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Assesment of the Morphometry of Gullies in Kastina-Ala, Nigeria

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Abstract:
The analysis of morphometry characteristics of four gullies in Katsina-Ala local government area of Benue State was carried out to assess the severity and economic losses associated with it. Field inspection at various sites and reduced level against various chainages at the identified gully sites were carried out in attempt to define the initial and final geometry of the gully sites. The mophometric characteristics of length, depth width, slope and shape were evaluated on site by geophysical survey of dumpy and physical measurement. Mathematical model of simpson's rule was used in quantifying the volume of earth lost to gullies. From the analysis of mophometry of these gullies, the total volume of earth lost is standing at 17,680.36m^3 covering 737.01m^2 of urban land area. The estimated cost of recovering this area by earth filling is put at N61,500.000.00 which will be an economic set back to the inhabitant of the old urban centre.
Key words: Kastina-Ala, Gullies, Mophometry, Severity, Remediation

Introduction

Gully erosion causes severe damages to Agriculture and constructed sites such as bridges, roads and settlements (Poesen,2003). Gully erosion is one of the most important forms of water erosion that reduces the economic life of reservoirs and land productivity due to high level of soil loss and land dissecting. The relationship between gully and some controlling factors such as soil characteristics, rainfall intensity, land use and slope gradient are of importance in predicting gully initiation and development of gully morphology. Studying gully channels under forest canopy has now been made more feasible using LiDAR data (James at al. 2007). Significant advances in the detection of in-filled gullies on top of tertiary landscapes in Belgium were recently made by Saey et al. (2008) using electromagnetic induction sensors. However the geomorphometric properties of each gully including length, width, depth and volume can be measured using Geographical Information System (GIS) or by physical measurement, the correlation between the volume of gully erosion and width/depth and length /depth determines the understanding of gully evolution process.

Land use for urbanization involving road bridges construction diverting of surface water are most important human factors in gully initiation Nysene et al (2002). The initiation of gully by flowing water has been a problem since man began to put land into use especially in rural urban migration with the abuse of urban development laws (Jacob et al 2012). Gully remains a problem in the United State of America, in many tropical and semi tropical areas and is increasingly recognized as a hazard in temperate countries including Great Britain, Belgium, Iran, Germany, China, India, the western USA, Central USSR, and the Mediterranean Land. Many lives and properties are been damaged in such areas, due to the removal of vegetation cover for cropping, grazing or urbanization (Morgan, 1988).

Gully erosion has ever been with man but was seriously felt in Nigeria in the 19th century. The severity of erosion varies in time and space. The sediment production resulting from an individual climate event depends to a large extent on the local topography, soil and use conditions so that these factors cause regional variation in erosion.

Human impact such as urban development and fadama activities at the major river bank was recognized as the dominant process in gully initiation in Katsina Ala and has affected to a great extent the socio-economic activities of the people living in Kastina-Ala. A large volume of arable urban land has been lost to gullies as a result of these activites. This study will help to great extent in defining the mophometry of identified gullies thereby creating awareness that will help in preventing further gully formation and control in Katsina-Ala.

1. The Gully

For comparism, it may be mentioned that there is difference between normal i.e. geological erosion (refers to as natural erosion), and accelerated erosion, yet only accelerated erosion is being considered as soil erosion proper. Natural erosion is caused by abnormal drought, avalanches, plant diseases, pest etc. the task of soil conservation schemes is to reduce accelerated erosion to the normal or geological level.

According to the Soil Science Society of America (1997), erosion is characterized by numerous and randomly occurring small channels of only several centimetres in depth. It can follow tillage marks, or they may develop much like a drainage network of rivers in a large basin (Foster, 1986).

Channels formed by concentrated flow of water, removing upland soil and parent material and of a size to large to be obliterated by normal tillage operations are referred to as gullies. Bank gullies form where a concentrated flow zone, crosses and erodes an earth bank, e.g. a terrace, a river bank (Poesen, 1993; Poesen and Hooke, 1997). Bank gullies may develop upslope by head-cut migration. Gully erosion was first comprehensively discussed by Foster (1986). The introduction of ephemeral gullies as a separate erosion class resulted from the fact that in the 1980's soil conservationists in the US became progressively aware that if only rills and classical gullies are considered in soil erosion assessments, an important erosion area and source of sediment within fields is being overlooked (Foster, 1986). The topography of most fields causes runoff to collect and concentrate in a few major natural waterways before leaving the fields. Poesen (1995) added to the view of Foster (1986) that ephemeral gullies may also form where overland flow concentrates along (or in) linear landscape elements (e.g. drill lines, plough furrows, parcel borders, access roads).

1.1. Gullies are characterized by:

FAO cooperate document respository identify gullies with the following characteristics; Independent Gully Unit, Gully Catchment Area, gully basin, gully edge, gully zone, gully units. Many researchers gave basic definitions to these characteristics. The catchments is an area affected by erosive processes physically interrelated with one another but independent from any other gully erosion process outside the catchment gully unit. It is grouping of several gully units having a geographical and anthropoid consideration.

The gully basin is the drainage basin or catchment of an independent gully unit. it is the part of a gully catchment which is actually affected by active or stabilized erosive processes, it could be upstream or downstream. The erosion zone is bounded by a gully edge and the gully stable zone. The edge is the border of the erosion zone generally marked by sharp slope increase.

Each gully zone has a stable section which is the bottom and the side slope of this section is not likely to become any lower from considerable length of time.

1.2. Gully Control system

Control measures can be classified according to the function they are intended to perform. These include Reclaimative measures and Preventive measures. Reclaimative measures are aimed at reclaiming areas that are actually affected by erosion (process) phenomena. While preventive is the initiation of new erosion processes in areas prone to or susceptible to erosion. In the reclamation, the control works include those in the gully catchment and those in the erosion zone.

The key objective is to achieve total rather that partial control. In order words, there are no half measures in gully control. Gully control measures should consider applying techniques that increases the resistance of the soil and reduce the erosion potential of runoff. Measures must consist of simple but effective technology and erosion should be well integrated. Control measures can be summarized thus:

- Runoff measurement in the gully catchment or upstream catchment.
- Installation of measures to reduce the erosion potential of runoff by reducing the flood velocity or volume.
- Adapting measures to increase the soil resistance to erosion.

When designing strategies in control of gully erosion, it is not possible to treat all gullies in the same way. In did the danger of so doing is inherent in the failure to take account of whether surface or sub surface erosion is the major cause. Difference between gullies becomes even more marked when networked rather than individual channels being considered. Three types of networks are recognized as axial, dipitates and frontal and the three are related by difference and soil effects on the process of gully formation. Axial gully which consist of individual gullies with single head cuts are retreats in slope by surface erosion which occurs in gravely deposits (Pelacini et al 2009). Dipitate gully, where retreat occurs in several head cuts extending in the direction of tributary, depression is characteristics of clayey loams. Frontal gully is associated with gapping and found particularly on loamy sands with columnar structure. This later type generally starts from river banks where pipes have their outlets and collapse ensure.

1.3. Gully Morphometry

Gully morphometrics are the physical features of gully. Ebisemiju (1988); and Ebisemiju and Ado (1989) analyzed the morphology of 46 gullies in a laterite terrain, examined the nature of the interrelationships of the parameters, and related observed gully form or processes and controlling factors, he focused his attention to gully morphometric properties such as length, shoulder width, depth, slope etc. His study was conducted on laterite soil with poor structural conditions at the soil surface, high rainfall intensity, low infiltration rates, high runoff and the bunchy habit of the grass growth.

The result of the Pearson's product moment correlation analysis indicates that most of the gully morphometric proportions are strongly interrelated. This finding is important as it indicates that equilibrium conditions between the form elements of fluvial system that were established even at the youthful and early mature stages of their development. It also suggested that there is considerably redundancy in the morphometric parameters of gullies as widely reported for drainage basins. These means that it is possible to reduce the parameters to a small sub set that adequately simulate gully morphology. There are, however, some variable which have extremely low correlations with most of the morphometrics properties. These are bed width, the ratio of the side slope to the bed slope, and gully length (Hamilton, 1977).

2. Study Area

Katsina-Ala lies between latitude 7^O 03`00``N and longitude 9^o 25`00`E and 126km away from Makurdi the state capital in the eastern part of Benue state Nigeria. It falls within the Koppen's AW (wet and dry) climatic system. The wet and dry seasons begin following the northward passage and southward retreat of the inter-tropical convergence zone (ITCZ) over the area in late March and October respectively (Dam 2012). Temperatures are mostly high throughout the year with average range between 23 ^{o}C – 28 ^{o} C with the peak of 38 ^{o}C. The coolest part of the season is during harmattan period between December and January. The dominant soil of the study area is hydromorphic soil (Alluvial or fadama soils). The major drainage channel of the study area is the River Katsina-Ala (Kenting Earth Science Limited, 1981). The geo-political entity called Katsina-Ala came into being in 1970 along two others from the then Tiv native authority with Headquarters at Katsina-Ala. It has since undergone a series of political restructuring.

Katsina-Ala Local Government area is predominantly inhabited by Tiv people with scores of other ethnic group like Hausa and Etulos who formed in big settlement at the Eastern bank of River Katsina-Ala (Fig 1). It has a population of about 258,473 persons.

3. Methodology

The following gullies sites were identified at Katsina-Ala by field inspection Fig 2 and 3).

1. Gully sites behind Victory Bible Church
2. Hausa Quarters Gully
3. Gully site adjacent to the College of Education Katsina-Ala main gate.
4. Gully site behind JurraDako Hospital

The shapes and sizes (that is the orientation) of the gully areas before the ripple effect by the excess direct runoff were evaluated by comparing the area with an adjacent study area after taking the reduced levels. These initial geometry details of the area were necessary guide to how the soil was before any ripple effect was encountered. The gully morphometrics were measured using a geophysical survey of dumpy level. The morphometrics were measured at varying intervals and the values recorded (table 1).

The final geometry of the areas was also observed properly and consecutively for the rainfall periods by reduced level at intervals. Reduce level are the depths from the ground level taking from the leveling staff in meters to determine the degree of gully caused by precipitation. The geometry of the area were observed for the whole period of wet season and two months after wet season to examine soil deformations as a result of rainfall that has weaken the strata of the soil profile.

4. Result and Discussion

The values of the reduced levels for different gully sites at varying changes were presented in table 1. Direct runoff that emanates excessively deforms the soil as gully in areas where there are no definite drains. The losses of earth crust due to the effect of excess direct runoff were taken as the reduced level at varying ordinates (table 2).

Fig 4 give the physical interpretation of gully formation by reduced level at the respective gully sites.

4.1. Volume of Earth Loss to erosion

Areas of earth lost for each gully site were obtained by application of simpson’s rule (John, 2003). Each ordinate is used once and only once and the greater the number of strips the more accurate it becomes for the area of gully.

Area of Gully, $Ag = \int_{x=1}^{x=n} y dx$

$$= \frac{S}{3}[(F + L) + 4E + 2R]$$

Where $S = \frac{Difference\ in\ Critical\ Points}{Number\ of\ strips}$

F + L = Sum of the first and last ordinates.
4E = 4 x the sum of the Even numbered ordinates
2R = 2 x the sum of the remaining odd – numbered ordinates.
The Gully function is used for evaluating the size of strips.
Volume (V_g) = Area (A_g) x depth (D_g)

5. Conclusion

This study has identified gullies in Katsina – Ala local Government Area of Benue State with their mophometry and physical geometry. It has become pertinent for a total of 17680.35m^3 volume of earth covering 783.02m^2 of township land been lost to gullies. This menace is calling for urban land reclamation by applying all possible measures in order to arrest further loss of arable land, buildings and other properties, transportation and communication links. This however may be feasible but an estimated N61, 500,000.00 may be required for back filling based on 2,482 trips of standard truck volume at N25, 000.00 per trip. For a long term success of gully stabilization, Imaseun et al (2011) attested that a good vegetative cover has to be established on the gully floor. This will prevent further gullying and allows the gully floor to gradually silt up reducing the fall over the gully head. Using wire netting, logs or concrete a series of small weirs can be constructed to trap sediment as well as encourage vegetative growth. Cavey (2006) also suggested that an alternative vegetative weirs can be established by planting species with erect growth forms such as vetiver grass and lomandra,

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Table. 1 Chainage/reduce level at gully sites

	Reduce Level on site			
Chainage(m)	1	2	3	4
00	105.55	40.70	35.6	-
05	94.22	-	-	-
10	92.10	18.5	20.5	-
15	104.44	-	35.6	-
25	79.8	-	-	1.04
30	-	-	30.8	-
35	-	40.8	22.4	3.9
45	-	20.4	33.7	-
80	-	39.4	-	17.4
90	-	-	-	12.8
110	-	-	-	8.40

Table. 2. Ordinate/distance from gully sites

Ordinate	Site Length (m)			
	1	2	3	4
1	96.1	18.4	0.2	3.9
2	94.22	12.8	0.52	9.4
3	90.00	12.4	0.70	16.9
4	91.00	15.1	0.32	17.4
5	98.3	22.6	0.2	17.8
6	100.0	13.3	1.19	15.8
7	100.2	12.8	10.89	14.9
8	87.4	21.5	14.89	11.1
9	75.7	-	18.48	7.5
10	-	-	13.40	8.4
11	-	-	9.87	-

Table3 : Results of Area and Volume of earth lost in the four Locations.

Site	Ag(m^2)	Dg(m)	Vg(m^3)
1	583.36	25.57	1488.04
2	75.08	20.40	1531.53
3	44.49	15.10	671.80
4	34.08	17.40	593.99
Total	737.01	74.47	17680.35

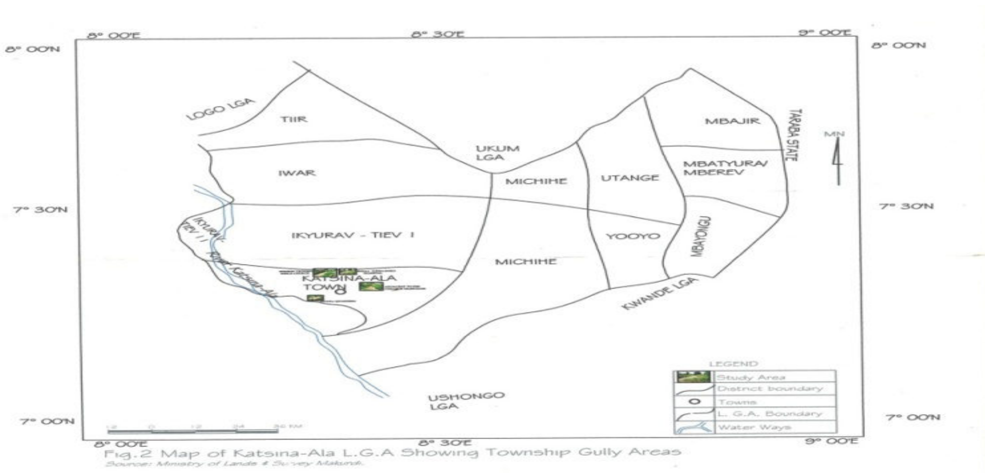

Fig.1: Map of Katsina-Ala local government area showing township gully areas.

Fig 2. Gully site 1.

Fig 3: Gully site 4.

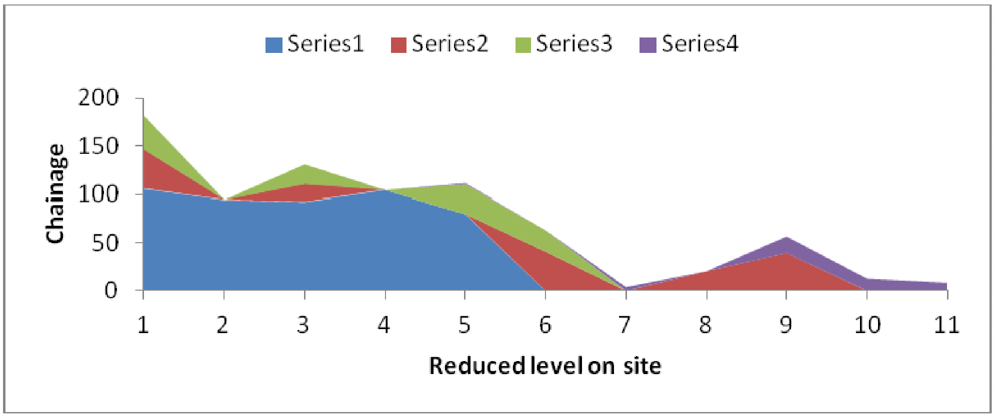

Fig.4. Gully geometry

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