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Deleterious Effect of Gully Erosion in Biu Area, Borno state, Nigeria

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Abstract – **Gully erosion in Biu Area is severe because of the topography, texture and rinfall intensity. There is very limited knowledge on soil erosion process and rates in this region in comparisons to other regions in Northern Nigeria. The aim of this present paper is to assess the severity or extent of soil loss (mass of soil loss) from gully erosion in Biu Area. Erosion pins were used to monitor gully erosion. Multiple Regressions analyses, soil erosion prediction variables were also used to access the extent of gully erosion in the region, from April to October (2016). The rainfall and run off factor ranged from 299.12 to 399.12mm, exchangeable calcium, magnesium and sodium rates range from 3.8 – 16.4, 0.60 – 2.80, and 0.39 – 1.74 Cmol (+) kg respectively. The basic cations (Ca, Mg) and Organic matter known for resisting erosion were significant (p< 0.05) different among sides. Where as Na and run off facilitate erosion. The annual mars of soil loss (MSL) values were 28.446, 30.050, 35.170, 48.229, 48.467 and 52.239 kg/ha/yr for Kigir, Piku, Garwashina, Daura, Miringa and Tum sites, respectively, in the study area. Gully erosion was significantly (p< 0.05) higher at Tum, Miringa, Daura and Garwashina, while it was low at Kigir and Piku sites in this study. The model showed low to high prediction strength at vocational basis.**

Keywords – **Gully Erosion, Soil Organic Matter, Soil Calcium, Soil Sodium, Soil pH, Soil Magnesium.**

I. Introduction

Gully erosion can be defined as the displacement of soil or soft rock particles by a flow of water that forms narrow incisions that are larger and deeper than rills that usually carry water along during and immediately after heavy storms [7] (Soil erosion is widely recognized as a major environmental and agricultural problem affecting many parts of the world [3] Soil degradation is often manifested in the form of erosion losses, Stalinization, alkalinization, Leaching, and destruction of soil structure and texture, as well as decline in biodiversity and humus quantity, as well as a result of human activities, water or wind agents over time. Of these factors, human – induced soil degradation which affects an estimated global land area of 2 billion hectare spearheads other agents of soil degradation, followed by water and wind erosion estimated at 1100 Mha and 550 Mha, respectively [11]. In Africa, a total land area of 227 Mha and 186 Mha are respectively affected by water and wind erosion. Nigeria, with a land area of 910,771 km^2 out of which 37.33 % is currently put under arable agriculture with permanent crops and other use occupying 3.14 and 59.53 % respectively, are largely affected by water erosion than wind erosion, with the menace more pronounced in the southern parts compound to the northern parts of Nigeria as a result of regional precipitation (amount and intensity and soil types) [10], [23], [2].

Soil erosion is a key issue in mountain region worldwide [12], [13], [8], [22]. Gully contribution to overall sediment production means between 10 and 94%. This contribution can provoke flow contamination and reduction of reservoirs lifetime and channel capacity, increasing risk of floods [7]. Biu lies on the Biu Plateau at an average elevation of 768m. The region is semi – Arid, the local Government Area is mostly located in the Northern Guinea Savannah (NGS) agro-ecological zone, with small portion in the north east, the Kimba area lies in the drier Sudan Savannah zone [1] Soil loss caused by erosion on farmlands in Biu and Sade towns, both in Borno and Bauchi states of north eastern Nigeria ranged from 1000 and 31000 tones /ha/yr [16] [4], Aerial photos with a scale of 1:55000 (1954) and 1:40000, topography maps with a scale of 1: 50000 and 1:2500 were used to determined the area of different land uses involving ranged land, irrigated crop land, rainfall farms, gardens, bare land, residential area and road length in the study of gully erosion by some authors [17], and some researchers used content analysis of information which helps to explore data from a large body of existing literature in the study of gully erosion. [18] Defined content analysis as "any technique for making inferences by objectively and systematically identifying specific characteristics of messages.

Despite gully erosion problem, there is still lack of information on the scale and magnitude of the scourge in Biu and therefore there is need to design appropriate management techniques in order to reduce gully erosion progress on farmlands. The present research is expected to provide necessary information on the extent, measures and direction for prospective users including government agencies and a number of policy makers in their effort to manage, erosion problem in the area.

II. Study Area

The study was conducted in Biu, north eastern Nigeria in Borno State in 2016. Biu town is located on Latitude 10^{o} 36^{1} and longitude 10^{o} 13^{1} E, (fig.1) width an elevation of 768m above sea level. Six locations Garwashina (10^{o} 34^{1} N, 12^{O} 15'E), Piku (10^{o} 38^{1} N, 12^{o} 10^{1}E), Miringa (10^{o} 35^{1} N, 12^{0} 07^{1} E), Tum (10^{0} 32^{1} N, 12 $^{0}17^{1}$ E), Kigir (10^{0} 30^{1} N, 12^{0} 13^{1}) and Daura (10^{0} 34^{1} N, 12^{0} 14^{1} E). The locations were selected based on their differences in land use, topography, vegetation crop and soil types, which

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constitute significant factors for estimating soil loss by gully erosion.

Biu town has tropical climate consisting of dry season from November to March followed by wet season from April to October. The rainfall pattern varies with season. The average rainfall of the area is 917.19mm (Table. 1.) During the season, the average maximum daily temperatures are between 22^0C and 24^0C, and during the harmatan the average maximum temperature are between 26^oC and 28^0C (Table 3) the Biu Plateau basalt show little petrographic variations which are related to the mode of occurrence and origin, petrographic differentiation supported by geochemical evidence reveals that there are two basic types of basalts in the Biu Plateau; the Biu types and the Miringa types [9], the soil types vary according, to the slopes of the land and locations along which they are found [20] .

III. Materials and Methods

There are six locations, and at each locations a Transect of 200m by 100m was measured and gully erosion features were observe along the corridor of the transect (fig.1). The locations are as follows: Kigir, Piku, Daura, Miringa, Garwashina and Tum. Gully erosion takes place by retreating vertical face (head wall erosion) and erosion of channel side slopes [5] The rainfall data is the 25 year-twenty four hours (24 hrs) rainfall amount and was collected using a rain gauge device for all rainfall events during the study period. In this study the 25yr - 24hr is termed as the amount of rainfall received using a rain gauge between 9.00 am (the first day) and 9.00 am (the next day) totaling 24hr duration having a 25yrs return period. Head wall erosion was monitored by respectively measuring the distance between the edge of the gully head and bench mark puns established around the gully head. Bench mark pins were spaced in channel side erosion walls was measured by inserting iron pins normal to the side slope surface and repeatedly measuring the exposed segment. At all location, the pins were visited from April to October, 2016.

At each gully erosion site, three (3) soil samples, totaling eighteen (18) composite soil samples were collected for physiochemical soil properties test in the laboratory, for throwing standard procedure. The particles size distributing was determined by the Bouyocous n hydrometer methods [19]. The bulk density (B_d) was determined by cloud method [24], while the water holding capacity was measured by gravimetric water content of a given quantity of soil fully saturated with water [19]. The soil pH was measured in a 1:2:5 soils water suspension ratio using a glass electrode, pH meter (models) inserted into the suspension and left for one hour until equilibrium was reached for one hour with occasional stirring [24]. The electrical conductivity (EC) was determined on a saturation paste using an EC meter. The organic carbon (OC) content was determined using potassium dichromate wet – oxidation methods of [21]. The O.C content was converted to organic matters (OM) by multiplying with a factor of 1.724. Sodium (Na) was determined by flame photometry [32]. The exchangeable calcium (Ca) and magnesium (Mg) were determined by titrimetric method. The details on the measured gully parameters are shown in table 1. Regressions analysis was also used to assess the extent of soil loss at locational bases.

The volume of eroded soil mass was estimated using the following equation.

$$V = (L_h \times H_h \times E_h) + N \times (2 \times L_c \times H_c \times E_c) – [5].$$

Whose,
V: = Total volume of eroded soil, M3
L_h = The length of the head wall, M
H_h = Length of gully head wall, M
E_h = Erosion depth of head wall, M
L_c = Length of the channel, M
H_c = Slope length of the channel sidewall, M
E_c = Erosion Depth of the channel sidewall, M
N = Number of channels.

The parameter L_h, H_h, L_c, H_c and were obtained from fields measurements. The multiplication factor of 2 is for taking account of erosion from two side slopes of a channel.

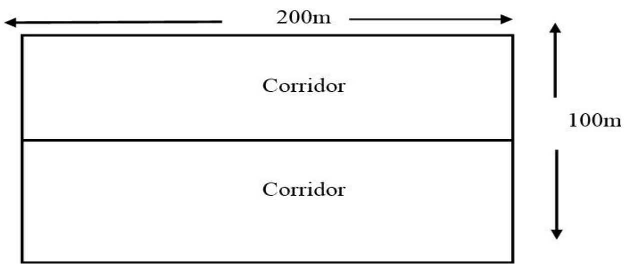

Fig. 1. A Transect of 200m by 100m

IV. Results and Discussions

4.1. *Gully Erosion*

At all the six locations two component of gully erosion were monitored and investigated – head wall erosion and channel side shape erosion. It was observed that gully erosion varied remarkably each year from April due to the intensity of rain fall received at each location. The mean head wall erosion (retreat) varied from 3 to 20 cm, and the channel side slope erosion range from 2.1-2.5 cm per year (Table 1) this observation concurs with that of [15], who stated that gullies are linked with concentrated run off process. The rainfall and run off factor ranged from 299.12 mm to 399.12 mm at turn and Daura location respectively (Table 1) the gullies were similar in terms of size topography and land cover.

Table 1. Measurement parameter of gully feature and Rainfall and run off

Location	L_h (cm)	H_h (cm)	E_h (cm)	N	L_c (cm)	H_c (cm)	E_c (cm)	Temp. (°C)	RRF (cm)
Kigir	3.0	20.0	0.39	5	4.0	2.10	0.03	27	329.00
Piku	2.7	3.2	0.08	6	3.0	1.70	0.07	28	350.00
Daura	2.0	3.2	0.08	8	3.5	2.50	0.31	30	399.12
Miringa	3.7	3.0	0.65	7	4.12	1.80	0.4	29	300.2
Garwasina	2.8	4.0	0.7	4	5.6	2.10	0.05	31	320.2
Tum	2.6	3.2	0.56	9	4.0	2.50	0.22	32	299.12
SE± 0.05	**0.178**	**11.210**	**0.098**		**0.357**	**0.137**	**0.0628**	**0.022**	**16.009**

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4.2. *Physical and Chemical Properties and Vegetation of the Study Area*

The study sites (locations) have the textures which ranged from clay loam, loam and sandy clay loam, and the topography varied from hilly mountainous and steep. Exchangeable calcium ranged from 16.4 to 3.8 cmol (+) kg, exchangeable sodium varies from 0.39-1.74 cmol (+) kg, exchangeable magnesium range from 0.60-2.80 cmol (+) kg. pH ranged from 7.28 -7.96 soil organic matter varied from 2.34 – 6.57%, Balk density varied from 1.24-1.3 g/cm^3, electrical conductivity of saturation extract varied from 0.03-0.04 dsm^{-1} and the vegetation ranged from a site which was cultivated with corn, to a field with shrubs and grasses (Table 2).

The stability of soil aggregates increase with increase in organic matters content. The high macroporosity and permeability of these aggregates decreases run off and soil erosion rates [30], the basic cations (Ca, Mg) known for resisting erosion were significantly ($P<0.05$) different among site, where exchangeable Ca and Na content were rates as moderate to high and to moderate in time Mg saturation. This perhaps explains why soil loss was minimal at Kigir side with comparable moderate estimate of Na run off (Table 1&2) which are widely reported as erosion facilitators in most environment these concurs with report of [29], [26] that organic matter, calcium are soil erosion mitigators.

Table 2 Physio-chemical Properties and vegetation of the study area.

Site	Texture	Topography	Exch.Na (cmol$^{(+)}$na)	Exch.Ca (cmol$^{(+)}$ka)	Exch.Mg (cmol$^{(+)}$kg)	pH	OM %	Bd gkm^3	Ec dsm^{-1}	Vegetation
Kigir	CL	Mountain	1.13	16.4	2.20	7.81	2.34	1.24	0.03	cultivated with corn
Piku	L	Sleep	1.75	6.20	1.60	7.96	6.47	1.38	0.04	cultivated with corn
Daura	SL	Mountain	0.78	5.60	1.00	7.28	2.91	1.38	0.03	cultivated with corn
Miringa	SCL	Hilly	0.50	6.00	0.60	7.42	3.48	1.38	0.04	shcrubs & grasses
Garwasina	CL	Mountain	0.39	9.80	2.80	7.39	3.07	1.38	0.04	cultivated with corn
Tum	L	Hilly	0.65	3.80	1.60	7.43	6.22	1.22	0.04	cultivated with corn & grasses
SE + 0.05			**0.022**	**2.117**	**0.324**	**0.110**	**0.026**	**0.028**	**1.529**	

Key: clay loam (cl), l = loam, Sl = silt loam, scl = sounding clay loam. EC = Electrical conductivity

4.3. *Monthly Measurement of Soil in the Study Site*

Table 3, presents the result of monthly measurement of mass of soil loss at various sites. The excess soil loss wet recorded at the rainfall peak period (June, July, August and September). The mass of soil loss ranged from 13.2222-99.720 kg both at Kigir and Daura sites respectively the variation was due to the stated months. [25], [28], [27] reported similar influence of rain on erosion activities on watersheds.

Table 4, also shows, mean erosion rate at various sites in the study area. The mass of soil loss varies from 28.446-52.289 kg ha^{-1}y^{r1} at Kigir and Tum sites respectively. The highest soil loss at these sites (Tum, Mirnga and Daura) was perhaps due to soil texture or topography of their wider catchments (Table 2) which increased run off collection through their depth of erosion feature in 2016. [33], [10], [31], [27] acknowledged the impact of drainage area as quite influential on volume of run off on consequent soil loss.

Table 3. Monthly rates of mass of soil loss from gully erosion (kg ha^{-1}) at various sites

Months	Kigir	Piku	Daura	Mirnga	Garwa--shina	Tum	Tempe--rature
April	15.221	16.215	14.571	55.127	40.398	20.567	22
May	47.321	88.214	16.581	99.721	30.551	85.722	28
June	13.321	25.921	85.220	25.711	50.822	27.172	27
July	18.121	15.127	99.720	12.881	75.881	76.233	24
August	72.110	35.124	35.980	67.127	22.112	22.726	24
September	34.312	16.827	55.278	27.832	16.235	79.127	22
October	15.812	12.92	30.255	50.867	10.255	54.127	25
SE + 0.05	4.2218 **						

Volume = 2 x N x L_C x H_C x E_C (for two side slopes), volume of soil loss x soil bulk density of each site.

Table 4. Mean Erosion Rate at the Various Sites

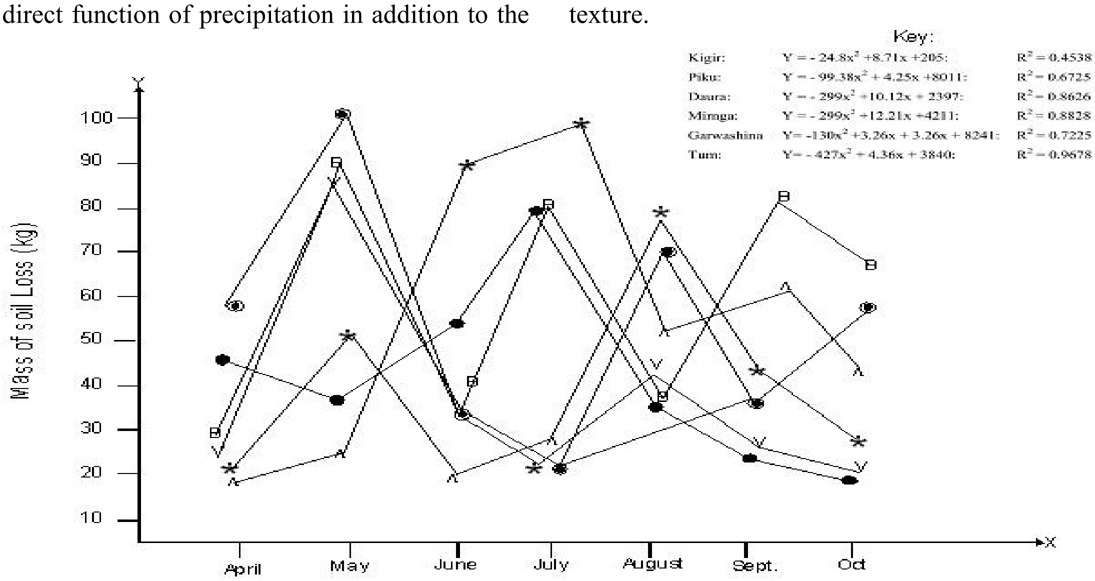
Sites	Mass of soil loss kgha^{-1}yr^{-1}
Kigir	28.416
Piku	30.050
Daura	48.229
Mirnga	48.467
Garwashina	35.170
Tum	52.239

Source: (Based on field Data, 2016).

4.4. *Monthly Rates of Mass of Soil Loss at the Various Sites over a Period of Seven Months.*

Fig. 2, presents monthly rates of mass of soil loss at the various sites over a period of seven months, in 2016. The pattern expressed a 2nd order polynomial curve, with r^2 value for the best fit equation of 0.8828- 0.9678 in respect of mass of soil loss respectively, at Mirnga and Tum sites.

Polynomial regression depicted both rate of increase (positive) and thereafter a decrease (negative) in soil loss as the season progressed. The rate of increase in mass of soil loss across sites ranged from 13.222-99.720 kg respectively. The rate of increase in soil loss was significantly ($p>0.05$) higher at Tum followed by Daura, Mirnga, Garwashina, Piku and Kigir. The rate of increase also followed similar order. The range was 12.881-16.882 kg ha^{-1}y^{r-1} for mass of soil loss due to rainfall and rain factor and texture at the various sites. This concurs with the report of [14], [30] that the soil erosion severity is largely a direct function of precipitation in addition to the texture.



Months

Fig. 2. Monthly Rates of Mass of Soil Loss (MSL) at the different sites over a period of 7months.

V. Conclusion

The severity of gully erosion was quantified using geomorphologic technique devised by [5] under some condition of Biu environment. The pattern, rate and estimate of mass of soil loss (MSL) confirmed to rainfall amount as the season progressed to a peak in the months of July and thereafter decline with cessation of rainfall in October in the study area. The predictor variable had both mitigating and facilitatory impact on soil loss in the study area. The annual mass of soil loss (MSL) values were 28.446, 30.050, 35.170, 48.229, 48.467 and 52.239 kg ha^{-1} for Kigir, Piku, Garwashina, Daura, Mirnga and Tum respectively, in the study area.

Gully erosion was significantly ($P<0.05$) higher at Tum, Mirnga Daura and Garwashina, while it was low at Kigir and Piku locations in this study. The model showed low to high prediction strength at locations bases.

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