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The Effects of Gully Erosion on Infrastructural Facilities in Gboko Township of Benue State, Nigeria.

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Abstract: *This study examined the effects of gully erosion on infrastructural facilities in Gboko Township to ascertain the magnitude of gully effects on infrastructural Facilities. Gullies were purposively selected from each of the five (5) unit of the town, Gboko north, south, east, west and Gboko central. Data collected were analysed using inferential statistics of mean, standard deviation, coefficient of variation and correlation matrix. Results of the analysis indicate that the gullies were both narrow U and broad U shape, gully dimensions and elements were varied. The correlation between cross sectional area, soil loss and slope angle has the high positive correlation of 0.958, 0.968 having an* r^2 *of 0.975 respectively. The correlation between gully length and gully depth, gully width, shoulder width, slope angle, cross sectional area soil loss indicate 0.588 0.534,- 0.113, - 0.154, 0.0525) having* r^2 *of (0.958, 0.927, 0.570, 0.968) respectively. The impact of gully erosion on electricity poles and water supply is less visible while the streets, bridges/culverts are the most affected since their maintenance is very poor. The study concludes that gully erosion has affected infrastructural facilities in the study area. It recommends that adequate effort be made both by government and individuals to prevent the occurrence of gully erosion by planting cover vegetation in the areas that are found to be open. Proper channelization be made with a view to channel the excess water from paved surfaces.*

Keywords: *Gully sites, infrastructural facilities, gully elements, descriptive Statistics*

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I. INTRODUCTION

Soil erosion is one the biggest environmental problem in the world (Pimentel, 2011). Soil erosion is also a complex process that depends on soil properties, ground slope, vegetation and rainfall amount and intensity, (Iorkua and Kerenku, 2007). Gully erosion is one of the most visible environmental problems globally, in Africa and in parts of Nigeria in particular. However, when viewed in terms of its dimension and the effects, it has an implication on various forms of land use activities. Gully is an enormous type of environmental degradation which leads to loss of valuable land use for agricultural, domestic, industrial and aesthetic purposes and other infrastructure as well as loss of property and even human lives (Aboje, 2005). Gully erosion is the dominant form of erosion in the urban areas due to concentrated runoff, poorly channeled drainages and unregulated urban storms. Benue State may not be on the list of severely ravaged states as observed in other parts of Nigeria, gully erosion is common in parts of the urban areas in the state especially Otukpo, Makurdi, Katsina-Ala among other towns (Aboje, 2005; Iorkua and Kerenku, 2007; and Iyortyer, 2010).

Gully erosion has been the cause of changes in the environment. The changes result from rainfall (runoff), urbanization and anthropogenic factors. Soil loss due to gullying has been studied by different scholars such as (Morgan 1980) who tries to describe soil loss due to rainfall intensity and Zachar, (1982) on the other hand who emphasized that soil loss is closely associated with runoff. In recent time, the activities of gully erosion have increased in Gboko township and is becoming a problem. This is because infrastructural facilities like hospitals, schools, bridges, roads, water supply, electrical grids, drainage channels, building, and telecommunications are now under a serious threat. Gboko as one of the largest settlements in Benue State and as the ancestral home of the Tiv people, it has a long history of basic infrastructure. These are somehow dated and now seeking for rehabilitation. Unfortunately, the increasing pressure on available land has aggravated soil erosion. This inducement has now exposed the dilapidated infrastructure to further degradation by soil erosion. This called for a study of the effect of soil erosion on infrastructure in the study area. This study is aimed at assessing gully erosion in Gboko, ascertain the magnitude of gully erosion and the effects of gully erosion on infrastructure use in Gboko.

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II. STUDY AREA AND METHODS

Location

Gboko township is located between Latitude 7° 13' N and 7° 15' N and Longitude 8°58'E and 9° 03'E. It has a nodal structure with intra-state and inter-state road radiating from or crossing the town. The town has Gboko North, West, East and Gboko South as council wards that comprise its development area. Gboko is situated between the hills of Mkar, to the East and Gboko hill to the West on the undulating plain that gives rise to the headwaters of the Konshisha and Kontein. Gboko town has a land area of about 10 square kilometers and the prominent geographical features are Mkar hills, Gboko hiils, rivers like konshisha, kontein, Nguembi among others (Tser, 1983) in Aondoakaa, (2005) as shown in Figure 1 and 2.

Basement complex rocks of sedimentary origin underlie 98% of the Gboko township leaving only 2% for volcanic rocks. The intrusive volcanic rocks appear as dykes near Gyado Hospital and are fine-grained in texture. Soil distribution in the study area varies from one another. However, the dominant type of soil type is the tropical ferruginous soil. They are coarse loamy soils with sandy particles. The soils are generally well drained, with few areas being water-logged especially along streamline areas. Also, hydromorphic soil is found along major river courses. These soil are rich in humus, therefore, they can support urban agriculture (gardening). Drainage in the study area is basically the surface drainage systems. It is drained by small streams such as Kontein, Konshisha and Nguembi. The situation of Gboko Township at an elevation makes it serves as a quasi watershed for streams. Thus rainwater easily drains away from the surface into the stream. Some household uses the streams as dumpsites. This pollutes the water and blocks the channel thereby resulting to gradual expansion and head ward recession (Kwaghga, 2006).

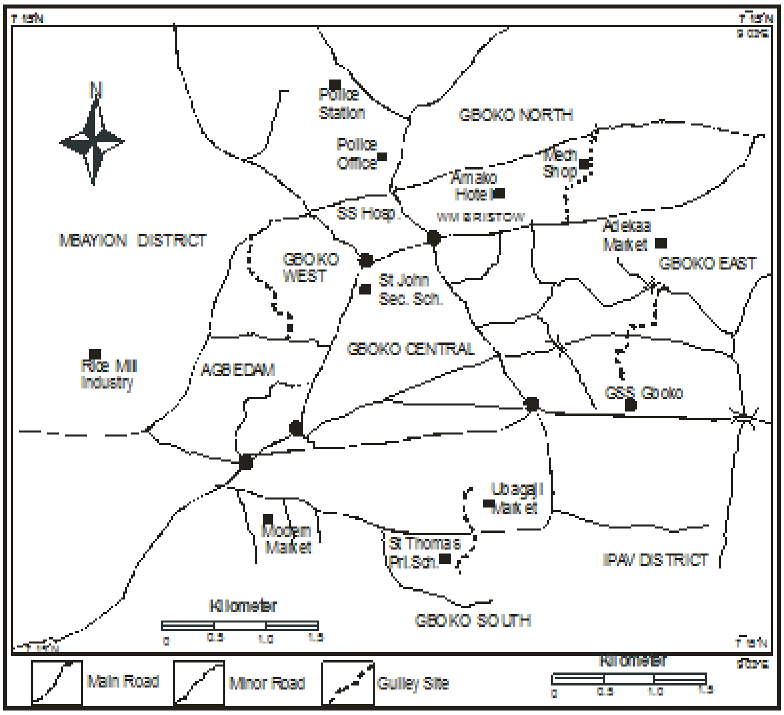

Figure 1 Map of the Study Area Showing Gully Sites
Source: Ministry of Land and Survey, Makurdi

The climate of Gboko township in general is of the tropic wet and dry climate (Aw) according to Koppen classification scheme. It experiences two main season, dry and wet. The wet season starts from April to October, with total annual rainfall in the range of 966.4 to 1049.2mm (Akperan Orshi College of Agriculture Yandev meteorological station). The rains experienced in this area are usually intense and torrential. The rains may occur during the dry season one or two time year in January or February or even March from East-West moving depressions known as line-squalls (Nyagba (1995). The dry season commences from November and ends in March. The nature of land use in Gboko township varies from one parts of the town to another. It is residential, industrial, commercial, institutional, educational, or open space areas. The

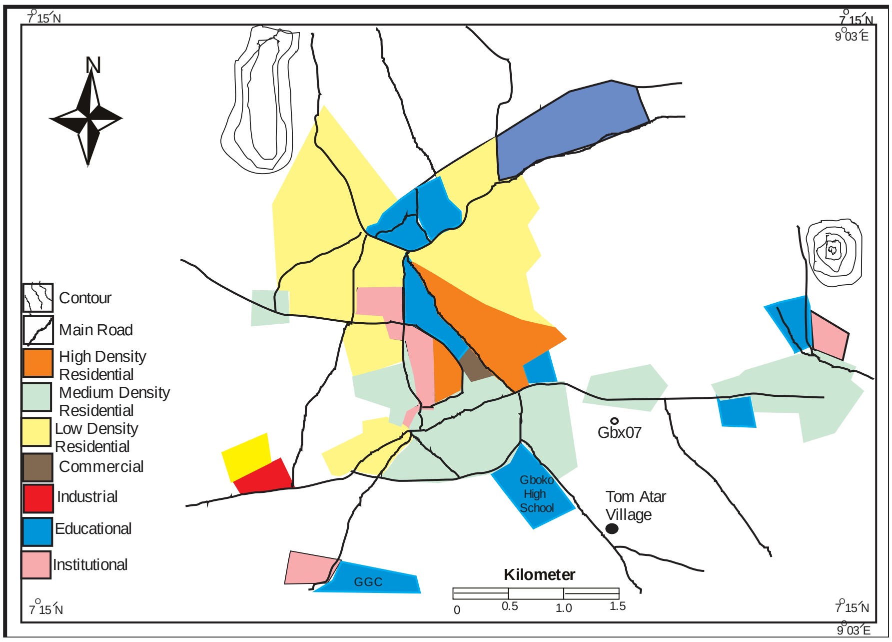

Figure 2. Land Use Map of the Study Area
Source: Ministry of Land and Survey, Makurdi

heavily built up areas are considered as high density residential areas; moderately built are considered as medium density residential areas; and fairly built are low density residential area as shown in Fig 2. Institutional areas are hospitals, prison, the Tor Tiv palace, stadium, and telecommunication installations. While educational areas are schools and colleges. Industrial areas are mechanic and rice milling sites whereas commercial areas are markets. Open spaces are areas where neither of the above activities take place as shown in Fig 2

III. METHODS

The data needed for the study include the following information; erosion sites, total number and dimensions of gullies (gully depth, gully length, bed width, shoulder width, and slope angle).these were obtained through counting and measurement to assess the severity the effects of gullies. The variables used in measuring the effects of erosion on infrastructure are number of collapsed building, fallen electric poles, cut transport routes, exposition/disconnection of water lines, collapse of drainage channels and culverts along gully sites.

Three (3) gullies each were purposively selected from each of the five (5) unit of the town namely Gboko north, south, east, west and Gboko central. Hence, Fifteen (15) gullies were considered. A total of one hundred and fourteen (114) infrastructures were affected. Data collection for this study was through field measurement and observations. Information were also collected depth (D), gully length (L), shoulder width (SW), bed width (BW) and slope angle (SA) of the gullies. Using this formula thus, GL x GD x GW, an estimated level of soil loss in the study area (Gboko township) was carried out. The gully elements were measured at intervals of 15 meters each along each of the selected gullies starting from the gully source. A linen tape measuring 100m, a, 30m twine, a cutlass 3 graduated ranging poles (each measuring 2.0m), clinometers, exercise book and pen were the materials used in the field measurement. Two assistants and a camera were employed in the field as part of the field work crew to assist the researcher in taking various measurements and in keeping records.

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IV. RESULTS

Generally, gully erosion is one the active form of erosion as observed in the study area particularly in the lower segment of the area adjoining the stream channels found in Gboko east, Gboko south, and Gboko west; while less gullies exist in the upper segments of the area that is. Gboko north and Gboko central (see Table 1). Gully classification is based primarily on the nature and depth of various channels, the nature and levels of materials carried as well as information obtained from the field.

Table 1: Selected gullies measured in Gboko township

S/No	Location	Gully's Length (M)	Gully Depth (M)	Bed Width (M)	Shoulder Width (M)	Slope Angle º
GBOKO SOUTH						
1.	Shaahu Road	105	5.2	3.5	4.5	07.0
2.	Solomon Akaahan Street	90	4.5	4.1	3.05	06.0
3.	Street behind Tor-Tiv Palace	95	3.9	3.2	3.00	04.0
GBOKO EAST						
4.	Behind NKST Church Gboko East	87	3.5	3.10	2.6	03.0
5.	Adekaa Gboko East	85	2.3	2.25	2.2	04.0
6.	Along Lagos Street	100	4.2	2.85	3.5	04.0
GBOKO WEST						
7.	Yua Akaahan Street	70	2.2	3.0	3.4	01.0
8.	Yua Kyume Street	65	3.1	2.4	2.70	03.0
9.	Ambassador Ukume Street	68	2.5	1.50	3.4	02.0
GBOKO NORTH						
10.	Low-Cost Estate Street	102	4.4	4.10	4.4	05.0
11.	Awaibo-gwa Street	101	3.8	3.4	4.0	0.0
12.	Tyowua Agudu Street	94	3.2	2.50	3.10	0.0
GBOKO CENTRAL						
13.	Agera Street	75	3.1	1.30	2.50	0.0
14.	Iorkyar-Ako Street	60	2.1	2.33	3.11	0.0
15.	Agom Street	55	2.4	1.85	2.30	0.0
	Total	**1252**	**80.4**	**41.38**	**47.76**	**53**
	Mean	**83.56**	**3.36**	**2.76**	**3.2**	**3.5**

Source: Field work, 2015

Table 1 show that gullies in Gboko South, Gboko East and Gboko west have the mean depths of 3.48m, Table 1 also showed that gullies in the upper segment, that is Gboko north and Gboko central have the mean depths of 3.17m. Bed and shoulder widths have means of 2.9m, and 3.12m, 2.58 and 3.24m respectively.

The forms of the gullies in Gboko township can be said to have a narrow U- shaped and the broad U-shaped shapes, these are similar to the Eleiyele gully reported by Faniran and Areola (1974) and the North Bank gully by Iorkua, (1999). There is variation in their dimension and magnitude. Faniran and Areola (1974) in their study on the Eleiyele gully reported a mean value of 1.1m for bed width and a shoulder width of 2.1m. It is described as having a narrow U-shape. Similarly, Iorkua, (1999) studied the North bank gully and reported that width shoulder and bed widths of 25,19m and 19.83m respectively. He also observed that these gullies are U shaped. Data presented in Table 2 shows that 15 gully sites were identified within the study area with varying dimensions and magnitude. The mean gully length in the area is 83.56m, gully depth 3.36m, while the mean shoulder and bed widths are 3.2m, and 2.76m respectively and a mean gully slope angle of 3.5^0 distributed around Gboko townships.

The above showed that the mean shoulder width of gullies in Gboko Township is more than the mean gully bed width 3.2 metres and 2.76 metres respectively. Most of the gullies are narrow U-shape and are in active state (Iorkua and Kerenku, 2007). Also some of the gullies have broad U-shaped form probably due to increase in the velocity of the gully waters, increases in its lateral corrasion, soil, vegetation and climatic factors. The implication of the active gully channels is that, they pose more risk to infrastructures.

Furthermore, soil erosion aggravates loss of volume of soil. Gully erosion, brings about depletion of productive soils, reduces available land, increase pressure on the remaining portion and consequently affects land use planning and river pollution as well as other numerous losses. Data in Table 2 indicates that there is variation in gully elements in the study area. Kerenku, (2012) stated that coefficient of variation less than 20 percent was not significant. Considering this result all the gully elements have coefficient of variation higher than 20 percent therefore they vary significantly with each other. The variability shows that shoulder width has the CV of 29.33%, gully width 46.07%, gully depth 51.02%.

Table 2: Gully Dimensions and Soil Loss observed in the Study Area

S/No	Gully Length (GL) (M)	Gully Depth (GD) (M)	Gully Width (GW) (M)	Shoulder width (SW) (M)	Slope Angle (SA) (0^o)	Cross Sectional Area S = W & D M^2	Volume of soil loss L x D x W	Soil loss SL (M^3)
1.	105	5.2	3.5	4.5	07.0	109.2	105 x 5.2 x 3.5	1911
2.	90	4.5	4.1	3.05	06.0	7.50	90 x 4.5 x 4.1	1660.5
3.	95	3.9	3.2	3.00	04.0	4.992	95 x 3.9 x 3.2	1185.6
4.	87	3.5	3.10	2.6	03.0	3.76	87 x 3.5 x 3.10	943.95
5.	85	2.3	2.85	3.5	04.0	1.52	85 x 2.3 x 2.85	557.175
6.	100	4.2	2.85	3.5	04.0	5.59	100 x 4.2 x 2.85	1197
7.	70	2.2	3.0	3.4	01.0	2.99	70 x 2.2 x 3.0	462
8.	65	3.1	2.4	2.70	03.0	2.68	65 x 3.1 x 2.4	483.6
9.	68	2.5	1.50	3.4	02.0	1.7	68 x 2.5 x 1.50	255
10.	102	4.4	4.10	4.4	05.0	10.6	102 x 4.4 x 4.10	1840.08
11.	101	3.8	3.4	4.0	06.0	6.89	101 x 3.8 x 3.4	1304.92
12.	94	3.2	2.50	3.10	02.0	3.31	94 x 3.2 x 2.50	752
13.	75	3.1	1.30	2.50	01.0	1.343	75 x 3.1 x 1.30	302.25
14.	60	2.1	2.33	3.11	03.0	2.028	60 x 2.1 x 2.33	293.58
15.	55	2.4	1.85	2.30	02.0	1.36	55 x 2.4 x 1.85	244.2
	Total	80.4	41.38	47.76	53	165.5	13392.92	
	Mean	5.36	2.76	3.2	3.5	11.0	892.9	
	SD	3.201	0.900	2.10,	1.102	4.185		
	CV%	51.02	46.07	29.33	85.12	42.45		

Source: Author's Field work, 2015

Key: GL = Gully Length, GD = Depth, GW = Gully Width, SW = Shoulder Width, SA = Slope Angle,SL = Soil Loss 0^o = Degree, SD = Standard Deviation, CV% = Coefficient of variation

Note: Total Soil Loss = 13392.855; Mean soil per Gully = 892.857

To understand the relationship between gully elements and how they impact on the land use in the study area, Table 3 presents data on autocorrelation of the gully elements that were studied. The correlation between cross sectional area, soil loss and slope angle has the high positive correlation of 0.958, 0.968 having an r^2 of 0.975 respectively. This implies that when there is increase in slope angle, the amount of soil loss and cross sectional area increases. The correlation between gully length and gully depth, gully width, shoulder width, slope angle, cross sectional area soil loss indicate 0.588 0.534,-0.113, - 0.154, 0.0525 having r^2 of (0.958, 0.927, 0.570, 0.968) respectively implies that, shoulder width, gully depth, and gully width increase with distance from the gully head, especially at some section where gully opens up to its tail at the tributaries and rivers in Gboko Township.

Table 3. Correlation Matrix among the Gully elements in Gboko township

Elements	GL	GD	GW	SW	SA	SL	CSA
GL	1.00	*0.534	-0.113	-0.154	*0.927	0.369	-0.88
GD		1.00	*0.525	0.288	*0.975	-0.359	*0.958
GW			1.00	*0.988	0.570	0.181	0.465
SW				1.00	*0.588	*0.968	0.154
SA					1.00	-0.159	*0.525
SL						1.00	0.288
CSA							1.00

Author's Comparison 2015

Data collected also revealed that, gullies in the study area have affected infrastructural facilities in various stages on the courses. The infrastructural facilities affected in Gboko township (the study area) electricity, bridges/culverts and water supply area equally affected by gully erosion as presented in Table 4.

Table 4. The effect of gully erosion on infrastructural facilities in different parts of Gboko township

The unit areas of Gboko township					
Affected infrastructural facilities	**Gboko South**	**Gboko East**	**Gboko West**	**Gboko North**	**Gboko Central**
Number of roads and street affected	9	8	5	16	9
Number of drainage channels destroyed	7	5	6	4	2
Number of bridges destroyed	1	1	-	-	-
Number of culverts	5	1	-	3	-
Number of water pipes destroyed	2	1	-	3	-
Number of building destroyed	1	1	-	-	-
Number of electric poles	5	3	2	2	-
Total	**30**	**20**	**13**	**28**	**11**

Source: Author's Fieldwork, 2014

The number of affected infrastructural facilities in different parts of Gboko township indicated that Gboko South has a total of 30 infrastructures facilities which are nine roads, 7 drainage channels, a bridge, five culvert, two water pipe, a building five electric poles. Gboko North 28 infrastructures facilities including 16 roads, 4 drainage channels, three culverts, three water pipes and two electric poles; Gboko East 20 infrastructural facilities includes eight roads, 5 drainage channels, one each of a bridge, water pipe, culvert and building, and three electric poles; Gboko West 13 infrastructures facilities includes five roads, 6 drainage channels, and two electric poles and Gboko Central 11 infrastructural facilities includes 9 roads and three drainage channels that were affected.

Observation has also shown that, poor laterized street construction without adequate drainage, undulating nature of landscape, constructed narrow culverts which are easily blocked by sediments forcing the runoff unto streets therefore a manifestation into gullies. According to Igbozurike (1991), Wisler and Brater (1959) the runoff unto street without drainage channels has led to the situation of soil erosion, creating gullies, thereby affect building, culverts, drainage channels, streets (potholes and great rills) exposure of water pipes among others. The nature of maintenance for electricity and water supply facilities in the study area is effective. Therefore, the impact of gully erosion on electricity poles and water supply is less visible while the streets, bridges/culverts are the most affected since their maintenance is very poor.

V. Conclusion

The study hereby concluded that gully erosion has negative effects on the environment of Gboko Township. The gullies are in the shapes of both narrow and wide U-shaped, they are very deep and varied from one another. Adequate effort be made to prevent the occurrence of gully erosion by planting cover vegetation in the areas that are found to be open. Proper channelization should be made with a view to channeling the excess water from paved surfaces.

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