Federal. Road. N/B	8^{0} 32' 7.383"E	7^{0} 45' 27.4354"N
Old bridge	8^{0} 32' 1.116"E	7^{0} 44' 38.4097"N
Judges Qtrs. Ext 1	8^{0}32' 7.5733"E	7^{0} 44'38.1823"N
High level	8^{0} 34' 8.3619"E	7^{0} 42' 28.1005"N
Judges Qtrs. Ext 2	8^{0} 32' 4.573"E	7^{0} 44' 38.1823"N

RESULTS AND DISCUSSION

The results of the physical and chemical properties of soils at gully sites are presented in tables 2 and 3. The results showed moisture content was high and varied with the gullies. It ranged from 77% to 94% with a mean of 87.27%, a standard deviation of 5.53 and a variance of 30.62. The variations observed of moisture content of soils at gully sites could be attributed to the nature of the soil texture and organic matter content. The high moisture content observed for the soils indicated that soil water will enhance the various soil physiochemical reactions and supply essential nutrients for both plants and animals. In a study in Gombe *Lazarus, et.al., (2012),* observed similar moisture content at gully sites and attributed this to the relatively high finer particles of soils in the area. Bulk density ranged from 1.27g/cm^3 to 1.53g/cm^3 with a mean 1.37g/cm^3, and a standard deviation of .080. The result revealed slight variation in bulk density with the gullies. The bulk density dropped at the control sites possibly due to high fine materials observed of soils at these points. Campbell and Henshal, (1992), observed also low bulk density at gully sites in Marcel Dekker, New York, and ascribed it to the reduction of biotic activities, low vegetal cover and nature of the soil. Total porosity was between 42.0% to 52% and with a mean 48.36%, Total porosity varied slightly with the gullies covered by this study it was however higher at the control sites as soils were mostly sandy. *A study by Ghodosi, (2006*) recorded total porosity within the range recorded by this study.

The electrical conductivity recorded of the soils varied from 60umhos to 210umhos, with a mean of 114.55umhos, and a standard deviation of 49.27. The result indicated salinity built up in soils of the gully at High level. This could be attributed to low leaching and accumulation of salts from deposited soils at the gully site while at control sites the drop in electrical conductivity of the soils was likely due to excessive erosion and eluviations of salts from the soil. Total dissolved solid was between 40 mg/l to 170 mg/l, with mean concentration of 78.18mg/l and a standard deviation 39.70. Total dissolved solids were highest for soils of the gully at High level and dropped at the control sites. The distribution of pH was between 4.55 to 10.18, with a mean of 6.43, and standard deviation of 1.60. The pH showed, most soils at the gullies sites were acidic and low in bases. This was likely due to leaching which resulted in the removal of the colloidal portion of the soil and its displacement hydroxyl ions. Yagba settlement 2, recorded the highest pH, and this could be attributed to high exchangeable basic cations, which tend to occupy the exchange sites of the soils by replacing exchangeable H and Al ions. The pH at the control sites was close to neutrality and consistent in distribution. Igwe and Ejiofor (2005) recorded similar distribution of pH in exposed gully wall in Eastern Nigeria. Organic carbon ranged from .01% to 1.70%, with a mean of .59%, and a standard deviation of .56. Organic carbon varied in distribution among the gullies. The highest concentration of organic carbon was recorded at the gully at Federal Low Cost, while the lowest was recorded at Federal Road Nasame Barrack, Old Bridge, Judges Quarters Extension 1, High Level, and Judges Quarters Extension 2. Organic carbon is high at the control sites due to high organic matter from plant litter and fertilization from animal droppings. In a similar study Brandy and Weil, (2005) observed the same trend in the distribution of organic carbon of soils at gully sites, in Delhi. Soil organic matter ranges from .02% to 1.55% with a mean of .77%, a standard deviation of .64, a variance of .41. Organic matter was generally low for all the gullies due the removal of this portion by erosion thus exposing the subsoil with little organic constituents. However, the control sites recorded higher organic matter in the soils as vegetal cover is rich and erosion and leaching is low. Rahab, (2008), observed similar distribution of organic matter in soils at gully sites in Zaria.

Nitrogen concentration was between .04% to .42%, with a mean of .13%, and a standard deviation of .11. Nitrogen was generally low for the soils at the gully sites. The low nitrogen observed for the soils was likely due to absence of organic matter and highly weathered soils of the humid environment, leaching and over cropping. The control sites however recorded high nitrogen due to the presence of organic matter and low leaching as well as fertilization of the soil with inorganic fertilizer during cultivation. The low nitrogen recorded for the soils fall within the range of most West African soils. The distribution of phosphorus was between 2.90ppm to 7.75ppm, with a mean of 4.05ppm, and a standard deviation of 1.42. The distribution of phosphorus among the gullies showed little variations, except for the gully site at

Yagba Settlement 2, which recorded the highest phosphorus concentration. This was likely due to the high organic matter and agricultural return flow rich in phosphorous from chemical fertilizer of surrounding farmlands. Brady and Weil, (2004) observed that erosion in some cases transport finer materials in the form of clay and organic matter that may be relatively rich in phosphorus. The concentration of calcium was from 3.38meq/kg to 4.01meq/kg, with a mean of 3.68meq/kg, and a standard deviation of .24. This showed little variation in the distribution except for the control sites which recorded a high concentration. The high concentration recorded of the control sites may be attributed to the high organic matter and the application of calcium rich fertilizer. Magnesium concentration ranged from 1.28meg/kg to 1.70meq/kg, with a mean of 1.55meq/kg, and a standard deviation of .13. The concentration of magnesium in soils was low and varied slightly with the gullies and the control sites which could be attributed to soils under continuous cultivation, application of acid forming inorganic fertilizers, high exchangeable and extractable Al and low pH. The concentration of potassium ranged from .10meq/kg to .39meq/kg, with a mean of .25meq/kg, and standard deviation of .10. The distribution of potassium varied with the gully sites. The variation observed in the distribution of potassium depends on the mineral present, particle size distribution, degree of weathering, soil management practices, climatic conditions, degree of soil development, the intensity of cultivation and the present material from which the soil is formed.

Sodium concentration was from .48meq/kg to .83meq/kg, with a mean of about .62meq/kg, and a standard deviation of .092. The distribution of sodium at the gullies site showed little variation in the soils and was generally low. However, a high concentration of sodium was recorded at Yagba Settlement 2. The high sodium ions observed at the gully at Yagba Settlement 2 could be attributed to built-up of this from deposition or the abundance of it from the weatherable rocks. At the control sites the concentration of sodium dropped as a result of the assimilation into growing plants and removal due to erosion. Exchangeable Acidity was between 1.0mg/l/kg to 6.17mg/kg, with a mean of 2.91mg/kg, and a standard deviation of 1.40. The distribution of exchangeable acidity showed no significant variation at 95% confidence level .*Gessess,et. al.,* (2009) recorded similar results in the distribution of exchangeable acidity in a study on soil conservation practices in Ethiopia. Cation Exchangeable Capacity ranged from 7.11meq/kg to13.10meq/kg, with a mean of 9.01meq/kg, and a standard deviation of 1.70. The distribution of cation exchange capacity at gully sites slightly varied except for Yagba Settlement 2 which recorded high cation exchange capacity of 13.1meq/kg, and this could be attributed to the presence of colloidal materials in the soil such as organic matter, clay and the use of chemical fertilizer.

Table 2: Physical and chemical properties of soils at gully sites in Makurdi.

Parameter	Gully sites	Range	Min	Max	Mean	Std. Deviation	Variance
%MC	11	17.00	77.00	94.00	87.2727	5.53337	30.62
BD(g/cm3)	11	.26	1.27	1.53	1.3664	.08016	.006
% TP	11	10.0	42.0	52.0	48.364	3.0748	9.46
EC(Umhos)	11	150	60	210	114.55	49.267	427.27
TDS (Mg/L)	11	130	40	170	78.18	39.703	1576.36
pHinH20	11	5.63	4.55	10.18	6.4255	1.60152	2.565
% OC	11	1.69	.01	1.70	.5882	.57595	.332
% OM	11	1.53	.02	1.55	.7655	.63799	.407
% N	11	.38	.04	.42	.1309	.10849	.012
P(ppm)	11	4.85	2.90	7.75	4.0500	1.41659	2.007
Ca (Meq/kg)	11	.63	3.38	4.01	3.6836	.24246	.059
Mg Meq/kg	11	.42	1.28	1.70	1.5509	.12919	.017
K (Meq/kg)	11	.29	.10	.39	.2455	.10309	.011
Na (Meq/kg)	11	.35	.48	.83	.6173	.09166	.008
EA(Meq/kg)	11	5.17	1.00	6.17	2.9091	1.40338	1.967

CEC (Meq/kg)	11	5.99	7.11	13.10	9.0064	1.70076	2.89
% BS	11	33	53	86	69.09	9.418	88.69
Fe (Mg/kg)	11	1.07	.11	1.18	.7618	.35102	.123
Z (Mg/kg)	11	1.23	2.78	4.01	3.3436	.47160	.222
Cu (Mg/kg)	11	.24	.09	.33	.1873	.07157	.005
Mn (Mg/kg)	11	.17	.95	1.12	1.0218	.06242	.004

Base saturation recorded by this study was between 56.0% to 86.0%, with a mean of 69.1%, and standard deviation of 9.42. The result showed variation among the gullies and the control sites. However, the base saturation of the soils at both the gully sites and the control sites were high. The concentrations of trace elements were low for the soils of the gullies covered by this study. Iron (Fe) concentration was between.11mg/kg to 1.18mg/kg, with a mean of .76mg/kg, and a standard deviation of .35. Zinc was from 2.78meq/kg to 4.01meq/kg, with a mean of 3.34meq/kg, and a standard deviation of .47. Copper was from .09mg/kg to .09mg/kg with a mean of .19mg/kg, and a standard deviation of .072. While manganese ranged from .95mg/kg to 1.12mg/kg, with a mean of 1.02mg/kg, and standard deviation of .06. The concentrations of these metals showed slight variation with the gullies. The variation observed could have been due the nature of the rocks and anthropogenic activities in the study area. The presence of iron concretion at the sites of some of the gullies could account for the high iron observed at such gullies. Generally, the presence of micronutrients is affected by parent material, soil reaction, soil texture and soil organic matter.

Table 3: Physical and chemical properties of soil at control sites in Makurdi.

Number of parameters	No of sam pl	Range	Min	Max	Mean	Std. Deviation	Variance
%MC	3	17.45	1.05	18.5 0	11.416 7	9.18	84.21
BOD(g/cm3)	3	.13	1.01	1.14	1.0633	.06807	.005
%TP	3	3.8	57.0	60.8	59.27	2.00	4.013
E.C (Um hos)	3	50	100	150	126.67	25.17	633.33
TDS (Mg/L)	3	60	80	140	106.67	30.55	933.33
pH in H20	3	.30	6.85	7.15	6.98	.15535	.024
% OC	3	.31	1.48	1.79	1.68	.17616	.031
% OM	3	.53	2.55	3.08	2.99	.30039	.090
% N	3	.08	.21	.29	.2600	.04359	.002
Bray-1P (Ppm)	3	.90	3.72	4.62	4.13	.45446	.207
Ca (Meq/kg)	3	3.17	3.50	6.67	4.68	1.73	3.00
Mg (Meq/kg)	3	.23	1.62	1.85	1.73	.11533	.013
K (Meq/kg)	3	.24	.16	.40	.2633	.12342	.015
Na (Meq/kg)	3	.10	.52	.62	.5667	.05033	.003
EA (Meq/kg)	3	.33	1.00	1.33	1.16	.16503	.027
CEC (Meq/kg)	3	.71	7.13	7.84	7.40	.38214	.146
% Bs	3	3	83	86	84.00	1.732	3.00
Fe (Mg/kg)	3	.45	.56	1.01	.7400	.23812	.057
Z (Mg/kg)	3	.61	1.25	1.86	1.59	.32130	.103
Cu (Mg/g)	3	.09	.07	.16	.1233	.04726	.002
Mn (Mg/kg)	3	.31	.68	.99	.8767	.17098	.029

CONCLUSION

Erosion degrades soils and reduces its potential for a variety of uses including agriculture and construction. The physical and chemical properties of the soil are depleted sometimes at levels that affect the productive capacity of the soils. Gully erosion as observed by this study has lowered the concentration of most of the physical and chemical properties of the soil thus, exposing the sub soil devoid of fertility to support gainful agricultural productivity. Due to erosion, the texture of the soils at the gully sites had lost most of colloidal portion leaving a soil that were mostly sandy in nature. The low concentration of macro nutrients observed for the soils at the gully sites implies that the soils were deficient in these important nutrients necessary for promoting high productivity for plants. Gully erosion especially in Makurdi should be taken a serious environmental problem and measures should be directed towards minimising it impacts, improve the soil quality of the area and reduce the possible negative effects this may have on agricultural lands and residential areas.

RECOMMENDATIONS

Since this study observed that gully erosion impact negatively on the soils properties in the study area the following recommendations are therefore proffered. There is the need to reclaim sites affected by gully erosion so as to restore them to a usable state for agriculture which the state is well known for. Farmers in the area should adopt improve agricultural methods, such as minimal tillage and agro-forestry methods to reduce possible acceleration of erosion in the study area. Aforestation programs should be encouraged in areas where erosion pose threat to the ecosystem. Alternative energy source should be made available to inhabitants in the area to reduce their dependence on forest products in providing energy. Where deforestation becomes necessary then there is the need for selective felling of trees. The inhabitants of the area should be enlightened on measures to employ in controlling soil erosion.

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