International Journal of Advanced Research in Social Sciences, Environmental Studies & Technology
p-ISSN: 2536-6505 | e-ISSN: 2536-6513
Volume 8, Number 1 April, 2023

IJARSSEST

Impact of Gully Erosion on the Residents of Kontagora, Niger State

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Article DOI: 10.48028/iiprds/ijarssest.v8.i1.05

Abstract

Gully erosion has become a serious environmental disaster and also a threat to well-being of people. It has threatened and destroyed many of the physical infrastructure, properties, as well as retarding the social and economic growth and development of the inhabitants. The research assesses the impacts of gully erosion on the residents viewing the physical structures and human activities in Kontagora, Niger State. Data were obtained through physical observation and questionnaire via interview; questionnaire was administered to household around the targeted residents within the study area. The questionnaires were administered based on the issues relating to the impacts of gully erosion on physical structures and the localities of the respondents. Result of the impacts of gullies on the physical and human activities revealed that, farming is the most identified means of livelihood affected by gully. Result of the gullies control measures revealed that, planting of trees and grasses, sandbag embankment, broken stone embankment and landfills were the method used in controlling gully erosion**.** The research, therefore, recommends channeling of runoff water to drainage for permanent control and planting of trees and other vegetation cover for temporary control of gully erosion.

Keywords: *Damages, Gully erosion, Human activities, Physical structures*

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Background to the Study

Soil erosion is the displacement of the upper layer of soil as a form of degradation. Over the years, tremendous contributions were recorded in understanding the operations of gully erosion and its controlling factors by many scholars using different criteria (Poesen, Nachtergaele, Verstraten, & Valentin, 2003), observed that Gullies are among the morphological indication of long period of soil erosion revealing the effects of atmospheric adjustment, example is heavy rain fall and land use practice. Both natural and anthropogenic activities have been reported to trigger the extent at which this gully erosion occurred. Among the natural factors are; climate, soil structure and composition, vegetation cover and topography. While the anthropogenic factors include agricultural practices, deforestation, roads and urbanization and as well as climate change.

Gully erosion is defined as the terminal phase of a four-stage erosion process involving splash, sheet, rill, and gully (Amangabara, Njoku & Iwuji 2017). Gullies could be considered as signals of disturbances and accelerated erosion brought about by climate or land-use change. Erosion by gullies can be an acute problem causing high sediment yield, removal of fertile soil, destabilization of hill slopes, and the lowering of water tables in alluvial aquifers. Apart from the loss in soil fertility and continuous diminutions of cultivable land, there is additional loss of properties to include losses of homes, household belongings, farm crops and utilities (Danladi & Ray, 2014).

Gullies could be considered as signals of disturbances and accelerated erosion brought about by climate or land-use change. Erosion by gullies can be an acute problem causing high sediment yield, removal of fertile soil, destabilization of hill slopes, and the lowering of water tables in alluvial aquifers. Apart from the loss in soil fertility and continuous diminutions of cultivable land, there is additional loss of properties to include losses of homes, household belongings, farm crops and utilities (Danladi & Ray, 2014). Erosion in Niger State is devastating and has caused a lot of human and material losses, most especially in Kontagora area where there are active gullies which is dispersed across. Gully erosion is active and at alarming rate due to soil texture and structure, slope, rainfall, human activities such as deforestation, over grazing, excessive cultivation, over grazing and construction works amongst others in Kontagora (Ojoye, 2021). Another major factor that contributes to erosion is population increase. The population growth rate of Kontagora Local Government Area was 3.5% according to National Population Commission (Niger State Population Statistics, 2020) and naturally when there is an increase in human population; both human and physical activities will be under pressure (Mbaya, 2012). It is against this background that this research examines the effects of gully erosion in the environment as a result of the interplay between human activities and natural elements in Kontagora.

Aim and Objectives

The aim of the study is to assess the impact of gully erosion on the residents of Kontagora, Niger state.

Therefore, the specific objectives are:

i. To identify the distribution of erosion in the study area
ii. To assess the causes of gully erosion
iii. To assess the extent of the damages of gully erosion
iv. To evaluate the control measures for the gully erosion

Research Questions

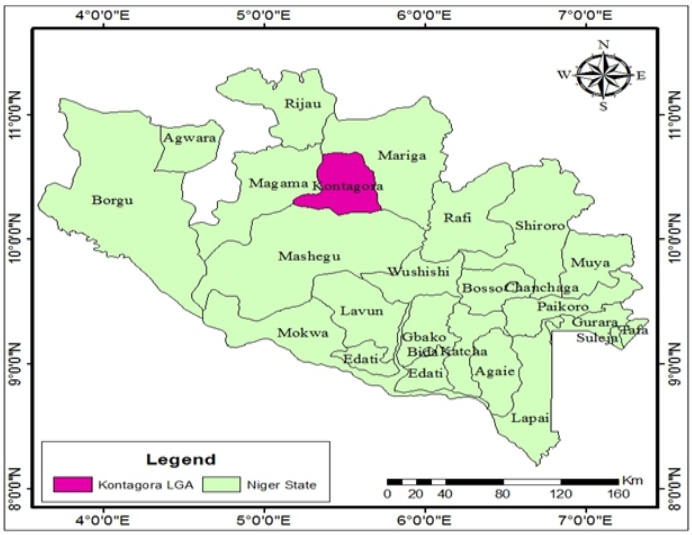
1. What are the distribution patterns of erosion in the study area?
2. What are the causes of gully erosion?
3. To what extent has gully erosion caused damages to the study area?
4. What are the possible control measures for gully erosion?

The Study Area

Kontagora reservoir lies in the Northern Guinea Savannah zone between Latitude 5° 10[1] and 5°40[1] East and longitude 10° 10[1] and 10° 40[1] North as seen figure 1.1. The climate is characterized by distinct dry and rainy season. In Kontagora, the wet season is oppressive and overcast, the dry season is partly cloudy, and it is hot year-round. Over the course of the year, the temperature typically varies from 58°F to 97°F and is rarely below 53°F or above 103°F.

Based on the tourism score, the best time of year to visit Kontagora for warm-weather activities is from early December to late January. The hot season lasts for 2 to 3 months, from February *to* April, with an average daily high temperature above 94°F. The hottest month of the year in Kontagora is April, with an average high of 96°F and low of 74°F. The cool season lasts for 4 months, from June to October, with an average daily high temperature below 86°F. The coldest months of the year in Kontagora is December and January, with an average low of 59°F and high of 88°F (Weatherspark, 2016).

Figure 1: Map of Niger State Showing Kontagora Local Government Area



Source: GIS Lab Department of Geography A.B.U Zaria, Using Arc GIS 10.3 Software

To show variation within the months and not just the monthly totals, we show the rainfall accumulated over a sliding 31-day period centered around each day of the year. Kontagora experiences *extreme* seasonal variation in monthly rainfall. The *rainy* period of the year lasts for *7 months*, from *March* to *November*, with a sliding 31-day rainfall of at least *0.5 inches*. The month with the most rain in Kontagora is *August,* with an average rainfall of *9.4 inches*. The *rainless* period of the year lasts for *5 months,* from *November* to *March*. The month with the least rain in Kontagora is *December,* with an average rainfall of *0.0 inches (*Weatherspark, 2016*).*

Methodology

Before the survey was carried out Field/ground observation was done. The investigation utilized personal observation methods and Photographs were taken to demonstrate the reality of erosion menace in the study area, and the pictures were presented in the analysis.

Sources of Data

The data used in this research are both qualitative and quantitative which are data on physical structures, gully's location, and extent of damages. Questionnaire was used as an instrument to collect information from the respondents, who are inhabitants of the study area. The questionnaires were administered to respondents via interview behind Abuja Electricity Distribution Corporation (AEDC) along Federal College of Education Kontagora (FCEK)) road, Along Universal Basic Education (UBE) primary school at old Kwangwara, beside (FCEK) fence and behind old market. Information collected include effects of gullies on physical and socio-economic activities, gullies control measures put in place and opinion on how best to manage the effects of gullies within the study area. Observation checklist method was used in data collection through field visitation and appraisal of gullies, in order to answer some questions relating the distribution, effects and management strategies of gullies within the study area.

The target populations of the study are the total number of people residing in the households either temporarily or permanently. After taking a census of the household along these sites of gully, approximately 2,000 was the number obtained. In other to determine a sample size of proportional or percentage Study (prevalence Study), (Poesen, 2011 Ronán, 2016) suggested a population size of 146 -333 for a total population of 1,000 - 2,500 with acceptable error margin of 5 -7.5%. Following the nature of this study and with the total population size 150 samples which represent 15% of the total population were considered. The total sample size of the population selected falls within the required population size of 146-333 and acceptance error margin of 5 -7.5% as documented by (Ronán, 2016), as such sample size of 15% from each sample area was considered in this study. For adequate coverage of the study area, the samples collected from the study area is based on a total of 150 questionnaires representing 15% of the study population, but only 135 questionnaires were retrieved from the respondents.

Sampling Technique

Purposeful sampling technique was adopted in the selection of localities where gulling are prevalent within the study area. It is a non-probability sampling which relies on the judgment of the researcher when it comes to selecting the units i.e. piece of data to be studied. Purposive

sampling procedure focus on particular characteristics of a population that are of interest, which best answer the research questions of the study. The researcher apply his own criteria purposely when defining sample of gully sites in four selected localities for the study because they possess some characteristics of interest to the researcher during the study. In other to determine a sample size of proportional or percentage Study (prevalence Study), Simple random sampling technique was applied in the administration of questionnaires. The questionnaire was administered to the respondents with the help of other group members represented as field assistants and it is expected that the respondent to fill as appropriate and return it to the researcher.

Method of Data Collection

For the field research, measuring tape and ranging poles were used to measure the height, depth and width of the selected gullies. The measurements were taken in meters. The gully length (L), depth (D), height (H) and width (W) were measured with a linen tape and ranging poles. The length of each gully was obtained by marking and measuring out points on the floor of the gully from the head to the mouth using the linen tape and the ranging poles. To measure the widths, each points was marked with a ranging pole in succession, and at each point, the tape was stretched across the gully bed from one side perpendicular to the other. At this point, the bed width reading on the tape was recorded in meters. The same procedure was repeated at the shoulder at the same point with the tape tight stretched across the gully to ensure that it did not sag at the middle. The depth was also recorded in meters to the last hole of the gully on the bed. The height of the gully was measured from the gully head to the top of the slope with record in meters.

These procedures were repeated for all the marked interval points along the floor and the average gully width (W) was computed as shown in Equations (1) and (3) respectively.

$$W_b = \frac{\text{Sum of bed width readings}}{\text{Number of interval points}} \quad (1)$$

$$Ws = \frac{\text{Sum of shoulder width readings}}{\text{Number of interval points}} \quad (2)$$

$$\text{Average gully width } W = \frac{Wb + Ws}{2} \quad (3)$$

The average gully depth (D) was measured by having a third person place one of the poles at the deepest part of the gully floor at the same interval point where the bed and shoulder widths were measured. The tape was placed at the ground level and stretched across the gully channel over the ranging pole. The third person holding the ranging pole on the gully floor noted and recorded the reading on the ranging pole as it made contact with the linen tape. At points where the gully depth was more than 1.90 m, the ranging poles were tied together using 10 m ropes to increase their total vertical length. The elongated poles were then used to measure the depths using the above procedures. Thus, the average gully depth was obtained by using equation 4.

$$D = \frac{\text{Sum of interval depths}}{\text{Number of intervals}} \quad (4)$$

The gully parameters actually measured in the field and collected were the Length (L), average depth (D), and the average width (W), average depth (D) and height. For these sets of variables (L, D, W, H), a total of four for each gully, the descriptive analysis and inferential analysis were used to investigate the relationships between gullies.

Method of Data Analysis

Analysis techniques for this study involved descriptive analysis. It deals with the methods and techniques of summarizing and describing information (data). That is, it tends to describe incidence, events, and qualities in the elements. This includes the use of tables, frequencies and pictograms.

Results and Discussions

Identification of Gully Erosion Areas

The field observation identified many gullies erosion vulnerable areas but by selection, four sites in Kontagora Local Government area were selected based on some of the characteristics observed in the survey, they are as follows:

1. Behind Abuja Electricity Distribution Corporation AEDC along Federal College of Education (FCE) road, in Kontagora: This is site A, in figure 2, it is selected because the site is used for molding of mud blocks and sand excavation during the rainy season. It is a rock formed as a result of accumulation of sand and stones. The red soil of the rock is clayey and very good for molding of blocks this is why human activities of this kind takes place there. During the rainy season the exposed soil is vulnerable to erosion and being excavated for sand filling eroded areas in the community. Human factor is the major cause.

Figure 2: A Mud block industry behind AEDC (Site A)

Figure 3: A damaged road beside UBE primary school, old Kwangwara (Site B)

2. Along Universal Basic Education (UBE) primary school at old kwangwara: This is site B, it is selected because the area is along a minor road surrounded by houses. The area is seen in figure 3; it is known to be vulnerable to erosion due to the local geologic setting, the permeability, porosity, cohesion and hydrodynamic events in the area. The gully erosion menace is thriving as a result of absence of well-coordinated control measures and inadequate and urgent attention it deserves.

Figure 4: A damaged road beside FCE Kontagora fence (Site C)

3. Beside Federal College of Education (FCE) fence: This is site C, as observed in figure 4, it is within clustered settlement beside FCE fence, and it is occupied by residents of staff and students of the college. Due to the porosity of the soil geology run-off played significant role in gulling, runoff at vulnerable region where there is poor drainage shows elevation changes within valley slopes which is observed in this site.

Figure 5: A modern block making industry with gully erosion behind old market (Site D)

4. Behind Old Market: This is site D, It is selected because it is within clustered settlement dominated by the indigenes of Kontagora behind old market as seen in figure 5. The areas has poor drainage pattern and it is also characterized by human activities such as modern block making and irrigation farming. Refuse are also dumped and cabbages litter around known as 'bolla' in Hausa language.

The Causes of Gully Erosion

In the Field/ground observation, the main factors found to cause gully include local geologic setting, depth to water table and annual rainfall. Others are permeability, porosity, cohesion and hydrodynamic events in the areas. The gully erosion menace is thriving as a result of absence of well-coordinated control measures and inadequate and urgent attention it deserves. For instance, in spite of the devastating impact on humans and structures and potential threats on more structures if not well managed the synoptic view of the affected area. Behind Abuja Electricity Distribution Corporation (AEDC) along FCE Kontagora road, the erosion is caused by anthropogenic influence.

Human activities of mud block making has affected the area thereby making it vulnerable to erosion, the area has a wide pit as a result of excavation and digging out of soil for construction purposes. An observation behind old market also shows that the area is influence by human activities of modern block making and irrigation farming. These Anthropogenic factors combine to weakened soils to produce severe gullies. The soils are hence loose and slumps under high intensive rainfall that renders them easily detachable. Some of the soils have the tendency to slake and form seals under such intense rainstorms thereby resulting in considerable runoff and soil erosion. The soil erodibility factor has since been recognized as a contributing factor to soil erosion hazard.

The area along Universal Basic Education (UBE) at old Kwangwara and the area beside the fence of FCEK lay gullies caused by natural and anthropogenic factors. The natural cause is

because of the geology of soil. The soil type or texture determines how water flows through it. Soil types with predominantly sandy characteristics allow for pockets of space that water easily moves through. For this reason, sandy soils do not have the ability to hold nutrients and support plant life. Without plants extending their roots into the soil and solidifying it, the chances of soil erosion increase even more. Since erosion plays a large role in soil depletion in this area, it is important to consider fertilization and irrigation when attempting to grow crops.

The soil in Kontagora is sandy, its geological materials are vulnerable to aggressive energy of wind, rainfall, and runoff. High erosion risks match with units of weak unconsolidated geological formations. This is more pronounced when such geological units coincide with medium to long and even very long slopes with marked gradients. In these formations, these sites of worst catastrophic soil erosion therefore play direct and indirect influence on the gully formation. The anthropogenic factor is caused by lack of good drainage system, self-effort by residents towards erosion control like pavement of their compounds, indiscriminate logging activities, lack of or implementation of erosion control measures by Governments at all levels.

In the event of uncontrollable grazing caused by the dwellers and indiscriminate foot paths created on the landscape helped the incipient channels on the landscape to form. These channels eventually metamorphose to gullies especially when they are not checked at inception. Road constructions including uncontrolled infrastructural developments have contributed significantly to gully developments. Some road networks under construction have been abandoned in the region due to gully formation. Even the road beside FCEK fence have collapsed and now become an abandoned road as a result of these factors. It is also observed that constant deforestation of plants and trees due to population explosion and increased agricultural activities in the region expose the bare soils to the vagaries of weather thus escalating the soil erosion problems. The implication is that the soils are frequently subjected to different degrees of erosion including accelerated erosion.

The Width, Height, Length and Depth of Gully Erosion

As observed in table 1, site A has the width of49m, height of 6m, length of 50m and depth of 10m. Site B has the width of 10m, height of 1.2m, length of 56m and depth of 1.3m. Site C has the width of 41m, height of 2.45m, length of 100m and depth of 2.85m. Site D has the width of 5m, height of 0.70m, length of 39m and depth of 1m.

Table 1: The Width, Height, Length and Depth of the selected sites

Measurement	Site A	Site B	Site C	Site D
Width	49m	10m	41m	5m
Height	6m	1.2m	2.45m	0.70m
Length	50m	56m	100m	39m
Depth	10m	1.3m	2.85m	1m

Source: Authors' Calculation 2022

From the above table, it is observed that site C beside FCEK fence has the longest length 100m, it is observed that the length extended to a long distance and collapsed a minor road which is now abandoned for only foot parts and used for waste land where cabbages, excreta and refuse are littered. More so, foundations of buildings along this part are collapsed. Site A has the deepest depth of 10m. This is as a result of continuous excavation of mud soil for block making and for sand filling over a long period of time which has finally led to a gully. In essence it has the highest height of 6m this shows how high the hill is. The gully in site B of old Kwangwara UBE primary school road has a peculiarity because the gully is formed on the road where humans and cars pass.

By observation, it is concluded that the gully is a result of natural and human cause. The soil type is very porous, and it lacks drainage pattern. There is a threat on the road presently because it could collapse at any time if control measures are not taken. The peculiarity in site D is that it is found beside a bridge, irrigation farm and modern block industry where the soil is threatened by all these human activities, and because of the geology of the soil, the soil is easily loosened and eroded.

The Extent of the Damages Caused Gully Erosion

In table 2, it was observed that 16.6% of the respondents indicated that gullies wash away farmland and farm produce. 17.2% of the respondents reveal that gullies lead to sedimentation of water bodies, 15.9% of the respondents reveals that gullies caused difficulty in farming activities, 17.8% of the respondents indicated that gullies destroyed grazing fields and uproot economic trees respectively. Others include 14.6% of the respondents who indicated that gullies damage other means of livelihood apart from the ones listed in their localities.

Table 2: Damages caused by Gullies.

Damage cause by gullies	Frequency (%)	Mild (%)	Moderate (%)	Severe (%)
Washing farmlands and produce	26(16.6)	6(14)	9(18.8)	11(16.7)
Sedimentation of water bodies	27(17.2)	7(16.3)	8(16.7)	12(18.2)
Difficulty in farming	25(15.9)	2(4.7)	10(20.8)	13(19.7)
Destruction of grazing fields	28(17.8)	8(18.6)	10(20.8)	10(15.2)
Uprooting of economic trees	28(17.8)	8(18.6)	7(14.6)	13(19.7)
Others	23(14.6)	12(27.9)	4(8.3)	7(10.6)
Total	129(100.0)	43 (100.0)	48(100.0)	66(100.0)

Source: Authors' Calculation 2022

Most of the respondents admitted that destruction of grazing fields and uprooting of economic trees are the most affected sector in the study area. The respondents also indicated the level of gullies severity on the various livelihood means. 40(27.4%) of the respondents reveals that the damages caused by gullies are Mild, while 48(30.6%) of the respondents believe that the damage caused by gullies are moderate and 66(42.0%) of the respondents

reveals that gullies action is severe on the diverse livelihood means of the inhabitants in the study area.

The Degree of Damages caused by gully Erosion.

The empirical evidence provided in table 3 revealed the proportions of gullies damaged on the existing physical infrastructural facilities as follows; the most damage is destruction of roads with 11.9% respondents, 11.5% was for cutting of bridges, destruction of culvert and difficulties in construction respectively. Also 11.1% of the respondents indicated that damages were collapse of built-up structures, danger pits and breaking of water pipes respectively.

Table 3: The Degree of Damage Caused by Gullies

Damage caused by gullies	Frequency (%)	Mild (%)	Moderate (%)	Severe (%)
Cutting of bridges	27(11.5)	16(22.9)	7(8.2)	4(4.8)
Destruction of coverts	27(11.5)	11(15.7)	10(11.8)	6(7.2)
Collapse of built-up structures	26(11.1)	4(5.7)	9(10.6)	13(15.7)
Danger pits	26(11.1)	10(14.3)	6(7.1)	10(12.0)
Difficulties in construction	27(11.5)	8(11.4)	10(11.8)	9(10.8)
Breaking of water pipes	26(11.1)	5(7.1)	14(16.5)	7(8.4)
Uprooting of power poles	24(10.2)	3(4.3)	10(11.8)	14(16.9)
Destruction of road	28(11.9)	3(4.3)	10(11.8)	15(18.1)
Others	24(10.2)	10(14.3)	9(10.6)	5(6.0)
Total	235(100.0)	70(100.0)	85(100.0)	83(100.0)

Source: Authors' Calculation 2022

Uprooting of power poles and others reveals 10.2% respondents. In terms if severity of gullies damage in the study area 70(29.8%) of the respondents claim that the damages by gullies are Mild, another 85(36.2%) of the respondents believe that the damage caused by gullies are moderate and 83(35.3%) of the respondents believe that gullies damages caused are severe on the existing physical infrastructural facilities in the study area.

Table 4: Gully Control Measures

Gully Control Measures	Frequency (%)	Lowly (%)	Moderate (%)	Highly (%)
Sand embankment	23(19.3)	8(25.5)	8(19.5)	7(14.9)
Broken stone embankment	24(20.1)	7(22.6)	8(19.5)	9(19.1)
Planting of trees and grasses	24(20.1)	4(12.9)	11(26.8)	9(19.1)
Land fills	24(20.1)	6(19.4)	10(24.4)	8(17.0)
Construction of drainage	24(20.1)	6(19.4)	4(9.8)	14(29.8)
Total	119 (100.0)	31(100.0)	41(100.0)	47(100.0)

Source: Authors Calculation 2022

Result of the major gullies control measures taken by the various sites as indicated in table 4 revealed that 19.3% of the respondents suggested that sandbag embankment will control the excesses of gullies, 20.1% of the respondents are of the opinion that broken stone

embankment, planting of trees and grasses, landfills and construction of drainages respectively will control gully erosion within their localities. Most of the respondents indicated relative successes as a result of adopting one or more of the various control measures. As seen in the table, 47(39.5%) of the respondents recorded high success in the control measures, 14.9% of the respondents was indicated for sand embankment, 19.1% for broken stone and planting of trees and grasses, 17.0% for landfills while 29.8% was for construction of drainages.

Discussions

In regard to the impact of gullies on the physical infrastructures, it was observed that, all the respondents admitted that gullies do exist in their localities ever since they were residing there, and gullies affect virtually all the physical infrastructural facilities type that exist in their respective communities. The most affected physical facility is identified to be housing which indicates that human shelter is most threatened by gullies in the study area which agreed with the view of Mbaya (2012). In addition, impact of gully erosion on human activities revealed that, farming is the most identified mean of livelihood affected by gully, which implies that, there is need for urgent control measures to check mate gullies in order to attain food security in the study area. This result agrees with the findings of Danladi and Ray (2014).

It was also observed that gullies have high impact on physical structures such as cutting of bridges abutments, destruction of culverts and roads. In addition, farmlands and farm produce are the most affected sector or means of livelihood by gully erosion in the study area. Following the information collected, it is clear that entire study area experience severe negative impact of gullies on various physical structures and means of livelihood of the residence.

Gullies control measures based on interview and questionnaires revealed that, the residence cannot adopt expensive erosion control measures such as construction of drainage channels, bridges among others, as such they adopted measures such planting of trees and grasses, sandbag embankment, broken stone embankment, sanitary landfills, construction of drainages which is similar with the view of Ojoye (2021). In addition, the respondent revealed that, they recorded relative success as a result of adopting one or more of the various control or mitigation measures used in controlling gully erosion but the methods with a highest success are the construction of drainages.

Conclusion and Recommendations

This study was conducted in order to ascertain the impact of gully erosion on the residents of Kontagora vis-à-vis distribution, causes, extent of damages and control measures. Generally, all erosion activities including gully are directly or indirectly induced and the fact remains that they are not boundary restricted. It is a function of the drainage line, soil type and characteristic, anthropogenic activities and of cause climate change of late. When erosion activities metamorphose into gully formation, the multiplier effect is always colossal and thereby requiring collective effort to mitigate. There is no doubt therefore that the residents of Kontagora communities have seriously contributed to the degradation of the entire area that is

tending toward badland formation causing loss of lives and properties in the area. Cultural practices such as agro-forestry system, planting of cover crops in their farms, planting trees along the streets as well as other local factors that can mitigate the gully erosion but there is need for the construction of drainages in the locality for the permanent control of gully erosion in the study area.

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