Journal of Research in Forestry, Wildlife & Environment Vol. 12(4) December, 2020
E-mail: jrfwe2019@gmail.com; jfewr@yahoo.com
http://www.ajol.info/index.php/jrfwe
jfewr ©2020 - jfewr Publications
ISBN: 2141 – 1778
Abbas, 2020

FACTORS THAT INFLUENCE THE GULLY EROSION SITUATION IN ZARIA, KADUNA STATE, NIGERIA

Abbas I. I.
Department of Geography, Kaduna State University, Kaduna, Nigeria
*** Corresponding Author:** *innoabbas@yahoo.com;* +234 803 642 1962

ABSTRACT

The study assessed the factors controlling gully erosion in Zaria, Kaduna state, Nigeria with the view of ameliorating the consequences of the gully erosion. Satellite imagery Quickbird 2013 1m resolution; 10 years rainfall data; soil samples; and Shuttle Radar Topographic Mission (SRTM) imagery were the data sets used. The study used Geographic Information Science and multi-criteria analysis to analyze the data sets taking into consideration the slope steepness, rainfall, soil texture and land cover of the study area to derive the results. The controlling factors of gully erosion shows that slope (56%) had the highest on gully erosion, followed by rainfall (26%), land cover (12%) and soil with 6% in the study area. The effect of gully erosion in the study area was in the form of loss of lands, houses, economic trees and lives. It is concluded that in some areas, a single factor had an overwhelming effect over others in controlling soil loss among the research sites.

Keywords: Control, Factor, Gully, Erosion, Slope

INTRODUCTION

Erosion, as it affects man and his environment, is natural and is as old as the earth itself (Omfara, 2003). It is seen as the gradual washing away of soil through the agents of denudation which include wind, water and man (Abegunde, 2003).These denudating agents loose, wear away, dislodge, transport and deposit wear off soil particles and nutrients in another location (Uche, 2012). Soil and water resources are crucial for sustainable social and economic development. Both soil and water resources can be threatened by process of soil erosion and sediment redistribution (Owenns, 2006 cited in Nasiri, 2013). In order to preserve sensitive areas, land should be appropriately used based on land cover classification, and illegal opening and cutting must be prevented (Bozali, Yuksel and Akay, 2008 cited in Nasiri, 2013). Of the types of erosion, water-induced erosion is common.

Water erosion can be divided into various types according to the mechanics of the processes in operations as pointed out by Oas (2011). Water induced soil erosion can be seen as a spectrum of processes ranging from those which are dominantly fluvial with relatively high water content under low gradient at one extreme to those which are gravitational with less water under gradient at the other. They form the following sequence; stream flow, mud flow, overland flow, soil creep, land slump and land slide. Horton and Smith (2006) categorized the first two as sheet and rill erosion, the third as gully and the last three as mass movement. All cause damage, both by the removal and by the deposition of material. They may occur singly or in combination and there is clearly some overlap among them. Rills for instance, as merely small gullies and sheet erosion is only a shallow form of mass movement, while during heavy rain storms, runoff water enlarges rill into deep channels called gully erosion (Wangida, 2006).

Gully erosion is a widespread and often dramatic form of soil erosion caused by flowing surface water with open, unstable channels that have been cut more than 30 centimetres deep into the ground (www.environment.nsw.gov.au). Gullies can be active (actively eroding) or inactive (stabilized).

The former according to Poesen, Nachtergaele, Verstracten and Valentin (2003) can occur where the erosion is actively moving up in the landscape by head-cut migration. The causes of gully erosion are poorly understood but the processes and factors involved in its growth and degradation are well known (Bettis, 2008).

The United Nations Education Scientific and Cultural Organization (UNESCO) (2009) recognized three main environmental problems facing Nigerian to be soil degradation and loss, water contamination and deforestation. Gully erosion is related to each of the three main problems and cause damage with an annual cost to the nation estimated at $100 million in 1990. The World Bank (1990:32) also reported that while there is much awareness in the country of environmental concerns, Nigeria's institutional capacity to address the challenges remains weak with population skyrocketing, cities expanding and greater number of Nigerians depending on a shrinking pool of arable land while degradation continues to worsen. As at 1997, there were 5,700 gully erosion sites nationwide (Agagu, 2009). Unfortunately, the situation has probably worsened by now.

Accelerated erosion with its effect on agriculture in Nigeria is well documented. Urban gully erosion affects only 18,517/km^2, representing only two percent of the total area of Nigeria (Titilola and Jeje, 2008) and so tends to be ignored in literature. However, the area of land affected by gullies is not the sole criterion for estimating the damage they inflict on the national economy. Gully erosion destroys valuable land, communication facilities, lives and buildings and involves expensive control measures, hence, requires more research.

Apparently, soil erosion has been recognized not only within the rural but also in the urban environment in Nigeria and in many other parts of the world. In areas like Zaria, population explosion, rapid urbanization, increased rainfall and poor agricultural practices are some of the factors that contribute to soil erosion (Michael, 2013). It is then of universal importance to understand soil erosion issues since man's activities, directly or indirectly, depend on the soil. Soil erosion thus constitutes a national hazard, and the containment is a prerequisite to national development (Isikwue *et al*., 2012).

The physical factors causing erosion are climate, soil, vegetation and topography ((Clinciu *et al*., 2010).). The principal factors that can be measured or estimated, and that therefore are useful in soil erosion modeling are rainfall erosivity, soil erodibility, protective cover provided by vegetation, landuse and management practices that affect the protective cover, soil resources and topography (Troech *et al*., 1991). It should be emphasized that none of these parameters control the pattern and magnitude of erosion (Morgan, 1995).

Soil erosion studies have some traditional approaches, but in recent times, Geographic Information System (GIS) has become versatile for investigating several earth processes including erosion modelling. The two types of erosion models are empirically based, and process based, or physically based. Empirical models such as those used for soil erosion assessment include (Universal Soil Loss Estimation model, Revised Universal Soil Loss Estimation model, and Soil Loss Estimation Model for South Africa among others). Empirical models are based on observation and are usually statistical in nature. They use inductive logic. Generally, they need to be calibrated and should be used only under conditions similar to those for which the model was designed. Empirical models by their nature are more reliable in the middle ranges of the input variables than for either of the extremes and can be applied with confidence only to conditions for which its predictive capability has been established (Bobe, 2004).

The physically based models are based on knowledge of the fundamental erosion process and incorporate the laws of conservation of mass and energy (Petter, 1992). Ideally, physically based models are developed to replace conceptually distributed models because they are firmly based on understanding of the physics of processes involved. Examples of physically based models include

Watershed Erosion Prediction Project (WEPP), CREAMS (Chemicals, Runoff, and Erosion from Agricultural Management Systems), European Soil Erosion Model (EUROSEM) etc. The main limitation of these models is that they are data hungry.

Micheal (2013) and Agi (2015) modelled erosion in Northern Makurdi, Benue State. The study used RUSLE to estimate the amount of soil loss in the study area as well as map and analyzed the distribution of erosion within Northern Makurdi for the years 2003 to 2013. The result shows that the estimated amount of soil loss range between 0 to 48tons/ha/year. While Horton and Smith (2006) concluded that soil erosion destroyed many farm lands, plot of land and other land use structures such as road, bridge, dug well, culverts and grave yard while many at the risk of being consumed by the menace of erosion in Uthai Thani Thailand.

Many lives have been lost as a result of the problem of gully erosion. Some people either fell into these gullies and sustained various degrees of injury or died. Some instances have also been reported in Southeastern Nigeria where people were drowned in some of the gully sites (Igwe, Akanigbo and Mbagwu, 1997). About 23 people reportedly lost their lives in a single event of gullying activities in Ibori, Ugbalo, Ewu-Eguare, Idogalo and Oludide communities of Edo State, Nigeria (Abdulfatai *et al*., 2014). Millions of people have been displaced and vacated from their homes following gully incidences. The erosion in Okoh community in Anambra State also created a deep gully and wider crater, threatening to sweep away the homes of about 826 families as this channel is continuously expanding at an alarming rate (Uche, 2012). For decades, soil erosion has been a major environmental problem in Anambra, Abia, Cross River, Sokoto, Kaduna, Kano and Borno States (Olofin, 1994).

As part of government commitment for the transformation of Nigeria's socio-economic landscape, a multi-sector project is being executed in Nigeria to mitigate the vulnerability to erosion and support the people as they relate to their land. The Nigeria Erosion and Watershed Management Project (NEWMAP) (2013) is an 8-year multi-sectoral and multi-scale program that targets states with acute gully erosion. In order to achieve this, the Federal Government of Nigeria (FGN) has received a credit of US$500 million from the International Development Association (IDA) for the implementation of the project. The Federal Government of Nigeria spent over 3 billion Naira to check the menace of soil erosion in some parts of the country which involved Auchi, Edo State in 1989, Bida, Niger State in 1988, Ebeu Ohiado, Abia State in 1990, Billiri, Bauchi State in 1990, Bambissa, Plateau State in 1990, Dawakin Tofa, Kano State and Kaduna State in 1990 and many other areas. However, the situation is still at an alarming rate.

This study therefore decided to assess the controlling factors of erosion in Zaria, Kaduna state so as to be able to ameliorate the ever increasing incidence of the effects.

MATERIALS AND METHODS

The data for this study are: Satellite imagery Quickbird 2013 1m resolution obtained from office of the Surveyor general of the federation; rainfall data was obtained from Institute of Agricultural Research, ABU, Zaria; soil samples were collected from gully erosion sites in the study area; SRTM imagery of the study area was sourced froglcfaap.glcf.umd.edu/data/; and satellite imagery, a 30m resolution LANDSAT ETM+ multispectral satellite imagery of the year 2014 of the study area was obtained from www.glovisusgs.gov.

A multi-criteria analysis was used to examine factors controlling gully erosion in the study area. This is by assigning weight to each gully erosion factor in order to get their percentage. The factors considered are slope steepness, rainfall, soil texture and land cover of the study area. The topographic map was geo-referenced or geo-rectified (registration) to a geographic coordinate system. The images were imported into Erdas Imagine 9.2 environment where they were rectified to a common projection (Universal Traverse Mercator). This was done to translate the images real world coordinate to digital format so that it can be matched with other relevant and related maps used in this study. Geo-referencing was carried out by assigning geographic information like location and position, to the data sets (images) to define the existence of those data sets in physical space as well as establishing their location in the real world.

Landsat imagery 8 was subset from each of the larger scenes using Erdas Imagine 9.2 software since the satellite images cover a large area. Supervised classification technique was performed using Maximum Likelihood Classification (MLC) algorithm. Based on the prior knowledge of the area and reconnaissance survey, a classification theme after Anderson, Hardey, Roach and Witmer (1976) was adopted for the study as in table 1.

Table 1: Land use and Land cover Classification System

Code	Land use/Land classes	Cover description
1	Buil-up land	Land used for settlement and building of urban infrastructure such as schools, roads, etc
2	Vegetated land	Land covered with natural vegetation such as grasses, shrubs, grass like plants and natural forest
3	Crop land	Land used as crop land, agricultural farmland etc
4	Water body	Rivers, streams, ponds and dams
5	Bare surface	Land devoid of vegetation cover and exposed soils

Source: Adapted from Anderson, Hardey, Roach and Witmer (1976)

Coordinates information collected was used for visual assessment and development of training site in Erdas Imagine 9.2. The SRTM was used to generate a digital elevation model (DEM) where the slope length (L) and thus the slope steepness (S) were calculated. This is one of the parameters used in estimating the controlling factors of gully erosion in the study area. The rainfall data was used to calculate the seasonal energy (E) which is also another parameter used in the SLEMSA equation for estimating the average amount of soil loss. Rainfall data using non recording rain gauge was sourced at the Institute of Agricultural Research, ABU, Zaria. The long term non recording rain gauge data (2003-2013) were used to compute long term averages for the study area. Rainfall data of 10 years was used as stated in the RUSLE handbook (Renard, Foster, Weesies, McCool and Yoder, 1997). Each of the rainfall charts was analysed by summing up the monthly averages to the yearly averages. To obtain rainfall amount in mm, the rainfall from January – December averages for the 10 years was calculated. Related to the rainfall runoff erosivity factor, the values of the rainfall records in the study area were used to generate the rainfall map. But due to the unavailability of other rainfall stations in the study besides the NIMET station in Zaria, surrounding rainfall stations and their averages were used and hence, the rainfall map of the study area extracted.

After data collection, R factor was determined for the selected rainfall gauging stations. Isohyet maps for R factor were generated using ArcGIS 10.1. All the data points were interpolated spatially using the Ordinary Kriging method found in the ArcGIS 10.1 Spatially Analyst tool to make the same resolution or grid cell size as the other maps inserted in the ArcGIS. Soil samples of various horizons from the sampled gully erosion sites in the study area were collected to carry out soil analysis to establish soil data base. Weighed samples were poured on to 2mm sieve and sieved. The collected soil samples were analysed in laboratory to generate the soil textural classes.

The value of 51.0g of air dry soil was passed through a 2mm sieve and transferred to a milkshake mix cu.50cc of 5.0% sodium hexametaphosphate along with 100cc of distilled water was added, the suspension was mixed together and allowed to set for 30 minutes. The suspension was stirred for 15 minutes with the multimix machine. The suspension was transferred to a cylinder, distilled water was added and the volume increased to 1130cc. The first and second reading was recorded on the hydrometer; the temperature was recorded as well. The first reading measures the percentage of silt and clay while the second reading measures the percentage of 2 micron (total) clay in suspension.

The slope factor (X) of the USLE (Wischmeier and Smith, 1965) was adapted to be more representative of the conditions of the experiments during the development of the model. Hence, the topographic factor is given by:

$$X = \sqrt{L}\,(0.76 + 0.53S + 0.076S2)/25.65$$

Where,
X = the ratio of soil loss from a plot of length L and slope percent S, to that lost from the standard plot
L = slope length in metre
S = slope gradient in percentage.

The DEM of the study area was extracted from the Shuttle Radar Topographic Mission (SRTM) data. This was achieved by using the extraction by mask Spatial Analyst tool of ArcGIS. DEM represents the surface terrain of the study area and permits to retrieve geographical information. Slopes of DEM in percentage were also generated using Surface Analysis under the Spatial Analyst function. Surfacing function was used to generate a DEM and to represent as a surface or one-band image file where the value of each pixel was a specific elevation value. A gray scale was used to differentiate variations in terrain. The slope map was generated in ArcGIS 10.1 software by using DEM. Slope map was classified based on USDA criteria given in the table 2.

Table 2: Slope Classes of Zaria

Class	Slope Range (%)	Slope Class
A	0-1	Nearly level
B	1-3	Very gentle sloping
C	3-5	Gently sloping
D	5-10	Moderately sloping
E	10-15	Strongly sloping
F	15-25	Moderately steep to steep Sloping
G	25-33	Steep sloping
H	33-50	Very steep
I	>50	Extremely steep slope

Source: Soil Survey Manual (Bhaware, 2006)

As the first step, the elevation value was modified by filling the sinks in the grid. This is done to avoid the problem of discontinuous flow when water is trapped in a cell which is surrounded by cells with higher elevation. This was done by using the Fill tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS 10.1. Then Flow direction was generated from the Fill grid. The Flow direction tool takes a terrain surface and identifies the down slope direction for each cell. This grid shows the on surface water flow direction from one cell to one of the eight neighbouring cells. This was done by using the Flow direction tool under Hydrology section found under Spatial Analyst Tool function in ArcGIS. Based on the Flow direction, Flow accumulation was calculated. Flow accumulation tool identifies how much surface flow accumulates in each cell; cells with high accumulation values are usually stream or river channels. It also identifies local topographic highs (areas of zero flow accumulation) such as mountain peaks and ridgelines. This was done by using the Flow accumulation tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS 10.1.

The crop management factor (C), calculated from the value of soil loss from standard bare soil condition and that of a cropped field (Morgan, 1995) depends on the percentage of the rainfall energy intercepted by the crop (i).

To generate the scenario of land use land cover, a 30m LANDSAT ETM+ multispectral image of Zaria was downloaded from www.usgs.gov website and the image bands from 1-1.0 were stacked and subsetted for the study area using using the ERDAS IMAGINE 9.2 software. The satellite image was interpreted making use of interpretation keys such as tone, texture, pattern, shape, size, shadow, site and association to derive thematic information. Characteristics of the land surface, including natural and artificial cover were considered. Existing land use practices were investigated through field survey and training sites for different land uses were marked to derive information about land use activities and land cover for plotting land use land (LULC) map cover. A maximum likelihood supervised classification was then applied to the imagery using the ArcGIS 10.1 software with the following training sites namely; Built-up land, Vegetated land, Crop land, Water body and bare surface as shown in table 3. From the LULC map derived C factor values were assigned for the various classes accordingly (Donald, 1997).

RESULTS

In an attempt to determine which factor influences gully erosion most in Zaria, Analytical Hierarchical Process (AHP) test was carried out on the criterion preferences. It was evaluated based on four preference factors thought to influence weightings. The preferences given to the factors are: slope, rainfall, soil and land cover. A separate hierarchical pair wise comparison of main criterion factors were made for each preference to analyze the sensitivity of the weights obtained. The pair wise comparisons of criteria factors were carried out independently and given same judgments for all the preferences. To reflect the preferences toward a certain factor, a definite to very strong preferences was given to that factor in their pair wise comparisons. The next stage in the analysis was that the consistency must be checked to verify the reliability of the judgment of the decision making. If CR ≤0.10, the ratio indicates a reasonable level of consistency in the pair wise comparisons (Malczewski, 1999). The assessment of the factors are:

Slope of Zaria

Slope steepness is one of the criteria for the estimation of erosivity potential. Run-off and erosion potential will increase as the slope steepness increases. Five classes were identified from the slope map (figure 1). The slope for the study area as weighed is shown in table 3 and figure 1. Where 0 - 0.8% slope represents slopes with the lowest run-off potential and 11.5 - 25.5% with the highest.

Table 3: Weights of slope of Zaria

Slope %	0-0.8	0.9-1.6	1.7-4.2	4.3-11.6	11.7-25.5	Weight %
0-0.8	1	1/3	1/5	1/7	1/9	3
0.9-1.6	3	1	1/3	1/5	1/7	6
1.7-4.2	5	3	1	1/3	1/5	13
4.3-11.6	7	5	3	1	1/3	26
11.7-25.5	9	7	5	3	1	51

Consistency Ratio = 0.03

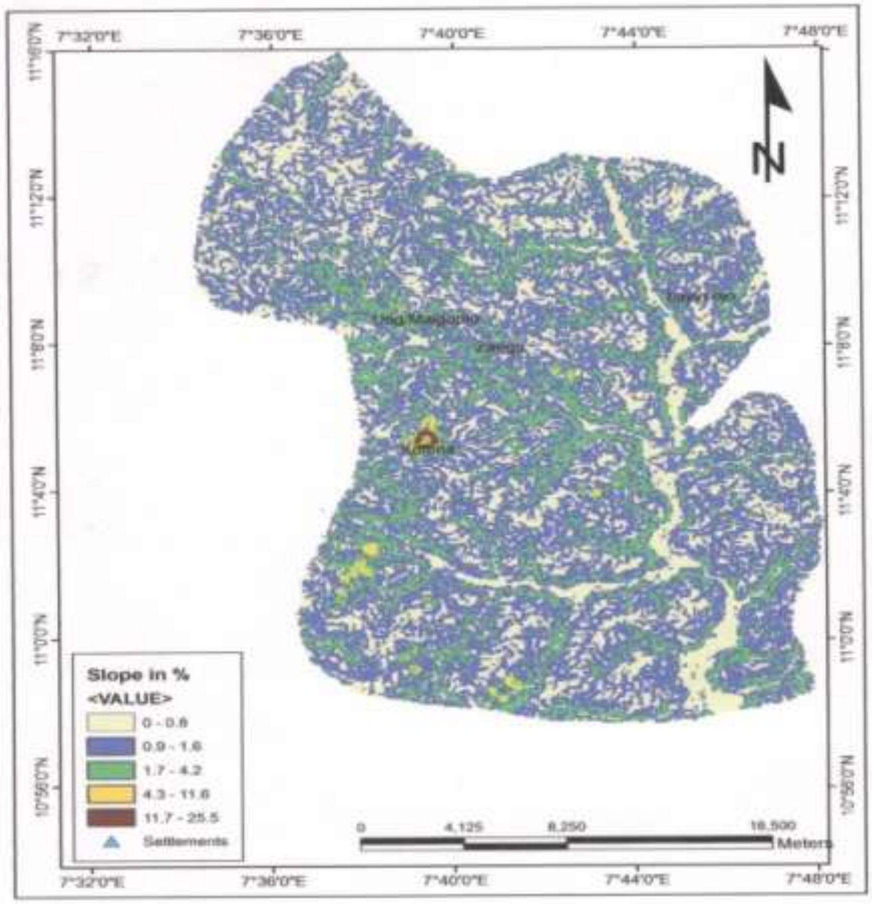

Figure 1: Slope Steepness of Zaria

Rainfall of Zaria

It is well established that the amount of soil loss that is detached by a particular rain event is related to the intensity at which this rain falls. Smaller drops that dominate low intensity rainfall are less efficient in detaching soil (Salles and Poesen and Govers, 2000) but at high intensity, rainfall may increase the efficiency of detachment. The result of the pairwise comparison in table 4 shows that increase in rainfall results to an increase in soil erosion in the study area. The energy of soil erosion by the rain is shown in figure 2.

Table 4: Weights of Rainfall of Zaria

Rainfall (mm)	308-536	537-701	702-895	896-1,082	1083-1257	Weight %
308-536	1	1/3	1/5	1/7	1/9	3
537-701	3	1	1/3	1/5	1/7	6
702-895	5	3	1	1/3	1/5	13
896-1,082	7	5	3	1	1/3	26
1,083-1,257	9	7	5	3	1	51

Consistency ratio = 0.05

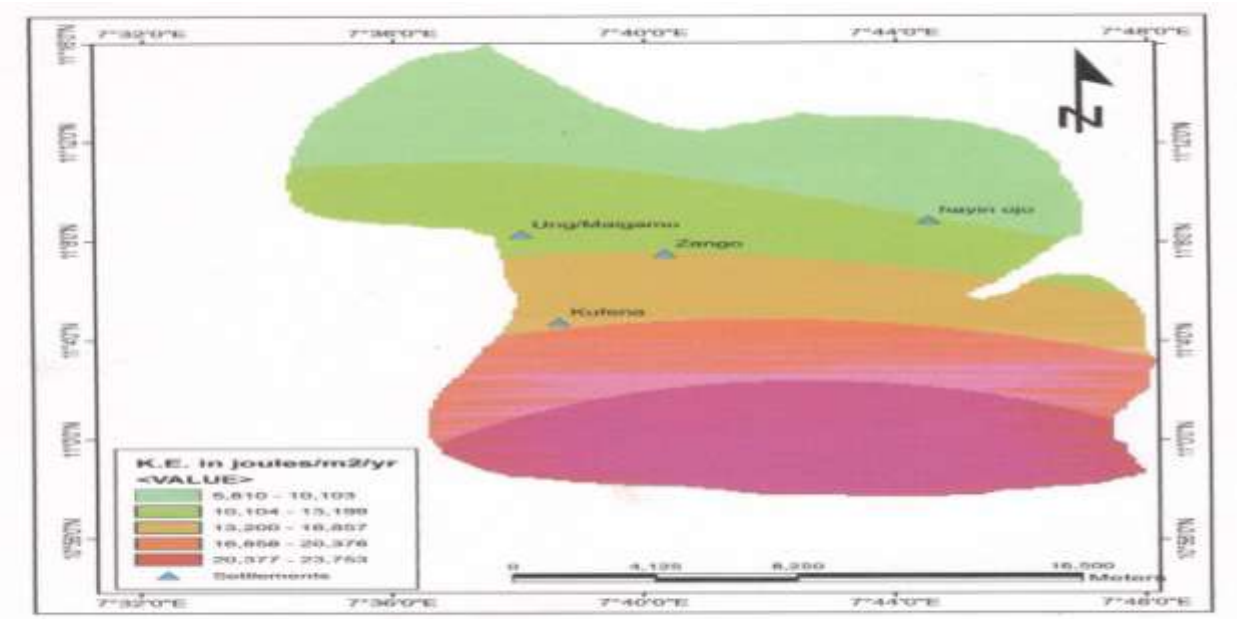

Figure 2: Rainfall Kinetic Energy of Zaria

Soil Texture of Zaria

Soil texture was taken as one of the factors for multi-criteria analysis. The soil was weighed based on the textural class as shown in table 3 and displayed in figure 3. Soil texture is important in determining aggregate stability, infiltration rate, run-off and erosion (Le Bissonnais and Singer, 1993). According to Bradford and Huang (1992), soil texture seems to be one of the most important soil variables influencing soil surface sealing and splash detachment. Although, crusts can form on soils of any texture, soils with high silt contents are more conducive to surface sealing. Table 3 shows that sandy soil has high infiltration rate and clay is low in the study area.

Table 3: Weights of Soil Texture of Zaria

Soil	**Sand**	**Loamy**	**Clay**	**Weight %**
Sand	1	3	6	64
Loamy	1/3	1	4	37
Clay	1/6	¼	1	9

Consistency Ratio = 0.06

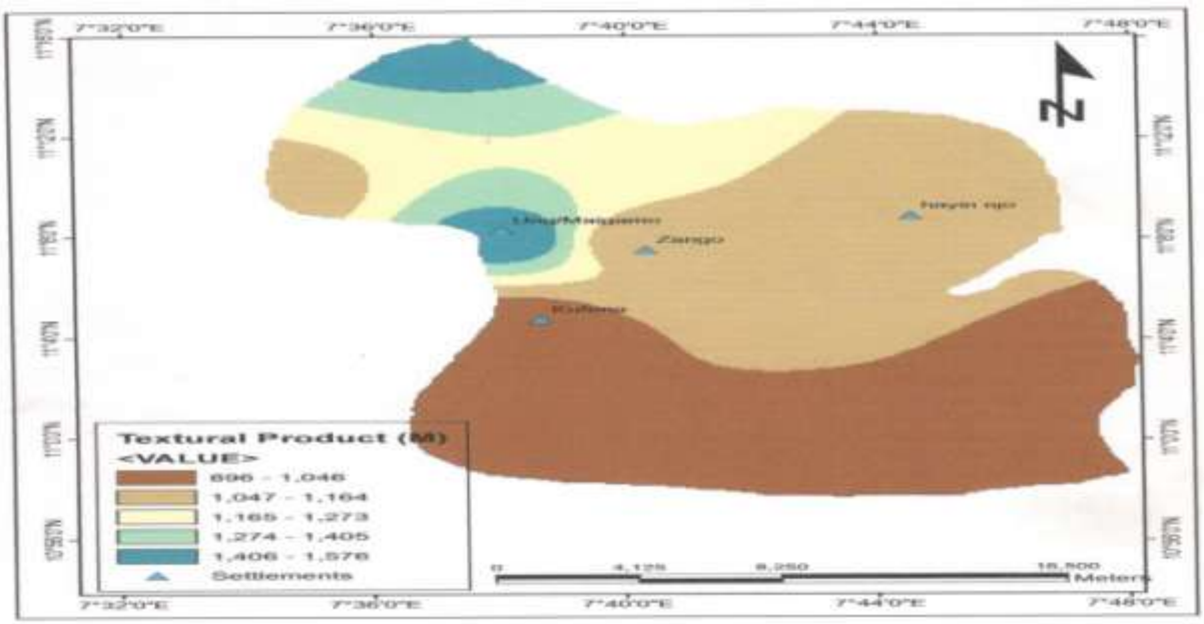

Figure 3: Soil Textural Class of Zaria

Land cover of Zaria

A land which has a good surface cover is characterized by low run-off while land with poor surface cover is characterized by high run-off and quick response to rainfall which is because of low surface roughness. Thus, spatial data on surface cover type was used to assess the resistance of terrain to erosion as a result of surface protection. The five LULC categories which were generated using supervised classification method were weighed as shown in table 6 and figure 4 where water body represents lowest erosion potential and bare-surface represents the highest.

Table 6: Weights of Land Cover of Zaria

LULC	Bare surface	Crop land	Vegetation	Built-up	Water Body	Weight %
Bare surface	1	2	3	5	9	41
Crop land	½	1	3	5	9	31
Vegetation	1/3	1/3	1	3	9	17
Built-up	1/5	1/5	1/3	1	9	9
Water body	1/9	1/9	1/9	1/9	1	2

Consistency Ratio = 0.08

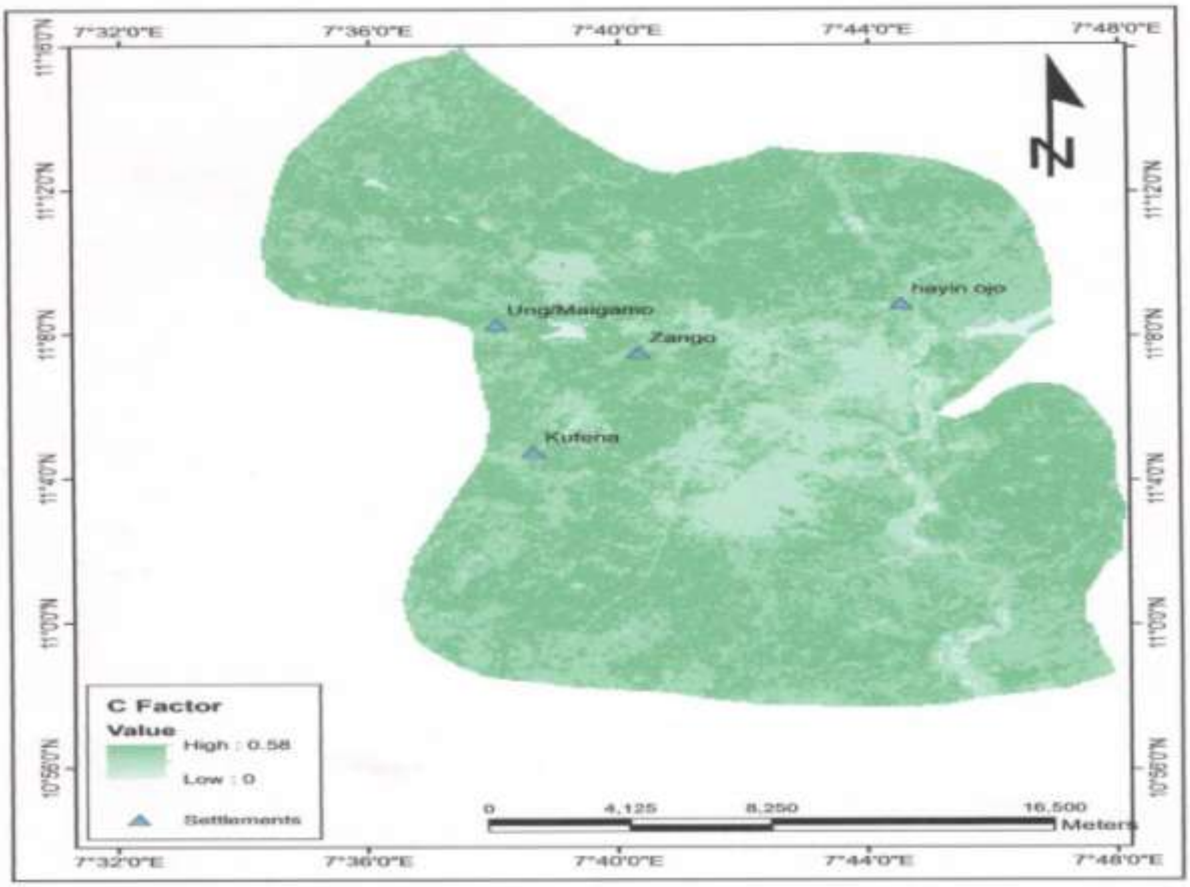

Figure 4: Land Cover of Zaria

The factors contributing to gully erosion in the study area were further assessed to determine the factor that most contributed to erosion process. The analytical hierarchical process was carried out using a pairwise comparison. Table 7 shows the various weights of the factors controlling gully erosion in the study area.

Table 7: Weight of Factors Controlling Gully Erosion in Zaria

Controlling factor	Slope	Rainfall	Land cover	Soil	Weight %
Slope	1	3	5	7	56
Rainfall	1/3	1	3	5	26
Land cover	1/5	1/3	1	3	12
Soil	1/7	1/5	1/3	1	6

Consistency Ratio = 0.08

DISCUSSION

The research finding above is similar to that of Qi (2011), who assessd soil erosion risk in the hilly-gullied area of Luoyugou watershed in Tianshui and observed that the probability of soil erosion had higher growth rate without vegetation cover than that having vegetation cover. Similar to findings by Gebreyesus, Tesfahunegn and Paul (2014) in Northern Ethiopia catchment. Also in most parts of the watershed (>80%), the model predicted soil loss rates higher than the maximum tolerable rate (18 t ha^{-1} y^{-1}) estimated for Ethiopia.

John *et al*. (2014) evaluated soil erosion risk in the basement complex terrain of Akure Metropolis, Southwestern Nigeria and found that most parts (91.4%) of the metropolis fell within the very low to low risk zones with tendency for erosional features. Soil erosion in the study area also altered vegetation cover, ground slope, slope length and shape, thereby influencing soil erosion rate leading to the formation of gullies and rills erosion. It also leads to significant soil loss and degradation, destruction of physical infrastructures such as buildings, drainages, roads and culverts especially. This demonstrates the importance of remote sensing data and GIS in successfully enabling rapid, as well as detailed, assessment of soil erosion risk/hazards (Kouli *et al.*, 2009). Steep slope, high rainfall, poor soil management, poor cover management and support practices, deforestation and land clearing in Zaria for agricultural, urbanization and infrastructural development have resulted in widespread of soil erosion over the land surface as equally attested to by Abbas and Lamido (2012). Soil as a contributory factor controlling gully erosion in the study area is in tandem with Le Bissonnais (1996) who indicated that soil erodibility increases when silt and fine sand fraction increases and clay decreases. The overbearing effect of slope on the cause of gully erosion in the study area is in conformity with the findings of Ezechi and Okagbue (1999).

The areas with very high were as the result of clay content between 9 and 30% and are the most susceptible to erosion (Richter and Negendank, 1977; Evans, 1980). From the study, erodibility of different soils causes erosion damages as confirmed by Renschler and Harbour, (2002). Also, Bewket and Sterk (2003) reported that soil erosion in south-eastern Nigeria was the results of field scale erosion by soil moisture in addition to infiltration rates which was also discovered by this research. Based on the study result, it could be said that the study area has risk to soil erosion as the area exhibited high risk of soil loss.

CONCLUSION

Based on the result from the four criteria (slope, rainfall, soil and land cover); slope (56%) had a high contribution to soil erosion. Next to slope was rainfall (26%), thereafter soil and land cover respectively. Soil and land cover contributed 12% and 6% respectively to gully erosion in the study area. The occurrence of soil erosion risk in the study area has also been on the increase and is not limited to a particular area but all part causing serious land degradation affecting a wide variety of soils prone to crusting and/or piping. The widths and depths of gully erosion increased with the increase in slope gradient and decrease with increase in percentage of vegetation cover, especially during the rainy season and confirm that soil erosion in the study area has altered vegetation cover, ground slope, slope length and shape. Remote sensing data and GIS successfully enabled rapid, as well as detailed assessment of gully erosion hazards and show spatial distributions of related factors and features. There is therefore the need for protective strategies and measures for sensitive management of the environment to reduce erosion rates and increasing water conservation.

REFERENCES

Abdulfatai, I.A., Okunlala, I.A., Akande, W.G., Momoh, L.O., Ibrahim, K.O., (2013). Review of gully Erosion in Nigeria; Causes, impacts and possible solutions. *Journal of Geosciences and Geomatics*, 2(3), 125-129.

Abegunde, A.A., Adeyinka, S.A., Peter, O.O. and Oludo, O.A., (2003). The impact of Erosion on Rural Economy; the Case of Nanka in Anambra State of Nigeria in Urban Finance and Infrastructure Development in Nigeria. Yomi Fawehinmi (ed.) Atlantis Books. PP227-243.

Agagu, O.K. (2009). Threats to the Nigerian Environment; a Call for Positive Action. Paper presented at the 7th Chief S.L Education Memorial Lecture held at the Nigerian Institute of International Affairs, Victoria Island, Lagos, Nigeria.

Agi, W.O. (2015). Erosion Modelling in Northern Makurdi, Benue State, Nigeria. Unpublished M.Sc Thesis of Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

Anderson, J.R., Hardy, E.E., Roach, J.T. and Witmer, E.R. (1976). *A land use and land cover classification system for use with remote sensor data.* Geologic survey professional paper 964, US geologic survey circular 671.

Bhatta, B. (2008). *Remote Sensing and GIS.* New York and New Delhi: Oxford University Press.

Bettis, E.A. (2008). Gully Erosion, Geological Survey. *Journal of geological survey.* The Iowa Department of Natural Resources Publication. 28, 81-94.

Bobe, B. (2004). Evaluation of Erosion in Harare Region of Ethiopia using soil loss models,Rainfall Simulation and Field Trials. Unpublished PhD Thesis, University of Pretoria, South Africa.

Bozali, N., Yuksel, A., Akay, A. (2008). Determing the Main Factors Affecting the Sediment Yield from Derindere Watershed of Sir Dam in Kahramanmaras using GIS Techniques. *International Journal of Natural and Engineering Sciences,* 2:29-32.

Bradford, J.M. and Huang, C. (1996). *Splash and detachment by water drops.* In Agassi, M. (ed). *Soil Erosion, Conservation and Rehabilitation*. New York: Marcel Dekker Inc

Clinciu, I., Petriţan, I.C. and Niţa, M.D. (2010). Bulletin of the Transilvania University of Braşov, 3 (52) - 2010Series II).

Donald, P. (1997). *GIS Modelling of Erosion and Sediment Yield in a Semi-Arid Environment* (Unpublished M.Sc. Thesis). University of Witwatersrand, London.

Eiswerth, A.B. (2003). An Evaluation of Soil Erosion Hazard; A case study of Southern Africa using geomatics technology. University of Arizona Ph.D. dissertation.

Elwell, H.A. (1978). Modelling soil losses in Southern Africa. *Journal of Agricultural Engineering Research,* 23: 117-127.

Ezechi, J.I. and Okagbue, C.A. (1999). Genetic Classification of Gullies in Eastern Nigeria and its Implication on Control Measures. *Journal of African Earth Science*, 8: 719

Gebreyesus, B. Tesfahunegn, L. T. and Paul, L. G. V. (2014). Soil Erosion Prediction Using Morgan-Morgan-Finney Model in a GIS Environment in Northern Ethiopia Catchment. *Journal of Applied and Environmental Soil Science*: 15, Hindawi Publishing Corporation V. 2014, Article ID 46875. http://dx.doi.org/10.1155/2014/46875

Horton, B. and Smith, K. (2006). Soil erosion hazard assessment and its policy implication in Uthai. *Journal of Engineering and Environmental Science, 29, 8-2.*

https://www.environment.nsw.gov.au/topics/land-and-soil/soil-degradation/gully-erosion

Isikwue, M.O., Abutu, C. and Onoja, S.B. (2012). Erodibility of Soils of the South West Benue, State, Nigeria. *Pacific Journal of Science and Technology,* 13(2): 437-44.

John, S. O., Matins, O. O., Francis, O. A., Sunday, B. O. J. A. and Gregory, O. O. (2014). Evaluating Soil Erosion Risk in the Basement Complex Terrain of Akure Metropolis, Southwestern Nigeria. Journal of Geography and Geology; 7(1); 56-64.

Kouli, M., Soupios, P. and Vallianatos, F., (2009). Soil erosion prediction using the Revised Universal Soil Loss Equation (RUSLE) in a GIS framework, Chania, Northwestern Crete, Greece. Environmental Geology, 57: 483-497.

Le Bissonnais, Y. and Singer, M.J. (1993). Seal formation, run off and interrill erosion from 17 California soils. *Soil Science Journal,* 57: 224-229.

Le Bissonnais, Y. (1996). Aggregate stability and assessment of soil crustability and erodibility: Theory and Methodology. *European Journal of Soil Science,* 47: 425-437.

Malczewski, J. (1999). *GIS and Multicriteria Decision Analysis.* Wiley and Sons Inc, 395pp.

Micheal, U.G. (2013). *An assessment of the impact of growth of Zaria on the surrounding vegetation cover* (Unpublished M.Sc. Thesis). Ahmadu Bello University, Zaria, Kaduna State, Nigeria.

Morgan, R.P.C. (1995). *Soil erosion and conservation.* Second Edition, Cranfield, UK University.

Nasiri, M. (2013). GIS modelling for locating the risk zone of soil erosion in a deciduous forest. *Journal of Forest Science,* 59(2): 87-91.

Oas, D.L., (2001). Inland Erosion Hazard Assessment and Mapping for Antigua, Barbuda and St Kitts and Nevis, Post-Georges *Disaster Mitigation Project in Antigua and Barbuda and Stlitss, April, 2001.*

Olofin, E.A. (1994). *Application of SLEMSA in Estimating Soil Erosion and the issue of Productivity in the dry lands of Nigeria.* Paper presented at the 37th Annual Conference of the NGA, Ikere, Ekiti.

OMAFAR Staff (2003). Soil Erosio, Causes and Effects. Ridge Town and College of Agricultural Technology, Ontario, Institute of Pedelogy. http://www.search.gov.on.ca.8002/compass?view-template=simplr.

Owens, P.N. and Collins, A.J. (2006). *Soil Erosion and Sediment Redistribution in River Catchments, Measurement, Modelling and Management.* (1sted.) Wallingford, CABI: 342.

Petter, P. (1992). *GIS and Remote Sensing for Soil Erosion Studies in Semi-Arid Environments.* PhD, University of Lund, Lund.

Poesen, J., Nachtergaele, J., Verstracten, G. and Valentin, C. (2003). Gully Erosion and Environmental Change, Importance and Research needs. Catena.

Qi, S. (2011). Assessing Soil Erosion Risk in the Hilly-gullied Area: A Case Study of Luoyugou Watershed in Tianshui, Loess Plateau, North China. *Institute of Economic Development East China University of Science and Technology Shanghai*, China. ©2011 IEEE

Salles, C., Poesen, J. and Govers, G. (2000). Statistical and physical analysis of soil detachment by raindrops impact. *Water Resources Research Journal,* 36: 2721-2729.

Titilola, S.T. and Jeje, L.K. (2008). *Environmental Degradation and its Implication for Agricultural and Rural Development, the issue of Land Erosion and Sustainable Development in Africa.* 6 Clarion University of Pennsylvania, Clarion.

Troeh, F.R., Hobbs, J.A. and Donahue, R.L. (1991). *Predicting soil loss.* Chapter Six in Soil and Water Conservation, 2nd edition, N.J., Prentice Hall.

Uche, O. (2012). Socio-economic effects of erosion in Anambra (a case study of Orumba North Local Government Area). *Journal of Science and Multi-disciplinary*, 33(38): 113-117.

UNESCO, (2009). The impact of global change on erosion and sediment transport by rivers: current progress and future challenges. Scientific Paper. The United Nations World Water Assessment Programme. http://unesdoc.unesco.org/images/0018/001850/185078e.pdf (accessed on 12th April, 2016).

Wangida, S.O. (2006). *Landscape Dynamics.* Keynote Address; International Conference on Ecosystem Changes and Implication on Livelihood of rural Communities in Africa, Daresalam, October 18-20, 2006.