

ASSESSMENT OF RATE OF GULLY RETREAT USING FIXED-BENCHMARK TECHNIQUE IN DUTSIN-MA, KATSINA STATE, NIGERIA

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ABSTRACT

This paper examined the rate of retreat of selected gully erosion in Dutsin-ma local government in Katsina State, Nigeria. The technique used in this research is adopted from the work of Dyke et al (2005). This is the use of "Fixed Benchmark" to measure the distance the edge of the banks has retreated. Generally erosion rate along most of the segments studied differ considerably over short distance ranging from 0.5 to 2 meters within the 100 meters strip. The highest rate of retreat is found along Wakaji with an average rate of 36cm/yr and a standard deviation of 14. The lowest value is found in Dutsin-ma with only 11 cm/yr and a standard deviation of 08. The study concluded that the use of "fixed Benchmark" technique was found effective and have yielded reliable results as much as the "Pin method" of Lawler 1993a. The technique can be useful for short timescale depiction of rate of retreat as applied to this study area. It is therefore, recommended that the technique should be applied in other areas and on individual gullies for more experimentation to explore its merits and demerits for appropriate decision.

Keywords: Gully; Rate of retreat; Benchmark; Dutsin-ma

Introduction

The term erosion refers to a systematic removal of soil from the land surface by various agents of denudation such as running water, wind and waves. It involves the loosening, wearing, dislodging and transportation of the soil from one location to another (Lang, 2001). Soil erosion has many severe consequences for agricultural and other type of landscape. At present, it is the single most important environmental degradation problem in the developing world, especially the tropics (Ananda and Herath,

2003). United Nations (UN) Convention to Combat Land Degradation (CCD) opines that soil erosion automatically results in reduction or loss of the biological and economic productivity and complexity of terrestrial ecosystems, including soil nutrients, vegetation, other biota, and the ecological processes that operate therein (Claassen, 2004).

There are reports of accelerated erosion in sub-Saharan Africa between 1960's and 2000, and this is explained by the ongoing land use

intensification. Land use intensification is recorded in form of the expansion of the cultivated land and the disappearance of the fallow system in many places (Junge and Stahr, 2006), as well as the degradation of the traditional agro forestry farmed parkland system of the unified management of scattered farm trees and crops. A transect survey from the derived Savanna to the northern Guinea Savanna of Nigeria showed land use intensification and accelerated erosion in the same years, 1960;s and 2000. In northern Nigeria, sheet erosion exposed iron-pan on lower slopes and destroyed farmland in some studied villages (Junge and Stahr, 2006).

According to FAO 1978, many African countries have already lost a significant quantity of their soils to various forms of degradation. Many areas in the continent are said to be losing over 50 tonnes of soil per hectare per year. This is roughly equivalent to a loss of about 20 billion tones of Nitrogen, 2 billion tones of Phosphorus and 41 billion tones of potassium per year. Serious erosion areas in the continent can be found in Sierra Leone, Liberia, Guinea, Ghana and Nigeria among others.

Soil erosion is one of the major problems confronting agriculture worldwide. It is a major threat to the soil resource, soil fertility, productivity, and food and fibre production, mainly on farm and range lands. Although the problem is as old as settled agriculture, its extent and impact on human welfare and global environment are more now, than ever before. (Gujral, 1984).

Gully erosion is one of the most severe forms of soil erosion processes and often results in much displacement of the soil mass, culminating in sedimentation, and degradation of the land. In Nigeria the population has been on the increase and hence the demand for food shelter and other vital needs. This has led

to destruction and is still destroying vast areas of land meant for crop production, transportation and other important land uses. This study area is a locality in which erosion has led to the change of viable and useful land.

Gully erosion in this study area is dynamic with a high magnitude of increase. The landward movement of gully sides along roads, farmlands and settlements are noticeable and very alarming but yet doesn't seem to be receiving adequate and proper attention by the people concerned (Ibrahim, 2013). This makes the situation relevant to research works in different fields including geomorphology. This is because of its usefulness to consider measuring the rate at which the devastating phenomena increases and how it relates or affects other components of the ecosystem. To this end, the experimentation and development of methodologies used by researchers on different environments remain very important as connoted by this work.

The Study Area

The study area is within Dutsin-ma local government area of Katsina State in northern part of Nigeria. The area lies between 12° 00' and 12° 50' north of the Equator, and between 07°00' and 08°00' east of Greenwich (figure 1). As the area falls within the Sudan savannah zone, it is experiencing a continental wet and dry type of climate, controlled by the inter-tropical discontinuity (ITD), also known as the inter-tropical convergence zone (ITCZ) (Thompson, 1975).

The year is divided into the rainy season from mid May to beginning of October and into the dry season, from November to March. During dry season, descending tropical continental air from the desert extends far to the south.

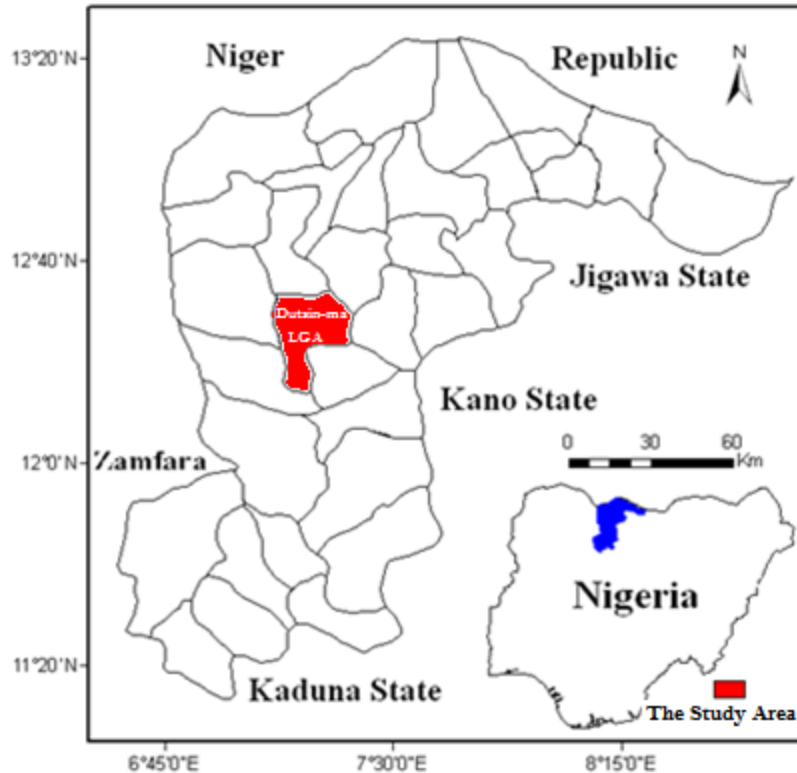


Figure 1: Map showing the study area

The region experiences relatively cool weather from November to March with a daily maximum of 24 - 33⁰c and minimum of 10-16⁰c. Through April and May temperatures increases and the daily maximum are 33 - 38⁰c and minimum of 16 – 24⁰c. The mean monthly temperature varies from 29⁰c - 36⁰c and reaching about 38⁰c in March. In the months of December and January the temperatures falls to about 30⁰c and 29⁰c respectively.

Rainfall in the area is usually marked with wide gabs of rainy days. The mean annual rainfall is 562mm. All climatic elements in the region of the study area show wide annual and seasonal variability, (UMYIA MS, 2017).

The soil type of Katsina region is ferruginous tropical brown and reddish-brown soils derived from basement complex rock. The Aeolian drift materials are mostly derived from the Cretaceous sandstones lying in the area, and the parent material underlying the

study area are composed of unconsolidated sands, the nature of which makes part of the area very porous and susceptible to erosion, (Scott, 1985).

The soils of the study area have developed under a savannah woodland type of vegetation and in a climate which permits downward percolation of water in wet season. The difference in topography of the study area is found to be very small over vast areas, which makes it less important in soil formation of this area, (WAKUTI, 1978). Over the whole study area, except on eroded and some alluvial soils, top soils are largely influenced by the drift material and are thus similar in properties. They are generally sandy, have little humus and are easily cultivated, (FAO, 1978).

Most of the Katsina State according to Maxlock Group (1977) lies within the so-called Sudan savannah zone. This is where trees and

short grass species (less than one meter) predominate. The hydrology of the study area could be depicted from the information on rainfall characteristics of the study area given above. Runoff from arid and semi-arid catchments is often characterized by short and high-peaked hydrographs (Raghunath, 1990). The temporal parameters of the flood hydrographs (time of start, time of concentration) follow each other without delay. This is partly due to the rainfall occurring at short but high-intensity bursts and partly due to the characteristics of soil type.

Methodology

According to Lawler (1993), the many methods of bank retreat measurement can be classified into long-timescale, medium timescale, and short-timescale techniques. Long-timescale methods employ sedimentological, botanical or cartographic evidence to reveal channel change over decades or thousands of years; Medium-timescale techniques include the periodic field survey of bank lines with Theodolites, EDMs (Electronic Distance Measurers), Total Stations or GPS (Global Positioning Systems); short-timescale techniques are more useful for process studies, because the geomorphological change can be related to forces associated with hydrological and meteorological events.

On these bases he described the erosion pin technique as one of the methods adopted in short-timescale techniques. Erosion pins can be inserted into banks: erosion then exposes more pin, the length of which is recorded periodically (Lawler 1993a). This coincides with the technique adopted in this work as both techniques operate using a reference point or a distinguishing symbol from which the rate of gully retreats can be depicted.

The technique used in this research is adopted from the work of Dyke *et al* (2005) in his ecological studies under the project of Sanctuary Integrated Monitoring Network. This is the use of “*Fixed Benchmarks*” to measure the distance the edge of the banks has retreated. This method is to physically measure rates of bank retreat along primary and secondary channels within the depressions.

The Field Technique

The determination of rate of gully retreat was done manually in the field by the researcher with the help of field assistants. The measurements in this work were achieved by using specific gully sites as samples. That is gullies with marked demarcations which are constructed or made at certain known period, and currently the edge have now retreated landward leaving just a sign of the former bank. Figure 2 below shows the field technique on a sampled gully.

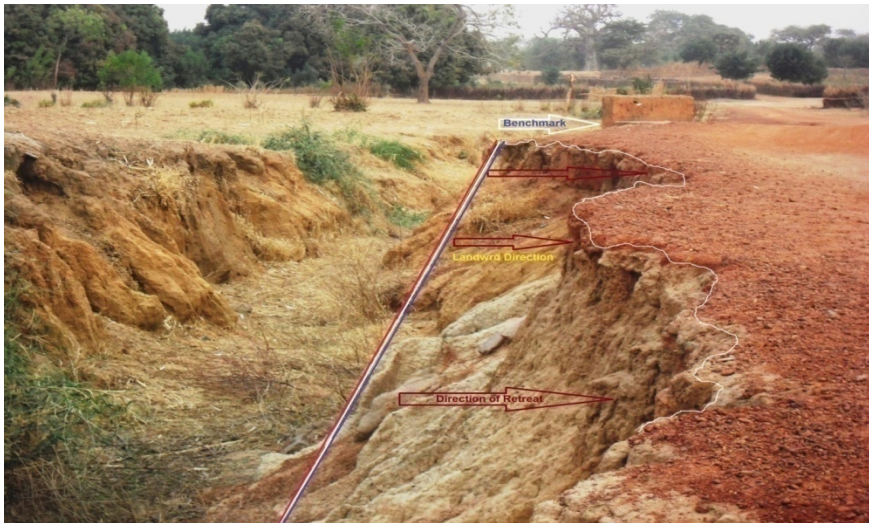


Figure 2: Sampled Gully Retreating from a Benchmark

The procedure demonstrated on the gully shown on the figure above was achieved because of the nearby culvert and embankment constructed along the channel which is used as the Benchmark. The choice of a benchmark depends on individual location of a gully under studies and should be based on certain considerations. For example, the age of the Benchmark as it relates with the gully. In this study, the features used as benchmark in figure 2 was constructed with an extended concrete wall aligned with the original edge of the drainage line.

The exercise was undertaken by identifying the former initial edge of the structure through a spectacular benchmark. The position of the bench mark was spotted using ranging poles at both ends. The two positions were joined by tying a rope on the erected poles. Then the interval between the two points along the rope was divided up into ten equal distances. At this point in time

distance was taken using a tape at each and every graduation from the rope to eroded edge of gully that washed landward.

The distances measured at each point were recorded against the name of the points. The sum of the distances of all the points divided by the time period taken is considered as the total rate of retreat of that gully segment over that considered period of time.

Results

These distances measured at each point along the gully side are presented in table 1 below. Table 2 presents an approximate estimated rate of erosion of some gullies across the study area in centimetres per year (cm/yr). To account for local variability in retreat rates, a mean erosion rate is calculated for each segment. The names used in the table are relative locations of the gully sites being the closest nearby settlements.

Table 1: Rate of Gully Retreat at each Point of Measurement

SN	Location	Field Measured Gully Retreat (cm)									
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
1	Wakaji	14	24	42	36	32	48	58	46	34	30
2	Dutsin-ma	08	06	12	18	06	24	18	10	04	06
3	Makera	08	12	24	36	20	12	18	26	10	14
4	Kurechi	18	33	26	30	12	10	14	07	04	14

Source: Author's Field work.

Table 2: Rate of Retreat/erosion along Gully sides

S/N	Location	Yearly Rate of Retreat/Erosion	
		Mean (cm/yr)	Standard Deviation
1	Wakaji	36	14
2	Dutsin-ma	11	08
3	Makera	18	10
4	Kurechi	16	06

Source: Authors' Field Work.

Despite the fact that most gully sides cut and retreat in a high rate, there are locations where erosion rate is relatively low. This is why the average results presented in the table are not significantly very high. There are locations identified as erosion hot spots with a rate of retreat up to 72cm/yr along Wakaji gully site.

Figures 2, 3, 4 and 5 give a sketch of the rate of retreat in the four different gully sites at 100 meters segments each. These figures present a picture of the curvatures produced by erosion in each segment in the course of their retreat.

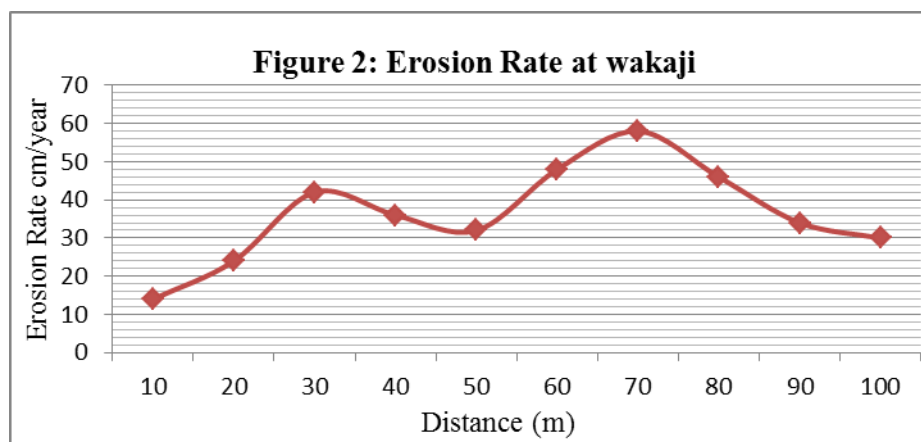


Figure 3: Erosion Rate at Dutsin-ma

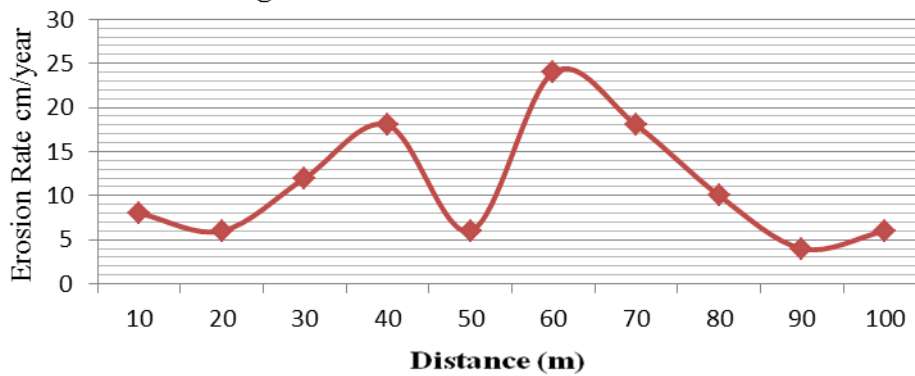


Figure 4: Erosion Rate at Makera

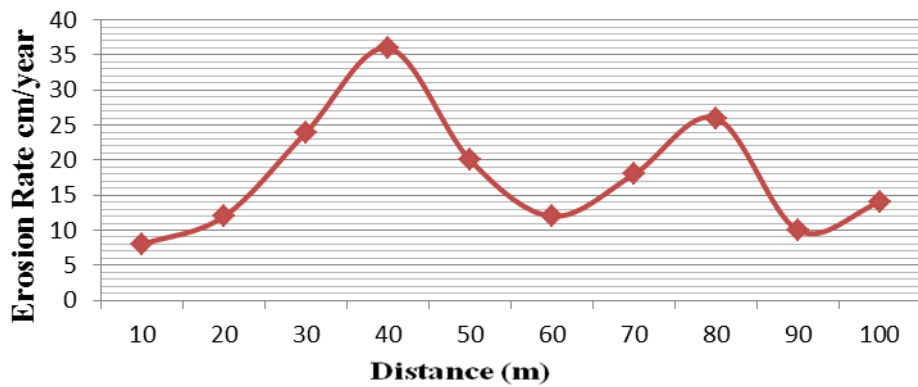
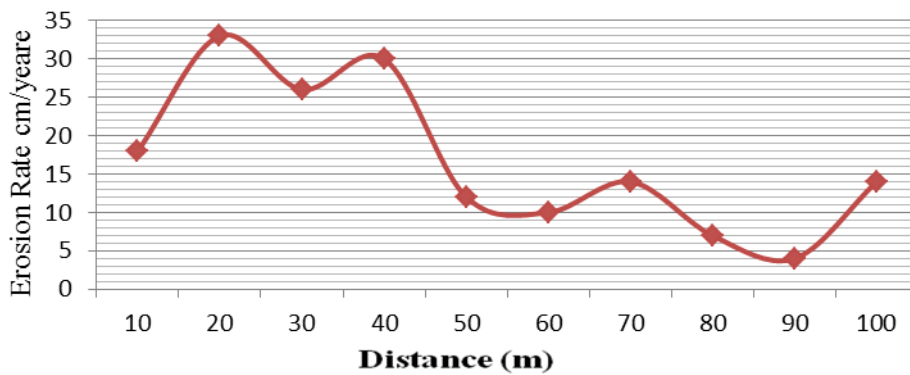


Figure 5: Erosion Rate at Kurechi



From what is presented in table 1, generally erosion rate along most of the segments studied here differ considerably over short distance ranging from 0.5 to 2 meters within the 100 meters strip. The highest rate of retreat is found along Wakaji with an average rate of 36cm/yr and a standard deviation of 14. The lowest value is found in Dutsin-ma with only 11 cm/yr and a standard deviation of 08.

Conclusion

The use of the “*fixed Benchmark*” technique was found to have been very effective and have yielded reliable results as much as the “*Pin method*” of Lawler 1993a. The technique can be useful for short timescale depiction of rate of retreat along rural feeder roads in order to have a clue on their potential well being through a rainy season in agricultural areas such as this study area.

The common geomorphic processes are denudational and the most common are rill and gully erosion. These were found to have

wrecked many places and affected land use surfaces to a large extent. The rate of retreat in sampled gullied amount to as high as 36cm/yr and averaged more than 19cm/yr. The inherent characteristics of the local soils and the tropical climate type, presented briefly in the description of the study area above, to a large extent promote the spread of soil erosion especially the gully type in the study area. This is no more than the impacts by man’s activities, particularly agricultural.

For more reliability of the technique, it is recommended to be applied in other areas and on many individual gullies. Comparison of numerous results from different areas will reveal the tendency of errors to ascertain the quality of the methods for continuous application or otherwise. It is also recommended that gulley developing along road side, settled areas and in farmlands should be monitored regularly. This is because this study reveals an effective, simple and low-cost methodology for monitoring erosion hazard as part of its management.

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