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FACTORS OF GULLY EXPANSION IN DAURA GULLY SITES IN DAURA LOCAL GOVERNMENT AREA OF KATSINA STATE, NORTH-WEST NIGERIA

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ABSTRACT

This study explored and examined the relationship between the variables controlling gully expansion and the rates of gully expansion in Daura Local Government Area of Katsina State, North West of Nigeria. Rainfall data for Daura from 1990 to 2020 was acquired from NiMet, Abuja. Using the Global Positioning System, field measurements and satellite pictures in the gully zone of Daura LGA were used to determine topographic and soil characteristics. Data on rainfall trend, total annual rainfall, and yearly trend were extracted and utilised to demonstrate the trend of rainfall events in the area. The 30-year period from 1990 to 2020 was used to analyse the study area's changes in land use and land cover. Results show that government intervention has helped in the increase of vegetation cover of Daura LGA from 0.14% in 1990 to 6% in 2020 but the vegetation increase has not been enough to prevent gully erosion in the study area. It was recommended that there should be continuous afforestation through tree planting campaign by the Katsina state government and Daura LGA authorities to increase the area with enough vegetation cover that can prevent or withstand subsequent gully occurrences.

Keywords: Daura LGA, Erosion, Gully Expansion, Rainfall Intensity, Soil variable.

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INTRODUCTION

The earth crust is usually continuously subjected to forces of change by both natural and human processes. Some of these forces act internally within the earth crust to give rise to the major inequalities of the earth while others act externally to rectify the inequalities of the earth's relief features and the interaction of these forces give rise to the various landforms that exist on the earth surface (Ofomata, 2008). The natural processes are called denudation and they come with various forces such as; earthquakes, slumps, erosion and landslides etc. They reduce the earth landscape from rugged mountains to plains throughout the world especially in places where these forces act negatively.

Serious environmental deterioration is plaguing Sub-Saharan African nations, leading to soil erosion, drought, and desert encroachment. This is caused by either wind impact or extremely high, intense rainfall, which causes massive runoff and soil loss. The issues have had a negative impact on agricultural output, raising concerns about the region's food security. The zone's social and ecological contexts are frequently skewed, which can occasionally result in losses of material and human resources. In due course of time, as the earth's population grow, it also became clear that human beings could also bring about changes on the earth's surface through various land uses (Ofomata, 2001a). This concept of landscapes changes by man was formalized by the members of the German School of Geography. They classified land as the primary landscape or urlandschaft and graded into the human landscape – the cultural landscape called kulturlandschaft (Ofomata, 2001b). The denudation of the landscape proceeds through weathering, erosion and all forms of gravity-controlled processes (Surmmerfield, 2000).

The main environmental issues in Nigeria, particularly in Northwestern Nigeria, are desertification and aridity, which allow for heavy rainfall and strong winds to create an environment that is conducive to catastrophic soil erosion. These denudational processes are considered to be the primary cause of landscape change in Northwestern Nigeria (Ofomata, 2008). The main environmental issues facing Katsina State include erosion, desertification, drought, and flooding. They pose huge threats to essential infrastructure including roads, power and electrical facilities, housing and farmlands amongst others. Aminu and Jaiyeoba (2015) highlighted that Katsina State being one of the frontline states neighboring Niger Republic, has its own peculiar environmental issues. However, the major landscape changes in the landscape of Northwest Nigeria and especially Daura Local Government Area of Katsina State is Gully erosion menace. Because of this, Daura's environmental problems are interconnected and mostly the result of local residents' deeds and inactions. The majority of these are related to climate change, overgrazing of animals, building on waterways, needless tree cutting, and excavating land for structures and construction (Aminu & Jaiyeoba, 2015). The loss of agricultural lands, ancestral homes, and other infrastructure are due to the hazard, this massive environmental degradation problem has had a negative impact on the socioeconomic well-being of the residents of Katsina State's Daura Local Government Area.

The erosional process is modified by biophysical environment comprising soil, climate, terrain, ground cover and interactions between them. Gully erosion menace is mainly induced by the occurrence of running water, gravity, use and management of soil, topography alongside other factors.

The gully erosion in Daura Local Government Area of Katsina State has remained active over the years, claiming people's properties and agricultural lands and has been declared national disaster due to its size and its continuous widening, defying various control measures put in place by individual, communities, government etc. It is known that various factors contribute to the course, expansion and growth of the gully erosion in Daura ranging from physical to anthropogenic factors. Therefore, the research focuses on examining the main causes at play on the site and the rate of gully expansion in the Daura Local Government Area of Katsina State, while also addressing the numerous physical and anthropogenic elements that contribute to the cause of the gully in the area.

LITERATURE REVIEW

According to Okeke and Enwelu (2010), soil erosion is the separation and movement of soil caused by natural forces such as gravity, ice masses, flowing water, and wind. It typically takes three forms: sheet erosion, gully erosion, and rill erosion. The threat of gully erosion is mostly caused by gravity, running water, soil usage and management, terrain, and other factors. Additionally, the path deepens into trenches known as gullies as the runoff velocity rises (Renschler et al., 1999). Even when the region is experiencing desert encroachment, the intensity and duration of rainfall in Northwestern Nigeria has had a significant impact on the landscape, slope stability, and other geomorphological structures of the area. This is because vegetation cannot withstand the velocity of flowing water, which leads to gully erosion. According to Ehiorobo and Audu (2012), gully erosion happens when floods flow extremely quickly and energetically, removing and moving soil particles down hillslopes. Gully formation or expansion is ultimately caused by the amount of soil particles that are dissolved, displaced, and transported, which increases with rainfall rate (Chimelu et al., 2013; Labriere et al., 2015).

Researchers have identified a number of reasons that have contributed to the increased prevalence of soil and gully erosion (Ofomata, 1985, 2008; Egboka & Okoro, 2007; Mozie 2010; Ajearo & Mozie, 2011; Aminu & Jaiyeoba, 2015; Igwe et al., 2017). The nature of the surface and subsurface layers (solum), the climatic features like rainfall intensity and runoff, the pedology, the geology, the hydrogeology, and the geotechnical features of the regions, as well as the impact of human activities on the natural and geologic processes, are some of the causative factors that interact with one another (Igwe, 2012; Aminu & Jaiyeoba, 2015; Igwe, 2018; Nwakanma et al., 2018).

The factors linked to gully erosion work together to alter or deteriorate the environment's landscape. Additionally, they can operate independently to harm the ecosystem. The dearth of research on the mechanisms and failure processes in the region may be a contributing factor to the containment efforts' repeated failures. Several workers (Osadebe et al., 2014; Okeyeh et al., 2014; Okengwo et al., 2015; Igwe, 2018) have researched on the causes and effects of the gully erosion in southeastern Nigeria but at present, there is no detailed quantitative and specific study devoted to gully erosion in Northwestern Nigeria and especially the Daura gully in relation to the rate of gully expansion, the causative factors and their significant effect on gully development.

Daura town is situated in Daura Local Government Area of Katsina State in northwestern Nigeria. Daura is located near the Niger Republic border, and is approximately centered on latitude 13° 06' N and longitude 08° 21' E. Fig 1: Daura Local Government Area. Source: Google Earth, 2024.

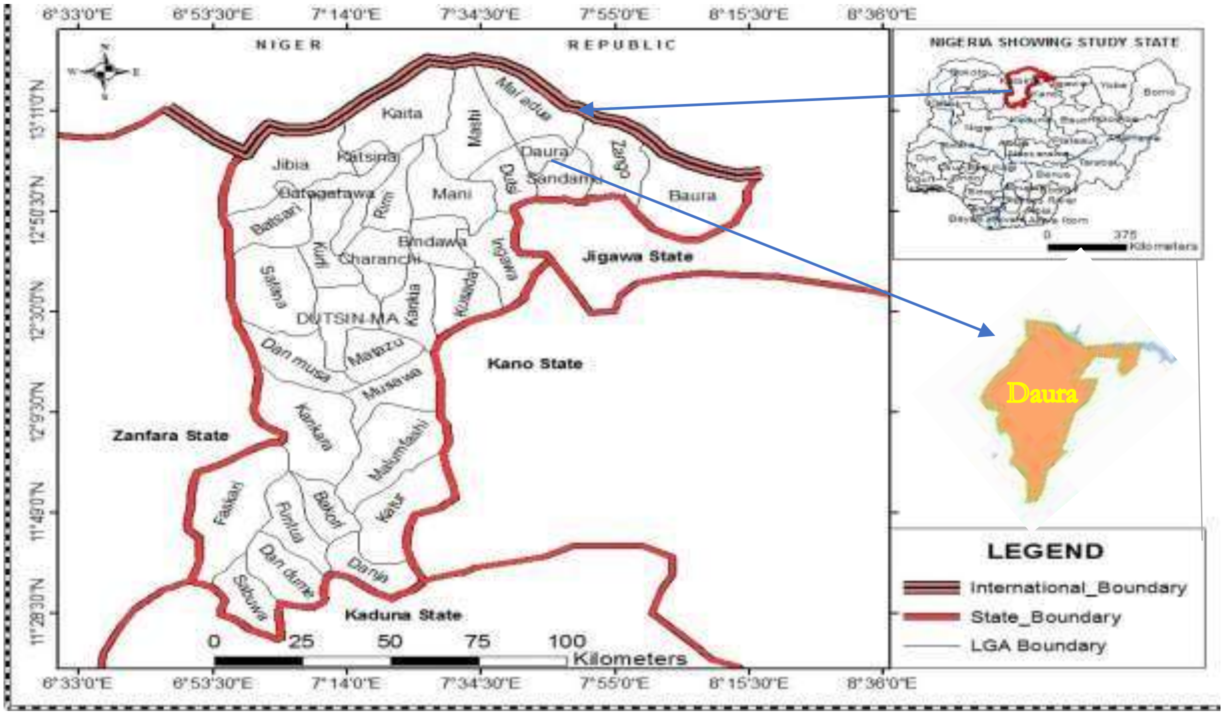

Figure 1: Katsina State showing Daura Local Government Area. Source: GIS unit, Department of Geography and Environmental Sustainability, UNN.

Daura has a tropical climate with a distinct rainy season and temperatures ranging from 18.5°C in the cool season to 39.5°C in the hot season and it is roughly 1.43% higher than Nigeria averages. Every year, Katsina experiences 54.63 rainy days (14.97% of the time) and approximately 791.61 millimetres of precipitation (Monthly Weather Averages and Historical Data, 2023). Three agroecological zones are covered by Katsina state: the Northern Guinea Savanna, which has wet and savanna soils, the Sahel, and Sudan (Mohammed et al., 2023). Semi-arid steppe types designated AW and BS coexist with a tropical wet and dry climate (Umar et al. 2021). Daura LGA in Katsina state experiences 350–1000 mm of rainfall annually, with temperatures ranging from 290-310 degrees Celsius (Idris et al., 2019). High inter-annual variability in both spatial and temporal dimensions of the zone's rainfall pattern frequently result in severe and pervasive droughts.

Boreholes in the sedimentary terrain of Daura explore shallower aquifers, while boreholes in the Basement Complex rock terrain explore deeper aquifers. In Daura, the main products traded locally are cotton, peanuts, sorghum, millet, onions, hides, and skins. In Daura, gathering peanuts and weaving cotton are important economic pursuits. The population of Daura Local Government Area in Katsina State, Nigeria was estimated to be 401,900 in 2022. The population density was 1,849 people per square kilometer, and the annual population change between 2006 and 2022 was 3.7% (NBS, 2022).

METHODOLOGY

Data Collection

This research was based on primary and secondary data. The primary data would be based on field survey and photographs. A reconnaissance survey was conducted on the study area by the researchers to verify and examine the factors and consequences of the gully erosion in the study area. The primary data that was collected include the location of coordinates which will be collected with the use of Global Positioning System (GPS), field survey and soil sample collection. The secondary data were also used in the research work and they include the use of Land SAT Imagery which was created to present a view of the scenario of gully growth, and topography of the study area. Also, average annual rainfall for 30-year period (1990 - 2020) for Daura Local Government Area of Katsina State was collected from the Nigerian Meteorological Agency Abuja.

The Meteorological Information containing rainfall data of a period of thirty (30) years between 1990-2020 of the study areas were collected from the Nigeria Metrological Agency Station (NiMeT) in Abuja. This data was analysed to understand the rainfall pattern, and fluctuation of rainfall in the study area so as to analyse the trend and effect of moisture supply to the rate of the gully expansion as rainfall events are among the most important factors inducing soil erosion and landslides (Igwe et al., 2017).

Soil Sampling

The subject of observation is the soil and it is mainly collected by sampling. In geomorphological theory, Belcher (1942) and Mozie (2010) stated that soils formed from similar geologic substrates, under similar environmental conditions and climate will have similar properties, and exhibit similar behaviour to external forces. The soil samples were collected within geologic and slope land classes revealed on the gully walls in the gully site ranging from 1meter to 30meter (Osadebe et al., 2014; Okengwo et al., 2015). As a result of the unconsolidated nature of the sediments (Igwe, 2018), sample collection was quite easy and a total of eight (8) samples were collected, four samples each from the two arms of the gully walls in Daura LGA. The points collected includes – a) Top soil - clayey sand and partially laterite layer of 1.0-1.5m thick, b) –top middle layer - sandy and fine sands, c) a lower middle layer- wet sandy sand and (d) bottom layer. The vertical soil sampling on the gully walls was to ascertain changes on soil properties down the soil profile (Okengwo et al., 2015). The soils were collected using cores and stored in plastic bags. The engineering attributes (particle size aggregate (PSA), hydraulic transmissivity, porosity, and soil strength parameters, etc.) of these newly taken representative samples from the gullies were examined in a lab. The identification of parameters and factors influencing the initiation, velocity, and deposition of debris, assist soil analysis plays a crucial role in modelling slope motions and enhances our understanding of soil failure mechanisms (Igwe, 2018).

Along with examining the behaviour of the soils at various normal stresses and strengths in accordance with Wang et al. (2002), Wang et al. (2003), and Iverson et al. (2010), it also assesses the shear resistance-displacement behaviour, pore pressure development, effective stress characteristics, and natural moisture content of the soils.

The slope angle of the study area was also collected via Google imagery archives (2018). Since the length of the slope and the amount of soil erosion are proportionate to the slope's steepness, this is done because relief and soil erosion have a positive relationship (Ofomata, 1985). Additionally, gully formation and soil loss are frequently greatly influenced by the slope geometry of hill sides, specifically whether they are convex or concave (Lal 1976; Ofomata, 1985; Igwe, 2012).

Therefore, the Digital Elevation Model (DEM) of the study area, obtained from the SRTM (Shuttle Radar Topography Mission) for 2020 was created using geographic information system tool, to present a view of the topography of the study site. In order to convey the geologic condition of the research area below the surface, the SRTM collection was utilised due to its high-resolution topographic database and specially customised radar system, which determine the area's elevation and slope angles (Ayadiuno, 2014).

Land satellite imageries of the gully area were used to digitalize the exposed gully surfaces using the Q-GIS software in order to get the rate of gully expansion over time reviewing the Land SAT imageries of year 1990, 2000, 2010 and 2020, of the study area. This is done in order to derive the rate of gully expansion in the gully sites.

Data Analysis Method

The data analyses in this study are well in line with the objective of the study. The rainfall data were analysed using the SPSS software (statistical packages for social sciences) version 20 which ran the regression analysis and produce a trend of rainfall pattern using a two-year filter. The annual mean trend of rainfall from 1990-2020 was used as the data for computation of the analysis. The land use and land cover analysis were analysed through the use of Land Satellite imageries to determine the ratio of built-up, housing index, bare land, vegetated area and gullied area. This is done to know the rate of human influence on the natural landscape. The topography, and rate of gully expansion were obtained through analysis of the digital elevation model (DEM) and satellite imageries using the Quantum-GIS software (Ayadiuno, 2014).

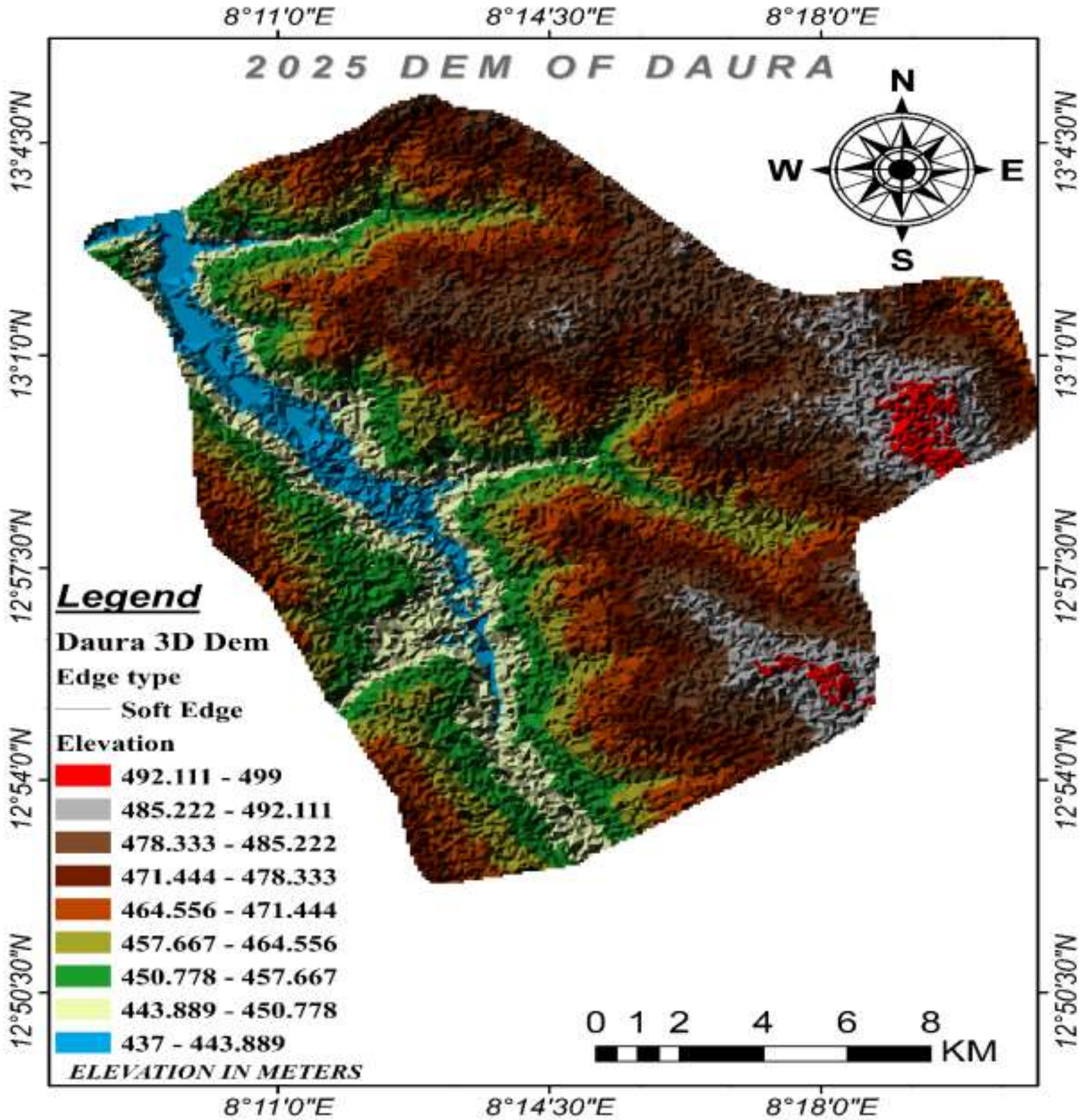

Figure 2: Year-2020 Digital Elevation Model of Daura LGA of Katsina State
Source: GIS Unit, Dept. of Geography and Environmental Sustainability, UNN.

RESULTS

The results and the interpretation of the variables such as the trend of rainfall in the study area, the soil stratigraphy, geology, topography, land use, land cover evidence and the area of gully expansion over the years in the study area are reported in this section.

Table 1: Annual Rainfall Characteristics of Daura LGA of Katsina State and other neighboring communities for 30- year period

S/N	Year	Rainfall (mm)
1	1990	541.5
2	1991	300.2
3	1992	333.1
4	1993	262
5	1994	473.2
6	1994	431.1
7	1996	259.8
8	1997	473.1
9	1998	431.6
10	1999	397.9
11	2000	676.6
12	2001	699.1
13	2002	726.2
14	2003	599.6
15	2004	698
16	2005	882.6
17	2006	711.4
18	2007	1310.2
19	2008	505.5
20	2009	473.8
21	2010	929.5
22	2011	572
23	2012	698.7
24	2013	663.8
25	2014	481.5
26	2015	598
27	2016	482.7
28	2017	676.1
29	2018	774.2
30	2019	696.2
	Annual Average rainfall	**595.3**

Source: NiMet (Abuja)

The mean annual rainfall for Daura LGA of Katsina State from 1990 to 2019 was calculated to be 591.3mm. The highest rainfall for Daura LGA for the 30-year period is 1310.2mm and this was observed in year 2007 while the lowest rainfall 259.8mm occurred in the year 1996. The annual average/mean rainfall for Daura LGA was found to be 595.3mm.

In major gullying cases, the main triggers to gullying and slope failures is heavy and prolonged rainfall. Generally, the sequence occurs through intense rainfall events which generate strong surface runoffs that remove considerable quantities of soil and bedrock which are inherently weak because of their low strength which is about 18kPa or less (Brady & Weil, 2016). The rainfall weakens the soil fabric making them prone to failure by gravity pull down the slope as landslides. The Daura rainfall though usually of short duration, come with intense pressure that create enormous gully on impact with the soil. This is because of the elevation of the study area which has very high elevation as was shown in the Digital Elevation Model of the area (Figure 2). The high elevation allows for high flow velocity of the flood thereby triggering gully erosion. The trend of the variation in rainfall data for the study area from 1990- 2019 was computed using the Statistical Package for the Social Sciences (SPSS) software version 20.

Some of the Erosion Sites at Daura Local Government Area of Katsina State

Figure 3: Gully site at Sadanmu Area of Daura LGA

Figure 4: Gully site at Mazoji Area of Daura LGA

The mean annual rainfall distribution was observed throughout the 30-year period and it was observed that the continuous receipt of rainfall, the wetting of the slopes, the increase in the amount of water that percolates through the sediment porous formation to the impervious shale to issue contact springs increases the erosion of the valley sides and the basal flow of the streams causes eating up of the base area of the valley thereby causing a basal sapping and ultimate collapse of valley wall and hence, expansion of the gully. No one single rainfall is responsible for landslides instead several rains come promoting the continuous weathering and disintegration of the hill sides and valley sides preparing them for events that will cause their failure.

The annual fluctuations in rainfall are also clearly brought out thus reinforcing the fact that rainfall differs in occurrence from year to year. The region receives rainfall from the south west tropical maritime airmass, and from the annual analysis it shows that the area receives an average annual rainfall of 595.3mm but with intense duration whenever it rains. Studies of landslides by which the gullies expand indicates a preparatory stage of the creation of a weathered mantle called Regolith which is influenced by the annual impact of rainfall which subjects them to continuous softening, deep rotting of rocks and sand stones in the area of geologic weakness, resulting in slumping, slides, faults and eventually to expansion of the gullies in many locations including the Daura gully site.

The Anthropogenic Factors that lead to Expansion of Gully Erosion in the Study Area

Through agricultural techniques and other land use activities, humans have significantly accelerated runoff, contributed to and encouraged the collapse of soil structure, and caused soil loss (Ofomata, 1981). In the humid tropics, the problem of inadequate agricultural systems and unplanned, uncontrolled grazing usually involves the destruction of flora through forest fires and land clearing for cultivation. The relative proportions of infiltration and runoff are greatly altered by this method, and when vegetation is destroyed more frequently, the risks of erosion increase. When this occurs, the natural water channel becomes blocked or altered due to decreased infiltration and increased runoff.

Also, extensive deforestation occurred as forest are cleared for agricultural purposes, animal rearing, road construction and urban development thereby leaving the area devoid of vegetation, exposing the soils and rocks to severe gulling (Egboka & Nwankwo, 1985; Ofomata, 1987). On the other hand, the various land use activities by man such as; surface mining, road building, urbanisation, industrialisation and general infrastructural development amongst others results in the development and expansion of soil erosion as it deprives the soil surface of its vegetation and also contribute directly to sliding (Ofomata, 1966), slumping, sheet erosion and gullying (Ofomata, 1981).

Land Use and Land Cover Changes in the Study Area for 30-year Period

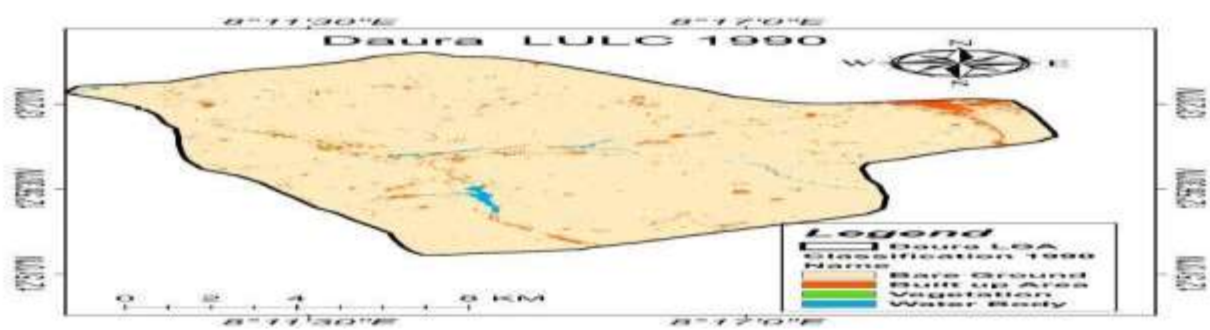

Figure 4: Landuse and Lancover changes of Daura LGA for the year 1990. Source: GIS unit, Department of Geography, University of Nigeria, Nsukka

Table 2: Result of Landuse/Landcover of the study area for 1990

1990	km2	
Name	Sum of Area	Percentage
Bare Ground	300.4677	95.83%
Built up Area	10.4463	3%
Vegetation	0.4356	0.14%
Water Body	2.1825	1%
Grand Total	**313.5321**	**100%**

From Table 2, Bare ground was 95.83% or 300.47km^2 while vegetation was 0.14% or 0.4356km^2. Also, built-up area is 10.4463km^2 or 3% of the total area of Daura LGA. This shows that the environment of Daura LGA as at year 1990 is almost with zero vegetation. This is attributed to anthropogenic factors of animal grazing, bush clearing and bush burning for farming purposes. These human activities invariably leave the land bare giving rise to extensive gullying during the rainy season.

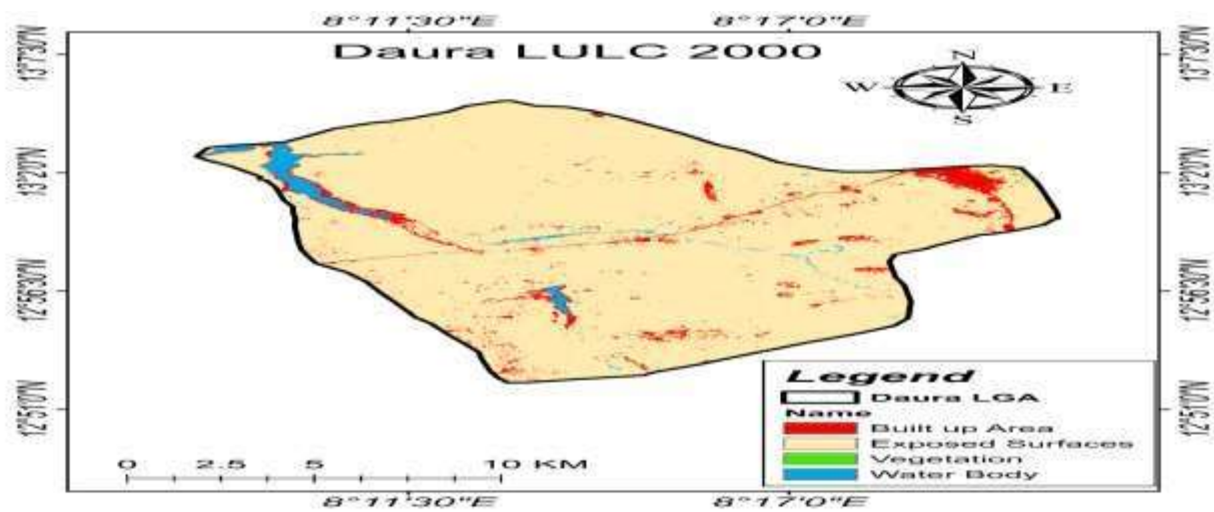

Figure 5: Landuse and Lancover changes of Daura LGA for the year 2000. Source: GIS unit, Department of Geography, University of Nigeria, Nsukka

Table 3: vegetation map of year 2000

2000	km2	
Name	Sum of Area	Percent
Built up Area	14.4162	5%
Bare ground	291.9051	93%
Vegetation	1.0008	0.32%
Water Body	6.21	2%
Grand Total	**313.5321**	**100%**

In the year 2000, the built-up area increased to 14.4162km^2 or 5% of the total area of the study area as a result of population increase as many people are migrating into the urban area of Daura LGA. There is an increased in vegetation to 0.32% form 0.14%. This may be due to the intervention of the Katsina State Government in fighting desert encroachment in all areas of Katsina State. Also, there was a reduction of the bare ground from 95% to 93%. This gave room for the small increase in the vegetation increase in the study area as a result of the Katsina State's government intervention in fighting desert encroachment in the State.

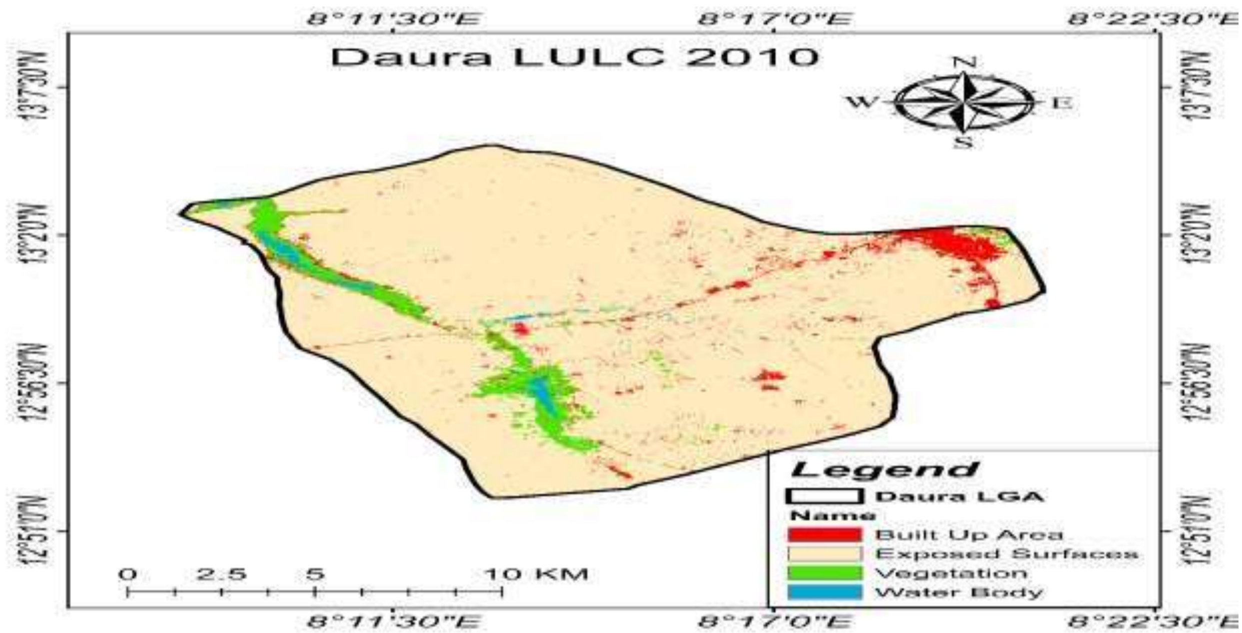

Figure 6: Landuse and Lancover changes of Daura LGA for 2010. Source: GIS unit, Department of Geography, University of Nigeria, Nsukka

Table 4: vegetation map of year 2010

2010	Km2	
Name	Sum of Area	Percent
Built Up Area	13.1436	4%
Bare ground	282.5973	90%
Vegetation	15.1209	5%
Water Body	2.6703	1%
Grand Total	**313.5321**	**100%**

From the vegetation map of year 2010, Katsina State's government intervention in fighting desert encroachment was seriously gaining ground as there was a great increase in vegetation area from 1.008km^2 or 0.32% in year-2010 to 15.1209km^2 or 5%. This increase in vegetation showed the positive rating of the Katsina State government intervention in the control of desertification and gully erosion. The bare ground decrease from 291.9051km^2 93% in year2000 to 282.5973Km^2 or 90% in year-2010. Though the vegetation increase in the state is too meagre to prevent gully erosion. More and concerted efforts should continue be made in the management of gully erosion in Daura LGA of Katsina State.

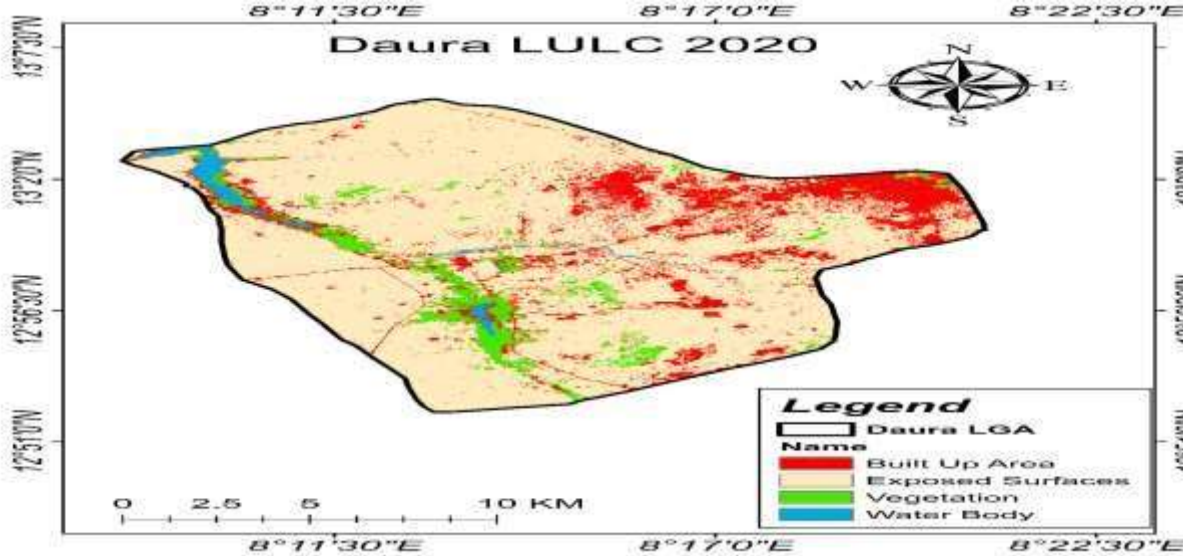

Figure 7: Landuse and Lancover changes of Daura LGA for 2020. Source: GIS unit, Department of Geography, University of Nigeria, Nsukka

Table 5: vegetation map of year 2020

2020	**Km2**	
Name	Sum of Area	Percentage
Built Up Area	45.3762	14%
Bare ground	243.8757	78%
Vegetation	19.035	6%
Water Body	5.2452	2%
Grand Total	**313.5321**	**100%**

In 2020, there was a slight increase in vegetation from15.1209Km^2 or 5% in 2010 to 19.035km^2 or 6%. The built-up area in the study area increased from 13.1436Km^2 or 4% to 45.3762Km^2 or 14%. This shows increased in urbanization and rural – urban migration from other areas to Daura LGA. Bare-ground decreased also from 282.5973Km^2 or 90% to 243.8757Km^2 or 78%. The vegetation increases of just 6% of the total land area of the Daura LGA is not enough to curb gully erosion in Daura LGA despite government efforts to drastically reduce desert encroachment and gully erosion in Daura LGA. Basically, more efforts are needed in fighting human encroachment into the forest. This is because, the rate of vegetation increase is not enough in curbing gully expansion since bare-ground has enormous percentage will allow gullying since not much vegetation is available to control gully expansion in Daura LGA of Katsina State.

CONCLUSION

The results show that gully erosion in Daura LGA is an active gully and catastrophic environmental disaster which is being affected by environmental factors and anthropogenic factors. The results show that gully erosion in Daura LGA is as a result of intermittent and intense rainfall, overgrazing and other environmental factors. It expands through the mechanism of basal flow which leads to mechanism of basal collapse, thereby inducing loss of farmlands and properties to the indigenes of Daura LGA of Katsina State.

Recommendations

It is recommended that:

- There should be continuous practice of afforestation through government intervention and awareness to the inhabitants of Daura on the best way to manage gully erosion in Daura LGA.
- There should also be continuous tree planting campaign by the Katsina state government and Daura LGA authorities to increase the area with enough vegetation cover that can prevent or withstand any gully occurrence.
- People should be discouraged from building on flood channels to avoid excessive flooding that leads to gully erosion.

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