Analysis of the Impact of Soil on Gully Erosion in Tumfure, Gombe Urban, Gombe State, Nigeria

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Abstract

This paper examines the impact of soil on gully erosion in Tumfure, Gombe urban, Gombe State Nigeria. The specific objectives are: to determine whether some properties of the soil in Tumfure enhance gully erosion, identify and map out the areas affected by gully, measure the morphologies of the gully sites and assess the impact of the gully erosion in the area. Data used in this study were derived from field measurements, satellite imageries, and field investigation. The study used laboratory and Arc GIS software for the analysis. Laboratory analysis of soil particle size revealed that the mean particle distribution of soil texture along the gully wall shows sand 73%, silt 17% and clay 8%. Sand has significant relationship with gully advancement. Soil chemical properties also showed that the soils are slightly acidic (top layer) and moderately acidic, contained low organic matter. Results from the interpretation of satellite imageries (2005) and (2016) imageries and field measurements showed that gully variables (length, depth and widths) have significantly increased in the last 12 years. The study showed that the socioeconomic impact of gully erosion includes loss of lives and properties where over 100 houses were either at the verge of collapse or destruction, displacement of people, destruction of road networks and culverts. The study recommends, among others, that enlightenment campaign on soil conservation measures, cheap and effective methods such as biological and engineering measures of controlling as well as preventing gully erosion be put in place by the people and government. Similarly, reforestation of catchment areas and eroded lands can be effective in reclaiming and controlling gully corridors in the affected areas.

Keywords: Gombe State, Gully erosion, Nigeria, Soil and Tumfure.

Introduction

Soil erosion generally is caused by a combination of factors working concurrently or individually to remove, transport and deposit soil particles other locations other than where they were removed. The consequences of this processes are deep cuttings and badlands which dissects the entire environment. These are very common features all over the geographical regions of Nigeria and Gombe in particular. It has been established by earth scientists that several environmental factors as well as soil parameter accelerate the extent of soil erosion where ever it occurs. These factors are, perhaps, facilitated by human factors known as anthropogenic factors. However, man has assisted greatly in modifying and conserving the environment, yet, man has also engaged in creating instability of equilibrium in the natural environment resulting in wide range of environmental problems such as gully erosion.

The rate of erosion depends on many physical and human factors. Physical factors include climate, geology, landform (slope), soil and vegetation. The amount and intensity of precipitation, the average temperature as well as the temperature range, the wind speed, and storm frequency are some climatic elements that correlate with erosion (Ziebell and Leongtha, 1999). The geologic factors include the rock type; its porosity and permeability, the slope (gradient) of the land, and the rock structure such as tilt, fault and weathered mantle while biological factors include the ground cover by vegetation and the type of organisms inhabiting the area, and the land use.

Soil erodibility is an estimate of the ability of soil 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 (Hilborn and Stone, 2000). Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils. Tillage and cropping practices, which lower soil organic matter levels, cause poor soil structure, and result of compacted soils, contribute to increases in soil erodibility. Decreased infiltration and increased runoff can be a result of compacted subsurface soil layers. On some sites, a soil crust might decrease the amount of soil loss from sheet or rain splash erosion, however, a corresponding increase in the amount of runoff water can contribute to greater rill erosion problems. Past erosion has an effect on a soil's erodibility for a number of reasons. Many exposed subsurface soils on eroded sites tend to be more erodible than the original soils were because of their poorer structure and lower organic matter. The lower nutrient levels often associated with subsoil contribute to lower crop yields and generally poorer crop cover, which in turn provides less crop protection for the soil (Albert, Samson, Adeyinka, Peter and Olufunmilayo, 2006).

Gully erosion is one of the major environmental problems threatening the environment in Nigeria and Gombe town in particular since 1980s. Gully erosion is caused by both natural and man-made factors but the impact of either natural or man-made factors vary from one environment to another. The condition of gully erosion in Gombe is getting worse every year; from the very moment Gombe town was made a state capital. The quest for infrastructural development coupled with population explosion, have significantly increased the problems of gully erosion in the Tumfure, Gombe urban. Over the years, it has been observed that places that were characterized with small rills have now developed into gullies. Despite the efforts made by both Federal and State Governments towards addressing the problem of gully erosion through various contracts for gully erosion control at some gully sites in Gombe town, it is not yielding the expected results in curtailing the menace which could be attributed to lack of adequate information on the other factors responsible for gully erosion especially nature of soil in the area. Thus, effort at curtailing the menace of gully erosion in Tumfure, Gombe urban requires understanding of the dynamics of the processes responsible for its development.

This study is, therefore, aimed at examining the effects of soil on gully erosion in Tumfure in order to suggest adequate mitigation measures especially in the context of achieving sustainable development. The specific objectives of the study are: to identify and map out the gully sites; determine whether some properties of the soil in Tumfure enhance gully erosion and to measure the morphologies of the gully sites and its effects on the environment.

Literature Review

The sub-Saharan African countries are faced by serious environmental degradation resulting in desert encroachment, desertification, draught and soil erosion due to either wind impact or very high intensive rainfall resulting in heavy runoff and soil loss (Igwe, 2012). The high torrential rainfall, geology, soil, topography, scanty vegetation and human activities in the environment create an enabling environment for destructive soil erosion. Although the starting point of soil erosion through splash, sheet, rill and inter-rill are common, they are easily managed by the people through recommended soil conservation practices (Ofomata, 2007). Igwe (2012) observes that the gully forms of erosion have assumed a different dimension such that settlements and scarce arable land are threatened. Therefore, gully erosion problems have become a course for concern or subject of discussion among geographers, geologists, environmentalists and soil scientists (Jeje and Agu 1990). Ofomata (2007) observes that gully erosion is the most spectacular forms of erosion in Nigeria mainly because of the remarkable feature they leave on the environment. As a result of an increase in development activities coupled with soil factors, the number and magnitude of gully erosion have increased significantly.

Since1930s, the colonial government in Nigeria has undertaken the campaign of tree planting with the primary purpose of controlling erosion especially around areas characterized by steep slopes. Ever since then, there has been concerted efforts at understanding the causes of thisenvironmental problem. Several studies such as Ofomata (1975and 1985) and Igwe (1999) have indicated that the environmental factors of climate in form of rainfall intensity and duration, vegetation, geology, geomorphology and the soil factor, all play significant role in the formation and development of gully erosion. The consequence of the soil erosion is loss of land for development, agriculture and other human activities.

Igwe (1994) has observed that the human factors comprise mainly of land use and agricultural practices and the nature of agro-technology. Giordano, Bonfils and Briggs (1991) establish that among the factors that accelerate soil erosion is clearance of vegetation, intensive harvesting (deforestation) and over-grazing leaving the soil susceptible to erosion. Other factors are destruction of soil structure, texture and soil compaction as a result of human activities such as construction which reduces the infiltration capacity of the soil and generates excessive surface runoff that accelerates soil erosion. In studies carried out by Renard, Foster, Weesies, McCool and Yoder (1997), and Igwe, Akamigbo and Mbagwu (1999) have recognized, among other factors, vegetation, topography, rainfall and pedological factors as being the primary determinant factors that influence the formation and development of gully erosion.

Hudson (1981) in his study established that steep slopes is more susceptible to water erosion compared to flat land for reasons that erosive forces, splash, scour and transport, all have greater effect on steep slopes. Thus, slope steepness, length and the amount of soil erosion has always been proportional to the steepness of the slope. Ofomata (1999) establishes that there is a significant relationship between relief and soil erosion rate. According to Lal (1976) there is a significant increase of soil erosion as the slope changes from 5 to 15%. For example, he recorded a total soil loss of 230 t/ha/yr from bare plots on a 15% slope as against soil loss of 11.2 t/ha/yr on 1% slope.

According to Igwe (1995) the erodibility of soil is defined as the vulnerability or susceptibility of the soil to the agents of erosion. Igwe further observes that a number of factors such as both physical and the chemical properties of the soil determine its erodibility. Igwe (1995) observes that the level of soil organic matter (SOM), the clay content of soil and sesquioxides such as *Fe* oxides and *Al*, mean-weight diameter (MWD), clay dispersion ratio (CDR), and geometric-mean weight diameter(GMD) of soil aggregates all accelerate soil erosion problem.

Landuse and Vegetation are one of the most significant factors in the process of soil erosion. Stocking (1987) observes that vegetation acts in a variety of ways as an umbrella by intercepting raindrops through encouraging greater infiltration of water and through increasing surface soil organic matter thereby reducing soil erodibility. Lal (1983) finds out that choosing an appropriate landuse practice can significantly reduce soil erosion in an area.

Materials and Methods

Tumfure forms part of Gombe town and also the capital of Gombe State. It is located between latitudes $10^{0}16^{1''}$N to $10^{0}09^{''1}$N and longitudes$11^{0}04^{1}$E and $11^{0}07^{'1}$E as shown in Fig. 1. It is bordered with Wuroand Billiri to the South, Shango to the North, Gombe town to the East and Lafiyawo in the West. It covers an area of about $12km^2$ (Lands and Survey, Gombe, 2008).

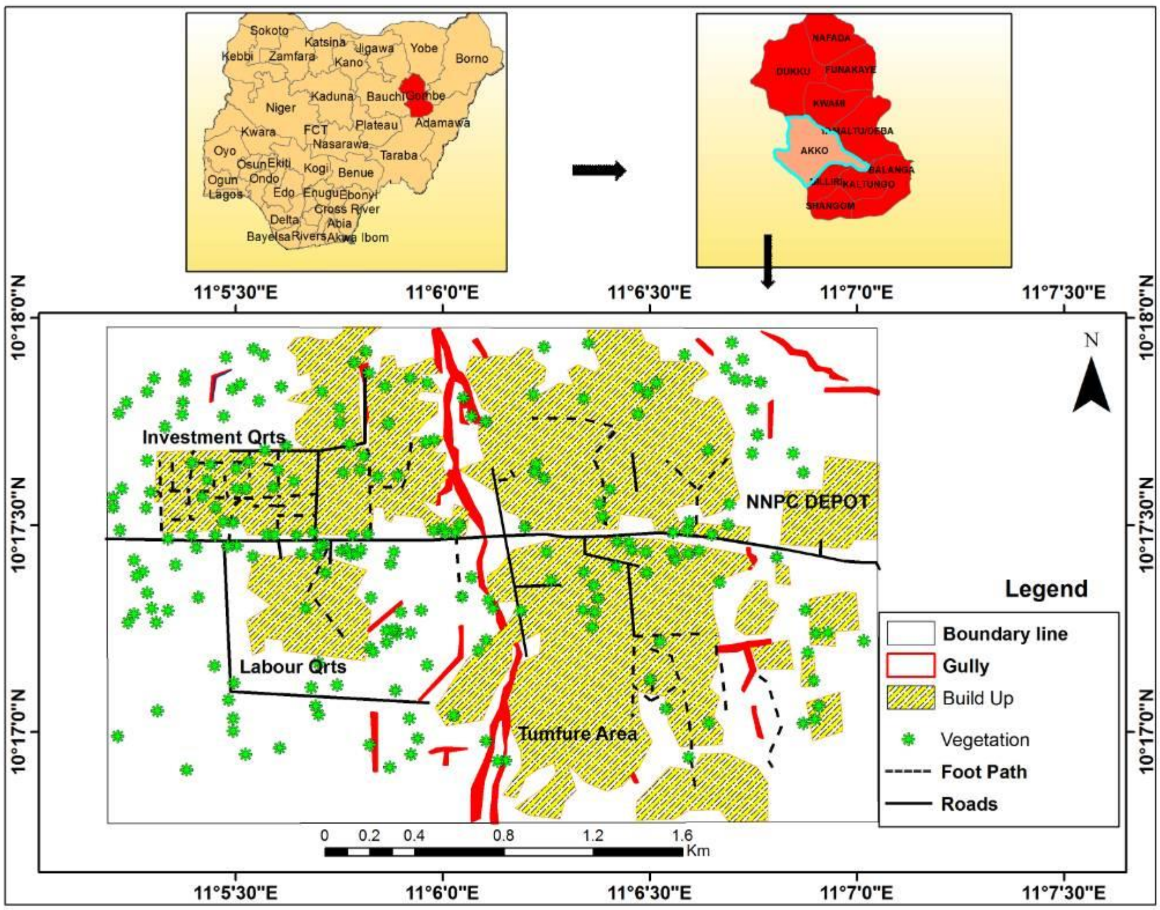

Fig 1: Akko LGA Showing Tumfure
Source: Modified from Quick Bird Satellite Imagery (2018)

Soil sampling

Soil samples were collected from the gully sites at an interval of 200m. This is to determine the susceptibility of soil to gully erosion. Soil samples were taken at the top and bottom of the gully side wall, noting changes in soil colour using 30m linen tape. A total of thirty (30) samples at fifteen (15) points were collected and kept in polythene bags for laboratory analysis. The guiding principle for sample collections was based on the point where measurement of the gully morphology was carried out at the main gully site (Tumfure stream). The samples were collected simultaneously with measurement of the gully morphology and coordinates taken at each point so as to cover the entire Tumfure stream, which is the main gully site in the study area. All collected samples were labelled and named after the gully erosion site (with their geographic coordinates) where they were collected from and taken to Soil Science Laboratory, University of Maiduguri, for analysis using Standard Rating Scale (SRS).

Laboratory Analysis of Soil Samples

Both the physical and chemical properties of the soil samples were analysed using the standard laboratory techniques. The Cation-Exchange Capacity (CEC) by direct cation saturation method that is Ammonium Acetate. The Phosphorus determination by Bray No 1 and Kurt2 method (ppmp). The Lime requirement determination was carried out by Barium chloride Tri-ethanolamine method. The soil organic matter determination by Wakley Black wet oxidation method. The texture determination by Bouyouco (Hydrometer) method (%)The total Nitrogen determination by regular macro-Kjeldehi method (%). The pH determination by potentiometric method or by the electrode pH mete. Soil samples collected were analysed to determine the soil physical (proportion of sand, silt and clay), moisture content and chemical properties (organic matter, organic carbon and soil pH). These variables are considered as critical indicators in contributing to gully erosion.

pH determination in Soil samples

In determining the soil pH, 10g of soil sample was weighed into a 50ml beaker and 25ml distilled water was added. The suspension was allowed to stand for one hour with occasioned stirring using a glass-rod (stirrer). The pH meter was calibrated using buffer solutions of pH4.0 and pH7.0, before being immersed into the supernatant of suspension. The reading was taken when it was fairly stable without further stirring. The reading was then recorded as “soil pH measured in 1:2:5 soil water ratios”. The electrodes of the pH meter were then rinsed with distilled water and wiped dry with a clean tissue before being immersed in distilled water prior to each subsequent measurement. The suspensions were then stored for EC determination which was taken in the same manner with the use of an EC meter. The results of which were recorded in $MSCM^{-1}$ and DSM^{-1}.

Table1: Critical Value for pH Determination

S/N	Critical Value	pH Level
1.	4.5	Extremely acidic
2.	4.6-5.0	Very Strongly acidic
3.	5.1-5.5	Strongly acidic
4.	5.6-6.0	Moderately acidic
5.	6.1-6.5	Slightly acidic
6.	6.6-7.3	Neutral
7.	7.4- 7.8	Slightly alkaline
8.	7.9-8.5	Moderately alkaline
9.	8.6-9.0	Strongly alkaline
10.	9.0	Very strongly alkaline

Source: Critical Level for pH according to Mahler and McDole (1985; 1987)

Determination of Particle Size Analysis

The hydrometer method (Bouyoucos, 1962) was used for particle size analysis (soil texture). 40g of air-dried soil sample (passed through 2mm sieve) was weighed into a 500ml beaker. 200m^3 of water was added, followed by 5ml of 30% hydrogen peroxide (H_2O_2). The content was placed on a hot plate and heated for 15mins for the oxidation of organic matter while waiting for complete oxidation of the organic matter. 50ml of 5% sodium hexameta phosphate (calgon) solution was put into measuring cylinder and distilled water was added to the one litre mark. The content was mixed thoroughly and temperature was brought to room temperature (25^{0}C), this was recorded as the blank. The hydrometer was then inserted into the suspension and the reading was recorded as calibration correction (RL). After heating the content, the beaker was cooled to room temperature

50ml of 5% calgon solution was added to the 500ml and stirred well. The content was then transferred to a one litre measuring cylinder. Water was again added to the one litre mark. The cylinder was then covered with leather to avoid spillage. The cylinder was then placed on the table and the hydrometer was carefully but immediately inserted into the cylinder. The hydrometer reading was recorded at 40 seconds from the time of setting on the table. The same was repeated after two hours and recorded as R. The temperature was also recorded. The percentage of sand, silt and clay were calculated at different intervals using equation 1.

$\%S = \frac{R-RL+r+100}{W}$……………………………..Equation1

Where: S = %material in suspension
R = Hydrometer reading of sample
RL = Calibration correction (Blank)
r = Temperature correction factor
W = Weight of soil sample

Determination of Organic Carbon and Organic Matter (WeioxidationMetthod by Walkey Black)

The percentage of organic carbon %O.C was determined by the Black's (1965) wet oxidation method as described by Blacks (1965). 1g of air-dried (passed) through 0,5mm sieve) soil sample was weighed into a 250ml conical flask.10ml of 1N potassium dichromate was added with the help of clean pippete. Using a clean measuring cylinder 20ml of concentrated sulphuric acid was added, after cooling, 100ml of distilled water was added followed by 10ml of ortho-phospheric acid (H_3PO_4) and 0.2 of sodium fluoride (NaF). 5 drops of diphenumine indicator was added which turned the colour to deep violet.

The excess chromic acid was then titrated with 0.5 ferrous sulphate (1N$FeSO_4$). The end point was recorded as the colour changed from deep violet to deep green. The same procedure was repeated on the blank (without soil sample). The amount of soil sample was then recorded and the strength of $FeSO_4$ was determined and finally, the percentage organic carbon (%0.C), oxidised by potassium dichromate ($K_2Cr_2O_7$) was calculated using equation

$\%O.C = \frac{B-TXF}{W}$ X 0.39…………………………. Equation 2

Where: B = Amount of 0.5 $FeSO_4$ solution required in blank titration
T = Amount of 0.5 $FeSO_4$ solution required in blank titration of sample

F = Normality of$FeSO_4$
W = Weight of sample used
Critical Level
%O.C < 0.4 = Very low
0.4-1.0 = Low
1.0-1.5 = Moderate
>1.5 = High
And %O.M = %O.C x 1.724
Critical Level
< 0.7 = Very low
0.7-2.0 = Low
2.0-3.5 = Medium
3.5-4.5 = High
> 4.5 = Very high

Determination of Moisture Content

Moisture content refers to the volume of water in a given volume of soil. Result of soil analysis is usually calculated on the basis of oven-dry soil. Therefore, the moisture content of air-dry soil is usually determined shortly before soil analysis. 5-10g soil was weighed in a moisture can of known weight to 0.001g accuracy (W). Total weight of soli plus moisture can (W_2) was recorded and dried at 105^0C overnight and was allowed to cool in a desiccator and reweighed (W_3).

Therefore,% $M.C = \frac{Wt of Moisture}{Wt of soil used}$ X 100……………………..Equation 3

Moisture correction factor = $\frac{100 + \%moisture}{100}$

Generation of runoff data

The runoff data for the period under study were derived from Pentagon Design Consultant, (2003) formula, since there are no stream gauges in the study area. The indirect estimate of runoff was made from rainfall values obtained from Meteorological station, Gombe. The runoff formula is as presented in equation below;

Q_{max} =0.278CIA…………………………………Equation 4
Where Q_{max}= peak discharge (M^3/s)
C= dimensionless surface runoff coefficient (urban surface 0.40)
I= rainfall intensity (mm/hr)
A= the drainage area (km^2)
0.278 = the factor which take care of the unit when converted to S.I

Measurement of gully morphology

The main gully of second order hierarchy that initiated from the upstream to the downstream was selected for this study. The main gully includes parts of Farin-kasa, Reservoir (adjacent labour quarters), Kasuwangwari, (across Bauchi road), Longel and HammaIdrissa. The gully is a second order gully with numerous first order gullies. Gully morphological variables were analysed from GIS satellite images. This was followed by ground truth measurement of gully elements in order to compare with the satellite images. The procedure adopted for the measurement of the gully variables (gully length, width, and depth and slope angle) were as follows:

Gully Length- this is the longitudinal profiles of the gully site in the study area. The gully length was measured with a measuring tape (30m).

Gully width- this is the horizontal distance between gully banks. It was measured at 200m interval using measuring tape, ranging poles and GPS. Measuring tape was stretched across the gully to the opposite band and readings in meters were taken. The mean width was calculated following Jimoh (2001) methods:

$$\text{Average Width} = \frac{\text{Sum of Width reading}}{\text{Number of interval points}}$$

Gully depth- this is the vertical cross-section of the gullies. To measure the gully depth, stadia rod and hand levels were employed. The stadia rod was placed on the channel bed and holding the stadia rod vertical, estimates the height of bank full stage using the hand level to sight off the bank as in the case of width readings.

Data Analysis

For determining the gully morphology, the average depth and width was calculated using Jimoh (2001) by taking the total sum of width and depth divided by the total number of intervals. For soil physical and chemical properties, rainfall data and landuse changes, the descriptive analysis were employed which includes mean and standard deviation. Soil samples were collected and taken to the laboratory for analysis. The properties analyzed include; soil physical and chemical properties (organic matter, organic carbon, soil pH, CEC, EC, Ca^2, Mg^2, Na and K) and moisture content. These parameters were tested using different measuring instruments in the laboratory after which the results were obtained in order to achieve the stated objectives particularly on the properties of the soil and the factors that influence gully erosion in the study area. The inferential analysis includes Analysis of Variance (ANOVA) with the aid of Statistical Packages for Social Sciences (SPSS), version 16.0 which were used to find out the relationship between soil samples (top and bottom layers). These methods have been applied by Jimoh (1997, 2001), Irorkua (2006) and Mbaya (2012) in analyzing gully erosion in Ilorin, Markurdi and Gombe respectively and were found to be adequate.

Results of the Findings

The Role of Soil Chemical Properties in Gully Growth Soil pH

The study shows that nature and the long weathering history of the soils parent material as evident in the dominance of the sandy mineralogy by non-expanding minerals and low soil organic matter concentration as a result of high mineralization rates and excessive leaching of nutrients could be attributed to the worsening situation of gully erosion in the area. The highly weathered soils contain high concentrations of Fe and Al oxides.

Soil pH value indicates whether the soil is acidic or alkaline. The average soil pH of the top and sub soil sample collected at the gully profile were 6.19 and 5.82 respectively with standard deviation of 0.210 as presented in Table 2. This implied that the soils are slightly acidic at the top layer and moderately acidic at the bottom layer. Mbaya (2012) in Gombe found similar pH values. Similarly, Table 3 further showed that there was no significant difference (0.230 F-Test) between the top and bottom layers of the gully profile in terms of organic matter, organic carbon and soil pH.The implication of this finding is that the soil of the study area may not be affected by micro-organisms that work on the organic matter which might enhance the binding of soils to resist erosivity of rainfall and rainfall impact.

Organic Matter Content and Organic Carbon

The organic matter content and organic carbon using Blacks (1965) method for the 30 soil samples is given in Table 2. Table 3 shows the mean values for the top and bottom layers of the gully profile to be 0.93% and 2.43% respectively. These results are considered to be low. However, there was a significant difference at the top and bottom layers of the gully profile, (>0.00 F-Test) as presented in Table 4. The possible causes of these differences might be attributed to the leaching of the organic matter down the valley floors of the gully site. This finding agreed with similar work by Orazulike (1992) and Mbaya (2012) who found that the soils are red and contain nodules of ironstone and is marked by deposits of iron oxide, loos, very permeable and deficient in plant nutrients. Organic matter content of all soil samples falls below 3%, which is considered as the threshold below which soils are erodible according to Jeje and Agu (1990). This finding is also similar to the studies carried out by Danladi and Ray (2014) and Mallam, Iguisi and Tasi'u (2016). Therefore, erodibility factor plays a major role in enhancing soil erosion in the study area. Sealing and high surface runoff is also more pronounced in soils with very low organic matter content. A poor soil structure and low plant nutrient content will cause soil to be more prone to gully erosion. This might be a contributive factor to the occurrence of gully erosion in the study area. This also has negative implication on trees planted to check gully erosion as it affects their growth and development to check erosion in the area.

On the other hand, the result of the organic carbon test in Table 3 shows that the mean for the top and bottom layers of the gully profile are 0.54% and 0.41% respectively. These results are considered low, and there is a significant difference (0.000 F-Test) between the top and the bottom layers of the gully profile in the study area.

Table 2: Soil Chemical Properties of the Gully Profiles

S/N	Soil Ph		Organic Matter		Organic Carbon	
	Top	Bottom	Top	Bottom	Top	Bottom
1.	6.91	6.26	1.34	2.05	0.78	1.19
2.	6.78	6.11	1.03	2.38	0.60	1.38
3.	6.64	5.74	0.81	1.10	0.47	0.64
4.	6.28	5.89	0.60	2.52	0.34	1.46
5.	6.30	5.82	0.53	2.28	0.31	1.38
6.	6.38	5.61	1.02	2.90	0.59	1.33
7.	6.20	5.55	0.81	2.29	0.47	1.68
8.	5.40	5.82	0.34	2.90	0.20	1.68
9.	5.56	5.97	0.91	2.76	0.53	1.60
10.	5.48	6.02	0.95	2.69	0.55	1.56
11.	5.75	5.60	1.21	2.26	0.70	1.31
12.	6.02	5.69	0.64	2.52	0.37	1.46
13.	5.49	5.68	1.17	2.41	0.68	1.40
14.	6.95	5.61	1.02	2.93	0.59	1.70
15.	6.64	5.97	1.52	2.36	0.88	1.37

Source: Laboratory Analysis, 2018

Table 3: Soil Chemical Properties of the Gully Profiles

S/N	Soil Ph		Organic Matter		Organic Carbon	
	Top	Bottom	Top	Bottom	Top	Bottom
1.	6.91	6.26	1.34	2.05	0.78	1.19
2.	6.78	6.11	1.03	2.38	0.60	1.38
3.	6.64	5.74	0.81	1.10	0.47	0.64
4.	6.28	5.89	0.60	2.52	0.34	1.46
5.	6.30	5.82	0.53	2.28	0.31	1.38
6.	6.38	5.61	1.02	2.90	0.59	1.33
7.	6.20	5.55	0.81	2.29	0.47	1.68
8.	5.40	5.82	0.34	2.90	0.20	1.68
9.	5.56	5.97	0.91	2.76	0.53	1.60
10.	5.48	6.02	0.95	2.69	0.55	1.56
11.	5.75	5.60	1.21	2.26	0.70	1.31
12.	6.02	5.69	0.64	2.52	0.37	1.46
13.	5.49	5.68	1.17	2.41	0.68	1.40
14.	6.95	5.61	1.02	2.93	0.59	1.70
15.	6.64	5.97	1.52	2.36	0.88	1.37

Source: Laboratory Analysis, 2018

Table 4: Statistical Results of the Soil Chemical Properties of the Gully Profiles

Variables	Layers	Mean	SD	Variance	F -Test	Sig.
OC	TOP	0.537	0.184	0.034	0.000	Sig
	BOTTOM	1.409	0.261	0.068		
OM	TOP	0.927	0.317	0.101	0.000	Sig
	BOTTOM	2.430	0.452	0.204		
pH	TOP	6.185	0.544	0.296	0.230	NS
	BOTTOM	5.823	0.210	0.044		

Source: Laboratory Analysis, 2018

Key: OC=Organic Carbon, OM = Organic Matter, SD = Standard Deviation, NS = Non Significance, Sig= Significance

The Role of Soil Physical Properties Sand, Silt and Clay Content in Gully Growth

The mean particle size distribution of the soil texture along the gully site profile is presented in the Table 4. The top layer has 6.5% clay, 78.9% sand and 14.5% silt while the bottom layer has 9.7% clay, 71.3% sand and 19.5% silt. The overall mean proportion for the top and bottom layers of the gully profile shows 8.1% clay, 75.1% sand and 17% silt respectively, indicating high erodobility due to the high proportion of sand content. Table 5 further shows that no significant differences (0.106, 0.306 and 0.069 F-Test) in the proportions of both the top and bottom layer of the gully profile. This implies that the sandstones and shales (Gombe sandstone and Pindiga formations) that dominate the geology of Gombe town have accelerated the process of gully erosion. Earlier work by Orazulike (1987) found that the Gombe sandstone and Pindiga formations are prone to gully erosion. Similar work by Ebisemiju (1989), Mbaya (2012) and Mbaya, Ayuba and Abdullahi (2012) found that gully erosion is more severe in areas dominated by sand formation because they are dispersive.

Table 4 shows that the soil textures of the gully profile are dominated by sandy loam and loamy sand which were associated with high erodobility due to high sand content that renders it easily detachable. Similar works by Ofamata (2007), Olori (2006) and Olage (1986) have shown that the dominance of sand proportion in the Nigeria savannah has accelerated gully erosion in the region.

Moisture content

The mean values of the moisture content of the top and bottom layers of the gully profile as presented in Table 5 were 6.2% and 7.6% respectively. This implies low values and could have been contributed by the long dry season despite the impact of urban wastewater that flows into the gully site. This will also have implication on the survival of *paniculatu/pitadeniastrumafricanum* planted to check gully erosion in the area. Table 5 further shows no significant difference between soil moisture content of the top and the bottom layers of the gully profile ($P>0.487$). This implies that the proportion of moisture content for the top and bottom layers is similar.

Table 5 Soil Physical Properties and Textural Class of Gully Profile

S/N	Top				Bottom				Moisture Content (%)	
	Clay	Sand	Silt	TC	Clay	Sand	Silt	TC	Top	Bottom
1.	(%)	(%)	(%)		(%)	(%)	(%)			
2.	5.50	67.50	5.50	SL	5.50	69.50	25.00	SL	2.65	4.08
3.	10.50	67.00	10.50	SL	5.50	62.00	32.50	SL	2.55	15.90
4.	10.50	74.50	15.00	LS	5.50	74.50	20.00	LS	26.52	21.42
5.	5.50	74.50	20.00	LS	5.50	77.00	17.50	LS	5.34	5.15
6.	5.50	84.50	10.00	LS	10.50	74.50	15.00	SL	15.05	4.99
7.	8.00	82.00	10.00	SL	5.50	79.50	15.00	LS	3.96	8.44
8.	5.50	69.50	25.50	SL	5.50	69.50	25.00	SL	6.18	5.42
9.	5.50	67.50	5.50	SL	5.50	62.50	32.50	SL	2.99	7.42
10.	8.00	69.50	22.50	SL	5.50	69.50	25.00	SL	4.31	4.98
11.	5.50	74.50	20.00	LS	8.00	72.50	20.00	LS	5.11	4.19
12.	5.50	67.50	5.50	SL	20.50	67.00	12.50	SCL	6.76	6.68
13.	5.50	84.50	10.00	LS	25.50	57.00	17.50	SCL	2.32	6.24
14.	5.50	69.50	25.00	SL	10.50	79.50	10.00	LS	2.88	7.16
15.	5.50	82.00	12.50	LS	8.00	82.00	10.00	LS	2.64	6.40
	5.50	74.50	2.50	LS	10.50	74.50	74.50	SL	3.13	5.83

Source: Field work and Laboratory Analysis 2017 Key; TC-Textural Class, SL- Sandy Loam, LS-Loamy Sand, SCL-Sandy Clay Loam

Table 6: Statistical Results of the Soil Physical Properties

Variables	Layers	Mean	SD	Variance	F -Test	Sig
Clay	Top	6.533	1.889	3.567	0.106	NS
	Bottom	9.167	6.041	36.488		
Sand	Top	78.933	6.469	41.852	0.306	NS
	Bottom	71.333	7.163	51.310		
Silt	Top	14.533	7.150	51.124	0.069	NS
	Bottom	19.500	7.209	51.964		
Moisture	TOP	6.159	6.472	41.888	0.487	NS
content	BOTTOM	7.620	4.755	22.609		

Source: Laboratory Analysis, 2018.

Key: SD = Standard Deviation, F-test = Level of Significance, NS = Non Significance

Physical Dimension of Gully Sites

The main gully in the study area is the Tumfure stream channel, which is a second order hierarchy that was initiated from the upstream to the downstream, and was purposively selected for this study. Though the stream extends beyond the boundary of Tumfure to an open space and finally empties into Dadinkowa dam, however, this study is only restricted to the gully site within Tumfure area. The gully has numerous first order gullies that passed within the study area. Findings from the field (ground truth measurement) revealed that the total length of the gully site is 3.1km with an average width of 15.1m and average depth of 4.5m. Also comparing it with values in Table 6, it indicates a change from 0.03km to 0.06km. This increase might be due to the nature of the soil and increase in landuse that has increased the volume and velocity of water in the main gully as a result of the combination of rainfall intensity, rapid discharge from iron sheets, increased roads density, interlocking of compound and absence of vegetal cover.The implication of this finding is that increase in depth and width of gullies has resulted in the destruction of houses, trees, roads and culverts located along the vicinity of the gully.

Table 7: Physical Dimension of the Gully Sites

S/N	Coordinates			
	Latitude	**Longitude**	**Width (M)**	**Depth (M)**
1.	$10^0$16’34.14”N	$11^0$6’1.84”E	7.4	2.0
2.	$10^0$16’38.5”N	$11^0$6’3.64’’E	14.0	4.3
3.	$10^0$16’42.89”N	$11^0$6’5.54’’E	11.3	4.6
4.	$10^0$16’50.7”N	$11^0$6’7.63”E	14.2	3.5
5.	$10^0$16’59.8”N	$11^0$6’9.36”E	14.2	5.0
6.	$10^0$16’59.7”N	$11^0$6’10.3”E	9.0	3.7
7.	$10^0$17’9.64”N	$11^0$6’10.98”E	14.1	6.0
8.	$10^0$17’16.55”N	$11^0$6’9.5”E	25.2	4.7
9.	$10^0$17’23.75”N	$11^0$6’6.44”E	9.0	2.0
10.	$10^0$17’34.8”N	$11^0$6’37.12”E	23.2	5.0
11.	$10^0$17’41.2”N	$11^0$6’37.12”E	17.0	3.5
12.	$10^0$17’36.78”N	$11^0$5’59.86”E	20.9	4.0
13.	$10^0$17’55.82”N	$11^0$5’59.17”E	17.8	6.3
14.	$10^0$17’59.06”N	$11^0$5’58.63”E	16.0	6.4
15.	$10^0$18’2.92”N	$11^0$5’58.34”E	13.0	3.4
Mean			**15.1**	**4.5**

Source: Fieldwork, 2018

Effects of Gully Erosion in the Study Area

Field observations revealed cracked houses and falling of buildings into gullies are common features in the gully prone areas, while several others are at the risk of losing their houses and livelihood to gully erosion (Plate 1 and 2) if no holistic control measures are taken. As similar work by Ofomata (2007) reported that over 100 houses each year were destroyed by gully erosion in Auchi and AguluNanka communities in Nigeria.

Source: Fieldwork 2018

Plate 1: Exposed foundation of a house at the verge of collapsing due to gully activities

Gully erosion in the study area has also destroyed many roads and culverts/ bridges in the study area (plates2 and 3). Different streets/roads especially untarred culverts/ bridges and foot paths were destroyed thereby increasing the cost of intra city transport in the study area. Also, several other undeveloped plots of land were destroyed and others at the verge of destruction due to lack of proper drainage channel in the area.

Source: Fieldwork 2018

Plate 2: Collapsed Culvert along the gully site

Plate 3: Cutting down of Bauchi-Gombe road by gully erosion
Source: Fieldwork 2018

Conclusion

The paper assessed the impact of soil on gully erosion in Tumfure. The main gully site cut across Bauchi-Gombe road and was purposively used for the assessment of gully properties using satellite images of the year 2005 and 2016; soil physical and chemical properties, and effects of gully erosion in the area. The mean particle distribution of soil texture along the gully wall shows sand 73%, silt 17% and clay 8%; sand has a significant relationship with gully advancement. The 2016 image analyzed, revealed change in the urban expansion from $0.14km^2$ to $4.26km^2$ in 2016. This implies an increase of $4.13km^2$ over the 12 years. The effects of gully erosion in the study area include destruction of roads, bridges; plots of land, houses trees and biodiversity. The existence and development of gully erosion in Tumfure, therefore, could be explained in terms of fragile soil/geological formations, deforestation and poor landuse practices in the area. From the findings of the paper, it is evident that the nature of soil of the area is responsible for gully initiation and development in the area. This has increased deep cutting and has taken up valuable land. These have forced people to erect buildings on floodplains, consequently increase in both magnitude and frequency of gully in response to high runoff generated.

Recommendations

The paper recommends based on the findings of the study, the following measures;

i. Proper enlightenment campaign on soil conservation measures that can help to control gully erosion in the area be carried out by the management of the Federal College of Education Technical, Gombe especially among the students and the entire academic community.
ii. Effective measures of controlling gully expansion such as engineering and biological methods should be put in place by the management of the Federal College of Education Technical, Gombe.
iii. Reforestation of catchment areas and eroded lands can be effective at reclaiming and controlling gully corridors in the affected areas by the management of the Federal College of Education Technical, Gombe.

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