Global Journal of human-social science: B
Geography, Geo-Sciences, Environmental Science & Disaster Management
Volume 21 Issue 3 Version 1.0 Year 2021
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals
Online ISSN: 2249-460X & Print ISSN: 0975-587X

Morphometric and Morphological Analysis of Gullies in Lafia Lga, Nasarawa State, Nigeria

By Alkali Mohammed, A.T Ogah & I. M Anzku
Bayero University

Abstract- This study assessed morphometric of gullies in Nasarawa State. Soil erosion is among the most endemic environmental problems of modern times. Both primary and secondary sources of data were used for this study. As ample of 36 gully sites were carried out in three Local Government Areas representing the study area for this research work. Information on gullies morphometric, morphology, soil particles size and the coordinate of each identified gullies site were taken from the field. Instruments such as hand auger, global position system. (GPS), photograph, Abeny level, linen tape, ranging poles, pegs and measuring tape and field observation methods were also adopted. The results generated from the field were subjected to statistical and laboratory analysis. The results of the findings revealed that 44.4% of the gullies in the study area are discontinuous gullies, 55.6% were continuous gullies, while gullies in the study are at their 5% and above development. 58.3% of the sampled gullies were at a stable state of development, while 41.7% of the gullies were at an unstable state of development. It was also revealed that 38.9% of the sampled gullies in the study area were long-narrow gullies, while 22.2% were linear shaped gullies.

Keywords: *morphometric, morphology, gullies, erosion, degradation.*

GJHSS-B Classification: *FOR Code: 040699*

MORPHOMETRICANDMORPHOLOGICALANALYSISOFGULLIESINLAFIALGANASARAWASTATENIGERIA

Strictly as per the compliance and regulations of:

Morphometric and Morphological Analysis of Gullies in Lafia Lga, Nasarawa State, Nigeria

Alkali Mohammed [α], A.T Ogah [σ] & I.M Anzku [ρ]

Abstract- This study assessed morphometric of gullies in Nasarawa State. Soil erosion is among the most endemic environmental problems of modern times. Both primary and secondary sources of data were used for this study. As ample of 36 gully sites were carried out in three Local Government Areas representing the study area for this research work. Information on gullies morphometric, morphology, soil particles size and the coordinate of each identified gullies site were taken from the field. Instruments such as hand auger, global position system. (GPS), photograph, Abeny level, linen tape, ranging poles, pegs and measuring tape and field observation methods were also adopted. The results generated from the field were subjected to statistical and laboratory analysis. The results of the findings revealed that 44.4% of the gullies in the study area are discontinuous gullies, 55.6% were continuous gullies, while gullies in the study are at their 5% and above development. 58.3% of the sampled gullies were at a stable state of development, while 41.7% of the gullies were at an unstable state of development. It was also revealed that 38.9% of the sampled gullies in the study area were long-narrow gullies, while 22.2% were linear shaped gullies. Rectangular shaped gullies found in the study area consisted of 22.2% of the sampled gullies, while 13.9% were trapezoidal shaped gullies. Long-narrow and rectangular shaped gullies consisted of 2.8% in the study area. The results of the study revealed that very small size gullies develop on a mean slop angle surface of 9.0°, small size gullies develop on a mean slop angle surface of 7.60°, medium size gullies develop on a mean slop angle surface of 8.83°, while large size gullies develop on a mean slop angle surface of 5.60°. The correlation analysis carried out revealed a strong positive linear relationship between morphometric variables of gullies in the study area. On an aggregate level, the results of the study revealed that a mean value of 1400.39 metric tons of soil was loss in the study area as a result of gully erosion, with a relative variation of 155.07metric tones. 60% of gullies in the study area were discovered to U-shape gullies, 30% were V-shaped, while 10% U and V-shape gullies. more so, the results of the study revealed that the mean length of gullies in the study area was 134.44m while the mean width of gullies was 9.01m. The mean depth of gullies in the study area was 7.49m, while mean area covered by gullies was 1555.55m^2. The mean particle size distribution at gully sites included; sand 87%, silt was 4%, and clay 9%. Precaution measures and self-control methods are recommended.

Keywords: morphometric, morphology, gullies, erosion, degradation.

I. Introduction

Gully erosion is the removal of soil along drainage lines by surface water run-off. According to the Department of Primary Industries and Water – Tasmania, Australia (2008), gully erosion is known to be the most destructive form of soil erosion in Nigeria, which is caused by heavy or sudden rain storms which produce concentrated run-off enlarging rills into cheap channels, the run-off cuts deep gushes or gullies of over 10 meters to 20 meters and in severe situations reaching up to or over 100 meters into the land. It occurs more generally where land slopes are steep and surface run-off is exceptionally heavy. Once started, gullies will continue to move by head ward erosion or by slumping or collapsing of the side walls changing it from V-shape to U-shape valleys (Abengude *et al.,* 1991). The United States Department of Agriculture (2006) also regards gullies as channels formed by the concentrated flow of water, removing upland soil and parent material and of size too large to be obliterated by normal tillage operations (USDA, 2006).

Rills are initial stage in channel erosion which undergoes systematic transformation into gullies. Rill erosion is defined as erosion in numerous small channels that are uniformly distributed across a slope and can be obliterated by tillage (Hutchinson & Pritchard, 2002). In these and several other areas, gully erosion is a serious threat to economic development of the localities involved. Gullies are relentless destroyers of arable land. They cut up fields, agricultural lands and sometimes-entire village into small, odd-shaped parcels and restrict the free movement of farmers and animals. They are a menace to livestock as animal frequency fall in and are unable to escape. Gullies also threaten village roads, buildings and other structures. In Akwalbom State, for instance gullies have claimed two lives and several buildings in Obotme area (Udosen, 1991), more than 20 houses and a stadium complex have been destroyed by a 1km long gully system that was initiated along Eka Street in Uyo area (Armon, 1984). Currently, gullies are eroding deeply into the major Onitsha-Owerri Road near Onitsha.

According to Fubara (1988), about 16,668km^2 or 22.8 percent of the total land surface in eastern Nigeria is affected by severe forms of gully erosion. Available records also show that in all the south eastern states except the former Rivers State, about 25,000 hectares of land are lost annually to fluvial erosion, especially by gullying. In addition, the topsoil which contains significant proportion of soil nutrient and organic matter are being washed away at alarming rates by the invidious process of sheet erosion. As the

Author α: Bayero University, Kano, Nigeria. e-mail: madaki@ymail.com

stabilization of gullies is the most expensive of all erosion control works as the checking and elimination of gullies often requires. Extensive earth moving and construction of dams and/or other measures, it is vital to prevent gullies from developing and this can be done through the identification of critical factors for gully initiation and sometimes general lack of information on drainage basin parameters is a failure that has contributed to the significant lack of success in solving erosion parameters in the region.

In view of the foregoing, a question which arises is what are the actual environmental factors responsible for gully initiation and sustenance in the study area? Erosional factors are simply the critical condition or a combination of factors at which soil erosion is initiated. It may be induced when an internal or an intrinsic threshold or an external or extrinsic threshold is exceeded e.g., through changes in climate or land use. It is generally known that the pattern of soil erosion changes as the vegetation cover and other factors are altered. Thus, in a given landscape whether a gully is initiated or not depends on the nature of the earth material, the extent of the vegetal cover, and the slope length and gradient all of which combine to determine, the resistance to the attractive force of fluvial processes.

During the 17th and 18th centuries, Easter Island experienced severe erosion due to deforestation and unsustainable agricultural practices. The resulting loss of topsoil ultimately led to ecological collapse, causing mass starvation and the complete disintegration of the Easter Island civilization (Rattan *et al.,* 2010). Due to the severity of its ecological effects, and the scale on which it is occurring, erosion constitutes one of the most significant global environmental problems we are facing today. Water and wind erosion are now the two primary causes of land degradation combined; they are responsible for 84% of degraded acreage. Each year, about 75 billion tons of soil is eroded from the land - a rate that is about 13 – 40 times as fast as the natural rate of erosion. Approximately 40% of the world's agricultural land is seriously degraded (Morgan, 2015). According to the United Nations (2004), an area of fertile soil the size of Ukraine is lost every year because of drought, deforestation and climate change. In Africa, if current trends of soil degradation continue the continent might be able to feed just 25% of its population by 2025, according to UNU's Ghana – based institute for Natural Resources in Africa.

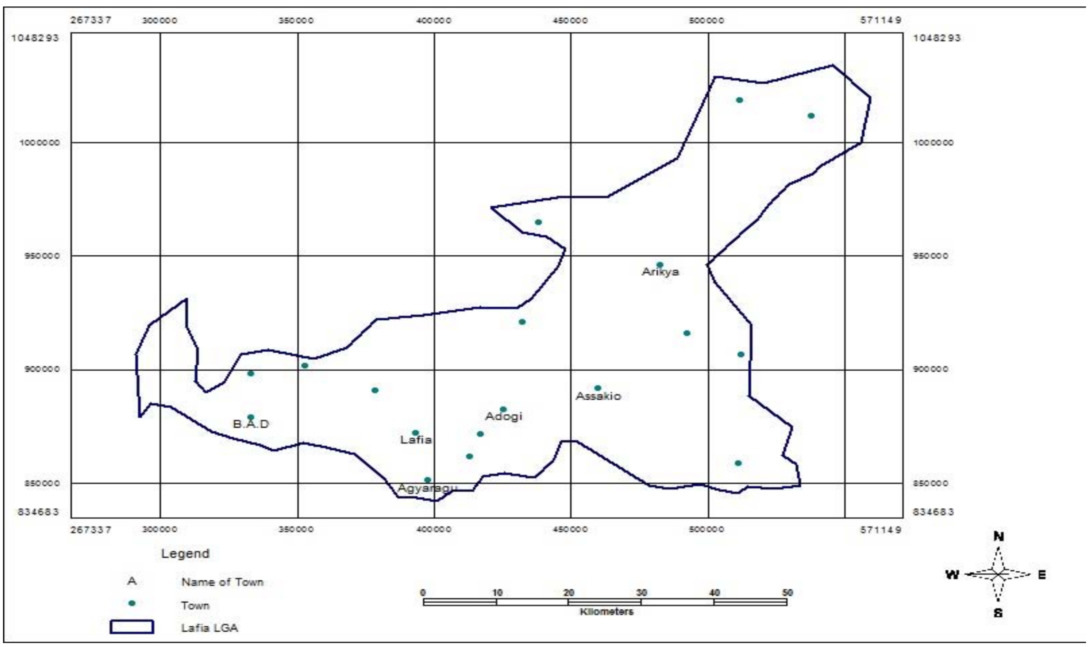
The loss of soil fertility due to erosion is further problematic because the response is often to apply chemical fertilizers, which lead to further water and soil pollution, rather than to allow the land to regenerate. Soil erosion (especially from agricultural activity) is considered to be the leading global cause of diffuse water pollution due to the effects of the excess sediments flowing into the world's waterways. The sediments themselves act as pollutants, as well as being carries for pollutants, such as attached pesticide molecules or heavy metals. The effect of increased sediments load on aquatic ecosystems can be catastrophic. Silt can smother the spawning beds of fish, by filling in the space between gravel on the stream bed. It also reduces their food supply, and causes major respiratory issues for them as sediments enter their gills. The biodiversity of aquatic plant and algal life is reduced, and invertebrates are also unable to survive and reproduce. While the sedimentation event itself might be relatively short-lived, the ecological disruption caused by mass die off of aquatic plant often persists long into the future.

One of the most serious and long-running water erosion problems worldwide is in the People's Republic of China, on the middle reaches of the Yellow River and the upper reaches of the Yangtze River. From the Yellow River, over 1.6 billion tons of sediment flows into the ocean each year. The sediment originates primarily from water erosion in the Loess Plateau region of the northwest (Abaje, 2007). Soil particles picked up during wind erosion are a major source of air pollution, in the form of airborne particulates "dust". These airborne soil particles are often contaminated with toxic chemicals such as pesticides or petroleum fuels, posing ecological and public health hazards when they later land, or the inhaled and/or ingested (Faniran, 1978). Dust from erosion acts to suppress rainfall and changes the sky colour from blue to white which lead to an increase in red sunsets. Over 50% of the African dust that reaches the United States affects Florida. Dust events have been linked to a decline in the health of coral reefs across the Caribbean and Florida, primarily since the 1970s. Similar dust plums originate in the Gobi Desert, which combined with pollutants, spread large distances eastward, into North America (Abaje, 2007). The removal by erosion of large amount of rock from a particular region, and its deposition elsewhere, can result in a lightening of the load and mantle, causing tectonic or isotactic uplift in the region (Giles, 2011). The apparent advance of land degradation and frequent erosion occurrence in middle belt region of the country during the last 12 decades have brought about a whole series of environmental, ecological and socio-economic problems.

In Nasarawa State, a vast area of farmlands has been lost due to the menace of gully erosion while others are at their various stages of destruction leading to drastic decrease in agricultural productivity and ultimately food shortage that can lead to famine (Anzaku, 2015). The gully erosion in the state has resulted in loss of vegetation as its continuous expansion encroaches into areas that are forest leading to falling of trees and exposure of more surface area to gully activities. Several properties such as building structures whose value cannot be quantified accurately have been destroyed. Besides, it was reported recently that several buildings were lost in Nasarawa State of Nigeria as a result of erosion (NBS News, 2014). Many lives have been lost as a result of the problem of gully erosion in the state NBS, (2012). Some either fell into these gullies or sustained various degree of injury. About 7 people have been reported in the past few years to have lost their lives as a result of flooding that drown them to gullies (NBS, 2012). Gully erosion therefore has resulted in the separation of adjacent villages and towns as it may involve collapse of bridges linking them together. This has had negative impacts on such areas since some facilities such as schools, hospitals and water supplies shared by the affected neighbouring communities may become inaccessible. Transportation of farm produce has also been affected and this also often leads to loss of agricultural products especially, the perishable ones.

II. Materials and Methods

a) *The Study Area*



Source: Ministry of Lands & Survey, Lafia, 2021

Fig. 1: Map of Lafia Local Government Area.

Lafia Local Government Area of Nasarawa state is located between latitudes 8° 20' and 8° 38'N and between longitudes 8°20' and 8°40'E. Lafia Local Government area has a land area of 2,797.5sq.km with a population of 330,712 (NPC, 2006). It is bordered by Nasarawa -Eggon Local Government Area and Wamba Local Government Area to the north, Doma Local Government Area to the west and south and Obi Local Government Area and Shendam Local Government Area in Plateau State to the east. Lafia's location at the junction of a regional road confers on its good linkage with Makurdi, Benue state to its south, Akwanga-Keffi and Abuja to its north-west and Jos, Plateau state its north-east.

b) *Sample and Sampling Technique*

Twelve (12) gully sites were purposively selected from Lafia. The sampling technique that was adopted by the researcher was the non-probability (purposive) sampling technique.

c) *Types and Sources of Data*

Both primary and secondary sources of data were employed in this study.

d) *Identification and Characterisation of Gullies in the Study Area*

Field survey, measurement, and observation was carried out. More so, soil samples of each sampled gully sites were collection and subjected to laboratory analysis, to determine the particle size of each of the sampled gully sites in the study area. GPS device was also used to get the coordinates of each identified gully in the study area. The rationale for adopting these methods was premised on the recommendations of Young (1999).

e) *Determination of the Volume of Soil Loss in the Study Area*

Revised University Soil Loss Equation (RUSLE) model was used for the quantification of soil loss. This was achieved by parameterizing, combining and classifying erosion physical factors in quantifying soil loss in the general landscape (Renard, Foster, & Weesies, 1997). The erosion physical factors include: rainfall, erosivity, soil erodibility and slope length (Weesies, 1997). $A=R \times K \times LS$

While a soil erosion study that involve agricultural land use and watershed, a biophysical factor could be used. Biophysical factors include: rainfall erosivity, soil erodibility, slope length, cover and management practices, and supporting practices factors. This can be illustrated in the formulae as follows:

$$A=R \times K \times LS \times P \times C$$

Where;

A= Average annual soil loss (Ton/ha/yr),

R= Rainfall erosivity factor (mj/mm/ha/yr),

K= Soil erodibility factor (ton ha/mj/mm),

LS= slope length factor,

C= cover and management factor and

P= supporting practice factors

The procedures for estimation of these factors and soil loss can be found in many studies (Farhan, Zregat, & Farhan, 2013; Ghosh, De, Bandyopadhyay, & Saha 2013; Javed, Yasser, Shams Al-Deen, & Mohd, 2014; Kamaludin *et al.,* 2013; Khosrokhani & Pradhan, 2014, Garedew, & Yimer, 2015).

f) Determination of Gully Morphometry in the Study Area

A 30m linen tape, ranging poles, Abney level and pegs in measuring the length, width, depths and area at carefully selected points, usually at regularly space intervals of between 0.5m and 20m depending on the length of the gully in each of the sampled area of the study. A was stretched taut across it to determine the top width. Gully depth were measure from the tape of the gully bed (with another tape). The depth was measured from the gully floor to the top string using a ranging pole (graduated in meters). An Abney level was used to measure the slope angle. The length of the slope from the crest to the base from the side was measured with a 30m tape wand expressed in meters. The average value for each sampling area was also computed. This method was adopted by the researcher, in line with Mbaya, *et al.* (2012), Seutloali *et al.* (2015), and Mallam *et al*. (2016).

g) Determination of Gully Morphology in the Study Area

Field observation method was adopted in determining the gullies morphology parameters. These include the class of gullies in the study area, their shapes, and stages of development, shape factor and direction of flow, is in line with the studies of Leopol and Miller (1956), Heede (1975), Bocco (1990,1991), Ireland *et al.* (1996), and Cudoson, (2005).

h) Gullies Mapping

GPS coordinates of gullies identified during the field survey were collected and used for mapping of areas affected by gully erosion in the study area. ArcGIS and ENVIS software were used for mapping at Nasarawa Geographic Information System (NAGIS). This method was adopted in line with the works of Mbaya *et al.* (2012), Seutloali *et al.* (2015), Mallam *et al.* (2016), and Dalil *et al.* (2016).

i) Method of Data Analysis

Both qualitative and quantitative methods of data analysis were adopted. Qualitative method of data analysis was used to explained and interpret the results of the study, with respect to data extracted from field work, map analysis, and laboratory soil particle size, while the quantitative method of analysis was adopted to analysed quantitative data collected from the field. The quantitative methods of analysis adopted with both descriptive and inferential methods or statistics. Descriptive statistics such as range, mean, standard deviation, variance, simple percentages, and coefficient of variation were used to determine the variability of gullies morphometric properties and the variability of rainfall in the study area, and soil particle size, while the inferential used in the study was the correlation analysis, employed to assess the correlation between the length, depth, area and width of gullies in the study area. specifically, the Pearson Product Moment Correlation was adopted. More so, the significance of the correlation between the length, depth, area and width of gullies in the study area was tested IBM SPSS software package (version 26). These methods of data analysis were adopted by the researcher in line with the works of Mbaya *et al.* (2012), Seutloali *et al.* (2015), and Mallam *et al.* (2016).

III. Results and Discussion

a) Characterisation of Gullies in the Study Area

It is important to note that the morphological expression of gullies depends on the landscape unit, stages of development of the gullies, the characteristics of the soil profile, the slope position on which they develop and the dominant processes of the gully deepening and widening. Two criteria are generally employed in the classification of gully system; topographic location in relation to an established drainage system, and the nature of the material in which they are formed (Brice, 1966, Ebisemiju, 1979). Brice (1966) argued that the depth of a gully, its real pattern and its growth are more closely related to the topographic position of the gully head than any other single factor. Generally, incipient gullies in the study area have deep and narrow channels with sharp pointed

Global Journal of Human-Social Science (B) Volume XXI Issue III Version I Year 2021

head scarp, while mature gullies are deep, wide and are characterised by broadly-lobed heads.

The data presented in Table 1, and 2, were obtained from Lafia Local Government Area of Nasarawa State. Table 1 depicts the general characteristics of gullies in the study area, such as the length of gullies, the area of gullies, the width of gullies, and the depth of gullies. The table also show the various cross sections of gullies in the study area, as well as particle sizes such as sand, silt, and clay. Table 2 on the other hand depicts the geographical coordinates of gully sites, as well as the magnitudes of gullies in the study area. From the results presented in these tables as well as photographs taken from the various gully sites visited, it is important to point out that gullies in the study areas are characterised by streams, dense vegetation, and terrain-steep slopes.

Table 1: General Characteristics of Gully System in the Study Area

S/N	Gully Site	Length (m)	Area (m^2)	Width (m)	Depth (m)	Cross Section	Particle Size (%)			Textural class
							Sand	Silt	Clay	
Lafia LGA										
1	Adogi	256	1536	6	5.3	V and U Shape	90.2	3.4	6.4	Sandy- Loam
2	Akunza	88	440	5	6	U-Shape	84.2	5.4	10.4	Sandy- Loam
3	Akurba	285	4930.5	17.3	12	U-Shape	86.2	5.4	8.4	Sandy- Loam
4	Bukan-kwato	111	666	6	5	U and V Shape	86.2	4.4	9.4	Sandy- Loam
5	Danka	78	390	5	5.7	U-Shape	92.2	2.4	5.4	Sandy- Loam
6	Gandu	123	676.5	5.5	7	U-Shape	87.2	3.4	9.4	Sandy- Loam
7	Gimare	127	1016	8	6	U-Shape	88.2	5.4	8.4	Sandy- Loam
8	Kilema	315	6678	21.2	8.2	U-Shape	91.2	3.4	5.4	Sandy- Loam
9	Kwandere	112	784	7	6.5	U-Shape	91.2	3.4	5.4	Sandy- Loam
10	Tudun-Allu	252	2772	11	7	V-Shape	90.2	3.4	6.4	Sandy- Loam
11	Ungwa Shawu	298	5542.8	18.6	14	U-Shape	88.2	4.4	9.4	Sandy- Loam
12	Ungwa Tiv	154	2541	16.5	10	V-Shape	91.2	3.4	5.4	Sandy- Loam

Source: Field and laboratory analysis, 2021.

Table 2: Coordinate Position of Gullies covered by this Study

S/N	Gully Site	Latitude (N)	Longitude (E)	Magnitude
Sites in Lafia LGA				
1	Adogi	8° 29' 46"N	8° 30' 2"E	Large gully
2	Akunza	8° 28' 6"N	8° 36' 14"E	Small gully
3	Akurba	8° 29' 29"N	8° 30' 25"E	Large gully
4	Bukan-kwato	8° 28' 16"N	8° 35' 14"E	Medium gully
5	Danka	8° 29' 16"N	8° 30' 56"E	Small gully
6	Gandu	8° 29' 19"N	8° 30' 42"E	Medium gully
7	Gimare	8° 29' 45"N	8° 30' 7"E	Medium gully
8	Kilema	8° 29' 34"N	8° 30' 19"E	Large gully
9	Kwandere	8° 29' 23"N	8° 31' 16"E	Medium gully
10	Tudun-Allu	8° 29' 44"N	8° 32' 9"E	Large gully
11	Ungwa Shawu	8° 29' 43"N	8° 32' 5"E	Large gully
12	Ungwa Tiv	8° 29'31"N	8° 31' 31"E	Large gully

Source: Field work, 2021.

From the data presented in the Table 1 and Table 2, it was observed that gullies in the study area are characterised with either U-shape, V-shape or V and U-shape cross sections. Similarly, the data present in both tables shows that the magnitude of gullies found in the study area are either small, very small, medium or

Global Journal of Human-Social Science (B) Volume XXI Issue III Version I Year 2021

large gullies. Hence, the peculiar characteristics of the sampled twelve gully sites in the study area gives a true picture of the general characteristics of gully system in the study area. More so, the mean length of gullies in the study area was 183.25m (meters), with a coefficient of variation of 0.01m, while the average area covered by gully erosion was 2331.07m^2 (meters square), with a relative variability of 0.04m^2. Similarly, the mean width of gullies in the study area was 10.59m, with a relative variability of 208.86m, while the mean depth of gullies in the study area was 6.08m, with a relative variability of 0.79m. With respect the soil particles sizes in the study area, the results depicted in Table 1, shows that the mean size of sand in the study area was 88.9%, with a relative variability of 0.03%, while the mean size of silt was 3.98%, with a relative variability of 0.25%. Similarly, the mean size of clay in gully sites in the study area was 7.48% with a relative variability of 0.37%. In terms of the cross-section of gullies, majority of gullies in the study area were U-shaped gullies. Explicitly, a total of 8 gullies in the study area were U-shaped gullies. The results (Table 2) also revealed the presence of V-shaped gullies, as well as U-V-shaped gullies in the study area. This discovery is in line with the work of Udosen (1999).

The results presented in Table 2 revealed the magnitudes of gullies in the study area. From the results, it can be observed that from the entire gully sites covered in the study area, a total of 6 large gullies were recorded in Lafia Local Government. These gullies were found in Adogi, Akurba, Kilema, Tudun-Allu, Ungwa Shawu, and Ungwa Tiv respectively. The large gully found in Akurba recorded a gully length of 285m, width of 17.3m, gully depth of 12m, and covering an area of 4930.5m^2. The particle size of sand found at this gully site was 90.2%, silt 5.4%, sand 86.2%, and clay 6.4%.

Source: Field work, 2021.

Plate 3: A typical gully site in Akurba, Lafia LGA

Gully found in Adogi recorded in a gully length of 256m, with a gully width of 6m, gully depth of 5.3m, and covering an area of 1536m^2. In terms of particle sizes recorded at Adogi site, sand had 90.2%, silt 3.4% and clay 6.4%. In Kilema, the gully found recorded a length of 315m, width of 21.2m, and depth of 8.2m. In the same vein, this gully covered an area of 6678m^2, with particle sizes of; sand 91.2%, silt 3.4 and clay 5.4%. It is important to point out here that Kilema had the largest gully recorded in Lafia Local Government Area, during the course of this study.

Source: Field work, 2021.

Plate 1: A typical gully site in Adogi, Lafia LGA

Source: Field work, 2021.

Plate 2: A typical gully site in Kilema, Lafia LGA

At Tudun-Allu site of the study area, the gully found covered an area of 2772m^2, with a depth of 7m, width of 11m and a length of 252m. In terms of particle size, Tudun-Allu site has the following underlying material; sand 90.2%, silt 3.4% and clay 6.4%. The second largest gully recorded in Lafia Local government Area in the course of the study, was at Ungwa Shawu. The gully found in this site covered an area of 5542.8m^2, with a depth of 14m, a width of 18.6m and a length of 298m. The particle size found at this site has the following; sand 88.2%, silt 4.4% and clay 9.4%.

Source: Field work, 2021.

Plate 4: A typical gully site in Ungwa Shawu, Lafia LGA

Another large gully recorded in Lafia Local Government Area was found in Ungwa Tiv. The gully found at this site covered an area of 2541m^2, with a gully length of 154m, gully depth of 10m and a gully width of 16.5m. more so, the particle size distribution recorded at this site had the following; sand 91.2%, silt 3.4% and clay 5.4%.

The results also revealed the presence of medium size gullies in the study area, as well as small size gullies. The medium size gullies recorded in the study area were found in Bukan-kwato, Gandu, Gimare, and Kwandere respectively, while the recorded small size gullies recorded were found in Akunza and Danka. At Bukan-Kwato site, the medium size gully recorded covered an area of 666m^2, with a gully depth of 5m, length of 111m and a gully width of 6m. The particle size at this gully site were; sand 86.2%, silt 4.4% and clay 9.4%. In Gundu site, the medium gully recorded had particle size distribution of clay 9.4%, silt 3.4% and sand 87.2%, covering an area of 676.5m^2, with a depth of 7m and a width of 5.5m, while the length of the gully was 123m. This site recorded particle size distribution of; clay 9.4%, silt 3.4% and sand 87.2%. Similarly, the medium gully in Gimare site covered an area of 1016m^2. In terms of length, width and depth, gullies recorded at this site had a length of 127m, width of 8m are were 6m deep. The particle size recorded at this site were sand; sand 88.2%, silt 5.4% and clay 8.4%. In Kwandere site, the medium size gully recorded had a length of 112m, covering an area of 784m^2, with a width of 7m and depth of 6.5m. The particle size distribution included; sand 91.2%, silt 3.4%, and clay 5.4%.

Source: Field work, 2021.

Plate 5: A typical gully site in Danka, Lafia LGA

The small size gully recorded in Danka site had a particle size distribution of; sand 92.2%, silt 2.4% and clay 5.4%. This gully covered and area of 390m^2, and recorded a gully length of 78m, gully width of 5m, and a gully depth of 5.7m. Similarly, Akunza site has a particle size distribution of sand 84.2%, silt 5.4% and clay 10.4%. In the same vein, the geometric characteristic, Akunza site recorded a depth of 6m, width of 5m, covering an area of 440m^2 with a length of 88m.

These findings are in agreement with Patrick (1999), Kurar and Jung (2005), Booldel*et al.* (2010), Kappel (1996) and Horton *et al.* (1996) who developed a scheme to classify water erosion hazard severity from vision erosion feature base on the destruction and intensity of erosion damage. Equally, Kappel and Horton *et al.* (1996) use the procedures of measurement of gullies in assessing erosion hazard classification. Plamental (2005) stated that, mean erosion rate in India was 25-30 tones/ha per year and about 40-1000 tones descend. Evans and Cooke (1986) stated that, in the late 1970's and early 1980's there was a sharp rise in the number of recorded cases of erosion in Britain. Soil having greater sand particles are prone to erosion compare to soil having greater clay contents (Mala, 2019). Texture of soil certainly affect soil erosion. Soil texture has its influence on infiltration or entry of water into the soil. When rainfall infiltrates rapidly, runoff is minimal thus erosion is less but when otherwise then erosion is much Mala. (2019). Clay is more resistant to erosion than sand. From the results in Table 1, it revealed that soil texture in the study area is more of Sandy-Loam. The implication was that it promotes erosion because Sand-Loam texture are not resistant to erosion (Mala, 2019).

b) Volume of Soil Loss in the Study Area

From the data presented in Table 3, it can be observed that in Adogi the volume of soil loss due to gully erosion in the area was 13037.8tons, while 11643.2tons of soil loss was recorded in Akunza site. In the same vein, 7483.2tons of soil loss was recorded in Akurba site, while Bukan-kwato had a soil loss of 12574.9tons. The data presented further indicates soil loss of 14361.2tons in Danka site, while 10005.4tons of soil loss was recorded at Gandu site.

Table 3: Volume of Soil Loss at Gully Sites Located in Lafia LGA

S/N	Gully Site	R	K	LS	Volume of Soil Loss (tons)
1	Adogi	265.86	219.7	20	13037.8
2	Akunza	265.86	196.2	20	11643.2
3	Akurba	265.86	126.1	20	7483.2
4	Bukan-kwato	265.86	211.9	20	12574.9
5	Danka	265.86	242.0	20	14361.2
6	Gandu	265.86	168.6	20	10005.4
7	Gimare	265.86	90.3	20	5358.7
8	Kilema	265.86	170.5	20	10118.1
9	Kwandere	265.86	171.8	20	10195.3
10	Tudun-Allu	265.86	118.2	20	35195.6
11	Ungwa Shawu	265.86	424.2	20	25173.6
12	Ungwa Tiv	265.86	120.6	20	2156.9
Mean Value of Soil Loss		13108.7			
Std. Deviation		8924.5			
CV of soil loss in Lafia LGA		68.1			

Source: Field and Laboratory work, 2021.

Kilema, Kwandere, and Tudun-Allu sites recorded soil losses of 10118.1ton, 10195.3ton, and 35195.6tons respectively, while Ungwa Shawu and UngwaT iv sites recorded soil losses of 25173.6tons and 2156.9tons respectively.

The mean volume of soil loss in the study area as result of gully erosion was 13108.7tons with a standard deviation of 8924.5. The coefficient of variation of soil loss in the various gully sites in the study area was 68.1tons. From the results presented in the table (Table 3), Tudun-Allu and Ungwan Shawu suffers more soil loss as a result of gully erosion in Lafia Local Government Area of Nasarawa State. The implication here is that urban settlements and building structures in this area are at a high risk of collapse, and in the occurrence of such scenario lives and properties will be lost (Dalil, *et al.,* 2016; Ibrahim, *et al.,* 2017).

Global Journal of Human-Social Science (B) Volume XXI Issue III Version I Year 2021

The above findings in respect to the volume of soil loss in the study area coincides with Baver *et al.* (2002), who were of the position that the effect of soil properties on water erosion can be in two ways: Firstly, certain properties determine the rate at which rainfall enters the soil. Secondly, some properties affect the resistance of the soil against dispersion and erosion during rainfall and runoff. The particle size distribution is an important soil property with regards to erodibility. Generally, it is found that 35% clay are often regarded as being cohesive and having stable aggregates which are resistant to dispersion by raindrops (Evans, 2015). Evans also stated that sands are not easily eroded by water due to its high infiltration rate. In contrast soils with a light silt or fine sand fraction are very erodible. The depth of erosion is determined by the soil profile (Evans, 2015). According to Evans soil horizons below the A horizon or plough and chemical composition of the sub surface horizon can also have an adverse affected. Normally deep gullies can be cut if the parent material is unconsolidated.

c) Morphometry of Gullies in the Study Area

The results presented in Table 4 establishes the morphometry of gullies in the study area.

Table 4: Gully Morphometry in the Study Area

Gully Size	Mean values of gully length (m)	Mean values of gully depth (m)	Slope angle surface on which gullies develop
Small gullies	83.0	5.9	7.6°
Medium gullies	118.3	6.1	8.8°
Large gullies	260.0	9.4	5.5°

Source: Field work, 2021.

From the results, gully Morphometry are presented in respect to the gully size. Small gullies in the study area recorded a mean length of 83.0m. In the same vein, the mean depth of small gullies in the study area was recorded at 5.9m, with a slope angle surface of 7.6º on which gullies develop. Medium gullies in the study area recorded a mean length of 118.3m. The mean value of the depth of this size of gully was estimated 6.1 with a slope angle of 8.8º on which gullies develop. For large gullies in the study area, mean gully length was estimated at 260.0m. Furthermore, the mean value of gully depth for this size of gully was estimated at 9.4m, with a 5.5º slope surface angle on which gullies develop. The results in Table 5 further reveals the morphometry of gullies in the study area in terms of their slope profile. From the results, it can be observed that the mean length of slope of gullies in the study area was 17.2m, with a coefficient of variation of 31.4m. Furthermore, the mean slop angle on which gullies develop in the study area was 5°, with a coefficient of variation of 52. These findings are in line with the work of Udosen (1999) on morphometry of gullies in Abutme area of Akwa-Ibom State, Nigeria.

Table 5: Slope Profile Measurement in the Study Area

S/N	Gully Site	Length (m)	Slope angle (in degrees)
1	Adogi	20	8°
2	Akunza	20	7°
3	Akurba	20	6°
4	Bukan-kwato	20	6°
5	Danka	20	2°
6	Gandu	20	3°
7	Gimare	10	9.5°
8	Kilema	10	3°
9	Kwandere	20	5°
10	Tudun-Allu	20	2°
11	Ungwa Shawu	6	2°
12	Ungwa Tiv	20	7°
	Mean	17.2	5°
	SD	5.4	2.6
	CV	31.4	52

Source: Field work, 2021

d) Correlation Matrix between Gully Morphometric Properties in the Study Area

The correlation matrix presented in Table 6 reveals the test statistics that measures the statistical relationship, or association between gully morphometric properties in the study area. The results as depicted in Table 6 reveals the Pearson correlation coefficient between the length and the depth of gullies in the study area at 0.614. This coefficient thus implies a strong positive linear relationship/association between the length and depth of gullies in the study area. More so, the 1-tailed test revealed a statistically significant relationship, with a significant value (*p*-value) of 0.017.

Similarly, the results also revealed a strong positive leaner relationship/association between the area of gullies and width of gullies in the study area. This strong positive leaner relationship was found to be statistically significant with a 1-tailed test at 0.01 level, with a significant value (*p*-value) of 0.000. These results by implication, implies that there is a strong positive relationship between the length and depth of gullies, as well as the area and depth of gullies in the study area. The findings of these correlation results are in line with the work of Udosen (1999).

Table 6: Correlation Matrix between Gully Morphometric Properties in the Study Area

Correlations			
		Length of gullies (m)	Dept of gullies (m)
Length of gullies (m)	Pearson Correlation	1	0.614*
	Sig. (1-tailed)		0.017
	N	12	12
Dept of gullies (m)	Pearson Correlation	0.614*	1
	Sig. (1-tailed)	0.017	
	N	12	12
*. Correlation is significant at the 0.01 level (1-tailed).			
		Area of gullies (m^2)	Width of gullies (m)
Area of gullies (m^2)	Pearson Correlation	1	0.951**
	Sig. (1-tailed)		0.000
	N	12	12
Width of gullies (m)	Pearson Correlation	0.951**	1
	Sig. (1-tailed)	0.000	
	N	12	12
**. Correlation is significant at the 0.01 level (1-tailed).			

Source: Author's computation, 2021.

e) Gullies Morphology in the Study Areas

Table 7: Gullies Morphology in the Study Area

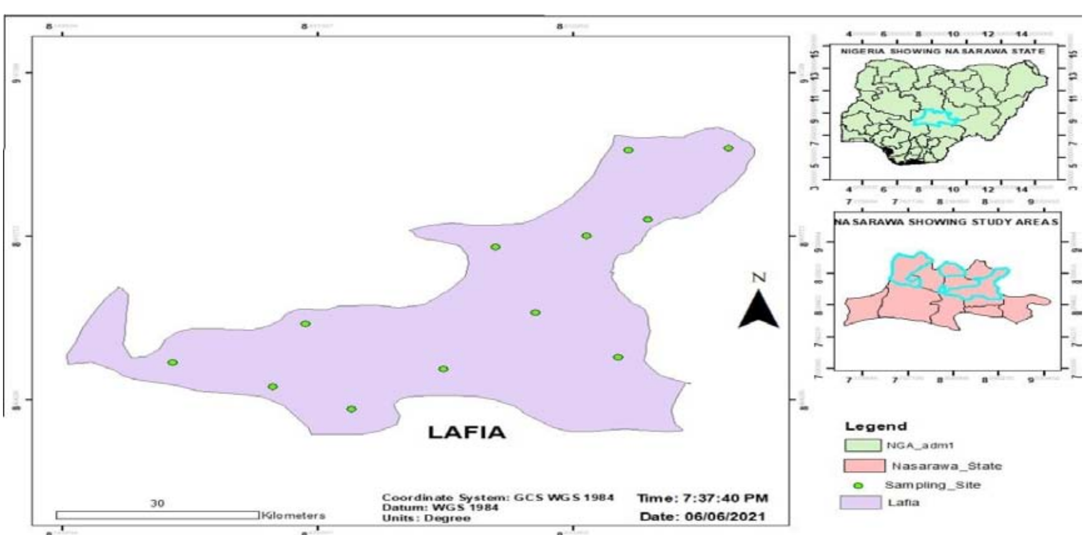
S/N	Gully Site	Gully Shape	Gully Class	Stage of Gully Development
Sites in Lafia LGA				
1	Adogi	Long-narrow	Discontinuous gullies	Unstable
2	Akunza	Trapezoidal	Discontinuous gullies	Unstable
3	Akurba	Rectangular	Discontinuous gullies	Stable
4	Bukan-kwato	Long-narrow	Continuous gullies	Stable
5	Danka	Long-narrow	Discontinuous gullies	Stable
6	Gandu	Linear	Discontinuous gullies	stable
7	Gimare	Rectangular	Discontinuous gullies	Unstable
8	Kilema	Trapezoidal	Discontinuous gullies	Unstable
9	Kwandere	Linear	Continuous gullies	Stable
10	Tudun-Allu	Long-narrow	Discontinuous gullies	Stable
11	Ungwa Shawu	Trapezoidal	Discontinuous gullies	Unstable
12	Ungwa Tiv	Long-narrow	Discontinuous gullies	Stable

In assessing the morphology of gullies in the study area, the study took into consideration the shapes of gullies in the study area, the various classes of gullies in the study area, as well as the stages of gullies development in the study area. The results presented in Table 7 shows the morphology of gullies in the study area. In determining the various classes of gullies in the study area, the methods of Ireland, *et al.* (1996) and Leopol and Miller (1956) were employed. From the results presented in the Table 4.5, it can be observed that 44.4% of the gullies in the study area are discontinuous gullies, while 55.6% were continuous gullies. Discontinuous gullies are characterized by respectively low or gentler gradients and they are caused by local over-steeping of slopes due to aggravation. This method was applied by Heede (1974, 1970, and 1976), Cudoson, (2005), and Blon (1966, 1970) in the north island of New Zealand. Mosley (1972), recorded in Bocco (1990) studied a discontinuous gully system in alluvial fills in the Colorado piedmont (USA). In this study, the characteristics of gully morphology were agent which operates frequently during heavy rain or strong winds. Gully system is said to be discontinuous when it reached it shape of maturity. Heede (1975) in an attempt to predict gully growth and guide consideration works combine the concept of discontinuity with that of stages of cyclic gully development. Based on field observation on the flanks of the Rocky Mountains (USA), he noted that discontinuous gullies represent youthful stages in gully development. Continuous gullies. These gullies in the study are at their 5% and above development. The stage of gully development consists of the development of the channel cut through the top soil and upper 'B' horizon. The early stage of a continuous gully, characterized by several knick points on the channel both on, can be termed the 'early mature' of development (Bocco, 1991).

The morphology of gullies in the study area in terms of the stages of gullies development was also analysed in line with the study of Heede (1975). From the results presented in the Table 7, 58.3% of the sampled gullies were at a stable state of development, while 41.7% of the gullies were at an unstable state of development. In respect to the shapes of gullies in the study area, in line with the study of Heede (1975), 38.9% of the sampled gullies were long-narrow gullies, while 22.2% were linear shaped gullies. In the same vein, rectangular shaped gullies found in the study area consisted of 22.2% of the sampled gullies in the study area, while 13.9% of the sampled gullies in the study area were trapezoidal shaped gullies. Long-narrow and rectangular shaped gullies consisted of 2.8% of the sampled gullies in the study area.

f) Mapping of Areas Affected by Gully Erosion in the Study Area

The effects of gully erosion in an environment can be control if only the most prone areas are properly mapped out, and precautionary measure are taken (Leopold *et al.,* 1964, and Mackin, 1948). Thus, the various areas affected by gully erosion in the study area were mapped using the coordinates collected from the identified site and depicted in Figure 3,4,5& 6. The dots in the map represents the identified gully sites in the study area (see the Map Legend). From the map, it can be observed that the various gully sites from Wamba Local Government Area were not too far from one another. This was because of the nature of the terrain of the sampled point. Similarly, Gully sites in Lafia Local government as indicated by the dots on the map are also close to each other. This finding is in line with the work of Kertész, and Gergely (2011)



Source; NAGIS, (2021)

Fig. 4: Mapping of sampling site in Lafia LGA (Results from table 4.2)

IV. Conclusion

This study assessed the Morphometry of gullies in Nasarawa State. Nasarawa State is facing severe problem of gully erosion, causing untold hardship and depression on the lives of the people of the State. Complex interdependent mechanism between rainfall characteristics, soil erodibility, land use, and topography has reduced infiltration, which caused a higher surface runoff. This has increased deep cutting, take up valuable land, raised the cost of living, and raised the cost of building and sinking of well water. The chain of the cause and effects hints most of the low-income groups of the communities where the population density is highest and where the worst damages of gully erosion are found. The paradigm of sustainable development requires equality and harmony of environment, economy, and society. And sustainable development is not possible unless this equality is felt by the masses.

Environmental degradation leads to resource degradation, declining standards of living, the extinctions of large numbers of species, health problems in the human population, conflicts between groups fighting for dwindling resources, water scarcity and many other major problems (UNESA, 2002). If this trend is allowed to continue, the long run impact of environmental degradation would result in local environments that are no longer able to sustain human populations. Such degradation on a global scale would, if not addressed, can lead to the extinction of human life on earth. In order to achieve sustainable development, a conscious effort needs to be made today to sustain the environment and prevent further degradation; various local, regional and national governments and local, regional, national and international agencies needs to work together towards promoting environment friendly lifestyle and protecting the fragile ecosystems of the planet.

V. Recommendations

On the basis of the findings of the study, the following recommendations were made;

1. Gully extent magnitude can have controlled grazing, conservation farming of vegetation barriers against run-off, especially around fresh gully leach-cats as measure of combating gully erosion in the affected areas.
2. The soil of Nasarawa State can be conserved from gully erosion by the construction of check-dams, vegetative catchment barriers and grass water ways across the gullies in order to reduce the volume of soil loss in the area.
3. Areas that are affected and vulnerable to gully erosion could be allocated to special uses. For example, such vulnerable area could be used for wild life and recreational purposes.

References Références Referencias

1. Abaje, I. B (2007) Introduction to Soil and Vegetation: Personal Touch.
2. Abegunde M. A, Adegoke A., Onwumere G. and Dahiru, A (1999). Introduction to Geography: Longman Nigeria Plc, Ikeja, Lagos.
3. Abernethy, B. and I. D. Rutherfurd. 1998. Where along a river's length will vegetation most effectively stabilize stream banks? *Geomorphology. 23(1): 55-75.*
4. Abegunde*et al.,* (1991): Impact of Soil Erosion on Production System; South Western Nigeria.
5. Abraham, A.D (2003). "Factor analysis of drainage basin properties evidence for a stream abstraction accompanying the degradation of relief" *Water Resources Research. Vol. 8, 624-633.*
6. Adebayo, A.A. (1999). Climate II.*In Adebayo and Tukvr (eds) Adamawa State in Maps. Yola:* Paraclete Publishers.
7. Adefolalu, D. O. (1989). Precipitation, Evapotranspiration and the Ecological zones in Nigeria. *Theory. Appl. Climatology, 39, 81-89*
8. Ahn, P.N. (1970). *West African Soils* London. Oxford University Press. 332p
9. Akintola, F.O (1974). *The parameters of Infiltration Equation of Urban Land Surfaces,* An Unpublished Ph. D Thesis, Dept. of Geography, University of Ibadan, Nigeria.
10. Akintola, F.O (1978). The hydrological consequences of urbanization: A case study of Ibadan city/. In P.O. Sada and J.S. Oguntoyinbo (eds). *Urbanization processes and problems in Nigeria,* Ibadan University press.
11. Anzaku I.M. (2015). *Effect of Gully Erosion on Agricultural Land Use in Lafia Nasarawa State.* Unpublished M.Sc. Dissertation, Dept. of Geography, Nasarawa State University, Keffi, Nigeria.
12. Areola, O (1990). *The Good Earth Inaugural* Lecture, University of Ibadan.
13. Areola, O and Faniran, A. (1999). *The Essential of Soils Study*. Heinemann. London.
14. Areola, O. and Faniran, A (2000). Landform examples from Nigeria: A Gully. *The Nigerian Geographical Journal. Vol. 17 17:57-60.*
15. Armon, M.N (1984). *Soil erosion and Degradation in South-Eastern Nigeria in Relation to Biophysical and Socio-economic factors,* Unpublished Ph. D Thesis, University of Ibadan, Ibadan.
16. Arnold, J.G., Williams, J.R., Griggs, R.H., And Sammons, N.B. (1990). *Swrrb - A Basin Scale Simulation Model for Soil and Water Resources Management.* Texas, A and M Press.
17. ASCE. (1998). River width adjustment. I: Processes and mechanisms. *Journal of Hydraulic Engineering. 124 (9): 881-902.*

18. Asce. (1998). River Width Adjustment. I: Processes and Mechanisms. *Journal of Hydraulic Engineering. 124(8): 881-9q2,*
19. Ayeni, B. (1994). *Quantitative Techniques for Geographers,* Research Support Service, Ibadan.
20. Ayoade, J. O. (1983). *Introduction to Climatology for the Tropics.* Abi prints and park.
21. Ayuba (2005): Central Nigeria Project on a Soil Conservation.
22. Ahmad (1990): Erosion and Land Degradation; Northern Nigeria.
23. Ahmad (1987) Effect of Gullies; Kano Region of Nigeria.
24. Babalola, O. (1988) "Soil properties affecting infiltration, runoff and erodibility" in Enabor, E. E. *et al.* (eds) Ecological Disasters in Nigeria: soil Erosion, Federal Ministry of Science and Technology, Lagos 131- 156.
25. Balling, R.C and wells, S; (1990) "Historical rainfall pattern and Arroyo activity within the Zuru river drainage basin". New Mexico. Association of American Geographers Vol. 80(4): 603-617.
26. Baldwin, (2003): Nigeria threatened Environment National Profile.
27. Baradford, J.M. Piest, R.F. and Sapomer, R.G. (2005). Failure sequence of gully headwalls in Western Iowa Soils Science Society off Nigeria. *Society of America 42, 323 – 328.*
28. Baura, M. (1995). *Comparative analysis of runoff soil nutrient loss under different cropping systems.* An unpublished Ph. D Thesis, University of Ibadan, Nigeria.
29. Baver, L.D. (2003). Edward woolly – A Pioneer in Soil and Water conservation Research. *Proceeding of Soil Sciences Society of America. Vol. 3: 330 – 340*
30. Beasley, D.B., Muggins, L.F., and Munke, E. J. (1980). Answers - A Model for Watershed Planning. *Trans Am Soc. Agric Eng., 23: 938-944.*
31. Beck M.B. (2012). Water Quality Modelling: A Review of Uncertainty. *Water Resources Res., 23 (8): 1393-1442.*
32. Begin, Z.B. and Schumm, S.A (1979). Instability of alluvial valley floors: A method for its assessment *Transaction of American Society of Agricultural Engineers 22, 347-350.*
33. Berry, M.J. (2007). Erosion control on Bukit Bakar, kelanton, *Malaysia Forester 19:3-11.*
34. Betson, R.P (1964). What is watershed runoff, *Journal of Geophysical Research 69:1541-1552.*
35. Bigwood, B.L. and Thomas, M.P. (1955). *A flood flow formula for Connecticut.* United States Geological Survey. Circ.
36. Blang, R.L. (2010). Gully sidewall development in New South Wales, Australia Ankeny: *Soil Science Society of American, 574 – 84.*
37. Blong, R.L (2002). The development of discontinuous gullies in a Pumice catchment. *American Journal of science. 268: 369-383.*
38. Blong, R.L. Graham, D.O.P and Vaeneoss, J.A; (1982). The role of sidewall Processes in gully development: some N.J.W. examples, *Earth Surface Processes and Landforms 7: 381–385*
39. Blume, L.J; H.F. Perkins and R.K. Hubbard (1987). Subsurface water movement in an Upland Coastal Pla0in Soil as influenced by Plinthite. *Soil Science Society of America. 52: 774- 779.*
40. Bobe B. W., (2004*). Evaluation of Soil Erosion in the Harerge Region of Ethiopia Using Soil Models, Rainfall Simulation*, Ph.D. Thesis submitted to the Department of Soil Science, Faculty of Natural and Agricultural Sciences, University of Pretoria.
41. Bocco, G. (1990). *Gully erosion analysis using remote sensing and geographic information systems.* Unpublished Ph.D. dissertation, University of Amsterdam.
42. Bocco, G. (1991). Gully erosion: Processes and models. In: Progress in Physical Geography 15, 4p0p. 392- 401.
43. Bradford, J.M. and Piest R. F (2009 "Erosional Development of Valley – Bottom Gullies in the Upper Midwestern United States" in Cates D. R. & Vitek J. K. (EDS) Thresholds in Geomorphology, London. Pp. 75–102.
44. Brater, E.F. (2007). Steps towards a better understanding or urban runoff processes. Water Resources Research. 4(2) 335–348.
45. Brice, J.C. (1966). Erosion and deposition in the Loess mantled Great Plains Medicine Greek drainage00 basin. Nebraska – U.S. Geological Survey professional Paper 352 H 255–339.
46. Brink, J.W. and Jungerius, P. D. (2008). The deposition of stony colluviums on clay soil as a cause of gully formation in the Rif Mountains: Morocco. *Earth Surface processes and Landforms 8: 281 – 285.*
47. Bryan, R. and Yair, A. (eds) (2013). *Badland Geomorphology and piping*, Norwich: Geobooks.
48. Bryan, R.B. (1999). The influence of slope angle on soil entrainment by sheet wash and rain splash. *Earth surface processes 4, 43–58*
49. Bryan, R.B. (2000). Rill erosion processes and significance Catena supplement 8.
50. Bryan, R.B. Govers, G. & Peosen, J. (2011). The concept of soil erodibility and some problems of assessment and applicable, *Catena 16, 393 -413.*
51. Bryan, R.D. (1998). The relative erodibility of soils developed in the peak District of Derbyshire. *Geografiska .70, Ser. A1969 394.*