A Spatial Assessment for the Extent and Severity of Gully Erosion in Dawakin-Tofa LGA, Kano State

[1]Amir Abdulazeez, [2]Faisal K. Sani & [3]Habibu B. Labaran
[1]Department of Geography & Regional Planning,
Federal University, Dutsinma, PMB 5001,
Katsina State. Nigeria.
[2&3]Department of Biological Sciences,
RMK College of Advanced and Remedial Studies,
T/Wada, Kano, State.
abdulazeezamir@hotmail.com

Abstract
An integrated approach with Geographic Information Systems (GIS), fieldwork techniques and secondary data was adopted to assess the severity and map out the spatial extent of the menace of gully erosion in Dawakin-Tofa Local Government Area. The coordinates of 19 gully sites were taken and imputed into a GIS environment (ArcGIS 10.2) to show the distribution of gully sites. Landsat TM, Quickbird and SPOT V Satellite imageries were processed and interpreted to produce spatial extents of three major gully sites; Rarun in Dawakin-Tofa, Romi gullies and 'Yan Shado in Marke. The Digital elevation model (DEM) was used to show how topography affected gully erosion in the area which showed patterns related to various land use practices as well. Over a six year period, area of gully profiles in Dawakin-Tofa range between 0.5 km^2 in 2008 to 6.2 km^2 in 2014, representing an increase of 5.7 km^2. Gully depth also witnessed increase from 6.1m to 11.8m leading to devastating consequences on roads, farmlands and vegetation. Field survey revealed abstinence from gully prone areas as the major adaptation strategy of the people. The research recommended Agricultural practices like strip cropping, contouring, terracing, cover cropping and mulching can be employed by the farmers so as to protect bare land and agricultural land and accurate spatial prediction of certain erosion input by the Kano State Ministry of Agriculture.

Key Words: *Gullies, environment, erosion, land use, land cover and mapping*

1.1 Introduction

Gullies as the most severe and chronic form of soil erosion are some of the greatest global and local environmental issues, past and current. They represent some of the most destructive form of erosion, destroying soil, undermining infrastructure, damaging farm lands, altering transportation corridors and lowering water tables (Valentin *et al.*, 2005). Socio-economically, gully erosion results in land deterioration and lowering agricultural productivity and promotes serious land degradation; physio-environmentally, it affects sediment budgets and flux rates, and influences stream dynamics.

In Nigeria, the impacts of gully erosion have been quite devastating across different parts of the country. Consequences of the menace have led to the displacement of communities, destruction of infrastructure and farm lands. Generally, aside natural denudational forces, human activities like deforestation, overgrazing, poor drainage networks, blockage of water ways, sand mining and poor urban planning have been identified as either the primary causes or accelerators of gully erosion.

The Nigerian environment is degraded through improper management and other human activities. Part of the problem is the creation of badlands condition in many areas of the country. People's life were lost to erosion, equally an average of 14, 862.8m^3 volume of soil between 1992 to 2002 were lost to erosion (Shu′aibu, 2002).

In Kano, areas particularly eastern part of the metropolitan Kano that include; Tsamiyar Matasa, 'Yankaba, Walalambe, Wuro Bagga, Tudun Fulani, Tokarawa, Gunduwawa, Tudun Murtala, Rimin Kebe, Gayawa, Maidile, PRP, Tsamiyar Tudu, Kawo Kureke, Dangwauro, Wailari, 'Yan Shana, Maradin and North Eastern by-pass are examples of areas in which erosion has led to the collapse of many houses and some are in imminent danger. Animals and children have died because of falling into deep gullies (Mallam, 2008).

Dawakin-Tofa local Government area in particular is one of the areas that are affected by gully erosion in Nigeria. The problem had developed gradually over time with increase in population, intensive land use and rapid urbanization of the area. This research aims to examine the extent and severity of the problem in order to proffer solutions that will help in curbing the menace. The resultant need to predict gully occurrences, its extent and severity has led to the development of spatial and temporal methodologies in assessing the menace. Such approaches are quite lacking in gully erosion researches in the study area. In developing a sustainable remediation procedure, an assessment of gully erosion through a spatial mapping of the areas vulnerable to gully formation is necessary.

1.2 Materials and Methods

1.2.1 Description of Study Area

Dawakin-Tofa, the Local Governments under consideration, lies between latitudes 11^0 90^1 and 12^0 27^1 North and longitudes 8^0 20^1 and 8^0 52^1 East with a total area of 479km^2. It is bordered to the North by Bichi Local Government Area, to the East by Makoda, Minjibir and Ungoggo Local Government Areas, to the South by Tofa and to the West by Bagwai Local Government Area (fig. 1).

1.2.2 Data Used

The types of data used in this study are both primary and secondary which were sourced from, field measurements, observations, satellite imageries, oral interviews, and questionnaire survey.

Satellite Imagery: The Satellite images used are; 2010 Landsat Thematic Mapper (TM) data (28.5m resolution), obtained from the United States Geological Survey (USGS); 2008 SPOT-V Multispectral data (20 m resolution) and Quickbird (2014) image data obtained from the Global Land Cover facility (GLCF) free database.

Digital Elevation Model: Digital Elevation Model (DEM) was sourced from the Shuttle Radar Topography Mission (SRTM) downloaded directly using Global Mapper 12. The DEM was used to produce the elevation map of the area in order to establish the relationship between gully erosion and nature of topography.

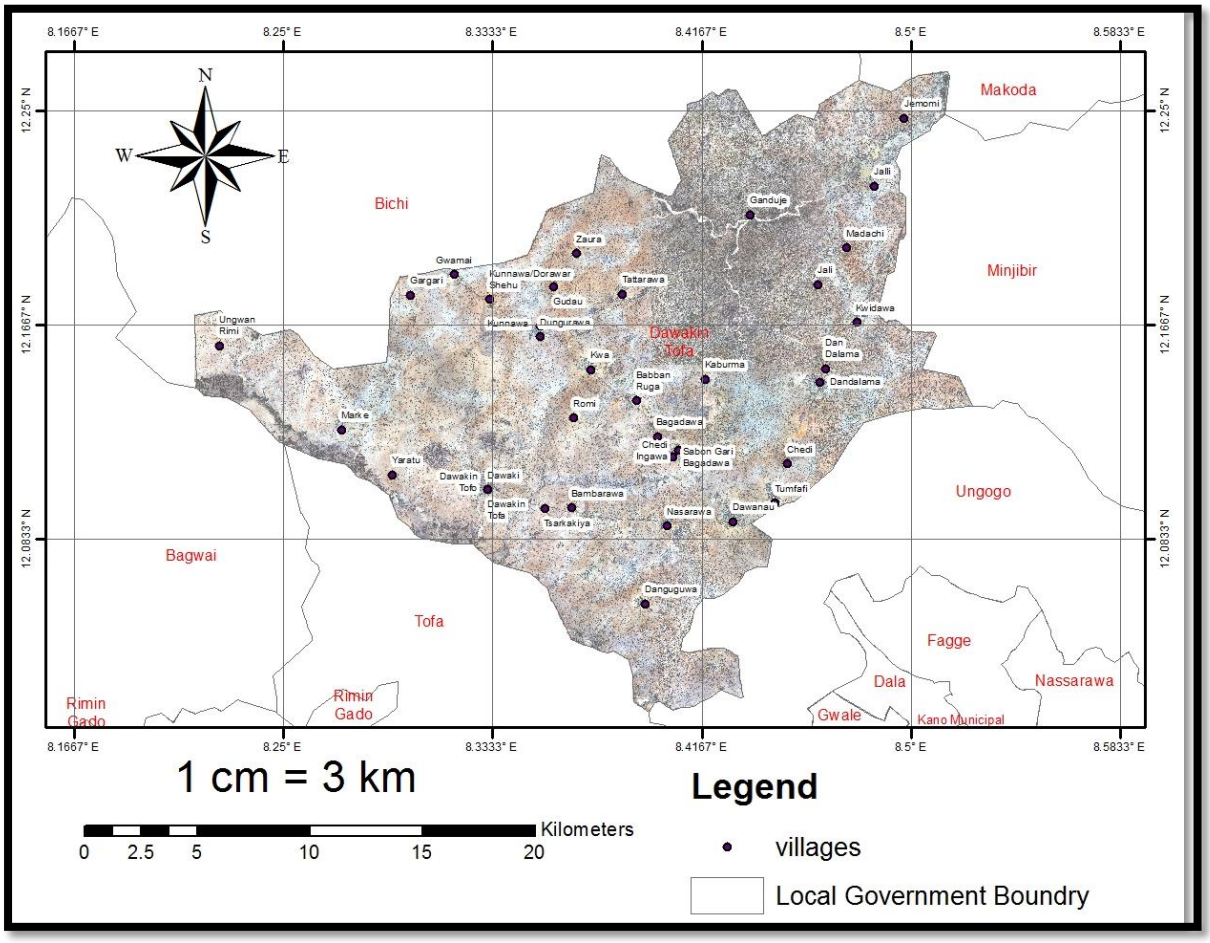

Fig 1: Dawakin-Tofa LGA Showing selected villages and Towns
Source: Kano Geographic Information System (KANGIS), 2016.

1.2.3 Materials Used

Computer Hardware and Soft wares: a personal computer with all the necessary input, output and storage components was used with certain parameters/algorithms of the following software for the processing and/or analysis of data/images; ENVI 4.5, Arc GIS 10.2 and Global Mapper 12. Geo-Positioning System (GPS) device (Garmin cx76 model) was use for taking coordinates and elevations of sampled points and other areas important for the research.

1.2.4 Land Cover Mapping

The procedure adopted involved Land cover mapping of the area to depict the spatial distribution of gully sites, determine their extent and severity as well as to assess the changes in erosion pattern over a 6 year (2008-2014) period. The supervised method of classification was used to classify the image based on prior knowledge of the area and use of topographical map and Google earth as reference. Accuracy assessments were performed using field knowledge and ground truth survey. Supervised and unsupervised image classifications were performed in **ENVI 4.5**.

1.3 Data Presentation and Analysis

1.3.1 Areas Affected By Gully Erosion in Dawakin-Tofa

The eleven (11) identified villages and towns suffering from gully erosion in Dawakin-Tofa Local government Area were found in parts of Tattarawa, Romi, Dawakin-Tofa, Chedi, Marke, Danguguwa, Dawanau, Gargari, Sarauniya, Ganduje and Jalli (Table 1).

Table 1: Total identified gullies in Dawakin-Tofa Local Government.

SN	AREA	NO. OF GULLIES	POTENTIAL GULLY SITES
1	Tattarawa	1	1
2	Romi	2	3
3	Dawakin-Tofa	4	6
4	Chedi	1	2
5	Marke	2	1
6	Danguguwa	2	0
7	Dawanau	1	0
8	Gargari	2	3
9	Sarauniya	1	4
10	Ganduje	1	0
11	Jalli	2	1
	TOTAL	**19**	**21**

Source: Fieldwork, 2017

A total of 19 established gullies are scattered across 11 locations in the Local Government. This does not include abandoned sand mining and excavation sites and other small gullies which were grouped under potential gully sites. There are also hundreds of small sand mining and excavation sites and ditches scattered across villages whose sizes ranges between 100m^2 to 300m^2 in area. Such features were not considered by this research.

1.3.2 Distribution of Gully Erosion Sites Within the Study Area

The spatial distribution of major gullies in Dawakin-Tofa Local Government shows their concentration in the north-western, southern and south-eastern part of the local government. Estimated soil losses leading to the creation of gullies were higher at Dawakin-Tofa town, Romi, Marke, parts of Sarauniya and Jalli. Other categories of erosion (moderate, high and very high) can be found in some parts of Ganduje, Chedi, Gargari and Tattarawa. (Figs 3 and 4)

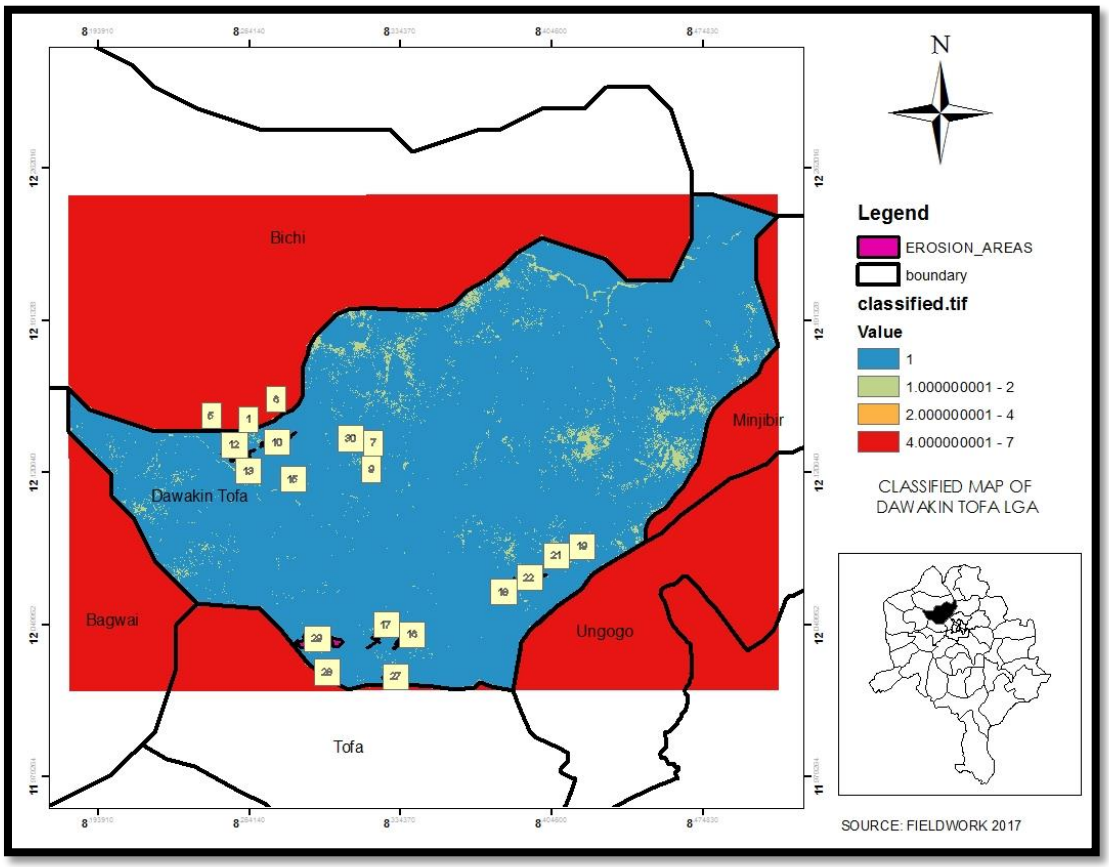

Figure 3: Spatial Distribution of major gully sites in Dawakin-Tofa LGA
Source: GIS Analysis and Fieldwork, 2017

This variation is largely due to the unevenness of the topography. It can also be attributed to more surface cover from developed urban environments, less water logging, less open spaces and the urban factor. Areas with a vegetal cover or some form of covering which could be infrastructure, buildings etc. can reduce the impact of erosion on the surface soil. This notwithstanding does not exclude the urban areas from any of the types of erosion especially gullies.

1.3.3 Gully Erosion from Land Use/Land Cover Mapping

A comprehensive land cover and land use mapping of the entire local government was done. The particular emphasis here was to highlight the spatial spread of gully erosion and its impact on the territories of Dawakin-Tofa. Multi-spectral land cover and land use classification was done for the area using both 2010 Landsat Thematic Mapper (TM) image 2008 SPOT-V Multispectral data. A comparative analysis of the results of classifications was done to determine the land cover and land use patterns in the two data dates, as a result of the development and spread of gullies.

Prior to the classification, the spatial as well as the spectral resolution of the images were improved by image fusion technique using both Landsat ETM Panchromatic band, SPOT V and Quick bird image data where appropriate.

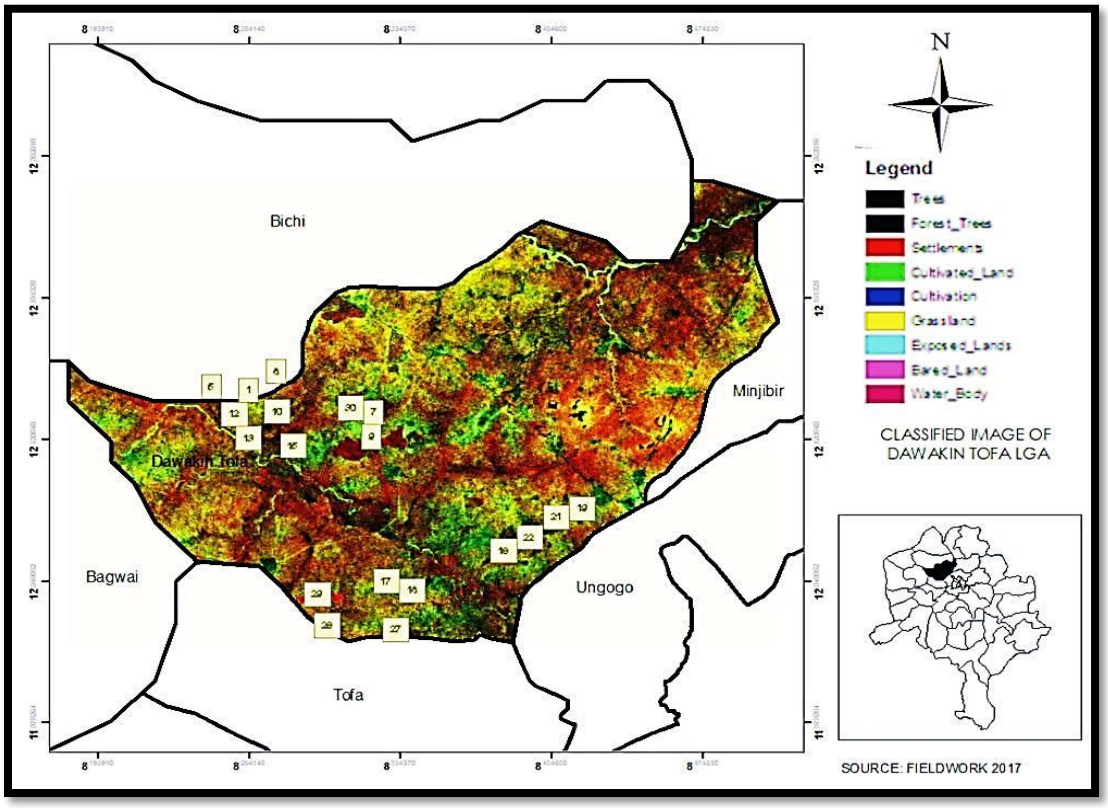

Figure 5: Land use and Land cover Map of Dawakin-Tofa LGA
Source: GIS Analysis and Fieldwork

1.3.4 Extent and Severity of Gully Erosion: Land Area Covered by Gully Erosion

The ArcGIS calculator was used to determine the total land size of the study area that has been affected by gully erosion. A total of 27.9km^2 area out of the 479km^2 total area size of Dawakin-Tofa local government has been destroyed by gully erosion. This represents 5.82% of the total land area (Table 2). Another 15.35km^2 is potentially under the threat of gully erosion and if adequate measures are not taken, in some few years, they may develop into full blown gullies. From table 2 below, the Rarun Gully in Dawakin-Tofa town and its extensions and annexes constitute a total of 6.2 km^2 which is the largest in the whole local government.

Table 2: Total Land Area Destroyed by Gullies in Local Government.

SN	AREA	NO. OF GULLIES	LAND AREA COVERED
1	Tattarawa	1	1.9 km^2
2	Romi	2	3.7 km^2
3	Dawakin-Tofa	4	6.2 km^2
4	Chedi	1	1.3 km^2
5	Marke	2	3.1 km^2
6	Danguguwa	2	2.1 km^2
7	Dawanau	1	1.7 km^2
8	Gargari	2	2.1 km^2
9	Sarauniya	1	2.6 km^2
10	Ganduje	1	0.9 km^2
11	Jalli	2	2.3 km^2
	TOTAL	**19**	**27.9km^2**

Source: Arc GIS 10.2 and Fieldwork, 2017

1.3.5 Areas with Most Severe Cases of Gully Erosion

The results showed that, among the areas most severely affected by gully erosion are Rarum gullies in Dawakin-Tofa Town, Romi gullies in Romi and 'Yan Shado gullies in Marke Town. Each of these gullies have stretched long distances (Figures 6, 7 and 8) developing annexed sub-gullies thereby destroying farmlands, infrastructure, houses and vegetation.

Rarun Gullies in Dawakin-Tofa Town: Satellite imagery analysis revealed that the Rarun gully site is the most severe in Dawakin-Tofa with a spatial extent of about 6.2 km^2. Fig 6 below shows the spatial extent of the Rarun gully area (plate 1). This particular gully site has destroyed many farm lands, a major road and is threatening many houses close to it.

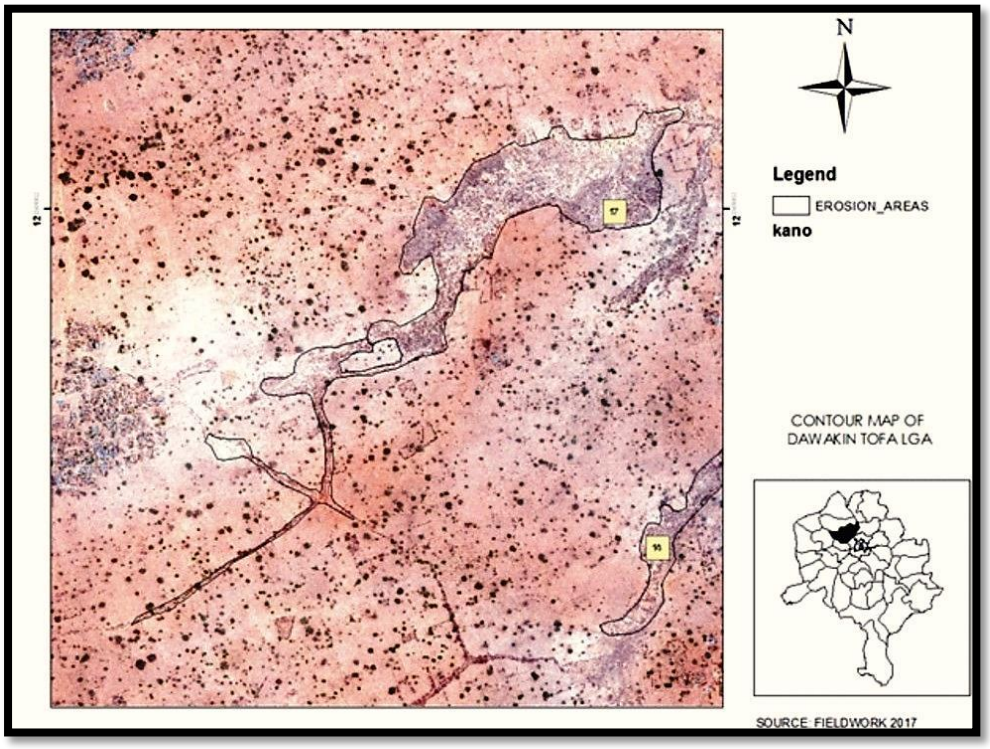

Figure 6: The spatial extent of Rarum Gully sites in Dawakin-Tofa town
Source: GIS Analysis and Fieldwork, 2017

Romi Village Gullies

The second most severe gully site in dawakin-Tofa Local government is the one in Romi covering a spatial area of 3.7 km^2. Its length is roughly half a kilometer and it has consumed the major road linking the village to the local government headquarters.

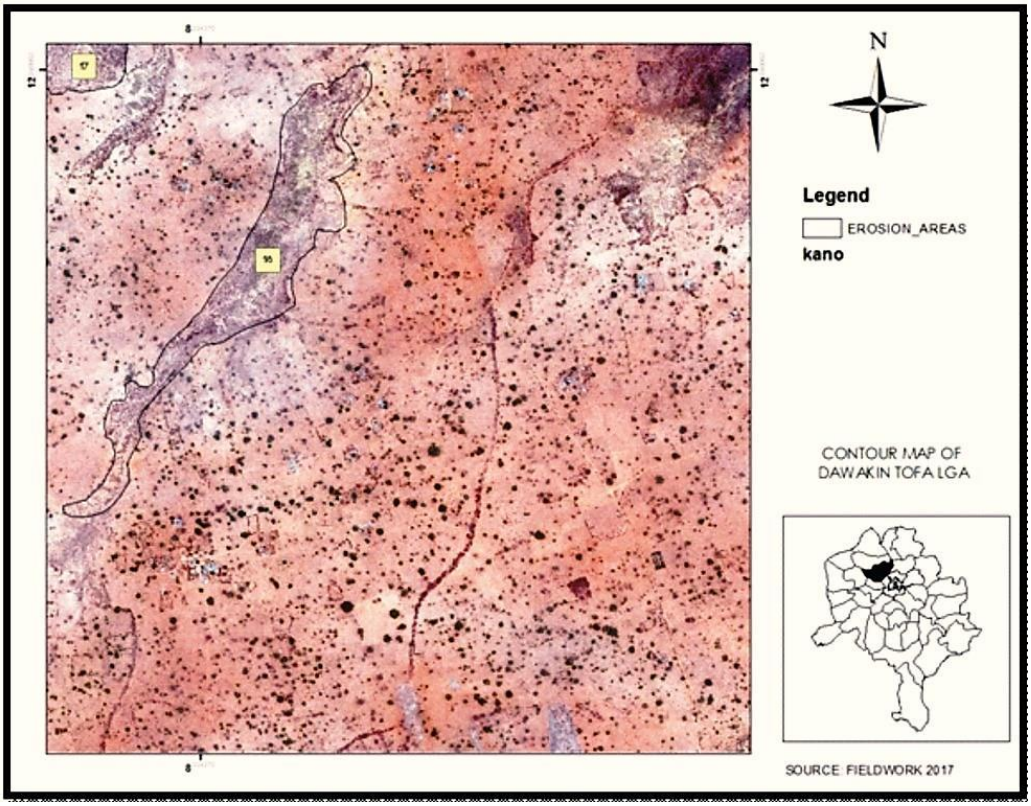

Figure 7: The spatial extent of Romi Gully sites in Romi Village
Source: GIS Analysis and Fieldwork

Plate 2: Sections of the Romi Gully site
Source: Fieldwork, 2017

Marke Village

The third most severe gully site in Dawakin-Tofa Local government is the one in Romi covering a spatial araea of 3.1 km^2.

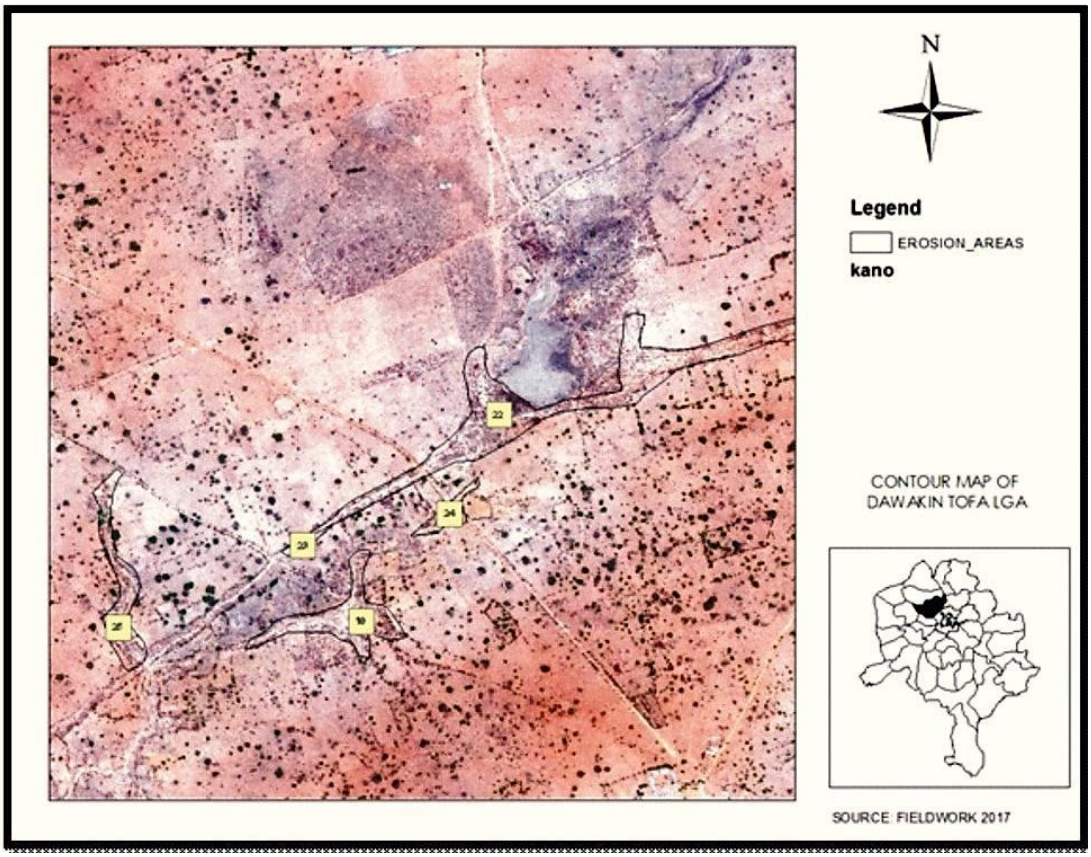

Figure 8: The spatial extent of 'Yan Shado Gully sites in Marke Village
Source: GIS Analysis and Fieldwork, 2017

Plate 3: Sections of the Marke steep Gully site
Source: Fieldwork, 2017

4.2.4 Visible Effects of Gully Erosion in Dawakin-Tofa LGA
Destruction of Roads and Transport Infrastructures: many roads have been destroyed by gully erosion and a handful of others are seriously threatened.

Plate 4: The on-going 5 kilometre road in Dawakin-Tofa town been encroached by gully erosion.
Source: Fieldwork, 2017

Destruction of Vegetation: trees are threatened by gully erosion as many were found to have collapsed due to the impact of the gullies.

Plate 5: Trees threatened by gully erosion in Romi
Source: Fieldwork, 2017

Table 3: Morphological Changes in Characteristics of Three Gully Sites in Dawakin-Tofa.

SN	GULLY /YEAR	DEPTH		WIDTH	
		2008	**2014**	**2008**	**2014**
1	Rarun	9m	10.5m	16.4m	20.8m
2	Romi	6.1m	6.7m	6.2m	8.7m
3	Marke	9.6m	11.8m	44.6m	52.5m
	TOTAL	**24.7m**	**29m**	**67.2m**	**82m**

Source: Arc GIS 10.2 and Fieldwork, 2017

4.3.2 Causes of Gully Erosion in Dawakin-Tofa

i. Nature of Topography: The study revealed that gully developments were more pronounced in areas with high terrain undulation as the Digital Elevation Model (DEM) analysis have shown. In these areas, the slopes of the ground are steep and vary. This inevitably results in increase in the speed and volume of the overland flow and subsequently the rate of detachment and transportation of soil particles.

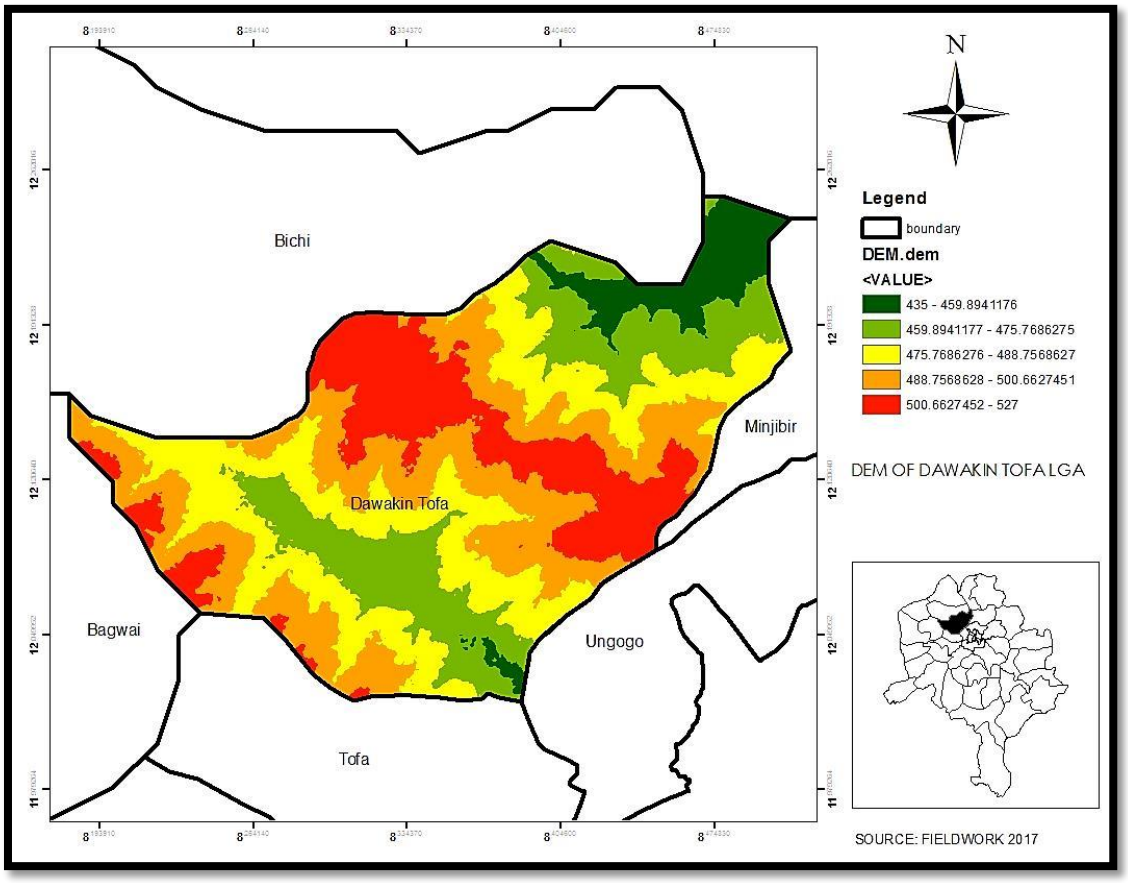

Figure 9: Topographical map of Dawakin-Tofa LGA
Source: Digital Elevation Model

When the topographical map above was co-related with the map showing distribution of gullies in the area, it was discovered the problem was mostly concentrated in area between 410 to 450 m above sea level. The map below is an overlay of the elevation and gully distribution maps of the area (Fig 10).

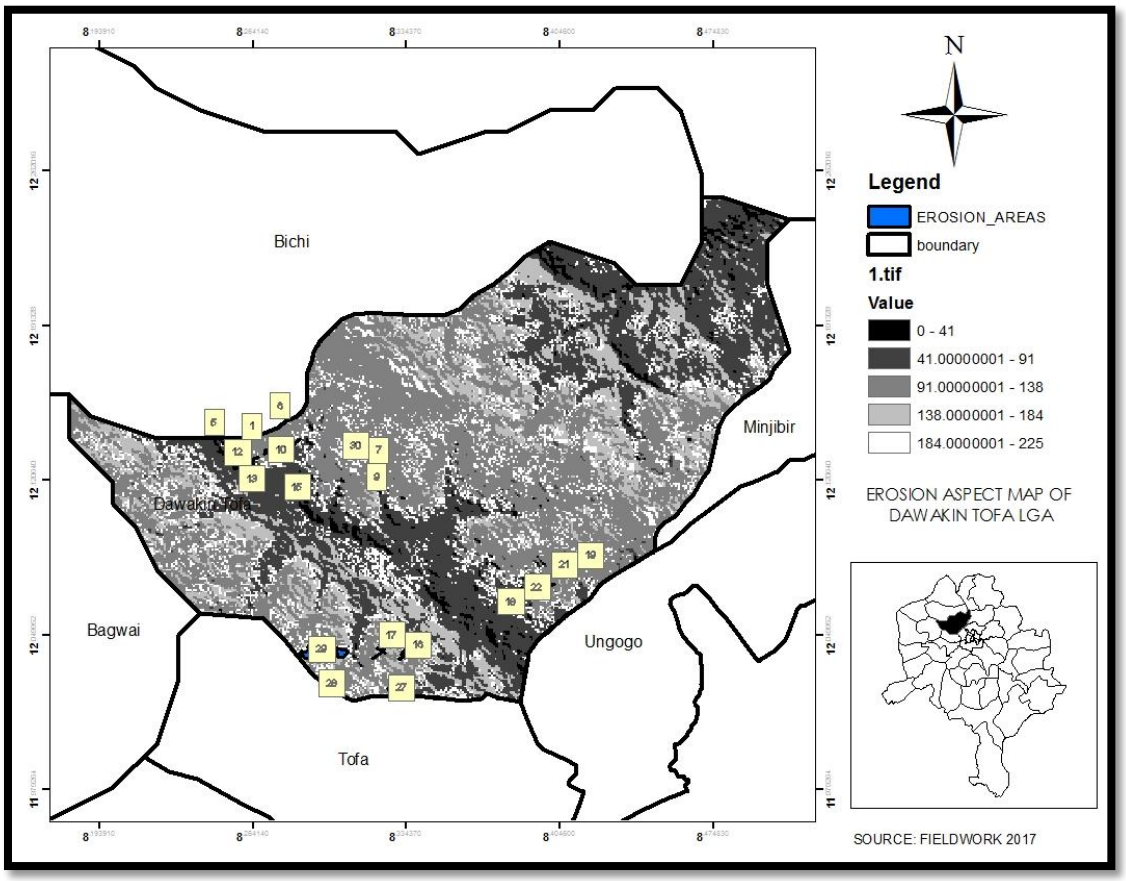

Figure 10: Topographical map and gully sites of Dawakin-Tofa LGA
Source: Digital Elevation Model

ii. Changes in Land Use Type between 2008 and 2014
The physical growth of many towns in Dawakin-Tofa Local Government can be traced to increase in population which resulted in the emergence of many built-up areas as well as the intensification of agriculture. This led to astronomical increase in deforestation, opening of sand mining sites as well as removal of top soils. The period between 2008 and 2014 therefore, has witnessed rapid increase in built up area which according to local government officials represents an annual increase of about 2.2 km^2.

iii. Agricultural Practices: Large portions of the vegetation cover are cleared annually for farming purposes, thereby exposing the top soil to erosion. With the soil exposed, it is no longer capable of resisting the erosive actions of the rainwater. The continuing action of the rain favours high rate of infiltration, enough to lubricate the underlying strata. Consequently this provokes heavy carrying away of the soil and leads to run off. This results in gulling as witnessed in many of the areas.

iv. Settlement Patterns, Urban and Infrastructural Development: Settlement patterns, the nature of housing and infrastructural development contribute to the development of gullies in the area. Settlements are not planned; houses are built indiscriminately without consideration to natural flood paths and drainage system. Infrastructures such as roads are built without proper environmental studies and tend to facilitate the gulling processes.

v. Population: The rapid population increase in the area is also a factor. As population increases, the need to provide housing and other facilities increases also. Where this is not properly managed as is the case in the local government, construction of new houses, roads etc will only exacerbate the situation. For example Dawanau has the highest population density in the whole of the area. With sand mining for building induced gully erosion gradually destroying a significant part of the land surface.

vi. Sand Mining (Laterite Excavation): One of the booming business in Dawakin-Tofa Local Government is sand excavation. The excavations are carried out by individuals across different villages. The action of rain which results into floods causes the washing off of the land surface and creating gullies as it moves. In some of the villages, construction companies have acquired the permission of local authorities to excavate sands commercially and these mining sites eventually develop into huge gullies as rainwater continues to impact on them.

5.3 Conclusion

This research can conclude that the menace of gully erosion in Dawakin-Tofa Local Government Area is quite severe and on the increase. The area, just like many other parts of Kano State is facing severe problem of gully erosion causing untold hardships and depression on the lives of the people. It is believed that going by the current trend of gully erosion in the area, the problem may completely get out of hand in the next few years if prompt, timely and decisive action against it is not initiated against it by all stakeholders.

Gullies are among the most hazardous of natural disasters. Government and research institutions worldwide have attempted for years to assess hazards and risks due to gully erosion and to show their spatial distribution. In this study, a geo-spatial approach for identifying the established and vulnerable areas of gully sites using GIS shows considerable promise. The integration of GIS with fieldwork exposes the great outputs of gully research, display, printing, management and spatial analysis. Thus, it is necessary to integrate the GIS to reduce the restrictions of using the two separate applications and increasing efficiency in gully vulnerability examination.

The Kano State and Dawakin-Tofa Local Government should employ immediate erosion controlling measures for areas that suffered severe erosion. Control measures such as land filling, immediate planting of some of trees and vegetal cover should be taken to stem the spread. Also other less forms of erosion should be checked preventing further degeneration.

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