Analysis of Gully Erosion Dynamics in Federal College of Education (Technical), Gombe, Gombe State, Nigeria

[1]John Abdullahi, PhD and [2]Dantata Danlami

[1]Department of Geography, Faculty of Social Sciences, University of Maiduguri, PMB 1069, Maiduguri, Borno State, Nigeria. drajohn74@gmail.com,
[2]Department of Geography, Faculty of Humanities, Management and Social Sciences, Federal University Kashere, PMB Gombe State, Nigeria dantata2004@gmail.com

Abstract

The paper examines dynamics of gully erosion sites at Federal College of Education (Technical), Gombe, Gombe State, Nigeria. The specific objectives are: to identify and map out areas affected by gully, examine factors responsible for gully erosion, calculate areas affected by gully, assess effects of the sinuosity of the gullies channel on the morphologies of the gully in the area. The study used primary source of data which includes field observations and measurement of depth, width, depth and length of the gully and sinuosity of the channel. The field survey was conducted to give an overview of the physical condition of the study area, including topography, vegetation and land use type. GPS points of gully sites were also taken. Land-use/land-cover types at five periods were extracted from Google earth, Landsat-TM, and ETM+. Slope and elevation information were also obtained from digital elevation model sourced from Africover portal of FAO website to determine the elevation of the zone. The study used Arc GIS software for the analysis. The findings of the study show that three major gully sites identified are Site A (Demonstration Secondary school), which covers an area of 13498.21 sqm (58.37%), gully site B (behind the Female Hostel) which covers an area of 3536.95sqm (15.30%) while gully site C behind (GOFCECON building) which accounted for 6088.58sqm (26.33%). Types of landuse/Landcover changes found in the area include plantation/trees, shrubs/grassland, build up areas, open space and gully sites. There was a significant decrease in plantation/trees and shrubs/grassland over the years from 49.02% in 2014 to 40.41% in 2018 with an increase in gully size from 0.68% in 2014 to 0.91% in 2018. The sinuosity index is 1.12 which has a significant effect on the expansion of the gully channel in the area. The paper concludes that the factors responsible for the dynamism of gully erosion in the area is a combination of interdependent mechanisms between topography, slope, soil erodibility, landuse/landcover change, which have changed over the years thereby reducing infiltration capacity, increased surface runoff on a steep slope environment. The paper recommends that a specific, scientific and systematic approach which integrates the influence of all factors observed as responsible for gully formation should be employed in the control of gullies in the area.

Keywords: Dynamics, FCE (T), Gombe, Gully erosion, GIS and Sinuosity.

Introduction

Gully erosion is defined as fluvial process through which top soil are removed along drainage channels by runoff; it is a common type of soil erosion that consists of an open, incised and unstable channel generally more than 30cm deep. Gully erosion may occur due to either natural or man-made activity in the environment which includes construction, mining, overgrazing,

deforestation and farming activities. The initial stage of gully erosion may begin at a small scale affecting insignificant proportion of land and will proceed to expand by headward erosion or slumping of the sidewalls of the channel banks until it devastated a large portion of land. This geomorphic process of gully erosion highly occurs in area characterized by loosed or sandy soil, bad agricultural practices, constructional activities, deforestation, overgrazing and steep slope.

Erosion is the process by which the surface of the earth gets worn down. **Erosion** can be caused by natural elements such as water, wind and ice. Therefore, erosion is the wearing away of the earth's surface by the action of natural forces, such as, water, wind and ice. The loose and dissolved materials are transported from their primary locations to secondary locations. Basically, there are four types of erosion; splash, sheet, rill and gully. Splash erosion occurs when raindrops hit bare soil with enough kinetic force to break the soil aggregates. These fragments wash into soil pores and prevent water from infiltrating the soil. Water then accumulates on the surface and increases runoff which transports particles as sheet erosion. As the volume of water increases and begins to move in confined way, it develop into rill erosion and later gully erosion developed.

Nigeria as a nation is threatened by the problem of gully erosion since before 1980, and it affects both rural and urban communities. It is an environmental, ecological, economic and humanitarian disaster resulting as a result of land degradation that leads to loss of lives and properties worth millions of dollars. The estimated number of gullies in the country is put at 3,000. Areas exposed to gully erosion in the Southeastern part of Nigeria is said to be tripled from 1.33% (1,021 km^2) in 1976 to about 3.7% (2,820 km^2) in 2006 making the region the most susceptible region to gully erosion in the country. Gully erosion may occur as a result of continuous and heavy rainfall. The greater the duration of a rainfall, the higher the erosion potential. The impact of raindrops on the soil surface can break down soil sediments which are transported down streams. It may equally occur as a result of lack of vegetal cover caused by overgrazing, deforestation, bush burning, over cultivations, improper constructional activities Ofomata (2007). Gully erosion can also occur as a result of mining activities. Mining processes is usually carried out on the surface of the earth for the purpose of extracting mineral resources such as tin, diamond, gold, iron ore and others. During the process, artificial channels and pits are created which are later transformed into large expanse of gullies Arabi (2009). Such pits are dangerous and they serve as death traps to lives and properties. Such examples of artificial gullies as a result of mining activities are commonly found in Jos and its environs in Nigeria.

Statement of the Research Problem

Gully erosion is one of the environmental problems faced in Gombe and its environs. Several studies have been carried out on gully erosion menace in different parts of Gombe and its environs Mbaya (2012), Mbaya, Ayuba and Abdullahi (2012), Mbaya (2013), Danladi and Ray (2014), Abdullahi and Ngadda (2018). However, these studies did not focus on the gully erosion dynamics at Federal College of Education Technical Gombe. These studies looked at different aspect of gully erosion in and around Gombe town. For instance Mbaya (2012) studied gully erosion in Gombe town, Mbaya *et al* (2012) looked at gully erosion in Gombe and its environs, Mbaya (2013) studied inter-relations among gully variable in Gombe town, Mbaya (2016) studied socio-economic effects of gully erosion in Gombe town, Danladi and Ray looked at socio economic effects of gully erosion on land use in Gombe and Abdullahi and Nggada (2019) carried out gully erosion dynamics in Tumfure but none of these studies has specifically looked at the

dynamics of gully erosion in the Federal College of Education Technical Gombe. Therefore, this paper intends to analyze the dynamics of gully erosion in the College environ with a view to proffer solution to the menace of gully erosion in the area, considering the significance of the area affected by the gully to the future development of the college. The study examined the dynamics of gully erosion in Federal College of Education Technical, Gombe State, Nigeria. The specific objectives are: to identify and map out areas affected by gully erosion, factors responsible for gully, the landuse /landcover changes from 2014-2018, areas affected by gully and the effects of the sinuosity of the gully channels on the morphology of the gullies.

Description of Study Area

The study area lies between latitude Latitude10^{O} 10'' N to 10^{O} 50' 30'' N and Longitude 11^{o} 01'E to 11^{o} 40'E (Fig.1). The study area, Federal College of Education Technical, Gombe, is located inside Gombe town, the State capital. Gombe town occupied an area of about 45km^2(Ministry of Land and Survey, Gombe, 2008). It is well connected by road to other parts of the country such as Bauchi, Jos, Yola, Jalingo, Biu- Maiduguri and Potiskum.The climate of Gombe is characterized by six (6) months of dry season, alternating with a rainy season of six (6) months and mean annual precipitation of 835 mm^3.The mean annual temperature is about 26°C. The relative humidity has the same pattern, being 94% in Augustand reducing drastically to about 10% during the harmattan period (Balzerek, Werner, Jürgen, Klaus-martin, and Markus, 2003).

Rainfall is one of the most vital determinant factor in triggering soil erosion and gully formation and development. Its average values only, are not sufficient to determine the potentiality of single rainstorms events. Study carried out on runoff and soil erosion on Bama Beach Ridge (BBR) by (Nyanganji, 1997) on test plots with sandy top soils established that runoff and sediment transport is only obtainable when the total depth of rainfall exceeds 10 mm^3supported by rainfall intensities greater than 0.2 mm^3/min.

The study area is characterized by spectacular landform features which include the Gombe and Lijji hills which form part of the Benue Trough popularly known as the Zambuk ridge (Mbaya, (2016). The stratigraphy of the area consists of the Kerri Kerri formation, the alluvium, Yolde formation, the Bima Sandstone, Gombe formation, Pindiga formation and the basement rocks as the oldest formations (Mbaya, 2016).

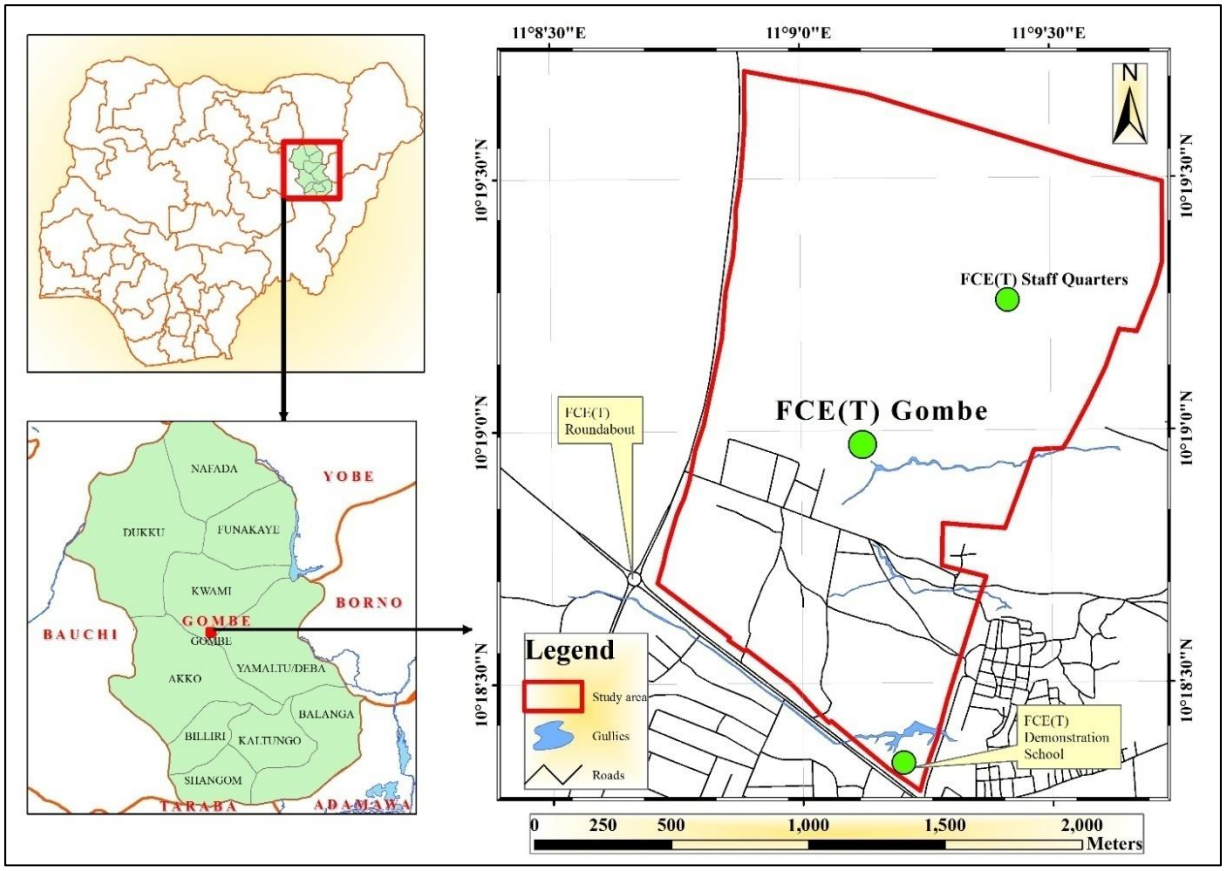


Fig. 1: The Study Area
Source: GIS Analysis

Conceptual Framework

Concept of Land Degradation

The concept of environmental degradation was used in this study. Environmental degradation is the reduction or deterioration of the quality of the environment through the pollution and depletion of natural resources such as land, water and air through man's activities which include farming, mining, deforestation, bush burning, overgrazing, fishing, hunting, and destruction of ecosystems and the extinction of wildlife (Egboka, and Okpoko1984).

Environmental degradation is the process through which the various components of the environment such as water (hydrosphere), air (atmosphere), and land (lithosphere), are continuously polluted, overexploited and damaged. Environmental degradation can mainly be viewed under: ecosystem imbalance, forest depletion, freshwater pollution, soil degradation, air pollution and Global warming (Akagbue and Uma 1987).

Environmental degradation can be seen as any serious disturbance or significant change to the environment that is perceived to be disastrous or undesirable. Environmental degradation is regarded as one of the ten threats that has officially recognized by the high level threat panel of

the United Nations (https://www.researchgate.net).Environmental degradation is viewed by the United Nations International Strategy for Disaster Reduction as "the reduction of the capacity of the environment to meet social and ecological aims and objectives (Arabi, Nur and Dewu, 2009). In other words, when the environment becomes less valuable or destroyed, environmental degradation is said to occur. There are various forms of environmental degradation. When habitats are damaged, biodiversity is lost, or natural resources are depleted, the environment is degraded. Environmental degradation can occur as a result of natural processes, or through human activities that are harmful to the environment. The course for concern at present is the loss of land to gully erosion at Federal College of Education Technical Gombe.

Literature Review

In order to combat environmental degradation, environmental studies are necessary. Environmental studies are the systematic study of human interaction with their environment. It is a broad field of study that includes the natural environment, social environments, organizational environments, and the relationships between them. Current environmental problems have evolved into a complex set of interdisciplinary issues involving ecological, political, economic, social, as well as physical and biological considerations Mbaya (2016).

Necessary steps are to be planned after environmental studies and proper implementation of those suggested steps is essential. The environmental imbalance gives rise to various environmental problems. It is our duty to remove the environmental imbalances by proper implementation of the necessary remedial acts to make our environment cleaner, safer, and greener that could support sustainable development (Mbaya, 2012). Several studies in different parts of Nigeria and Gombe in particular have attributed the formation and development of gullies to the influence of both human activities on natural and geologic processes, while others suggested that gullies are associated with concentrated runoff processes down slope. For instance, Nwajide and Hogue (1979) attributed the causes of gullies to the combination of physical, biotic and anthropogenic factors while Egboka and Nwankwor (1986) observed that gullies are caused by hydrogeological, hydrogeochemical and geotechnical properties of the rocks in the area. Based on the studies carried out by Okagbue and Uma (1987) are in agreement with Nwajide and Hogue on the causes of gullies in South Eastern Nigeria. Research work carried out on the effectiveness of gully erosion control measures in Gombe metropolis Mbaya (2012 and 2016) and Danladi and Ray (2014) revealed that most of the previous uncontrolled or partially checked gullies have increased in length to 131.02 km as against the 121.50 km in 2003. Out of the 131.02 km length of gully erosion inventory in Gombe town in 2015, only 41.32 km length has been controlled and 35.92 km under engineering control method representing 87%; 5.1 km (12.3%) length of vegetation and only 0.3km under stone wall control measures (Gombe State, Ministry of Water Resources and Environment, 2003).

It has been observed that Tropical forest constitutes seven percent (7%) of world land surface area, yet it contains over 50% of all plant and animal species (Danladi and Ray 2014). Almost half of all tropical forests have been destroyed. By 2020, three quarters may be lost if proper and urgent measures have not been put in place. In addition to that, about 20–50% of global wetlands might have been damaged (54% thus far in the US, with an additional 115,000 acres/year), (World Bank 1990).

The undulating nature of Gombe terrain which is characterized with steep slopes that generates concentrated runoff from steep lands, flowing into cleared drainage depressions. The steeper the slope, the lesser the infiltration of water, hence, soil erodes more on steeper slopes than on grounds that have mild slope. This happens more on area where there is increase speed of runoff.

The unstable nature of soils along gully channels makes lighter particles of soil such as very fine sand, silt, clay and organic matter to be easily eroded by the rain splash and runoff water, while for more larger sand and gravel particles to be washed away, it requires heavy raindrops and heavy flow of runoff. These are some of the characteristics of the processes that were observed around the Federal College of Education Technical Gombe and its environs.

It has been observed that since the beginning of the nineteenth century, there was a significant increase in the needs of the world's population associated with modern technological advances which have altered our natural environment. In quest for survival, man has overexploited the natural resources to an extent that it leads to losing the environmental balance in the ecosystem which leads to environmental degradation.

Materials and Methods

Data used for this study were obtained from field survey, satellite/goggle earth images and topographical maps. The field survey was conducted to give an overview of the physical condition of the study area, including topography, vegetation and land use type. Coordinates of gully sites were also taken using Geographic Information System (GPS). Land-use/land-cover types at five periods were extracted from goggle earth, Landsat-TM, and ETM+. Slope and elevation information were also obtained from a digital elevation model sourced from Africover portal of Food and Agriculture Organization (FAO) website to determine the elevation of the area. Boundary of the study area, streams and various category of road networks were generated from topographic map on scale of 1:50,000 through manual digitizing. TM data has spatial resolution of 28.5 m and includes two middle-infrared and one thermal channel. These high-resolution scanners have seven spectral bands with a swath of 185-by-185 km area. For the study area, a single scene, path 170 and row 60, taken in 2014 and 2015 by TM sensor on board Landsat 5. The image of 2016, 2017 and 2018 was obtained with ETM+ Landsat-7, carried on-board the Enhanced Thematic Mapper plus (ETM+) instrument. Both images were obtained from the Global Land Cover Facility (GLCF) online.

Accuracy Assessment

To verify the quality and reliability of the classification exercise, accuracy assessment test was performed. Topographic maps and Global Positioning System (GPS) were used to obtain ground control pointfor accuracy test. A total of 20 points was obtained randomly within the study area.

Post classification

In this process, images of every year was classified and labeled separately. The classified images were then compared to determine the change that has taken place between the two images using a change matrix. This made it possible to extract the changed areas and by how much through

the computation of change maps and change matrix statistics. With this information obtained, it was easier to quantify and explain the change in each landuse class.

Sinuosity of the Gully Channel

Sinuosity (S) deals with the meandering nature of the river. It is the ratio between actual length and the straight length of the river.

Channel sinuosity = $\frac{OL}{EL}$

Where OL = observed (actual) path of a stream.
EL = expected straight path of a stream.
The sinuosity indices of the gully channel reaches were calculated for the years 2018. According to sinuosity index, channels can be categorized into three classes:
Straight (SI < 1.05),
Sinuous (SI 1.05–1.5), and
Meandering (SI > 1.5)

Result of Findings

Areas affected by gully erosion

The study revealed that the areas affected by gully erosion were numbered as A, B and C as shown in Table 1, 2 and Fig. 2. Gully site A is located at the Demonstration Secondary School which covers an area of 13498.21m^2 (58.37%). Gully site B is located right behind the female hostel which covers an area of 3536.95m^2 (15.30%) while gully site C which is located close to GOFCECON building which accounted for 6088.58m^2 (26.33%). This shows that gully site A is the largest, followed by gully site C while gully site B is the smallest.

Table 1: Showing Areas Affected by Gully Erosion

Gully_name	Area_ha	area_m^2	Area (%)
Gully A	1.35	13498.21	58.37
Gully B	0.35	3536.95	15.30
Gully C	0.61	6088.58	26.33
	2.31	**23123.74**	**100.00**

Source: GIS Analysis, 2019

Table 2: **Showing Gully Coordinates, Elevation and Processes**

Site	North	East	Elevation	Description
A	10º 18’ 55.6’’	11º 09’ 10.6’’	503m	GOFCECON
B	10º 18’ 54.2’’	11º 09’ 13.4’’	502m	Footpath crossing
C	10º 18’ 54.6’’	11º 09’ 12.8’’	501m	Sandstone checking expansion
D	10º 18’ 55.1’’	11º 09’ 15.5’’	494m	Soil creep
E	10º 18’ 54.8’’	11º 09’ 20.0’’	493m	Rockfall
F	10º 18’ 55.0’’	11º 09’ 26.1’’	484m	Soil creep
G	10º 18’ 55.8’’	11º 09’ 29.7’’	478m	Ending point at Eastern Fence

Source: Fieldwork, 2019

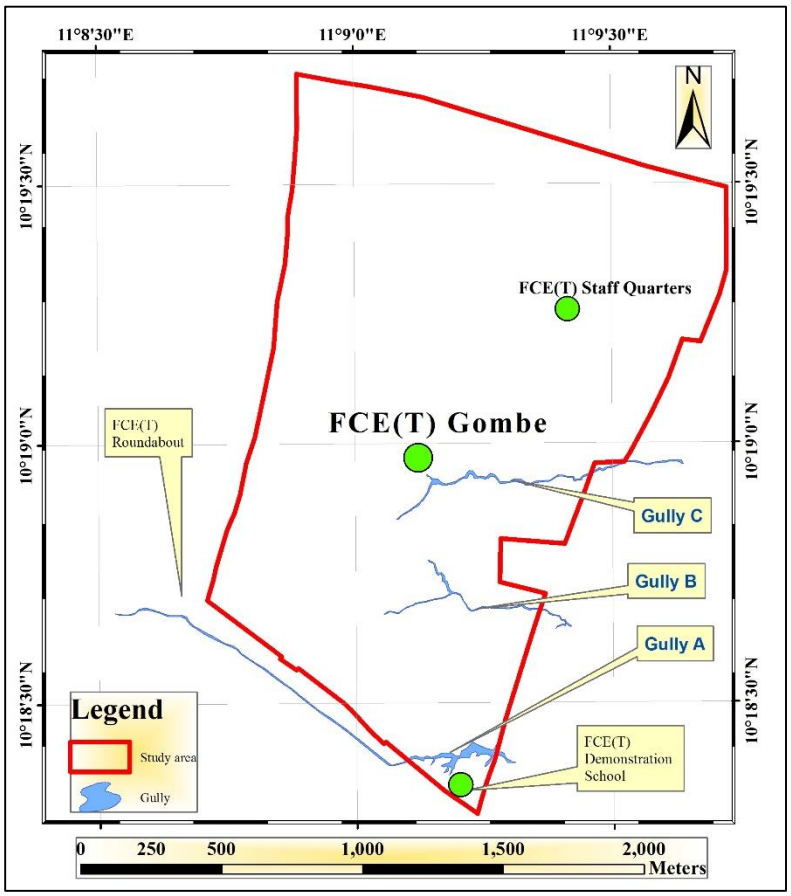


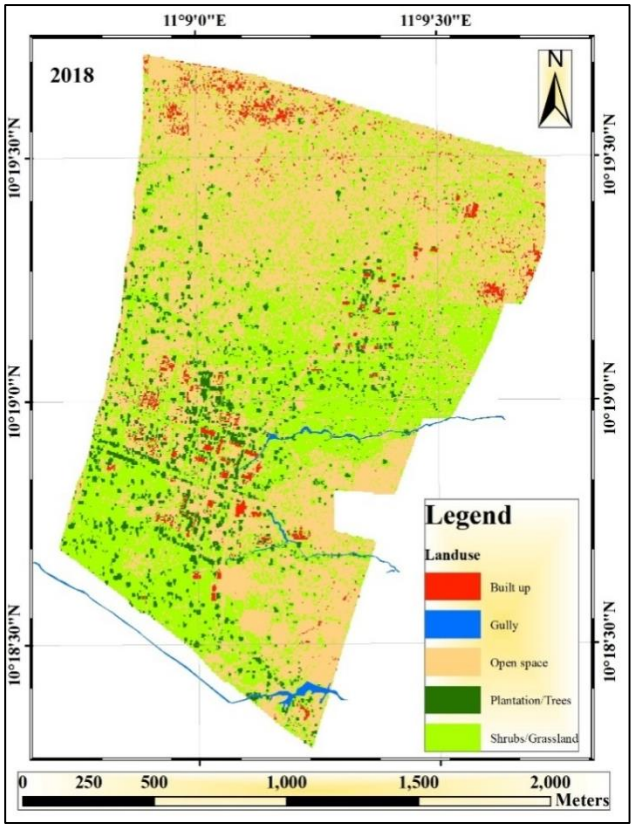
Fig 2: Showing Gully locations

Factors responsible for gully erosion

The findings of the study reveals that the factors responsible for the formation and development of gully erosion in Federal College of Education Technical Gombe are interdependent in nature which combine both natural (topography, geology, soil, vegetation) and man-made factors (constructional activities without proper and adequate drainage system, landuse/lancover change, overgrazing and poor farming practices). The findings of this paper is similar to works carried out by Nwajide and Hogue (1979) who established that gullies are formed and developed as a result of the combination of physical, biotic and anthropogenic factors. Similarly, Okagbue and Uma (1987), Ezechi and Okagbue (1989) in their separate studies agreed with Nwajide and Hogue on the causes of gullies in South Eastern Nigeria to be both natural and man-made factors.

Landuse and Landcover Change from 2014-2018 (5 years)

The study shows that the types of landuse/Lancover changes found in FCE(T) Gombe includes Plantation/trees, shrubs/grassland, build up areas, open space and gully sites as shown in Figures 3, 4, 5,6 and 7 and Tables3, 4, 5, 6 and 7 respectively. The paper shows that there was a significant decrease in plantation/trees and shrubs/grassland over the years from 49.02 % in 2014 to 40.41% in 2018 with an increase in gully size from 0.68% in 2014 to 0.91% in 2018.The paper further reveals that there was an increase in open space from 41.27% in 2014 to 50.71% in 2018 and there was equally an increase in build up areas from 2.07% in 2014 to 2.57% in the year 2018. This could be attributed to the developmental projects ongoing in the college.

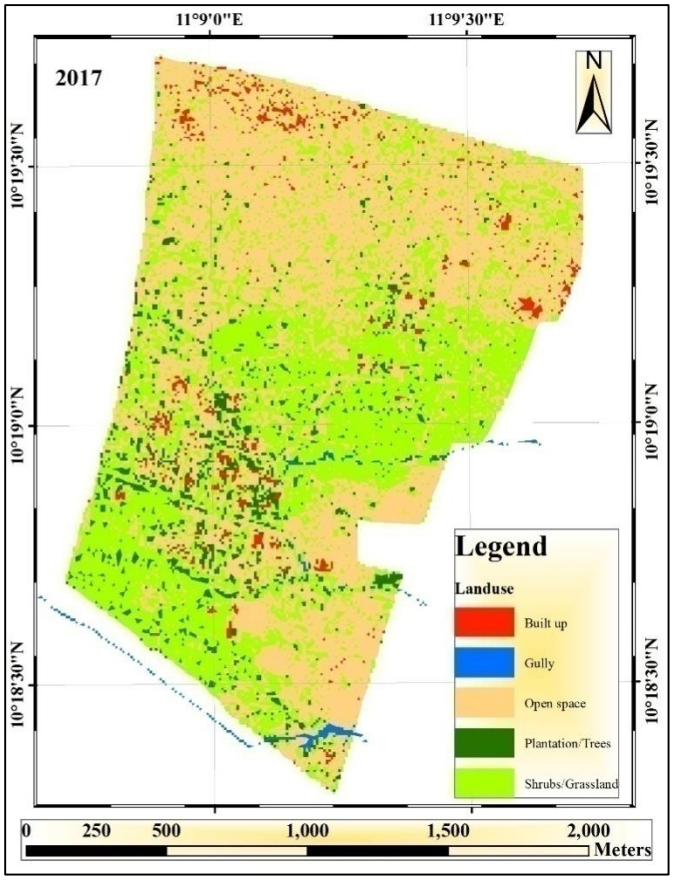


Source: GIS Analysis
Figure 3: Landuse and Landcover Change in 2018

Table 3: Landuse and Landcover change in 2018

Landuse	Area_sqm	Area_Ha	%
Plantation/Trees	151074.04	15.10	5.39
Shrubs/Grassland	1131462.06	113.15	40.41
Open space	1420009.11	142.00	50.71
Built up	72043.50	7.20	2.57
Gully	2559.74	2.55	0.91
	2799957.26	**280.00**	100.00

Source: GIS Analysis



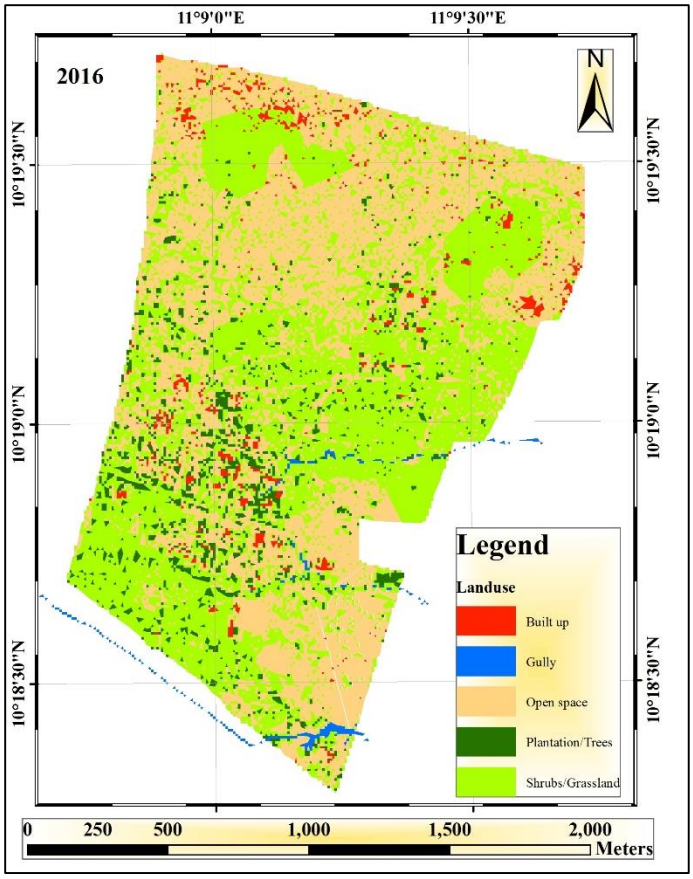
Source: GIS Analysis 2019

Figure 4: Showing Landuse and Landcover Change in 2017

Table 4: Landuse and Landcover Change in 2017

Landuse	Area_sqm	Area_Ha	%
Plantation/Trees	159959.53	15.99	**5.71**
Shrubs/Grassland	1132086.41	113.21	**40.43**
Open space	1419540.53	141.95	**50.70**
Built up	64504.75	6.45	**2.30**
Gully	24016.03	2.40	**0.86**
	2800107.26	**280.00**	**100.00**

Source: GIS Analysis 2019



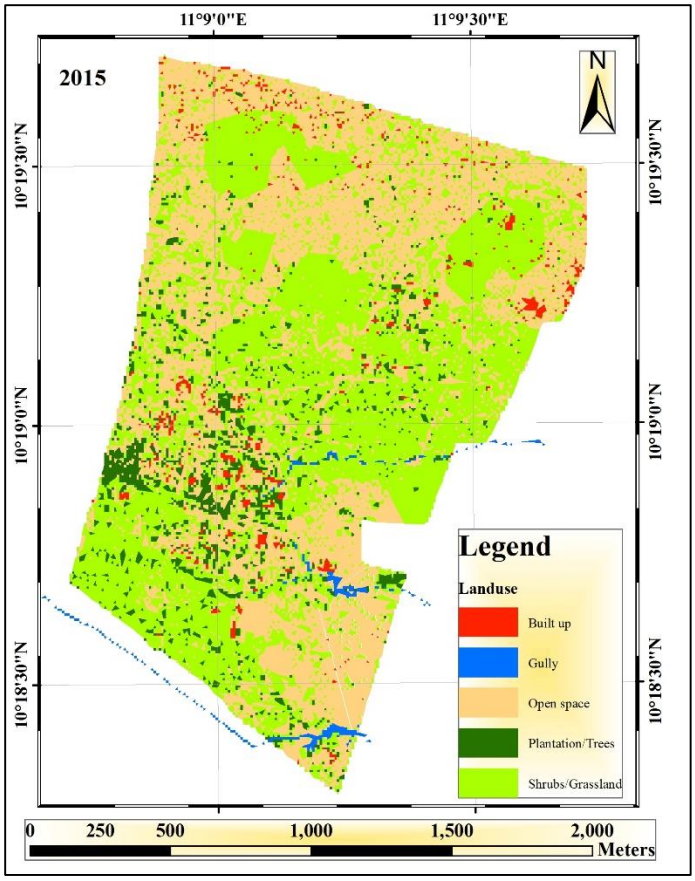
Source: GIS Analysis 2019

Figure 5: Showing Landuse and Landcover Change in 2016

Table 5: Landuse and Landcover Change in 2016

Landuse	Area_sqm	Area_Ha	%
Plantation/Trees	161129.08	16.11	**5.75**
Shrubs/Grassland	1304224.44	130.42	**46.58**
Open space	1247657.80	124.77	**44.56**
Built up	63990.04	6.40	**2.29**
Gully	23043.71	2.30	**0.82**
	2800045.07	**280.00**	**100.00**

Source: GIS Analysis 2019



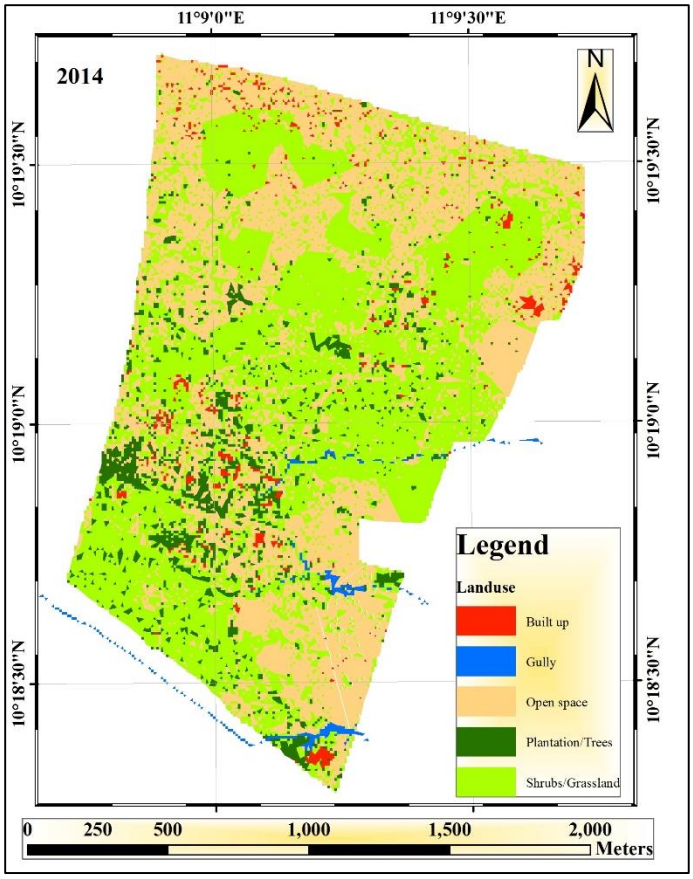
Source: GIS Analysis 2019

Figure 6: Showing Landuse and Landcover Change in 2015

Table 6: Landuse and Landcover Change in 2015

Landuse	Area_sqm	Area_Ha	%
Plantation/Trees	185125.35	18.51	**6.61**
Shrubs/Grassland	1343485.83	134.35	**47.98**
Open space	1193155.98	119.31	**42.61**
Built up	58580.67	5.86	**2.09**
Gully	19807.24	1.98	**0.71**
	2800155.07	**280.00**	**100.00**

Source: GIS Analysis 2019



Source: GIS Analysis 2019

Figure 7: Showing Landuse and Landcover Change in 2014

Table 7: Landuse and Landcover Change in 2014

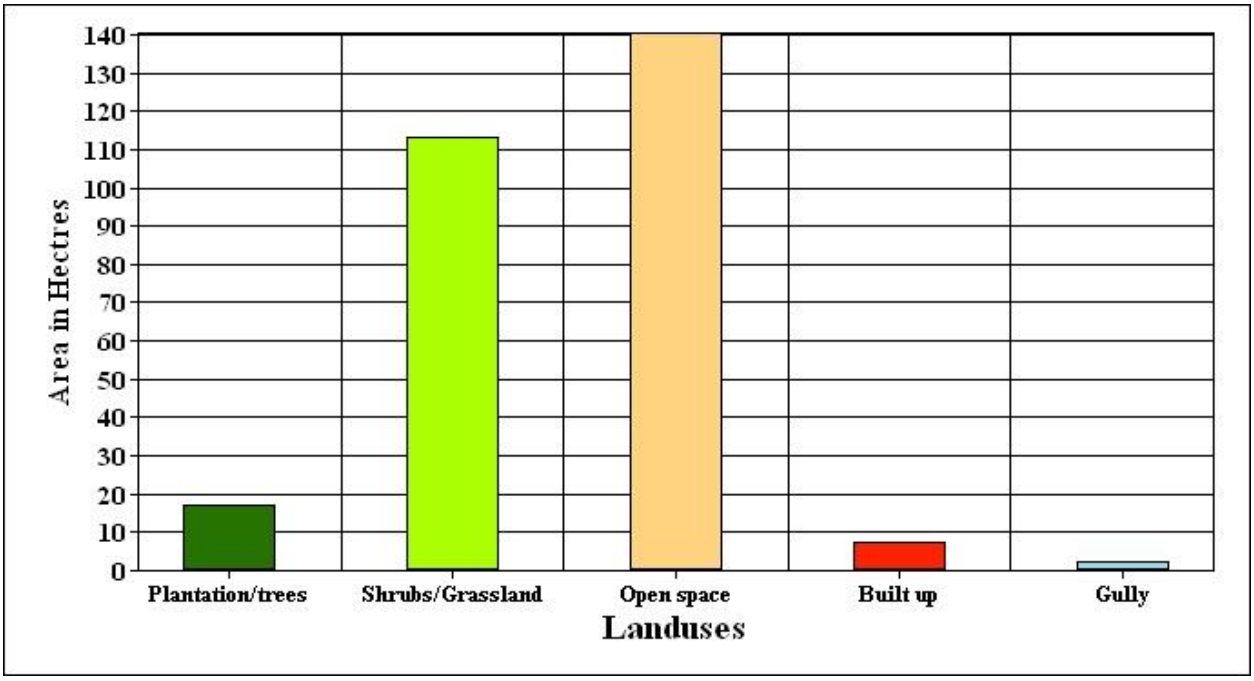
Landuse	Area_sqm	Area_Ha	%
Plantation/Trees	198908.86	19.50	**6.96**
Shrubs/Grassland	1363666.74	137.27	**49.02**
Open space	1155509.03	115.55	**41.27**
Built up	57863.21	5.79	**2.07**
Gully	19007.24	1.90	**0.68**
	2794955.08	**280.00**	**100.00**

Source: GIS Analysis 2019

Extent of gully erosion

The findings of the study revealed that extent of areas affected by gully erosion as at 2018 was 0.91% with open space having the largest percentage which makes the environment more susceptible to gully formation and development as shown in Fig. 8. The characteristics of the landuse and landcover change of the area include plantation/trees (near to primary forest with little human interference), shrubs/grasslands (include farmlands and grazing lands), open space

(exposed lands, degraded lands and open space), built-up areas (areas covered by building and structures) and gully sites (rivers and streams) as shown on Table 8.



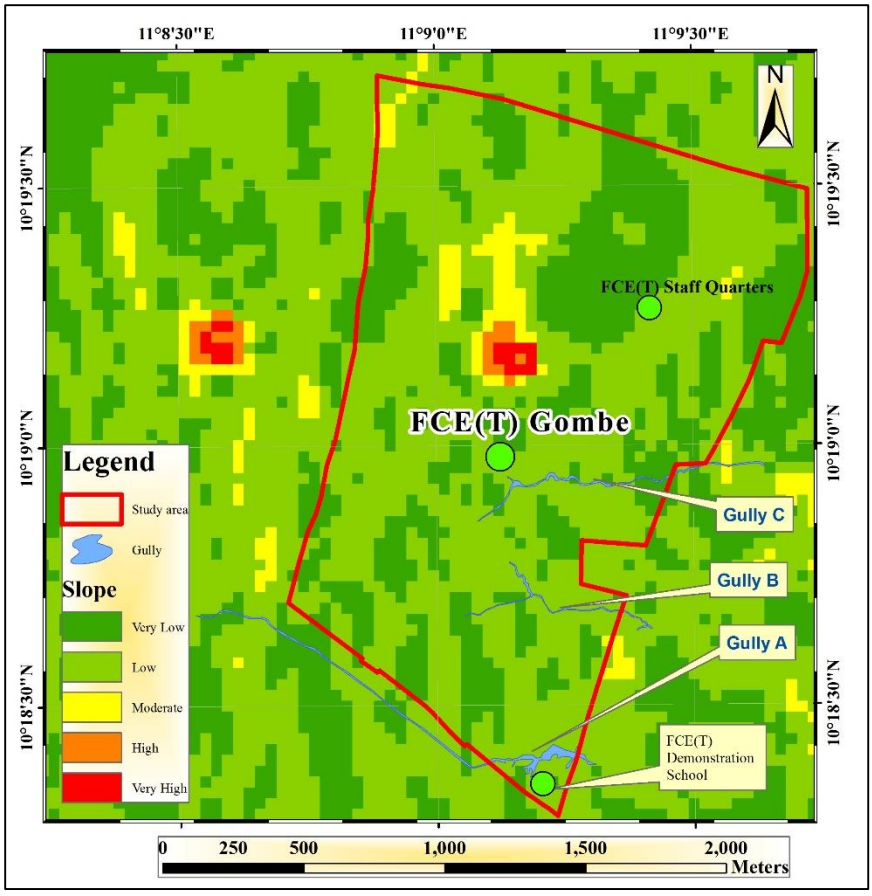
Source: GIS Analysis 2019
Figure 8: Graph Showing Landuse size

Table 8: Landuse and Landcover characteristics for the study area

Land cover	Description
Plantation/Trees	Near to primary forest with little human interference
Shrubs/grasslands	Includes farmlands and grazing land
Open spaces	Exposed land, degraded areas and open spaces.
Built up	Area covered by houses or other buildings.
Gully	Rivers, streams and Gullies

Source: GIS Analysis, 2018

The nature of the slopes in the study area starting from the main gate of the College moving towards the extreme end of the college's fence located at the eastern part of the college is characterized by steep slope as shown in fig. 9. The steep nature of the slope in the area coupled with tarred nature of the college road, with inadequate and poor drainage system is responsible for the generation of surface runoff that accelerate the formation and development of gullies within the college and its environs.



Source: GIS Analysis 2019
Figure 9: Slope map of the study Area

Effects of the sinuosity of the gully channels on the morphologies of the gully

Sinuosity index

Sinuosity is used to define the degree of meandering of a river channel which is used to establish geomorhological river types which affect the expansion of the channel both in terms of width and depth. Meandering is a natural geomorphic process in rivers which results in gradual migration of the river's course and erosion of the banks. Analysis of meander bends reveals the fact that meandering tendencies of the River channel based on the sinuosity index is;

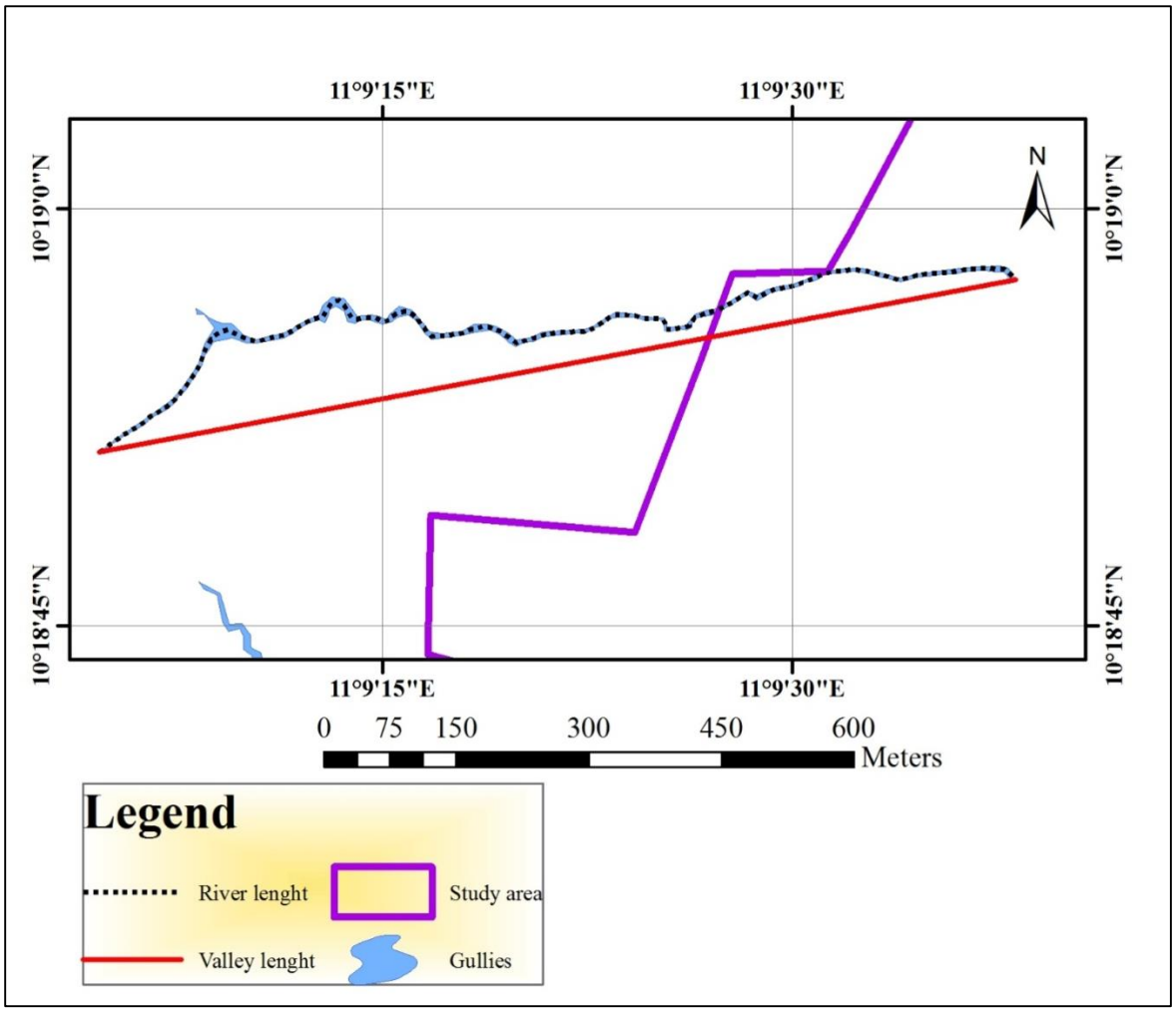
Sinuosity= river length/valley length

$$= \frac{1172.282458}{1038.734128} = 1.128568$$

The sinuosity indices of the gully channel reaches were calculated for the year 2018 as shown in fig. 10. According to sinuosity index, channels can be categorized into three classes:

Straight (SI < 1.05),
Sinuous (SI 1.05–1.5), and
Meandering (SI > 1.5)

Based on the calculated value of the sinuosity index 1.12, which is sinuous, implying that the sinuosity of the gully channel has a significant effect on the expansion of the gully channel in the study area, thereby accelerating rapid morphological modification of gullies in the area.



Source: GIS Analysis, 2019
Figure 10: Calculation of the Sinuosity of the Gully Channel

Conclusion

Federal College of Education Technical Gombe and its environs are currently facing serious problem of gully erosion, especially on the open land meant for future development of the College. The study reveals that the factors responsible for the formation and development of gully erosion in the study area is a combination of interdependent mechanisms between topography, slope, soil erodibility, landuse/landcover change, which have changed over the years thereby reducing infiltration capacity, increased surface runoff on steep slope in the environment. This has increased formation of new gully sites, expansion of existing ones through deep cutting, thereby destroying valuable land that will be used for future development in the College. The impact of the menace of gully erosion in Gombe State has been enormous ranging from loss of access roads to nearby settlements, farmland, and crops, livestock and properties, and to some

extent human lives. Government, at Federal, State and local levels, communities and individuals has tried to combat this environmental disaster with little or no success. This failure can partly be attributed to the peculiar topography, geology, soil, landuse/Lancover changes and non specific control technique employed in combating gully erosion.

Recommendations

Based on the findings of this study, the following recommendations are suggested: Specific, scientific and systematic approach which integrates the influence of all factors observed as responsible for gully formation and development should be employed for the control of gullies within the Federal College of Education Technical Gombe. Both engineering and biological techniques of gully erosion control measures should be put in place the control the dynamic nature of the gully erosion in the area to control its future expansion. The recommended control measures should be extensively applied and monitored for efficiency and effectiveness.

References

Abdullahi, J. and Nggada, T.S. (2019). Analysis of Gully Erosion in Tumfure, Gombe Urban, Gombe State, Nigeria. *Jalingo Journal of Social and Management Sciences, Volume 1, issue 2 April, 2019. pp 33.47.*

Arabi, A. S., Nur, A. and Dewu, B.B.M. (2009). Hydro Geo-Electrical Investigation in Gombe Town.*Journal of Applied Sciences & Environmental Management*, Vol. 13, No. 3 pp. 65-68.

Balzerek, H., Werner, F., Jürgen, H., Klaus-martin, M. and Markus, R. (2003). Man Made Flood Disaster in the Savanna Town of Gombe/NE Nigeria. In Erdkunde, 94-109.

Danladi Aliyu and Ray, A.A. (2014). Socio-economic effect of gully erosion on Land use in Gombe Metropolis, Gombe State. Nigeria. *Journal of Geography and Regional Planning*. Vol.7 (5), July 2014 PP 97-105

Egboka, B.C.E. and Okpoko, E.I. (1984). Gully erosion in the Agulu-Nanka region of Anambra State, Nigeria. Proceedings of the Harare symposium. IAHS Publication, 144, pp. 335-347.

Egboka, B.C.E. and Nwankwor, G.I. (1986). The hydrogeological and geotechnical parameters as causative agents in the generation of erosion in rain forest belt of Nigeria. Journal of African Earth Sciences, 3, pp. 417-425.

Ezechi, J.I. and Okagbue, C.O. (1989). A genetic classification of gullies in eastern Nigeria and its implications on control measures. Journal of African Earth Sciences, 9, pp 711-718.

Environmental Degradation: Causes and Consequences. Available from: https://www.researchgate.net/publication/284395582_Environmental_Degradation_Causes_and_Consequences [accessed Dec 24 2018].

Gombe State Ministry of Water Resources and Environment (2003). Gully Erosion Control Master Plan.

Ministry of Land and Survey Gombe (2008). Gombe Metropolis Land Area. Office of the Surveyor General of Gombe State.

Nyanganji, J. K. (1997). Some Basic Observations on Rainfall and Runoff related Factors on an Artificial Catchment in Maiduguri, NE Nigeria. In: Daura (ed) *Issues in Environmental Monitoring in Nigeria*, 152-165.

Nwajide, C.S. and Hoque, H. (1979). Gullying processes in south eastern Nigeria. The Nigerian Fields, 44, pp 64-74.

Mbaya, L. A. (2012). An Assessment of Gully Erosion in Gombe Town, Nigeria. Unpublished Ph.D Thesis, University of Maiduguri.

Mbaya L.A. (2013). A study of Inter-relations among gully variables in Gombe town, Gomb State, Nigeria. Wudpecker. Journal of Geography and Regional Planning. Vol 1 (1) pp 100-006.

Mbaya, L. A., Ayuba, H. K. and Abdullahi, J. (2012). An Assessment of Gully Erosion in Gombe Town, Nigeria. *Journal of Geography and Geology*; 3; 2012.

Mbaya L.A. (2016). Assessment of the socio-economic effects of gully erosion in Gombe town, Gombe State, Nigeria. *Ilimi Journal of Arts and Social Sciences (IJASS) Volume 2 no.1, May/June, 2016. PP 13-22.*

Ofomata, G.E.K. (2007). Missing Links in the Management of Soil Erosion Problems in Ofomata, G.E.K and Phil Eze, P.O. (eds.) *Environmental Problems and management in Nigeria, Geographical Perspective*: 23.

Okagbue, C.O and Uma, K.O. (1987). Performance of gully erosion control measures in south eastern Nigeria. Proceeding of the International Symposium on Forest Hydrology and Watershed Management, Vancouver, Canada. IAHS Publication, 167, pp 163-172.

World Bank (1990). Towards the Development of an Environmental Action Plan for Nigeria. World Bank, Washington, D.C, 139 p