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MORPHOMETRY AND MORPHOLOGYOF GULLIES IN NASARAWA STATE, NIGERIA

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ABSTRACT

This study assessed the morphometry and morphology of gullies in Nasarawa State. Both primary and secondary data source were employed for this study. The primary data were collected from direct field observation and measurements. Secondary data were gathered through the review of relevant literature. A recommendation survey to ascertain the general characteristics of gullies in the state was carried out with the aid of topography map of the study area. Lafia, Wamba and Karu LGA was selected from each senatorial district to represent the study area has an undulating topography and Furley (1996) observed that variation in topography could modify occurrence of land degradation. Variable were measured or divided randomly from each of the thirty-six-gully site in the study area. Twelve gully sites were selected from each Government representing the study area. The results generated from the field were subjected to statistical and laboratory analysis. The results of the findings revealed that gullies in Lafia and Wamba LGA of Nasarawa state are more affected 80% Kilema gully site in Lafia LGA recorded the highest intern of gully length 315m followed by Traffic in Wamba LGA 303m, UngwaSharu in Lafia LGA recorded the highest figure in term of gully length 325m followed by Traffic in Wamba LGA 285m respectively. In term of gully in the study area, it recorded number 21.2m, traffic in Wamba LGA 20.3m, Gangare wawa in Wamba LGA and Akurba in Lafia LGA recorded the same figure 17.3m, respectively. Gully site in Mama, in Wamba LGA and Uke in Karu LGA of the study area, recorded the last figure 4m in width magnitude. In term of area, gully site in Marhai in Wamba LGA, Mararaba in Karu LGA and UngwaTiv. In Lafia LGA recorded the highest number 0.21m^2 and Adogi gully site in Lafia LGA recorded the last of 0.5m^2. Majority of the gullies in the study area are characterized by U-S shape cross-section 60% and V-shape 30% U and V-shape 10%. The findings also revealed the results of the mean value of volume of soil loss in the study area was 14200.39tonnes/ha in all the gullies in the study area. The mean values of large gullies length were 254.77, depth was 11.86, while that of very small gullies was length 65.16, depth was 4.66 and slope angle was 9.0. Gullies in the area are long-narrow linear to rectangular shaped. 55.6% of gullies are at their continuous stage of development while 44.4% of gullies were at their continuous stage of development.

Keywords: Erosion, Gully erosion, Morphometry and Morphology.

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. Rills 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 Akwa Ibom 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 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 hither-to forest leading to falling of trees and exposure of more surface area to gully activities. Several properties whose value cannot be quantified accurately have been destroyed and others are under treat by this menace especially houses and other properties located on sloping and flood plain area. About 6 houses in Kilema, Emir Palace and UngwaTiv area of Lafia Local Government Area have been destroyed, 4 houses in Karu and 2 in Wamba town respectively. Besides, it was reported recently that about 45 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. 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 has resulted in the separation of adjacent villages and towns as it may involve collapse of the 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. It is in view of aforementioned, that this study assessed the morphometry and morphology of gullies in Nasarawa State, Nigeria.

METHODOLOGY

Description of the Study Area

The geographical entity known as Nasarawa State came into existence on the 1^{st} of October, 1996. It has a central location in the middle belt region of Nigeria. The state lies between latitude 7° 45^{I} and 9° 25^{I}N of the equator and between longitude 7° and 9° 37E^{I} of the Greenwich meridian. It shares boundary with Kaduna State in the North, Plateau State in the East, Taraba and Benue State in the South, while Kogi and the Federal Capital Territory flank it in the West (Binbol& Marcus, 2005). The State has a land area of 27, 137.8 square kilometre with a population of 1,863,275 according to 2006 provisional census.

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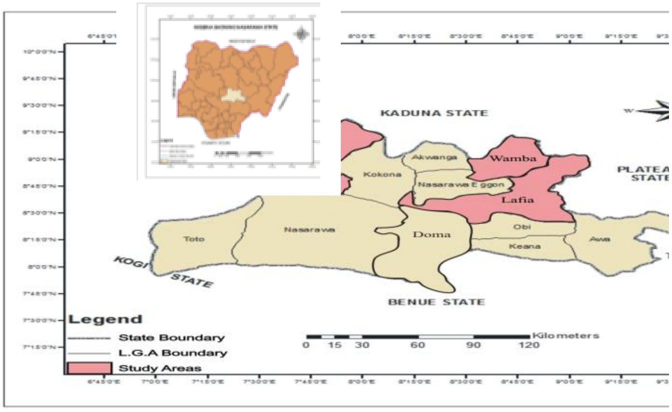

Figure 1: Map of the Study Area

Nature and Source of Data

Both primary and secondary sources of data were employed in this study. Primary data were collected from direct field observation and measurements. Data on particle size were determined. In the same vein, data on gullies morphometric properties, gullies morphology, general characteristics of gullies in the study area were also determined. Secondary data were gathered through the review of relevant literatures such as textbooks, journals, encyclopaedia and information from unpublished research findings with respect to morphometric analysis of gullies.

METHOD OF DATA ANALYSIS

Characteristics of Gullies in the Study Area

Field survey, measurement and observation were carried out to know the general characteristics of gullies in the study area. Soil samples were collected from the field and subjected to laboratory analysis to determine the particle size of each identified gully sites in the study area. The method was described by Young (1999) was applied.

Gully Morphometry

In each sampling area, a 30m linen tape, ranging poles, Abney level and pegs was used in measuring the length, top width, depths head and at carefully selected points, usually at regularly space intervals of between 0.5m and 20m depending on the length of the gully. A tape will be 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.

Gully Morphology

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.

RESULTS AND DISCUSSION

General Characteristics of Gully System in Nasarawa State

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, and 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 head scarp, while mature gullies are deep, wide and are characterized by broadly-lobed heads. The data presented in Table 1 and 2 were obtained from Lafia, Wamba and Karu Local Government Area of Nasarawa state respectively. Generally, the gullies in these areas are characterized by streams, dense vegetation and terrain-steep slopes. From the data presented in the Table 1 and Table 2, it will be observed that gullies in Nasarawa State 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 Nasarawa State are either small, very small, medium or large gullies. Hence, the peculiar characteristics of the sampled thirty-six gully sites in the study area gives a true picture of the general characteristics of gully in Nasarawa State. From the data presented in Table 1 and 2, it can be observed that in Lafia Local Government Area, Kilema site recorded the high gully erosion, with gullies in this site covering an area of 667.8m^2, with length of 3154m and a width of 21.2m. The depth of gully in this site was recorded at 8.2m. In terms of cross section, gullies found in this site were U-shaped gullies, and large in terms of magnitude. The particle size distribution for the underlined gully site were; sand 91.2%, silt 3.4% and clay 5.4%. Gully in this site are typically characterized by terrain-step slope.

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Table 1: General Characteristics of Gully System in Nasarawa State

S/N	Gully Site	Length (m)	Area (m²)	Width (m)	Depth (m)	Cross Section	Particle Size (%) Sand	Silt	clay
	Lafia LGA								
1	Adogi	256	153.6	6	5.3	V and U Shape	90.2	3.4	6.4
2	Akunza	88	44.0	5	6	U-Shaped	84.2	5.4	10.4
3	Akurba	285	493.05	17.3	12	U-Shape	86.2	5.4	8.4
4	Bukan-kwato	111	66.6	6	5	U and V Shape	86.2	4.4	9.4
5	Danka	78	39.0	5	5.7	U-Shape	92.2	2.4	5.4
6	Gandu	123	676.5	5.5	7	U-Shape	87.2	3.4	9.4
7	Gimare	127	101.6	8	6	U-Shape	88.2	5.4	8.4
8	Kilema	315	667.8	21.2	8.2	U-Shape	91.2	3.4	5.4
9	Kwandere	112	78.4	7	6.5	U-Shape	91.2	3.4	5.4
10	Tudun-Allu	252	277.2	11	7	V-Shape	90.2	3.4	6.4
11	Ung. Shawu	298	554.28	18.6	14	U-Shape	88.2	4.4	9.4
12	UngwaTiv	154	254.1	16.5	10	V-Shape	91.2	3.4	5.4
	Wamba LGA								
13	Abu	92	524.4	5.7	6.5	U-Shape	84.0	5.4	12.6
14	Agamati	95	76.0	8	5	U-Shape	86.2	5.4	8.4
15	Arum	221	335.92	15.2	15.3	U-Shape	84.0	5.4	12.6
16	Farinruwa	110	77.0	7	7.5	U-Shape	84.0	5.4	12.6
17	Gangare Wawa	277	479.21	17.3	9	U and V Shape	86.2	5.4	8.4
18	Mama	64	32.0	5	4	V-Shape	86.2	4.4	9.4
19	Marhai	67	462.3	6.9	4	V-Shape	84.0	5.4	12.6
20	Nakere	97	58.2	6	7	V-Shape	84.0	4.4	13.6
21	Sisimbaki	87	52.2	6	5	U-Shape	84.0	4.4	13.6
22	Traffic	303	615.09	20.3	16	U-Shape	88.2	3.4	8.4
23	UngwaGiya	111	66.6	6	9	V-Shape	86.2	5.4	8.4
24	UngwaKasa	121	992.2	8.2	7	V-Shape	86.2	4.4	9.4
	Karu LGA								
25	Ado	184	277.84	15.1	17	U-Shape	88.2	4.4	9.4
26	City College	74	525.4	7.1	6.9	U-Shape	87.2	3.4	9.4
27	GidanZakara	83	66.4	8	8	U-Shape	84.2	5.4	10.4
28	Karshi	66	396.9	6	5	U-Shape	84.0	5.4	12.6
29	Mararaba Karu	50	26.0	5.2	4	V-Shape	86.2	5.4	8.4
30	Massaka	82	65.6	8	6.3	U-Shape	87.2	3.4	9.4
31	NTA quarters	52	26.0	5	5.2	U and V Shape	84.2	3.4	12.4
32	One-man Village	114	68.4	6	8	U and V Shape	86.2	5.4	8.4
33	Sabon Gari	94	65.8	7	5	U and V Shape	84.2	3.4	12.4
34	Sharp-corner	47	277.3	5.9	5	V-Shape	84.2	4.4	11.4
35	Uke bridge	52	280.8	5.4	4	V-Shape	86.2	5.4	8.4
36	Ungwa Yerima	98	68.6	7	7.2	U-Shape	86.2	4.4	9.4

Source: *Field and laboratory work.*

In Kwandere site, the gully size in the area are small gully with a length of 112m, covering an area of 78.4m^2, with a width of 7m and depth of 6.5m. The cross section of the underline gully is V-shaped, with particle distribution of sand 91.2%, silt of 3.4% and clay size of 5.4%. Akunza site on the other hand has a particle distribution size of sand 84.2%, silt 5.4% and clay 10.4%. The cross section of the underline gully site is U-shaped, while gully sizes are very small gully. In the same vein, the geometric characteristic of Akunza site has a depth of 6m, width of 5m, covering an area of 44.0m^2 with a length of 88m. Adogi site was characterized by large gully size, with a length of 256m, covering an area of 153.6m^2, with a depth of 5.3m and a width of 6m. The particle size distribution in the underline gully site consist of; sand 90.2%, silt 3.4% and clay 6.4%, while the cross-section of the gully site of the area of study is V and U-shaped. In Gundu site of the study area the cross-section of gully is U-shaped, with particle size distribution of clay 9.4%, silt 3.4% and sand 87.2%. In terms of size, the gully size of Gandu site is a small gully, covering an area of 676.5m^2, with a depth of 7m and a width of 5.5m, while the length of the gully site is 123m.The characteristics of gully system in UngwaTiv site of the study area has V-shaped cross section and is a large gully in terms of size. The gully in the underline site covers an area of 254.1m^2, with a depth of 10m, width of 16.5m and a length of 154m. The gully in the site has a particle size distribution of the material underlying the gully as follows: sand 91.2%, silt 3.4% and clay 5.4%. In the same vein, Ungwa Shawu site of the study area has a particle size distribution of clay 9.2%, sand 59% and silt 33.6%. The underline gully is a large gully, with a U-shaped cross section. The gully in Ungwa Shawu covers an area of 554.28m^2, with a depth of 14m, a width of 18.6m and a length of 298m.

In Tudun-Allu site of the study area, the general characteristics of gully are not farfetched from the above discussed characteristics. However, the gully size of this site is a medium sized gully, covering an area of 277.2m^2, with a depth of 7m, width of 11m and a depth of 252m. in terms of particle size distribution, Tudun-Allu site has the following underlying material; sand 90.2%, silt 3.4% and clay 6.4%. Danka site on the other hand had a particle size distribution of; sand 92.2%, silt 2.4% and clay 5.4%.In Bukan-kwato site in Lafia Local Government of Nasarawa State, gullies located in the area are U and V-shape gullies, with length of 111m and a width of 6m, covering an area of 66.6m^2 and depth of 5m. The particle size of materials in the area are; sand 86.2%, silt 4.4% and clay 9.4%. Similarly, gullies in Gimare site in

Lafia Local Government Area covered are U-shape, covering an area of 101.6m². In terms of length, width and depth, gullies in this area recorded a length of 127m, width of 8m are were 6m deep. The particle size in of gullies in this were sand; sand 88.2%, silt 5.4% and clay 8.4%.

Gullies found in Wamba Local Government Area are typically characterised by stream and dense vegetation. It can be observed from a critical look at the data presented in Table 1 and 2 that the sites that recorded the work gully are Traffic and Farinruwa sites. It is important to point out that these sites recorded the most destruction caused by gully erosion among the entire sampled sites in the study. In traffic, the effect of gully erosion result to the destruction of houses, while in Farinruwa, the effect was the destruction of Access Bridge in the area. In cross section of gullies in Traffic are U-shaped gully and large in magnitude. the gully in this site covered and area of 615.09m² with a length of 303m and a width of 20.3m, recording a depth of 16m. The distribution of particle in the underlined gully site include; sand 88.2%, silt 3.4% and clay 8.4%. In the same vein, the cross section of gully in Farinruwa are U-shaped gullies. Gully in this site recorded a length of 110m, a width of 7m, and a depth of 7.5m, covering an area of 77.0m². In terms of particle size distribution, the underlined gully recorded sand at 84.0%, silt 5.4% and clay 12.6%.Gully found in Gangare Wawa was the most peculiar of all the gullies encountered in the study area. This is because the gully in this area was rectangular, and somewhat U and V-shaped in terms of cross section. The gully in the area covered an area of 479.21m² with a length of 277m, width of 17.2, and a depth of 9m. The magnitude of the gully is large, and characterised by stream and dense vegetation.

Table 2: General Characteristics of Gully System in Nasarawa State

S/N	Gully Site	Latitude			Longitude			Magnitude
		Degree	Minutes	Seconds	Degree	Minutes	Seconds	
Sites in Lafia LGA								
1	Adogi	8	29	46.6584	8	30	2.21	Large gully
2	Akunza	8	28	6.4704	8	36	14.465	Very small gully
3	Akurba	8	29	29.6268	8	30	25.258	Large gully
4	Bukan-kwato	8	28	16.662	8	35	14.208	Small gully
5	Danka	8	29	16.2492	8	30	56.412	Small gully
6	Gandu	8	29	19.8132	8	30	42.214	Small gully
7	Gimare	8	29	45.884	8	30	7.085	Medium gully
8	Kilema	8	29	34.1448	8	30	19.397	Large gully
9	Kwandere	8	29	23.3736	8	31	16.878	Small gully
10	Tudun-Allu	8	29	44.4732	8	32	9.611	Medium gully

11	Ung. Shawu	8	29	43.4256	8	32	5.622	Large gully
12	UngwaTiv	8	29	31.2396	8	31	31.588	Large gully
Sites in Wamba LGA								
13	Abu	8	56	43.1808	8	36	19.271	Small gully
14	Agamati	8	56	7.9296	8	36	31.788	Medium gully
15	Arum	8	55	57.2268	8	36	42.376	Large gully
16	Farinruwa	8	55	55.6392	8	36	49.547	Medium gully
17	Gangare wawa	8	56	21.966	8	36	35.471	Large gully
18	Mama	8	56	14.8308	8	36	0.67	Small gully
19	Marhai	8	56	58.8768	8	36	20.761	Very small gully
20	Nakere	8	56	1.3668	8	36	14.8	Small gully
21	Sisimbaki	8	56	23.1576	8	36	21.683	Very small gully
22	Traffic	8	57	6.1884	8	36	7.067	Large gully
23	UngwaGiya	8	56	34.5192	8	36	19.411	Medium gully
24	UngwaKasa	8	56	15.8856	8	36	11.902	Medium gully
Sites in Karu LGA								
25	Ado	8	53	38.2656	34	52	19.063	Large gully
26	City College	9	2	10.266	7	37	34.374	Small gully
27	GidanZakara	8	53	51.4788	7	43	21.313	Medium gully
28	Karshi	8	53	53.6532	7	43	0.257	Small gully
29	Mararaba Karu	9	2	1.6728	7	37	35.324	Very small gully
30	Massaka	8	53	37.1724	7	42	39.1	Small gully
31	NTA quarters	8	53	57.9948	7	42	45.346	Small gully
32	One-man Village	9	0	10.026	7	37	3.23	Medium gully
33	Sabon Gari	8	53	32.5716	7	42	35.975	Medium gully
34	Sharp-corner	8	54	1.1196	7	42	44.91	Very small gully
35	Uke bridge	8	54	11.3076	7	42	43.988	Versy small gully
36	Ungwa Yerima	9	1	43.6944	7	36	58.19	Medium gully

Source: *Field and laboratory work.*

Gully sites in Karu Local Government Area are typically characterised by dense vegetation and streams. Unlike that of Lafia and Wamba Local government Area, gullies in Karu are less in terms of terrene steep slope. Large gullies were only found in Ado, with a coverage of length of 184m, and area of 277.84m^2, with a width of 15.1mand a depth of 17m. in terms of cross section, this gullies found in the site are U-shaped, with particle size properties of; clay 9.4%, sand 88.2% and silt, 4.4%. Gullies found in both Sabon Gari and One-man Village were both medium gullies, with a cross

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section of V and U-shape. in terms of particle size distribution, Sabon Gari recorded; clay 12.4%, silt 3.4% and sand 84.2%, while One-man Village recorded clay 27.4, silt 29.9% and sand 43%. Furthermore, gullies found in One-man Village covered and area of 68.4m^2, with a width of 114m, width of 6m and a depth of 8m. In the same vein, gullies found in Sabon Gari covered and area of 65.8m^2, with a depth of 5m, width of 6m and a length coverage of 94m.

The findings here 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, average 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.

Morphometry of Gullies in Nasarawa State

Table 3: Gully Morphometry in the Study Area

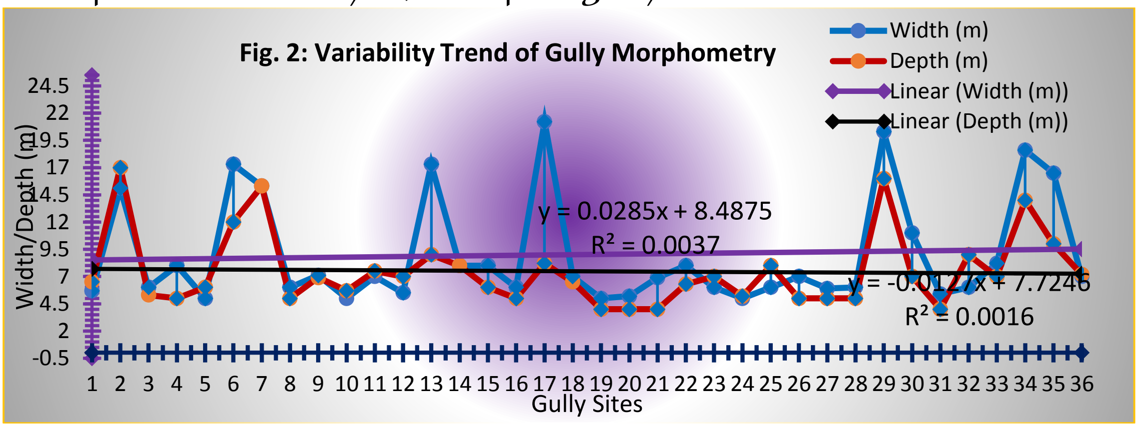
Gully Size	Mean values of gully length (m)	Mean values of gully depth (m)	Slope angle surface on which gullies develop
Very small gullies	65.16	4.66	9.0
Small gullies	86.45	5.91	7.60
Medium gullies	120.5	6.97	8.83
Large gullies	254.77	11.86	5.50

Source: *Field work.*

Gully Morphometry in the study area was established, and the results presented in Table 3. From the results, gully Morphometry are presented in respect to the gully size. Very small gullies in the study area had a mean value of gully length of 65.16m. Gully depth for very small gullies recorded a mean value 4.66m, with a slope angle surface of 9.0 on which gullies develop. Small gullies in the study area a recorded a mean value of 86.45m. In the same vein, the depth of small in the study area was recorded at 5.91m, with a slope angle surface of 7.60 on which gullies develop. In the vein, medium gullies in the study area have a gully length mean value of 120.5m. The mean value of the depth of this size of gully was estimated 6.97 with a slope angle of 8.83 on which gullies develop. For large gullies in the study area, gully length was estimated at 254.77m. Furthermore, the mean value of gully depth for this size of gully was estimated at 11.86m, with a 5.50 slope surface angle on which gullies develop.

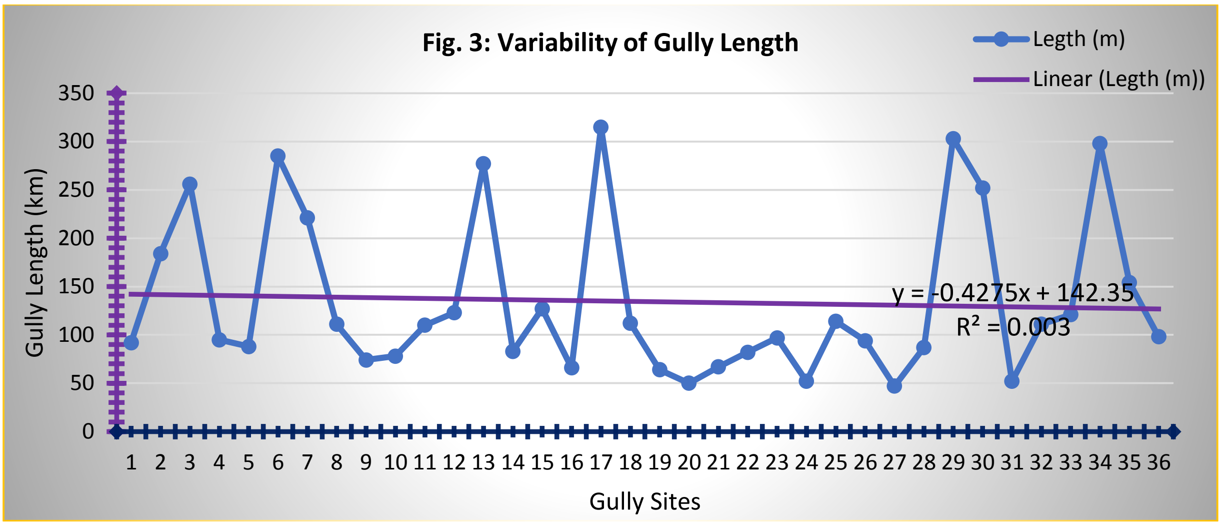
Variability of Gully Morphometric Properties

When we talk of variability (also called spread or dispersion) we as simply referring to how spread out a set of data is. Variability gives you a way to describe how much data sets vary and allows you to use statistics to compare your data to other sets of data. This section looks at the variability of gully morphometric properties in the study area.The severity of gully erosion in the study area is depicted by the trend chart in Figure 2, and Figure 3 which shows the variability of gully Morphometry in the study area. The variability trend depicted in Figure 2 shows the degree of variability in gully width and gully depth, hence, the severity of gully in the study area, in respect to the thirty-six sampled gully sites.



Source: *Field Work.*

From the information depicted in the Figure 2, it can be observed that there no significant variation between gully width and gully in the study area. However, the most notable variation between the width of gully erosion and the depth of gully erosion experienced in the study area was recorded in site 6, 13,17, 29, 34, and 35. Furthermore, the coefficient of variation (R^2) shows that the variability of gully Morphometry in the study area in terms of the gully width in the entire sampled site was 4%. The implication here is that the width of gully Morphometry in Nasarawa State is almost constant and varies at only 4%. Similarly, the coefficient of variation in respect to gully depth Morphometry was 2%. Hence, the implication here is that the depth of gully Morphometry in the study area is almost constant as indicated by the almost straight linear trend line, and varies at only 2%.



Source: *Field Work.*

Variability of gully Morphometry in respect to gully length in the study area was also analysed and depicted in Figure 3. From the trend chart, it can be observed that almost no site recorded the same measure in length of gully erosion in the thirty-six sampled gully sites in the area of study. However, it is important to point out that there was no significant variation in gully length in the area of study, as depicted by the almost sight linear trend line. The linear equation in the shows the coefficient of variation of gully length in the sample sites at 3%.

Slope Profile Measurement in the Study Area

Table 4: Slope Profile Measurement in the Study Area

S/N	Gully Site	Length (m)	Slope angle
1	Abu	20	4^o
2	Ado	20	2^o
3	Adogi	20	8^o
4	Agamati	20	6^o
5	Akunza	20	7^o
6	Akurba	20	6^o
7	Arum	20	6^o
8	Bukan-kwato	20	6^o
9	City College	20	5^o
10	Danka	20	2^o
11	Farinruwa	20	2^o
12	Gandu	20	3^o
13	Gangare wawa	20	2^o
14	GidanZakara	20	4^o

15	Gimare	10	9.5°
16	Karshi	10	9.5°
17	Kilema	10	3°
18	Kwandere	20	5°
19	Mama	20	4°
20	Mararaba	8	8°
21	Marhai	20	6°
22	Massaka	20	7°
23	Nakere	6	2°
24	NTA quarters	20	5°
25	One-man Village	10	9.5°
26	Sabon Gari	20	7°
27	Sharp-corner	10	9.5°
28	Sisimbaki	10	9.5°
29	Traffic	20	9.5°
30	Tudun-Allu	20	2°
31	Uke	10	9.5°
32	UngwaGiya	10	9.5°
33	UngwaKasa	20	8°
34	Ungwa Shawu	6	2°
35	UngwaTiv	20	7°
36	Ungwa Yerima	20	6°

Source: Field work.

Gullies Morphology in the Study Areas

Table 5: 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	Unstable

			gullies	
9	Kwandere	Linear	Continuous gullies	Stable
10	Tudun-Allu	Long-narrow	Discontinuous gullies	Stable
11	Ungwa Shawu	Trapezoidal	Discontinuous gullies	Unstable
12	UngwaTiv	Long-narrow	Discontinuous gullies	Stable
Sites in Wamba LGA				
13	Abu	Linear	Continuous gullies	Stable
14	Agamati	Long-narrow	Continuous gullies	Unstable
15	Arum	Rectangular	Discontinuous gullies	Unstable
16	Farinruwa	Long-narrow	Discontinuous gullies	Stable
17	Gangare wawa	Trapezoidal	Discontinuous gullies	Unstable
18	Mama	Rectangular	Continuous gullies	Stable
19	Marhai	Linear	Continuous gullies	Stable
20	Nakere	Rectangular	Continuous gullies	Unstable
21	Sisimbaki	Long-narrow	Continuous gullies	Stable
22	Traffic	Long-narrow and Rectangular	Discontinuous gullies	Unstable
23	UngwaGiya	Trapezoidal	Continuous gullies	Unstable
24	UngwaKasa	Rectangular	Continuous gullies	Stable
Sites in Karu LGA				
25	Ado	Long-narrow	Discontinuous gullies	Stable
26	City College	Long-narrow	Continuous gullies	Unstable
27	GidanZakara	Long-narrow	Continuous gullies	Stable
28	Karshi	Linear	Continuous gullies	Unstable
29	Mararaba Karu	Long-narrow	Continuous gullies	Stable
30	Massaka	Rectangular	Continuous gullies	Unstable
31	NTA quarters	Long-narrow	Continuous gullies	Stable
32	One-man Village	Linear	Discontinuous gullies	Unstable
33	Sabon Gari	Linear	Continuous gullies	Stable
34	Sharp-corner	Long-narrow	Continuous gullies	table
35	Uke bridge	Linear	Continuous gullies	Stable
36	Ungwa. Yerima	Rectangular	Continuous gullies	Stable

Source: Field and laboratory work.

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 class of gullies in the study area, as well as the stages of gullies development in the study area. The results presented in Table 5 shows the morphology of gullies in the study area. In determining the various class 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 4.4, 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 operate 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 5, 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.

Plate 1: A typical gully cross-section in Kilema, Lafia LGA
Source: Field work.

Plate 3: Linear shaped gully in Kwandere site, Lafia, LGA
Source: Field work.

CONCLUSION

Soil erosion is perhaps the most serious mechanism of land degradation in the tropics (EL– Swaify, *et al.,* 1982). The impacts of gully erosion in Nigeria are enormous and similar to that obtainable elsewhere in the world and these include: loss of farmland, treat to vegetation cover, effect on lives and property, isolation of villages and town and creation of bad lands. Thus, prevention of the processes to gully erosion should be of paramount importance to all the stakeholders in environmental management in the country. 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. 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. The gully wall and heads carps should be treated to produce gentle slope, in order to reduce the width, length, and depth of the gullies in the affected areas. Some human activities that are capable of causing erosion in the areas should be reduced, and those that can be avoided should be reduced at a minimal in order to reduce the menace of erosion.

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