Mathematical Modeling of Ecological Restoration of Gully Erosion in Chukun Local Government Area in Kaduna State

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ABSTRACT

Land is a major resource for many people in Africa. It is not only a social pride to own land in Africa, it also contributes significantly to individual income. In an attempt to sustain life by the exploitations of land directly for their long-term livelihood such as farming, animal husbandry and mining, build houses, and excavating the topsoil for various infrastructural developments, man also impacts, often negatively, the condition of the soil. Such impacts which include gullies, thereby create environmental hazards. In this study, a critical examination of the extents, socioeconomic, and human health impacts of Gully erosion in Chukun Local Government Area, Kaduna State, Nigeria was conducted.

A questionnaire is administered to 550 randomly selected respondents (110 to each of the four communities of Sabo Gaya, Gonin Gora, Kudendan, and Kujama) for primary data collection. Frequency and percentage distributions table were used in analyzing the data. To ascertain extents of gullies in the area, a non-deterministic cluster method approach was used to display the prevailing menace of gully erosion in the study area. The study identified low income and low levels of educational background are the major factors exacerbating the control of the menace of gully erosion in the regions. Hence, it is recommended that Government, NGOs, traditional rulers, and religious leaders to embark on an enlightenment and sensitization campaign on the impact of gully erosion to the communities affected. Governments should provide intervention through credit facilities, to boost the financial status of the people so that control measure of the erosion would be a function of all.

(Keywords: mathematical modeling, ecological restoration, gully erosion)

INTRODUCTION

The word *Kaduna* is said to be a corruption of the Hausa word '"Kada' for “crocodile” and the plural is "Kadduna" for crocodiles, as there were previously many crocodiles in the river Kaduna (KSG,2020). Another version of the etymology of the name is a narrative linked to the Gbagyi word/name 'Odna' for River Kaduna (KSG,2020). The State was created in 27th of May 1967 (KSG, 2020, Kaduna State Political Map, 2019).

The state is located at the Northern part of Nigeria's high plains on the coordinates $10^0$20’N and $7^0$45’ E. The vegetation cover is Sudan Savannah type, characterized by scattered short trees, shrubs and grasses (KSG, 2020). The soil is mostly loamy to sandy, though also found is a substantial amount of clay soil.

The state was ranked number four by total area 46,053 km^2 (17,781 sq m) of land and number three by population of 6,113.503 (2006 Census). The Kaduna River, a tributary of River Niger, flows through the state. There are rocky stones in Zaria and Kogoro Hill (KSG, 2020).

Chukun, is a suburb of Kaduna, and a local government which shares boundaries with Kachia local government area (LGA) to the south, Kajuru LGA to the east, Kaduna south LGA to the northeast, Igabi LGA to the northeast, Birnin Gwari LGA to the northwest, and Niger state to west (Kaduna State Political Map, 2019). Chukun LGA derives its name from a Gbagyi village named Chukun in the southeastern part of Kujama (KSG, 2020). The Gbagyi people originally populated the area but is now being subsumed by urbanization making it a cosmopolitan part of Kaduna. The administrative headquarter is located at Kujama, the local government, has the population of 372,272 people (2006 Census, Premium Times Newspaper Report, 2017, Kaduna State Political Map, 2019).

Soil erosion is a natural phenomenon, which wears away the topsoil of a field by physical forces of water, wind, or forces associated with land tillage due to excessive farming. Gully erosion is the removal of soil along drainage lines by surface water runoff. Unless steps are taken to stabilize the disturbances, gullies will continue to move by head ward erosion or by slumping of the sidewalls.

Large gullies that have been left unchecked are difficult and costly to repair. Also, their frequent occurrence can cause serious damages to the economy and wellbeing of a region. Gully erosion is the most impressive and striking erosion type, has been recognized as one of the major global environmental problems. Many States in Nigeria are currently under the threats of this phenomenal process, south-eastern part of the country being the most affected. It has numerous causes; and these causes can be both naturally and artificially induced, but the underlying geology and the severity of accompany surface processes play a key role. This erosion activity at various scales has resulted in the loss of lives and properties almost on a yearly basis.

Solutions that have been proffered include public awareness campaign, improved farming techniques, cultural methods of gully control, enactment of laws against any activities that favor gully growth, and thorough implementation of suggested solutions. According to Aliyu et al (2017), the cumulative *effect of Gully erosion in Kaduna State* is that the affected inhabitants are left homeless and jobless. The threats posed by gaping and daunting large *gullies* to farmlands, settlements, roads and human are enormous. Most communities in *Kaduna State* have been ravaged by *soil erosion* of different dimensions

Ecological restoration of gully erosion is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability. Frequently, gully erosion that required restoration has been degraded, damaged, transformed or entirely destroyed as the direct or indirect result of human activities. In some cases, these impacts to ecosystem have been caused or aggravated by natural agencies such as wildfire, floods, storms, or volcanic eruption, indiscriminate of pollutants and refuse dump.

Description of Study Area

The scope and coverage of the study area in Chukun LGA comprises of Kujama, Goni-gora, Kudendan, and Sabogaya. The figures below show the study areas and specific gully areas.

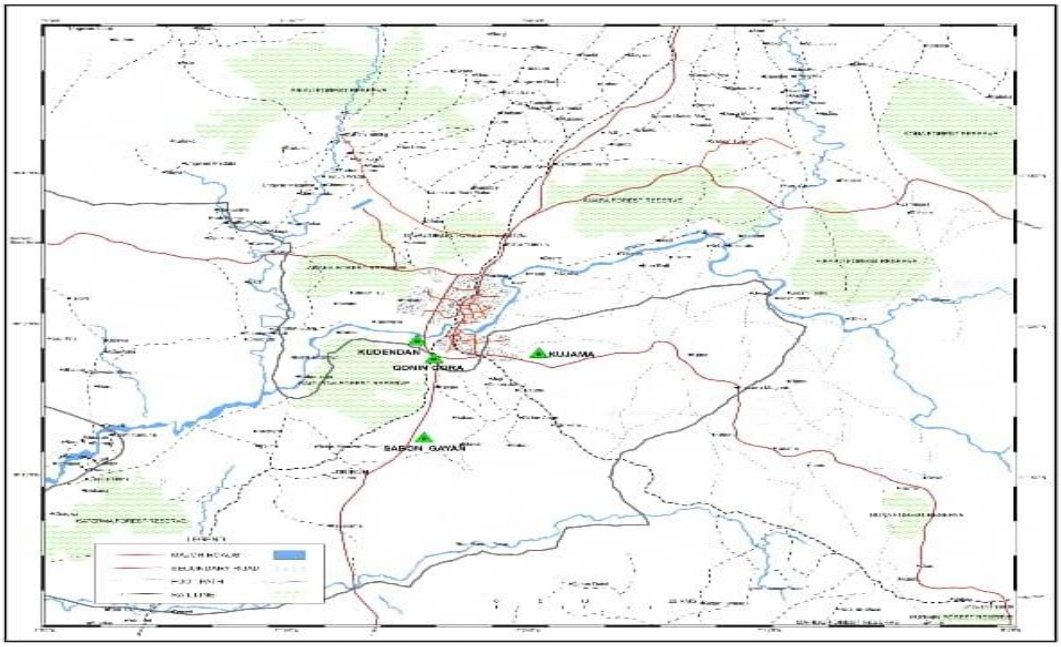

Figure 1: Map showing Four Study Areas in Green Triangles.

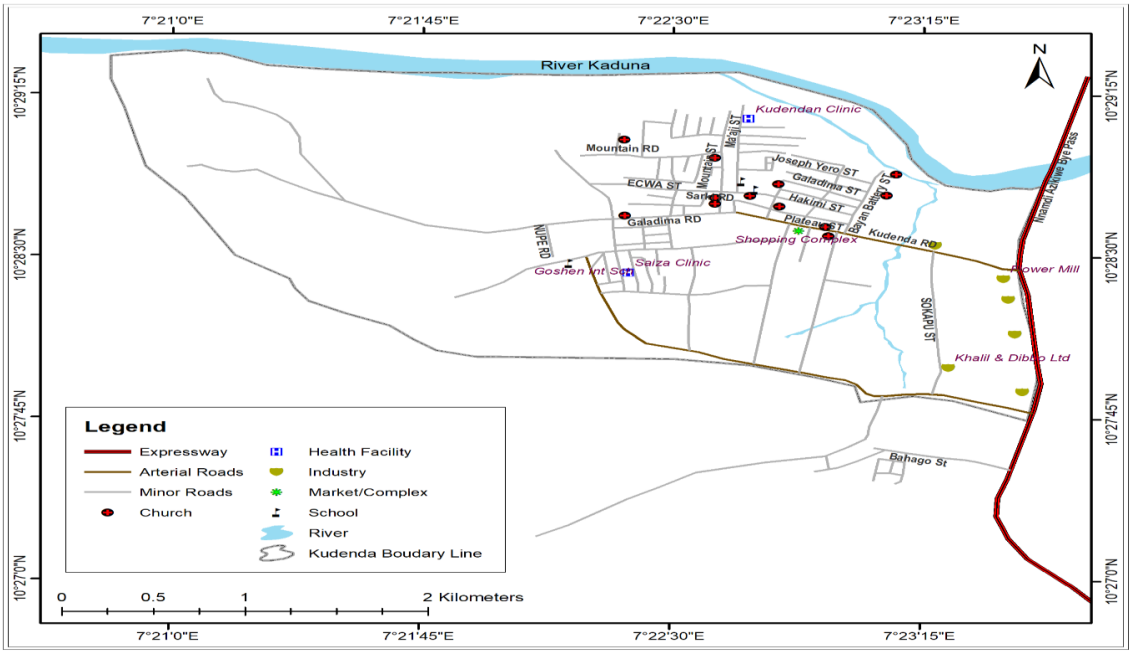

Figure 2: Geographical Map of Gonin Gora.

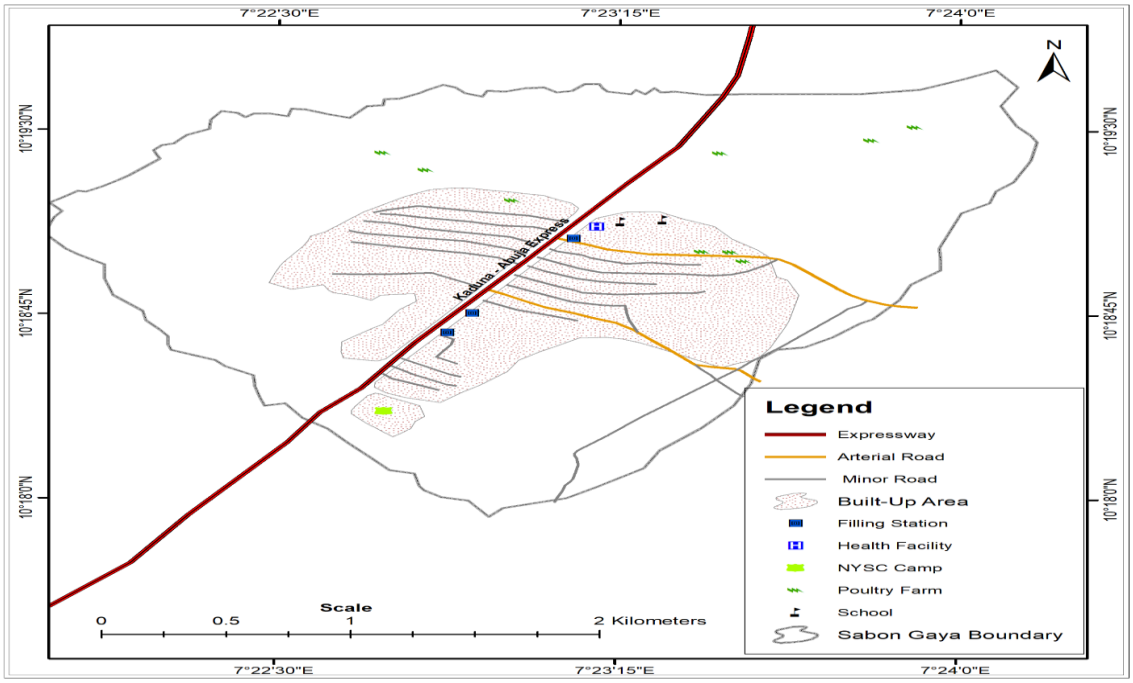

Figure 3: Geographical Map of Sabon Gayan.

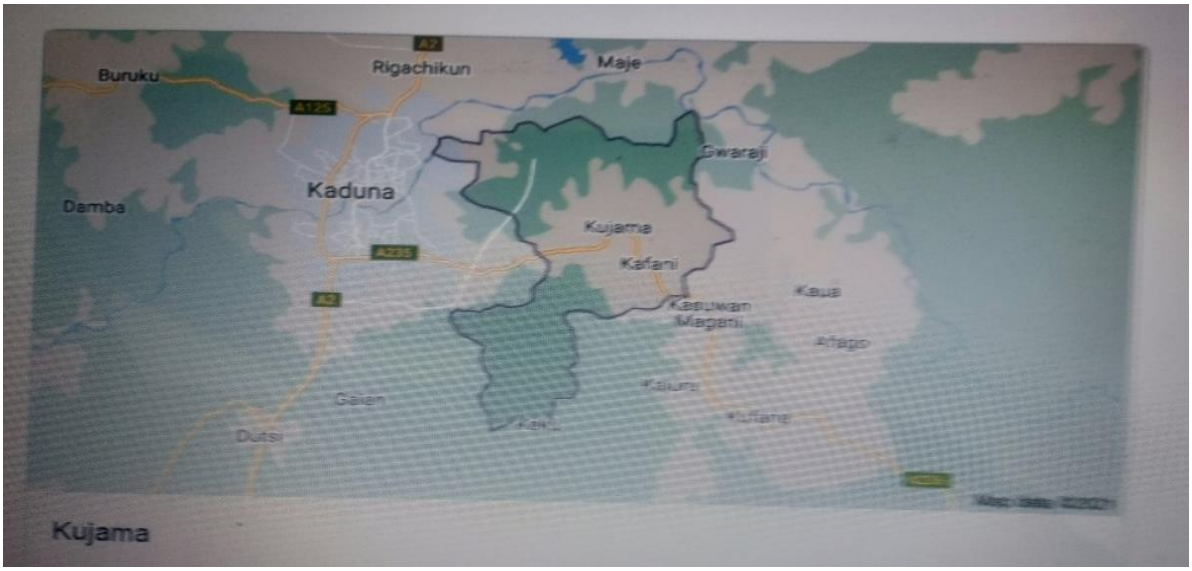

Figure 4: Geographical Map of Kujama.

Figure 5: Pictorial View of Gully Affected Area of Sabon Gaya Village.

Figure 6: Pictorial View of Gully Affected Area of Goni-Gora before the Rail.

Figure 7: Pictorial View of Some Gully Erosion Sites in Chukun.

Motivation of Research

There are serious adverse social and economic implications of gully erosion hazards in Chukun local government area of Kaduna State, Nigeria (Aliyu et al., 2017). This erosion activity at various scales has resulted in the loss of lives and properties almost on a yearly basis. Preventing the formation of a gully is much easier than controlling it once it has been formed. If incipient gullies are not stabilized, they become longer, larger, and deeper.

Land is a major resource for many people in Africa (Adewuyi, 2016). As a result, it contributes significantly to their income. More than half of the population depends on the exploitations of land directly for their long-term livelihood (Allen and Barnes, 1985). They extract/exploit the land in the forms of crop farming, animal husbandry and mining. Many also depend on the land to build their houses while construction companies equally excavate the topsoil for various infrastructural developments. All of these socio-economic activities are known to impact, often negatively, on the condition of the soil, vegetation and water resources (Adewuyi, et al., 2017). This research will assist in identifying the sources of erosion in the area, define the scope of operation of the erosion and establish the necessary re-orientation of the land users to forestall future occurrence. Also, well-informed planning and policy decisions, which are related to the sustainable land management (SLM) and to "zero net land degradation" target, require, credible and spatially explicit information on degraded lands

MATERIAL AND METHODS

The researchers ahead of the main fieldwork conducted a preliminary survey. The purpose of the visit was to get the researchers be acquainted and familiar with the physical and social settings of the study areas. The visit has also helped the researchers in creating rapport with the local people, preparing and planning for data collection instruments used during the fieldwork.

Data Collection for the Study

The instruments of data collection in this study are the questionnaire and observations conducted in the field. To succeed in attaining the objectives of this study, the type of data collected includes information on demographic, socio-economic, and residency characteristics of the sampled respondents, perceived causes of gully erosion and its impacts on their socio-economic activities and health status. To determine the extent of gully erosion in the area, four gullies site (one from each of the four study areas (Sabo Gaya, Gonin Gora, Kudendan, and Kujama)) were identified and measured in depth and width, using simple tools such as a tape rule and ranging pole. Pictures of the major gullies identified during the field survey were presented. For comparative analysis, secondary data on the major causes and effects of gullies were reviewed from related literature.

The sources of data for this study include both primary and secondary sources. The primary sources include researchers' personal observations, administration of a structured questionnaire to sampled respondents, and measurement of some gullies in depth and width. We administered 550 copies of a structured questionnaire (110 to each of the four communities (study clusters)) due to time factor and security challenge and to ensure high response rates. There were minimal differences between the populations of these four communities which informed the sharing of the questionnaire evenly. We employed the services of the Chukun LGA social workers from the department of education and social development to systematically administer the questionnaire. Relevant information from both published and unpublished articles, thesis, and proceedings constitutes the secondary sources of data.

Data Analysis Techniques

Descriptive statistics such as frequency and percentage distribution table were used to analyze the data collected, with each table preceded by a literal analysis of its contents. In addition, cluster analysis was carried out to distinguish/ discriminate the most evident features among the variables. Plots of dendrograms were used to display the similarities among the study variables.

Data Analysis

Table 1 summarizes the distribution of the questionnaire in the selected regions/sampling points.

Table 1: Collection of Questionnaire Administered.

Sample point	No. distributed	% distributed	No. returned	% retuned
Kujama	110	20	106	96
Marabanrido	110	20	95	86
Kundendom	110	20	105	95
Goningora	110	20	86	78
Sabongaya	110	20	105	86
Total	550		497	90

Table 2: Demographic Representation of the Respondent.

Variable	Response	Count	Percentage
Age	15-25	85	17.5
	26-35	128	25.8
	36-45	150	30.2
	46-55	87	17.5
	56 above	43	8.7
Occupation	Civil/public	194	39.0
	Business/trader	137	27.6
	Craftsmen	5	1.0
	Farming	50	10.1
	Student	62	12.5
	Unemployed	45	9.1
Marital status	Married	370	74.4
	Divorced	15	3.0
	Single	101	20.3
Educational qualification	Primary	41	8.2
	Secondary	115	23.1
	Tertiary	256	51.5
	Vocational	13	2.6
	Informal	24	4.8

For ease of presentation, the researchers used the total returned questionnaire to make valid conclusions on the state of erosion in Chikun LGA.

Demographic Presentation of the Respondents

Table 2 shows the demographic structure of the respondent in the five chosen communities. From the table, majority of the respondents are within the age of 26-45 years old (56.0%). These are the active age group where most of them are farmers, civil/public servants or businessmen/traders. It also shows majority are civil servant (39.0%), farmers (10.1%) and those engaging in business or trading (27.6%). These are people that are mostly affected by erosion directly or indirectly. Marital status of the respondents are mainly married men (74.4%) with majority have qualification ranging from secondary school leavers to those with tertiary institution certificates (82.8%). By summary, it shows that the affected population or people are mainly the active age group, and mostly are civil servants, businessmen and farmers.

Economic Implication of Gully Erosion

The impacts of gully erosion in Nigeria are enormous and similar to that obtainable elsewhere in the world and they include:

i) **Loss of Farmland**: A vast area of farmlands has been lost due to the menace of gully erosion while others are at their various stages of destruction leading to drastic decrease in agricultural productivity and ultimately food shortage that can lead to famine.

ii) **Treat to Vegetation**: The gully erosion in Chikun has led to loss of vegetation as its continuous expansion encroaches into areas that are hitherto forest leading to falling of trees and exposure of more surface areas to gully activities. The phenomenon if allowed to continue and remains unchecked may ultimately lead to climatic changes locally or globally.

iii) **Effect on Properties**: Several properties whose value cannot be quantified accurately here have been destroyed and others are under treat by this menace especially houses and other properties located on the floodplain. Over 10 houses have been lost in a single event of gully erosion in Chukun local Government area of Kaduna State.

iv) **Effect on Life**: Many lives have been lost as a result of the problem of gully erosion. Some either fell into these gullies and sustained various degrees of injury or died. Some instances have also been reported where people are drowned in some of the gully sites. About 20 people have been reported in the past few years to have lost their lives in a single event of gullying activities in River Romi in Anguwa Juji communities of Kaduna State. Millions of people have been displaced and evacuated their homes following the gully incidences.

v) **Loss of Land Quality:** Gully erosion has given rise to infertile and barren land that may need to be reclaimed. This usually brings untold hardship to the inhabitants and even if the land is still inhabitable but has been severely affected.

Social Implications of Gully Erosion

Extend to which the erosion has devastated the areas were measure in width and how deep by the using of measuring tape and ranging poles. We adopt the methods of gully erosion severity scales used in Hazo, *et al*. (2016) to classify the gully-affected areas as minor, moderate, or severe. Thus, the scales, according to their classification, are as follows:

"Any gully with a dimension of less than one meter (m) deep and less than one meter (m) wide, were considered as minor, a gully with a dimension of between 1m to 2.5m deep and 1m to 2.5m wide, will be considered as moderate in this study and finally, gullies that are over 2.5m deep and over 2.5m wide are considered as severe" (Hazo et al, 2016).

In the study areas for example, Kudende and Goningora that have 10.47 square kilometers and 16.08 square kilometers of landmass, respectively, are considered as having moderate gullies. Sabon Gaya that has 8.07 square kilometers of land is considered to have minor gullies.

In the structured questionnaire respondents were asked the nature of their jobs and their earnings per months. This is to ascertain whether there is a relationship between their job, income and impact of erosion in the areas. About 43.1% were self-employed (farmers, traders, etc.) and 16% are not employed currently. A majority of their income per month is below fifteen thousand N. That is to say that majority are leaving below poverty line. Furthermore, it shows that 67.8% of the respondents' source of water is by well. Since wells are normally situated at homes, 61.6% said erosion does not affect their source of water. But 61.8% agreed that it affect their business.

Causes of Gully Erosion in Chukun

Gully erosion, in the real sense of it, happened when water flows across unguarded piece of land surface. This washes away the topsoil creating drainage lines. Mostly in practice, planting trees weakens run-off, which generally holds the soil together, thereby protecting the excessive run-off and heavy rainfall that will bring environmental degradation.

While man is a principal actor in redesigning and preserving the surface of the earth, man also helped in causing instability in the natural environment and therefore, responsible for the rapid spread of environmental problems such as gully erosion.

Table 3: Social Implications of Gully Erosion.

Variable	Response	Count	Percentage
Nature of job	Self employed	214	43.1
	Govt employed	171	34.4
	Not employed	83	16.7
Income per mouth	Less than 15000 N	120	24.1
	15000-25000 N	92	18.5
	26000-35000 N	104	20.9
	36000-45000 N	72	14.5
	46000-above N	45	9.5
Size of house hold	2-5 persons	250	50.3
	6- 9persons	158	31.8
	10 and above	69	13.9
Source of water	Well	337	67.8
	Pipe water	7	1.4
	Borehole	119	23.9
	Dam	0	0.0
	River	3	0.6
	Pond	24	4.8
Does erosion affect your source of water	Yes	128	25.8
	No	306	61.6
	No idea	51	10.3
Does erosion impact your business	Yes	307	61.8
	No	109	21.9
	No idea	57	11.5

Table 4: Major Causes of Gully Erosion.

Variable	Yes		No		No idea	
	Count	Percentage	Count	Percentage	Count	Percentage
Bush burning	144	29	149	30	25	5
Surface pavement	204	41	75	15	18	3.6
Cont. cropping	169	34	116	23	3	0.6
Flooding (heavy rain)	335	67.4	14	2.8	12	2.4
Deforestation	199	40	99	19.9	14	2.8
Road constructive	285	57.3	57	11.5	11	2.2
Lack of drainage system	389	78.3	23	4.6	5	1.0
Evacuation of soil	191	38.4	95	19.1	9	1.8
Overgrazing	169	34.0	119	23.9	10	2.0
Mining activities	150	30.2	125	25.2	10	2.0
Nature soil	221	44.5	62	12.5	12	2.4

Gully erosion in the study is not different from what is obtainable globally. Table 4 summarizes the respondent's perceptions on the major causes of gully erosion in the study area.

From Table 4 above, the three major causes of gully erosion in the areas are flooding as a result of heavy rain (67.4%), road construction (57.3%) and lack of proper drainage (78.3%). All the respondents in the three selected areas believed and testified that these three variables are the major causes of gullies in the areas.

Single Linkage Cluster Analysis of the Variables

To further buttress the claim of the respondents, cluster analysis was carried out to distinguish/ discriminate the most evident features among the variables. Cluster analysis in a mathematical point of view, entails, for a given data set containing measurements on individuals, two cases are involved. The first case, we want to see if some natural groups or classes of individuals exist, and in the other case, we want to classify the individuals according to a set of existing groups.

For a given data matrix containing multivariate measurements on a large number of individuals (or objects), the objective is to build some natural subgroups or clusters of individuals or variables. Grouping individuals or variables that are "similar" according to some appropriate criterion does this. This method is statistically correct for situations in which individual observations are correlated within clusters, and multilevel models allow for inclusion of predictors at the participant and cluster level. Variables belonging to same cluster are more similar than variables belonging to different clusters (Härdle and Simar, 2000). In this study, we used agglomerative single linkage amalgamation method based on Euclidean distance measure.

If two objects or groups say, P and Q, are united, one computes the distance between this new group (object) $P + Q$ and group R using the following distance function:

$$d(R, P + Q) = \delta_1 d(R, P) + \delta_2 d(R, Q) + \delta_3 d(P, Q) + \delta_4 |d(R, P) - d(R, Q)|$$

The δ_j's are weighting factors that lead to different agglomerative algorithms. For single linkage method,

$$\delta_1 = \delta_2 = \frac{1}{2}, \delta_3 = 0 \text{ and } \delta_4 = -\frac{1}{2}$$

The single linkage method defines the distance between two groups as the smallest value of the individual distances (Härdle and Simar, 2000).

$$d(R, P + Q) = min\{d(R, P), d(R, Q)\}.$$

Table 5 shows similarities for the cluster method is displayed below. Figure 8 illustrates the natural grouping of the variables based on their similarity.

Table 5: Cluster Analysis of Major Causes of Gully Erosion

Number of Step	Similarity clusters	Distance level	Clusters level	New joined	Number of obsv in new cluster	cluster
1	10	94.2768	0.114463	3 9	3	2
2	9	93.6321	0.127358	3 10	3	3
3	8	90.0503	0.198994	3 11	3	4
4	7	89.9827	0.200347	3 5	3	5
5	6	89.8167	0.203667	3 8	3	6
6	5	89.5816	0.208368	1 3	1	7
7	4	89.5174	0.209652	1 2	1	8
8	3	81.9048	0.361903	1 6	1	9
9	2	81.5486	0.369028	1 4	1	10
10	1	75.9346	0.481307	1 7	1	11

Final Partition

Cluster 1

Bush Burning Surface pavement Cont. cropping Deforestation Evacuation soil Grazing Mining Soil nature

Cluster 2

Flooding

Cluster 3

Road construction

Cluster 4

Drainage system

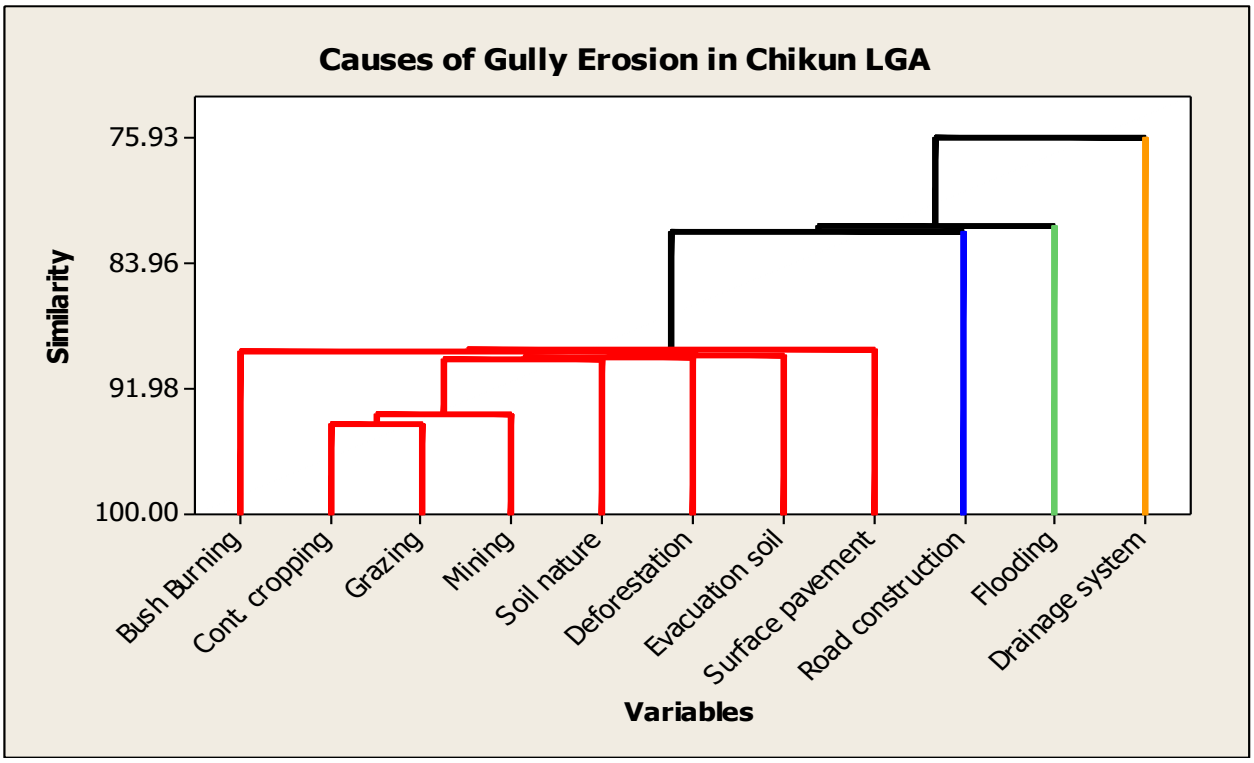

Figure 8: Dendrogram for the Cause of Erosion in Chikun LGA.

Figure 8 shows that the responses to the three variables (flooding, road construction, and poor drainage system) are independent of the other variables. This revealed there is discrimination in response to these variables. The other variables such as bush burning, surface pavement, continuous cropping, deforestation, evacuation of soil, overgrazing, mining, and soil nature are correlated in response. It shows the variables do not discriminate among themselves in all the areas.

Government, Non-Governmental Organization (NGO) and Community Intervention in Controlling Gully Erosion

Table 6 showed the level of government intervention towards controlling this menace of gully erosion. 384 (77.3%) respondents said there was no government intervention, while 79 (15.9%) of the sampled respondent posited that government intervention was adequate enough to manage the situation.

For NGO intervention, 341 (68.6%) of the respondents said there is no presence of NGO in their communities while 132 (26.6%) confirmed the presence and intervention of NGO.

On community services intervention as a control measure, 252 (50.7%) observed that there is no collective community service in controlling erosion whereas 209 (42.1%) have agreed that there is communal service. There is competitive view on whether traditional rulers do intervene on control measure, 234 (47.1%) said no while 217 (43.7%) said yes.

On the need for an enlightenment program for control measures, 292 (58.8%) said it is done on monthly basis, 159 (32%) said meeting were held on weekly basis and their mainly conducted in conjunction with Government, NGO or community (16.7%). Table 6 below summarizes the result.

Table 6: Intervention to Control Gully Erosion.

Indicator	Response	Count	Percentage
Erosion control by government	Yes	79	15.9
	No	384	77.3
	No idea	22	4.4
Intervention by NGO	Yes	132	26.6
	No	341	68.6
	No idea	12	2.4
Community services for control measures	Yes	209	42.1
	No	252	50.7
	No idea	24	4.8
Frequently community services	Weekly	5	1.0
	Monthly	37	7.4
	Yearly	81	16.3
	Once in a while	51	10.3
	When deemed necessary	96	19.3
Traditional rulers in fighting erosion	Yes	217	43.7
	No	234	47.1
	No idea	30	6.0
Enlightenment program for control measure	Weekly	159	32.0
	Monthly	292	58.8
	Yearly	30	6.0
	Once in a while	0	0.0
	When deemed necessary	0	0.0
Responsible for enlightenment program	Government	16	3.2
	NGO	16	3.2
	Both government & NGO	48	9.7
	Community Services	79	15.9
	All of the above	83	16.7

Table 7: Community Efforts in Controlling Gully Erosion.

Indicator	Yes		No		No idea	
	Count	Percentage	Count	Percentage	Count	Percentage
Dam construction	102	20.5	178	35.8	90	18.1
Building embankments	146	29.5	145	29.2	71	14.3
Tree planting	193	38.8	126	25.4	43	8.7
Controlling overgrazing	201	40.4	99	19.9	67	27.0
Discourage continuous cropping	147	29.6	181	36.4	41	8.2
Building drainage system	310	62.4	29	5.8	40	8.0

Community Control of Gully Erosion Adopted in the Regions

Despite these several control measures by government and NGOs, they failed to address the challenge of gully erosion in Chukun LGA. These are mainly due to inefficiencies in designing proper structures and lack of commitment in the part of the government to take action. These reasons prompted the researchers to go into finding out the indigenous control measure adopted by the communities. Table 7 summarizes the outcome of the investigation.

From the above table, it is obvious that building drainage system is the most popular strategy to control gully erosion (62.4%). This is followed by controlling overgrazing (40.4%) and tree planting (38.8%). The result of Table 7 is further confirmed by performing cluster analysis on the variables. Table 8 and Figure 9 below showed the final partition of the variables. Except building drainage that seems to be on its own, response of the other variables are correlated. Building drainage system seems to the option that is more popularly and independently adopted in the areas.

Table 8: Cluster Analysis of Community Base Control Measure.

Number of Step	Similarity clusters	Distance level	Clusters New level	Number of obs in new joined		cluster	cluster
1	5	92.6833	0.146333	3	4	3	2
2	4	91.5989	0.168023	3	5	3	3
3	3	89.3535	0.212929	2	3	2	4
4	2	87.5421	0.249157	1	2	1	5
5	1	86.8903	0.262194	1	6	1	6

Final Partition

Cluster 1

Dam construction Embarkments Tree planting Controlling overgrazing Stop continuous cropping

Cluster 2

Building drainage

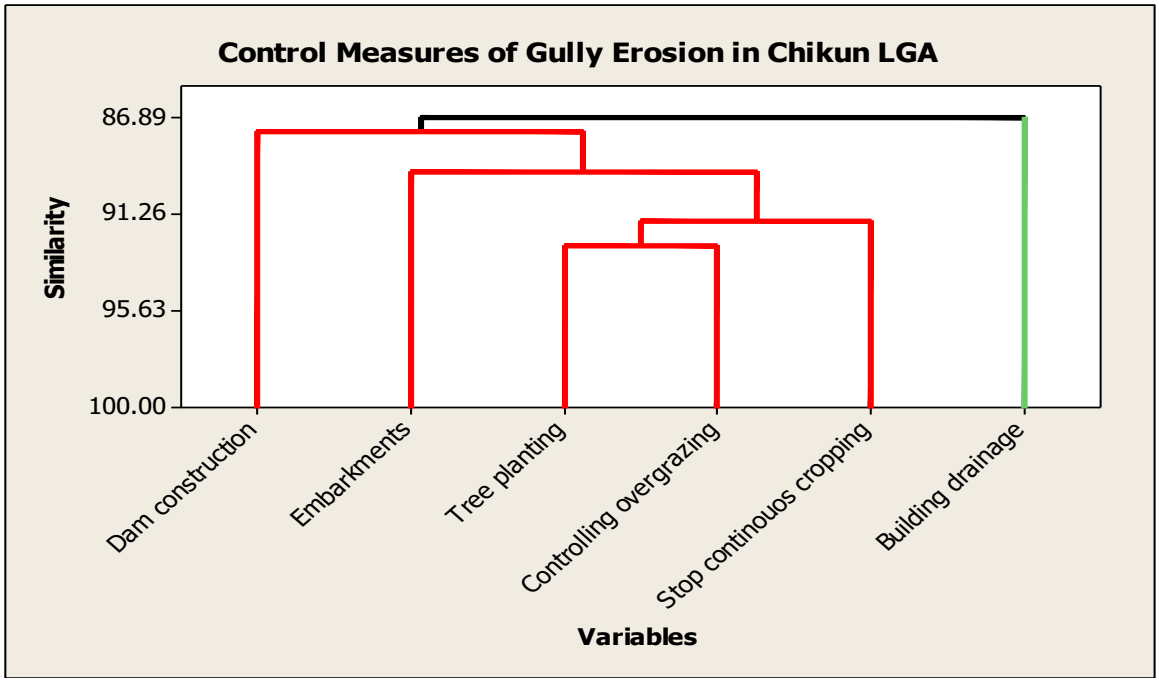

Figure 9: Dendrogram for Community Based Control Measure of Gully Erosion.

CONCLUSIONS AND RECOMMENDATION

Gully erosion is identified as the most threatening environmental hazard in Chikun Local Government Area. Information from stakeholders in the region stated that the origin of gully erosion is traced to some 30 years when the development of the region began. Human activities such as soil evacuations for buildings and physical activities such as torrential rains are the major causes of erosion in the region. This, happening over years, and not being well managed, has resulted in gullies in the region.

The scope and coverage of the study area in Chukun LGA comprises of Kujama, Goni-gora, Kudendan and Sabogaya. 550 copies of a structured questionnaire (110 to each of the four communities (study clusters)) were administered. The fewer number was due to time factor and security challenges and to ensure high response rate. In this study a simple descriptive method of analysis was employed, and non-deterministic cluster method approach was used to display the prevailing menace of gully erosion in the study area with the aim to reduce the social, ecological, and economic impact caused by the erosion.

The study has brought out the effects of the prevailing gully erosion affecting the socio-economic life and environmental impact of the study area and proper suggestions on ways to control it. The study found that government agencies, NGOs, traditional institutions, and community-based interventions in tackling erosion are almost below expectation. It was observed that the economic constraints of the people have mitigated in combatting the erosion. Another problem identified is the low level of educational status of the people posed greater challenge to proffer solution to erosion problem in the study area. As such, gully erosion can now be seen as a socio-economic and environmental problem that needs to be tackled with the entire exigency the problem portends, using available cost-economic beneficial measures. Hence, the following recommendation are suggested which would help restored the lost surface of the land and provide a control measure for the erosion.

I. There is the need to embark on building drainage systems, bush fallowing, embarking on massive tree planting (especially economic trees), and so on by the local communities.

II. Government, NGOs, traditional rulers, and religious leaders should embark on an enlightenment and sensitization campaign on the impact of gully erosion to the communities affected.

III. Due to rapid growth in population that resulted into soil evacuation for road construction, buildings and farming, this brings pressure on vegetation cover. As such, erosion is increasing exponentially. Therefore, biological methods (e.g. reforestation) and mechanical methods (e.g., construction of debris dams) are highly encouraged

IV. Government and stakeholders at all levels should train specialists in erosion management and control.

V. Federal Government should provide intervention through credit facilities, to boost the financial status of the people so that control measure of the erosion would be a function of all.

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