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Application of Geographic Information System (GIS) in Monitoring Gully Erosion in Gombe Metropolis, Gombe State, Nigeria

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Abstract

The development of gully erosion is a severe environmental problem in Gombe town. It has threatened urban infrastructures, properties, lives and the physical growth of the town. Gully erosion has devastated soils worldwide as a result of overuse and misuse. Knowing the rate of gully development in the past or last decades helped in explaining the reason for the current increase of the gully erosion. This researched therefore assessed the application of GIS in monitoring gully erosion in Gombe metropolis, in mapping the gully erosion, database of the gullies and methods of gully control and its efficacy. Data used in the study was from both primary and secondary source which include the satellite imagery (quick bird 2004 and 2015), ArcGIS 10.1 used in both digitization and morph metric analysis. The quick bird image digitization shows the increase in the length, width while the morph metric analyses show how the gully is spatially distributed as well as showing the increase of gully from 121.5km to 124.595km. the study was concluded that the expansion of gullies in Gombe metropolis is determined by poor drainage, poor waste disposal which lead to disposal of dirt's in gully channel, it causes obstruction to runoff and tend to increase the gully channel gradually and urbanization (population growth) resulting to high pressure on the land.

Keywords: *Gully erosion, Mapping, Gombe metropolis, Satellite image, GIS*

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Background to the Study

Gully erosion in Gombe town destroys valuable land, communication facilities, lives and buildings. It involves expensive control measures and requires more research work. The expansion of concreted surfaces in town, heightened volumes and velocity of runoff that is generated has tended to make many Nigerian towns increasingly susceptible to gully formation. When most of the available land in an urban area is built up, increased pressure on land might lead to extension of urban land use to the stream channels flood plain and restriction of stream to artificial channel. This is the situation being experienced in Gombe town. Gully erosion is a major problem in Gombe town since 1980s; however, the situation is getting worst annually, since Gombe town assumed the status of a state capital. The location of Gombe metropolis lying in low topography with a sloppy relief and undulating terrain, the nature of the soils, infrastructure development coupled with demographic increase are the major causative factors and have no doubt heightened the gullying problem in the town (Gombe SEED, 2006). Associated with the expanding population is the gradual destruction of the vegetal cover so as to accommodate human habitation and their various activities. Besides the soil is vulnerable because of its texture and structure; hence the vulnerable equilibrium between the physical and biological component of the environment and vegetal destruction began progressively until it exposes predominately the sandy top soil in the metropolis and increase in the amount of rainfall that could be intercepted. Resident of Gombe town have expressed concern over accelerated erosion rates. These concern addresses not only the loss of personal property, but also that gully erosion is causing functional and structural damage to infrastructures such as culvert outlets and roads within the stream channel as well as other public and private structures along the channel (Lazarus, 2012). The federal and state government has attempted to solve the problem at some key sites in Gombe town (Mbaya, 2012). However, the economic practicalities and engineering control measures have not met peoples' expectation, owing to lack of adequate information on the gullying problem, therefore gully erosion as an environmental problem has to be monitored.

Although there are few studies carried out however much of the studies dwell on causes, effects and development of gullies in the metropolis (Mbaya et al 2012, Danladi 2013, Florence 2010, and Abizari 2010), but no attempt has been made to use GIS and remote sensing in monitoring and mapping gully erosion. There is a particular need to combine detailed field observation and process based knowledge of contemporary gulling and GIS techniques to reconstruct conditions leading to gully channel incision, development and infilling.

Objectives of the Study

The aim of this study is to monitor gully erosion using geospatial data (GIS and remote sensing), more specifically the objectives of the study are to:

i. To map gully erosion sites in Gombe metropolis.
ii. To create a database of the gully in Gombe metropolis.
iii. To measure the rate of gullies.
iv. To identify methods of gully erosion control and their efficacy.

Study Area

Gombe Metropolis is located between latitude ' 10° to 100 20'Nand longitude 11°01 and 110 19'E (Gombe State Ministry of Land and Survey, 2003). The area comprises of Gombe town (the capital of Gombe State), Gombe Local Government Area, some parts of Akko LGA and Kwami LGA, and cover an area estimated at 45 km^2. It shares common boundaries with Kwami Local Government to the north and Akko Local Government Area to the south east and south west. The metropolis is a multi-cultural society consisting of different ethnic groups such as the Fulani, Hausa, Tera, Tangale, Bolawa, Waja, Igbo, Yoruba, and Kanuri tribes, with Islam and Christianity the dominant religions.

The total population of Gombe Metropolis was 266,844 in 2006 and increased to almost double (400,000) in 2010 (National Population Commission, 2006, Mbaya, 2013). The core part of the metropolis is the most densely populated area with 260 persons per square hectare and coincidentally the most densely part of the metropolis in terms of buildings. Topographically, the highest part of the metropolis can be found on the west with an elevation of 489 m (Federal Low Cost Quarters), while the lowest can be found in the extreme east with an elevation of 423 meters (Barunde) above sea level. Many gullies, rivers and streams in the metropolis have their sources from the foot of Akko escarpment and virtually all flow to the east (Figure 1).

Gombe Metropolis has evinced a rapid growth of built-up environment in progress on undeveloped ground in almost all parts of the metropolis, causing excessive building densities. The core town is becoming more compacted by spontaneous construction works more especially in the central metropolis that include: Jekadafari, Jankai, Dawaki, TudunWada, Pantami, Bolari/Madaki and Herwagana.

The pattern of population growth of Gombe town was slow from 1900 to 1952 (300 to 18,500 people) while; from 1964 to 1991 the population growth has increased tremendously from 47,000 to 138,000. However, from the year 1996, when Gombe became the state capital, there was a noticeable sharp increase in population from 169, 894 (1996) to 219,946 in 2006 (Tiffen, 2006) and 312,467 in 2010 (National Population Commission, 2007).

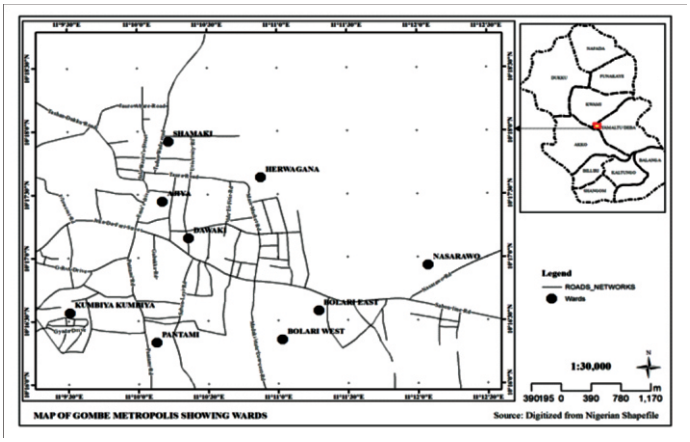

Figure 1: Map of Gombe State and the Study area (Gombe Metropolis)

Methodology

Datasets for this study include both spatial and the non-spatial data, categories into primary and secondary data. The primary data consists of information gathered from field observation and measurements: this includes vector and raster formats generated from on-screen digitization and classification. The secondary data are existing information on gully erosion collected from literature reviews and other materials. To prepare the base maps for analysis purpose and applying the different methods to achieve the study objectives, Quick bird satellite images of (2004 and 2015) were acquired from *National Center for Remote Sensing Jos* (*NCRS*).

Table.1: Details of Quick bird and Google earth Satellite Images

Year	Date	Resolution	Source
2015	07-01-2015	0.6m	NCRS, Jos, Plateau state
2004	18-12-2004	0.65m	NCRS, Jos, Plateau state

Topography of Gombe Metropolis (Slope, Length and Gradient)

According to Mbaya et al, (2012) Gombe metropolis is dominated by active gully erosion. There are two main gully types that exist in the study area which include: floor gullies and hill slope gullies. Bank gullies mainly occur at the boundary between the interfluves and the valleys, which are the areas with the steepest slopes. Gradients are as great as 608 to 808 and the heights from the gully heads to floor are often more than 40 to 50 m. Mass wasting and water erosion are both important processes of bank gully development. Floor gullies develop on the floor of the valley. They often occur at immediately downstream from the convergence of two branches, and we hypothesize that they form when the flow exceeds the strength, or critical shear stress, of the soil material. Hill slope gullies in the watershed mainly developed in the crop land portion of the interfluves. They developed mainly from scour by surface water flow and probably formed when critical flow stress at the soil surface was exceeded and all the active gully are attributed to the slope and gradient of the catchment that ranges from 327m-661m, using the digital elevation model to elucidate as well show the reason for why the western part of the metropolis is the main dominate of the gullies

Results

Types and Sources of Data

After the images have been geo-referenced in the Arc GIS 10.1 software environment, it was from this software environment that on-screen digitizing was carried out. Details on the images were traced out in segments as polygon. This was done by creating layers for each theme, naming the gullies A, B and C. Thus, themes such as area extent, length, width of gullies in Gombe metropolis, gully types as at 2004 and 2015 formed the polygon layer.

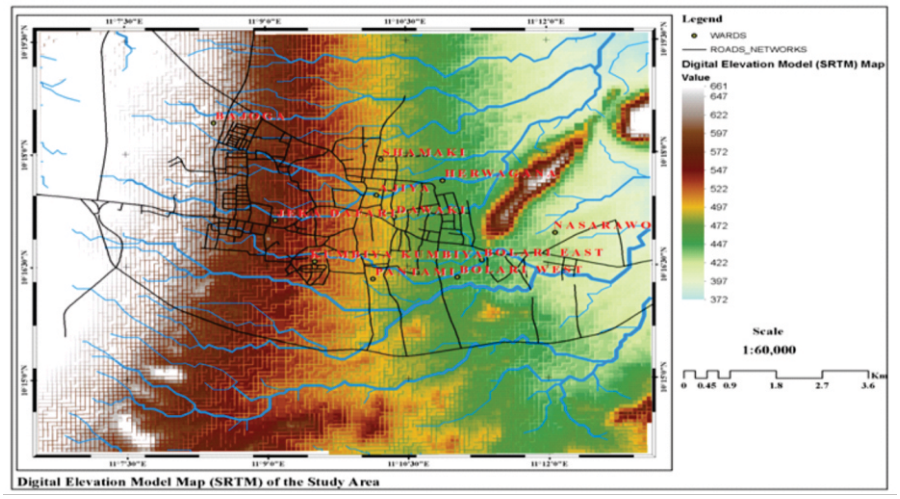

Figure 2: Digital elevation model of the study Area.

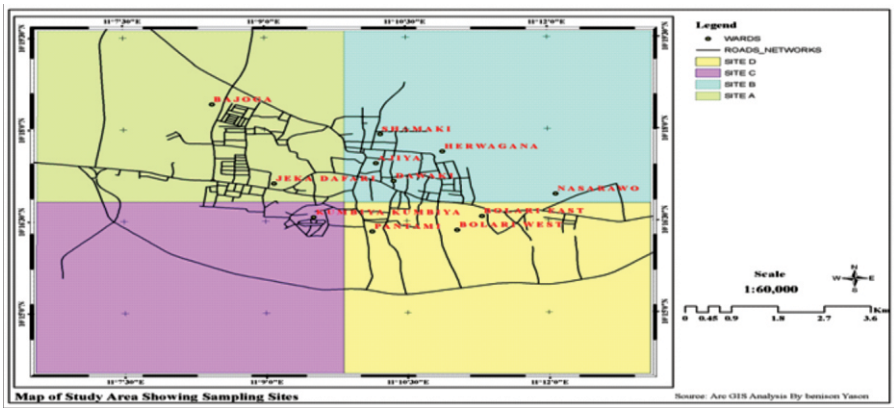

Figure 3: Study area, Gombe Metropolis

Attribute Data Creation

Subsequent to spatial database created above via on the screen vectorizing, several attribute tables were created in an automatic form. Thus, both geometric and attribute databases were geo-linked systematically in a database called ROAD LAYER. Similarly, Microsoft Excel was used to build attribute data for the entities identified, in other to get a wider view of the gullies the area was demarcated into four sectors (A, B, C, D).

Morphometric Analysis

The morphometric analysis of the drainage basin and channel network play an important role in understanding the geo-hydrology behavior of the drainage system of the study area and structural antecedents of the catchment. The morphometric parameters of the terrain slope, terrain aspect, profile curvature, tangential curvature and topographic residual surface are chosen for identifying the linear continuity of the morpho-structural features observed on the DEM. The criteria of lineament extraction are based on the identification of linear topographic surface features, such as Valleys, ridges, breaks in slope, boundaries of elevated areas aligned in a rectilinear or slightly curvilinear shape and that distinctly

differ from the patterns of adjacent features. The morphometric analysis was carried on the ArcGis environment using the SRTM imagery. The result identifies the streams orders (gullies) from order 1-6 in Gombe metropolis which was use in mapping out the gully in the metropolis.

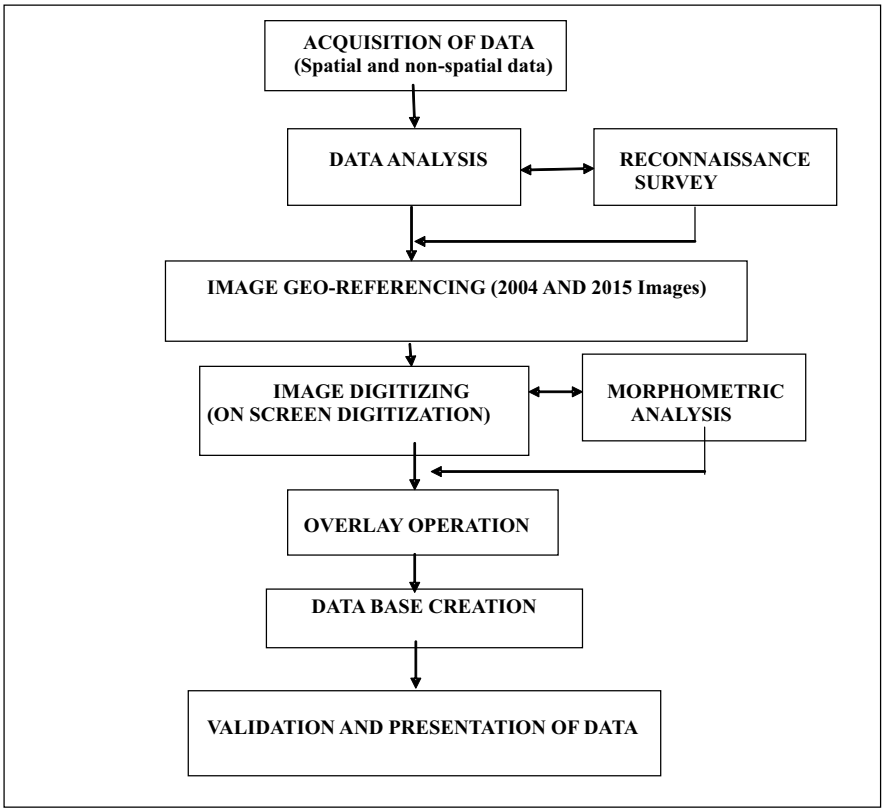

Figure 4: Flow chart of methodology applied in the monitoring gully erosion in Gombe metropolis

Discussion

This section shows how gully erosion is spatially distributed in Gombe metropolis. In order to achieve this, SRTM (Shuttle radar thematic map) of Gombe metropolis this was subjected to morphometric metric analysis were the streams orders from first order to sixth order was extracted and differentiated with color and thickness and it conform with (subsection 2.6) which shows that the stream or cycle of erosion are in forms of youth, maturity and old age according to W.H Davis (1900). The first order, second, third, fourth and fifth orders are the tributary that contributes to the main gully channel (sixth order) which is less dominant. In essence the most that constitute the metropolis is the first order with 63%, second order 19%, third order 12%, fourth order 5%, fifth order 2% and finally sixth order 1.05%.

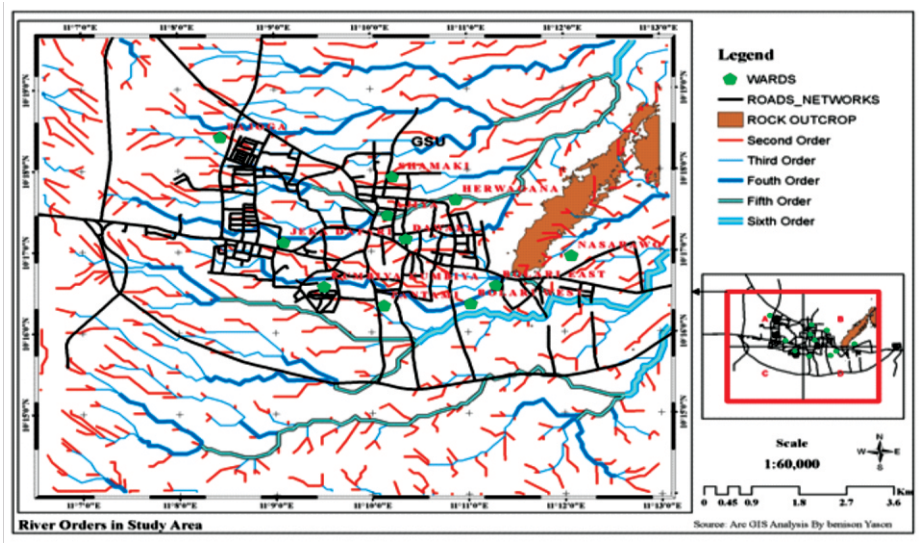

Figure 5: Merged the four sectors showing the spatial distribution of gully in Gombe

The above shows the spatial distribution of gully erosion according to ward/ sectors A, B, C, D in the metropolis with other stream orders such as rills and splash erosion which with time will also developed into gullies of gradable size as the factors such as unmanaged land, poor network of drainage system, urban sprawl and population growth continue to add stress to the land which with time will eventually develop into matured gully channels. The sixth, fifth and fourth orders are the main stream channel (main gullies) which tends to dominate the north-western part of the metropolis due to the effect of the terrain (topography) and this is because rivers/ streams flow from highlands to low lands.

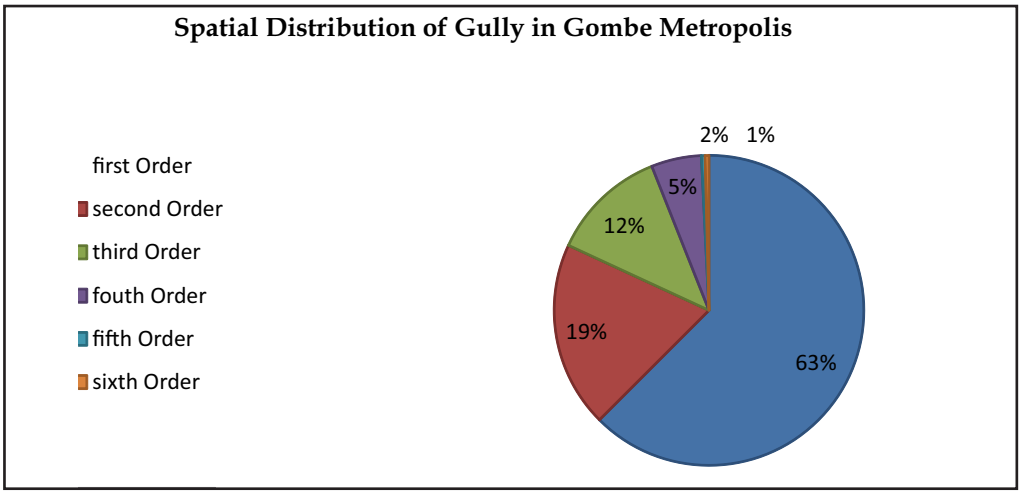

Figure 6: Spatial distribution of gully erosion and their percentages

Database of Gullies in Gombe Metropolis

Classes of streams orders were generated, each class assigned with different ID such OBJECTID, arcid, grid code, from_node, to_node, and Shape length (km) each class generated automatically as the analysis is being Run. The area was bisected in A, B, C and D having both the first, second, third, fourth, fifth and sixth orders of the stream in order to have a wider view of the gullies and also have the extent/length each of the gully covers with it number in total and length (km) of each orders in the metropolis. The table2 below is the summary of the database generated from the morphometric analysis that was used to map out the gullies in the metropolis.

Table 2: Summary of Database of Gullies in Gombe Metropolis

Orders of stream	Site A	Site B	Site C	Site D	Total	Mean
	No. of gullies	No. of gullies	No. of gullies	No. Of gullies	No. of gullies	
1st order	157.99	151.63	159.01	145.95	614.58	153.64
2nd order	49.00	42.00	43.00	39.00	173.00	43.25
3rd order	30.57	17.82	24.22	15.89	88.50	22.12
4th order	13.21	16.08	13.60	7.80	50.68	12.67
5th order	0.96	9.86	6.92	11.54	29.29	7.32
6th order	1.03	1.47	0.50	8.20	11.20	2.80
TOTAL	252.75	238.86	247.26	228.38	967.25	241.81

Source: GIS analysis/field work 2016

Rate of Gully Erosion (Gully Changes between 2004 -2015)

Figure 6: illustrate the manually digitized gullies with quick bird satellite imagery on the background. They range from small to large gullies of 0.1 to 96 hectares in size and are 967 in total number (calculation not shown here). Using manual digitizing technique, very small gullies are easily detected visually and mapped thus providing the most accurate results that can be utilized as reference data to test the accuracy of the technique adopted.

The result provided is distinguished by green and red coloreach indicating both gully extent as at 2004 and the present 2015. The green color gully (2015) shows the increase of gully in width and length, and this is as a result of stress on the land. The reason for the increase includes;

a. Dumping of refuse on the gully channels, with time this refuse tend to accumulate the channels as rain comes there will be an interaction between the soil particles (gully channels), refuse (obstacle) and the flowing water which give rise to the undercutting of the gully wall gradually.
b. The sandstones and shales (Gombe Sandstone and Pindiga Formations) that dominated Gombe town geology have therefore accelerated gully erosion through rock fracture and weathering which agrees with (Orazurlike, 1987 in Mbaya, 2012).

The soil type, texture and depth of the metropolis as explained in (subsection 2.8), which tend to encourage gully formation.

c. Non-Provision of collection system for roof rain water runoff and its subsequent reuse; drainage of surface runoff, or the establishment of interception, division and primary (trunk) drains that would help reduces roof rain water runoff.
d. Insufficient attention to land evaluation and land management." To every action there is an equal and opposite reaction" urbanization which has contributed a lot to the increase of this gully banks.

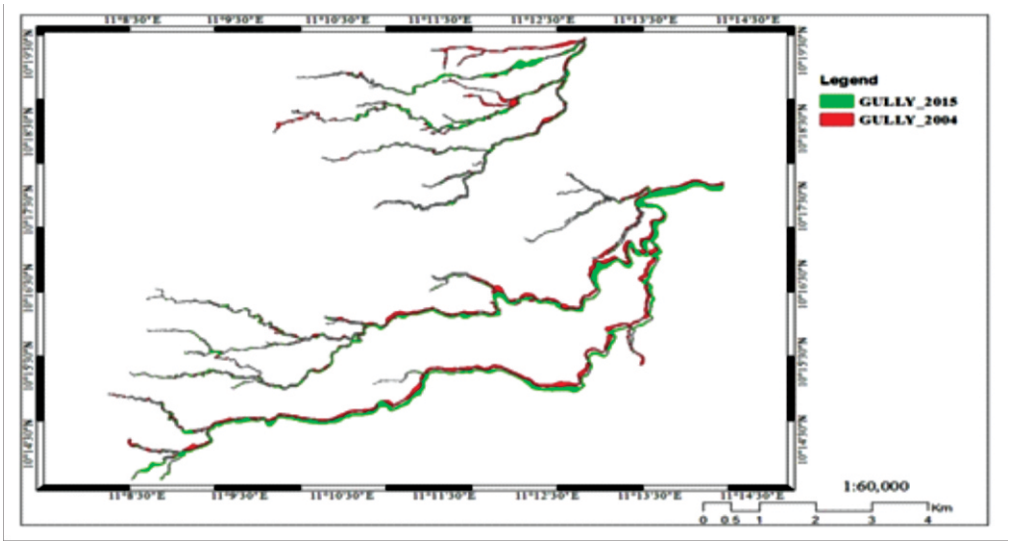

Figure 7: Overlay result of the 2004 and 2015 images of digitized Gully erosion.

Previous studies conducted in Gombe township erosion control shows that the total length of gully within the metropolis is about 121.5km, out of this only 5.6km in length have been controlled while 7.62km have been partially controlled leaving about 107.3km still uncontrolled, SEEDS(2006). Also other studies by the ministry of environment on the yearly physical assessment of gully situation after each rainy season in Gombe metropolis considering the hydrological, topographical, geotechnical and demographic parameters in the gully activities of 30 years shows that the total length of gully within Gombe is 121.59km, the length checked is 9.98km, length partially checked is 7.20km and length not yet checked is about 104.41km.

Presently comparing the result of the manually digitized gully and that of the morphometric analysis show that most of the previous uncontrolled or partially checked gullies had resulted to the increase of the gullies channels in length, which using the table 2 show that the length has increase presently from 121.5km (SEED,2006) to 124.545km following reasons which are explained in subsection 2.2 and 2.8 and in relation to the below explained in subsection 4.3.0.

Table 3: Showing the Length of Gullies in Each Site.

	Length of gullies(km)				
Orders of stream	Site A	Site B	Site C	Site D	Total
1st order	8.9	7.5	6.2	3.5	26.1
2nd order	2.9	5.8	5.6	6.3	20.8
3rd order	1.16	9	2.35	4.8	17.31
4th order	5.9	2.3	5.5	9	22.7
5th order	3.3	5.3	4.3	4.2	17.1
6th order	0.512	12	0.023	8	20.035
Total	22.672	41.9	23.973	36.0	124.545

Factors Leading to the Increment of Gullies

(a) Land use Pattern of Gombe Metropolitan Region

The land use pattern of the Study area iscategorized into five major land use types found in the metropolis which also contributors to the formation of gullies in Gombe metropolis. Since Gombe town assumed the status of a state capital, the infrastructural development coupled with demographic increase has no doubt heightened the problems of gully erosion in the state capital. When most of the available land in an urban area is built-up, increased pressure on land might lead to extension of urban land use to the stream channels, flood plain and restriction of stream to artificial channels.

(b) Rainfall Pattern of Gombe Metropolis

Below is a diagrammatic representation of rainfall pattern in Gombe metropolis. The highest years of rainfall is in 2007 followed by 2005 and then the subsequent, rainfall is one of the major factors that contribute to the increase of gully in the area amongst many such as increase in population, unplanned land, deforestation etc. because the area is mostly dominated by bare surface and area dominated with less vegetation yield more runoff than a vegetative area e.g. the northern part of the state as compared to the south part of Gombe metropolis.

(Capra et al., 2009 in Mbaya 2012) reported that a rainfall event is erosive if the height of rainfall is equal to or more than 13 mm per hour or the intensity in 15min is equal to or more than 6 mm. The implication of this finding is that every year gully erosion increases due to rainfall intensity that produces rapid saturation of the soil, causing down cutting. Rainfall contribute only about 45% (flow volume) to the formation of the gully in the metropolis leaving about 40% to the soil properties, soils of Gombe metropolis are easily weathered cause of no much vegetative cover to reduce the interception and infiltration.

Another factors are that Dumping of refuse on the gully channels, with time this refuse tends to accumulate the channels as rain comes there will be an interaction between the soil particles (gully channels), refuse (obstacle) and the flowing water which give rise to the

undercutting of the gully wall, gradually the wall would lose support and fall and also most of negligence from the locals also triggers the gully.

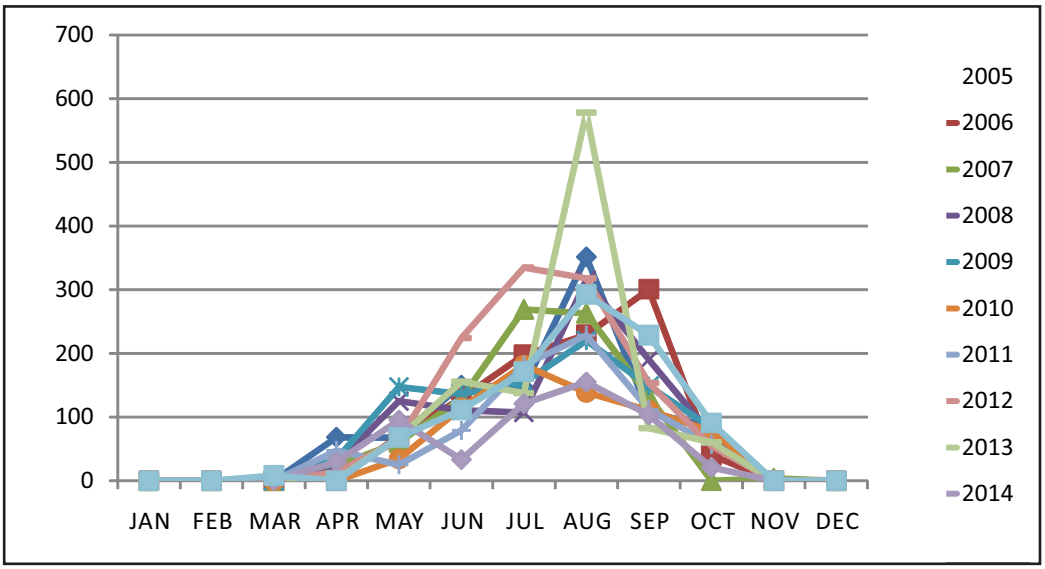

Figure 9: Rainfall pattern in Gombe metropolis from 2005 to 2015
Source: NIMET/ Field work (2016)

Methods of Gully Erosion Control and Their Efficacy

Methods of gully erosion control measures in the study area refers to the parameters and elements of control measures of gully erosion by different method which comprises of engineering control measures, vegetative, stone wall; sand bags control measures and others. In Tudun Wada ward the percentage of gully erosion control measure is 71.89% which comprises of the engineering control of about 50%, vegetative of about 15% and other 6.89%, in Jakadafari ward, the percentage of gully erosion control measures is 71.42% which comprises of engineering control measures 65.50% and vegetative control measure of about 5.92% respectively. Also in Bolari ward the percentage of gully erosion control measure is about 80.70% which comprises of the both the engineering of about 75.70% and other 5.0% respectively. In Pantami, Herwagana and Kumbiya-Kumbiya ward only about 9.65% of the gully have been controlled by engineering control measure leaving about 85.76% uncontrolled.

Engineering Control Measure and its Efficacy

This is the modern way of controlling gullies by construction of drainages, culverts and fence in order to reduce the rate of overloading and infiltration. In all control measures it's the very expensive method of control measures which is highly efficient and reliable in term of controlling gully erosion in the metropolis. Engineering control measures in the study area comprises of sample ward (Bolari, Jekadafari and Tudunwada, pantami (stadium) ward). The engineering control measures in Pantami ward is 43.58%, Bolari about 87.55%, Tudunwada 45.89% and Jekadafari ward 87.88%. The controlling of gully erosion in Gombe metropolis using engineering method is only limited to some areas or

concentrated on the major streams leaving some gullies to other control measure. Because it is expensive in terms of construction it does not conform to the urgencies in term of reducing the great menace "gully erosion" or fit as a measure that the community at large can adoptindividually in tackling gully erosion problem.

Conclusion

This project assessed the application of GIS in monitoring gully erosion in Gombe metropolis. Gully erosion based on several literatures have been said to be very disastrous and has been a threats to Gombe metropolis for more than a decade's destroying lives and property worth millions of naira as well as posing threat to the availability of arable land for both agriculture and buildings in the Gombe metropolis i.e. loss of land to gully erosion/buildings.

Data for this research was obtained from both primary and secondary sources which include reviews from literatures, journals, satellite images (2004 and 2016) and various techniques in GIS based approach was used to analyze the data so as to present the result and also meet the objectives of the research. Data analysis were summarized with the aid of maps, tables, percentages, graph and satellite images of the various years used.

The projection to the past of the measured gully retreat rate confirms the acceleration of gully erosion processes since the massive increase of demographic stress to the land as well as other environmental factors like soil type and mostly bare surface with little vegetative. On the other hand, the projection to the future of this retreat rate may be an important way to persuade the locals/ community and the Administration about the implementation of control measures.

Gully erosion has been on increase and advancing at alarming rates over the past few decades in Gombe metropolis causing untold hardship, misery, loss of houses, lives and other properties worth millions of naira. As human population within the metropolis rises, more land is cleared of its available natural vegetation and replaced with impervious surfaces leading to infiltration to runoff ratio. The situation is further worsened by rise in value of urban land due to population increase, that force people to erect building on floodplains, consequently increasing the magnitude and frequency of gully erosion in response to high storm water runoff and channel concentration. Complex interdependent mechanism between rainfall characteristics, land use, topography has reduced infiltration, which caused a higher surface runoff. This has increased deep cutting or under cut, take up valuable land, raised the cost of building and sinking of water well. This chain of cause and effect hits most of the low income groups of the community where the population density is highest and where the worst damages of gully erosion are found.

Based on these finding the study concluded that the sudden increase of gully length from 121.5km which out of this only 5.6km in length have been controlled, while 7.2km have been partially controlled leaving about 107.3km still uncontrolled(2006, SEED), led to the remarkable increase to 124.545km of gully length base on the following contributing factors such as inadequate proper waste disposal make people used the drainages and

gully channels as the point of dumping refused with subsequent leads to the flooding and increase bank erosion, and some other environmental and human related problem like demographic stress on land and environmental degradation.

G.I.S and its related technology will help greatly in the acquisition, organization, management and analysis of these large volumes of data, allowing for better understanding of natural disasters and the importance of record for future use on gullies in the metropolis.

Recommendations

In the light of what has been responsible for the continuous development of gullies and subsequent destruction of properties, roads and threat to life and environment in general the following recommendation has been suggested as regard to gully erosion problem in Gombe metropolis.

1. The method of monitoring using GIS based approach can be applied in all research related to environment or either in physical or regional Geography throughout Nation.
2. Finally, the loss of lands due to gully erosion and the increasing demand made on the land by agriculture, urban growth, industrialization and other human activities make the need for integrated landscape planning urgent.

The formation of gullies is one of the greatest environmental disasters in Gombe metropolis. Large areas of built-up lands are lost or have become unsuitable for construction due to gully erosion. There have been numerous attempts to curb gully erosion in the state (metropolis); especially through large-scale engineering projects, however, little has been discussed about ways to prevent their onset or the use of community-based low-technology approaches to mitigate their development. Erosionis a function of rainfall, a natural phenomenon which is outside human control and manipulation. The effects of this erosive action are made more severe by recent and rapid population growth. Although some gullies have become too severe to remedy, and will require huge engineering efforts, others can be prevented and incipient ones tackled through a variety of best land management practices and low-cost approaches. Control measures to stem gully erosion that are incipient are most effective when erosion is still at an early stage when sheet or rill erosion is still the erosion form and erosion is still amenable to low technology intervention.

Unlike soil properties and topography, which can only be manipulated by human action, land management is often very much under human control. Proper land use and watershed management can be used to reduce surface water runoff and control infiltration in order to dampen erosive forces and reduce the erodibility of soils. However, lack of awareness about the cause of the problem is very evident within the community. Many households in the community either do not know the cumulative effect of the lack of proper drainage systems or do not care because there are no direct and immediate repercussions for their poor land management. There is a lack of legislative frameworks to ensure that households refrain from practices that cause gully erosion, and enable these

communities enact enforcement mechanisms. In addition, information on the causes of gully erosion and how it can be prevented are scarce. Many of these communities are not aware of the major causes of gully erosion and how it can be prevented, or how their actions are contributing to gully formation but if they are enlightened on the adverse effect of their contribution as well as the significant direct effect of gully erosion then they can have a cautions mind of how to help in monitoring, and even prevent the gully. Below is an efficacy model that should be added to the above in other to bridge the gap for the controlling of gully in the study area.

References

Abegunde, S. A., Adeyinka, P. O. O. & Olufumilayo, A. O. (2006). *The impact of erosion on rural economy: the case of Nanka in Anambra state of Nigeria.*

Ananda, J. & Herath, G. (2003). Soil erosion in developing countries: a social economic appraisal. Pub Med (www.pub *med.gov.J.environ managr. Ang, 68* (4), 343-53 ELSEVIER.

Ayuba, H. K. (2005). *Environmental science: an introduction text.* Apan publication…. retrieved 14/12/2015.

Boje, F, Xilin, W. & Culinck, H. (2015). Soil erosion types in the loess hill and gully area of china. *J. Environ. Sci: Eng*. 266-272. Retrievd14/12/

Ebisemiju, F. S. (1989). *A morphometric approach to gully analysis*. *Geomorphologies, 33* (3), 307-322.

Ehiorobo, J. O. & Izinyon, O. C. (2011). *Monitoring of soil loss and erosion using Geo-informatics and Geotechnical Engineering methods*.

Hanyona, S. (2001). Soil erosion threatens farm land of Saharan Africa. In, *The Earth Times*, January 10, 2001. (http://forests.org/archieve/african/soerthre htm

Peosen, J., Ngehtergaele, J., Verstraeten, G. & Valentin, C. (2003). Gully erosion and environmental change, importance and Research needs. *Catena, 50*, 91 – 133.

Poesen, J. et al. (2002). Gully erosion in dryland environment. In, Bull, Louise J. & Kirby, M.J. *Dryland Rivers: Hydrology and geomorphology of semi-Arid channels*. John wiley & Sons. ISBN 978-0-471-49123-1.

Lang, A. & Bork, H. R. (2006). Past soil erosion in Europe. In, Bordman, J. & Poesoen, J. (Eds.) *Soil erosion in Europe*. UK: Wiley, chichester, pp 465-476.

Lazarus, A., Mbaya, H. K. A. & John, A. (2012). An assessment of gully erosion in Gombe town, Gombe State Nigeria. *Journal of Geography and Geology,* 110-117.

Michael, E. (2006). *Ritter geologic work of stream: the physical Environment: an introduction to physical geography*. University of Wisconsin, OCLC 79006225

Nyaganyi, J. K. (1993). *Landform, land use and settlement pattern in the Ngadda catchment: a contemporary perspective of the Kotogerienvirons.* A paper presentation at the 12th Archeological association of Nigeria conference, CTSS UNIMAID…. retrieved 14/12/2015.

OMAFRA Staff (2003). *Soil erosion, causes and effects*. Ridge Town and College of Agricultural Technology, Ontario Institute of Pedelogy. Retrived from http://www.search.gov.on.ca.8002/compass?view-template=simplr.

Ofomata, G. E. K. (1984). *Erosion in the forest zone of Nigeria*. A paper work at the 27th Annual conference of Geographical Association of Nigeria, university of Nigeria, Nsukka.

Okin, G. S. (2002). Toward a unified view of biophysical land degradation processes in arid and semi-arid lands. In, *Global Desertification: Do Humans Cause Deserts?* Edited by J.F. Reynolds and D.M. Stafford Smith. Dahlem University Press. Pp95-97.

Ologe, K. O. (1987). Soil erosion characteristics, processes and extent in the Nigerian savanna. In V. O. Sagua, E.E. Enabor, G. E. K. Ofomata, K. O. Ologe, & L. Oyebande (eds) *Ecological Disasters in Nigeria: Soil erosion*, pp 26-49.

Ries, J. B & Marzolf, H. L. (2003). Monitoring of gully erosion in central Ebro basin by large scale Aerial photograph taken from a remotely Controlled Blimp. *Cateria, 50,* 309-328.

Sazbo, J., Paztor, L. & Varallyay, G (1998). Integration of remote sensing techniques in land degradation mapping. *Proceeding of the 16th international congress of soil science*. France: Mont pellier. pp 63-75.

SEEDS (2006). *State Economic Empowerment and Development Strategy (SEEDS)*. Lagos, Nigeria: Management Review limited.

SCSA (2007). *Resource conservation glossary*. Ankeny, Iowa. USA: SCSA

Solè, Ll., Clotet, N., Gallart, F. & Sala, I. (1986). Análisis de las posibilidades de las imágenes TM en la detección de áreasdegradadasensectoresmontañosos. In: Coumunicacionescientíficas de la I ReuniónCientífica del Grupo de Trabajo de Teledetección, N. ClotetandLl. Solè (editors). *Institutd´InvestigacionsGeològiquesJaumeAlmera*. Barcelona.

Thomas, A. W., Welch, R. & Jordan, T. R. (1986). Quantifying concentrated-flow erosion on 12 crop land with aerial photogrammetric. *Journal of Soil and Water Conservation*, 249-252.

Thomas, J. T. Iverson, N. R., Burkest, M. R & Kramer, L. A. (2004). Long term growth of a valley- both Gully. Westorm Iowa. *Earth surface processed and landform, 29*, 995-1009.

Tiffen, M. (2006). *Gombe emirate, 1990-68; urban and commercial development*. A public lecture held in Gombe state university 12th February; 1-6.

Vandekerckhove, L., Muys, B., Poesen, J. & De Weerdt, B., C, (2001). A method for dendrochronological assessment of medium-term gully erosion rates. *Catena, 45* (2), 123–161.

Yongui, W. & Hong, C. (2005). Monitoring of gully erosion on the loess plateau of china using global positioning system. *Cateria, 63* (2), 154-166.

http://enwikipedia.org/wiki/erosion.html…..Retrieved 09/12/15
http://enwikipedia.org/wikifErosion.....Retrieved 07/12/2015
http://www.paralumum.com/enveron.htm 09/12/2015.....Retrieved 09/12/15
http://www.sntc.org.52/articles/soil..Retrieved 14/12/2015
www.accesorieslibrary.com/com21Retrieved 14/12/2015
www.interscience-wiley.com.journal….Retrieved 14/04/2015