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MORPHOMETRIC AND MORPHOLOGICAL ANALYSIS OF GULLIES IN WUKARI LGA, TARABA STATE, NIGERIA

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Abstract: *This study analyze morphometric and morphology of gullies in Wukari, Taraba state. Both the primary and secondary sources of data were used for this study. A pilot survey of twelve gully sites were carried out in Wukari 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 in the field. Instruments such as hand auger, global position system. (GPS), photograph, Abeny level, linen tape, ranging poles, pegs and measuring tape and other 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 gullies in Wukari LGA, Taraba state are more affected by 80% in the study area, by Rafin kada Wukari LGA recorded the highest figure in terms of gully length 315m followed by Puje in Wukari LGA 303m, Kenke 298m, Jibo in Wukari LGA 285m respectively. In term of gully width, Arufu gully site is more affected than any other gully in the study area. It recorded 21.2m, Traffic in Wukari LGA 20.3m, Chonku in Wukari LGA and Akwana in Wukari LGA recorded the same figure 17.3m, respectively. Gully site in Arufu, in Wukari LGA of the study area, recorded the least figure 4m in width magnitude. In term of area, gully site in Wukari LGA, Wukari LGA. In Wukari LGA recorded the highest number 0.21m^2 and Kenke gully site in Wukari LGA recorded the least of 0.5m^2. Majority of the gullies in the study area are characterized by U-shape cross-section 50%, V-shape 40%, U and V-shape 20%. The findings also revealed the results of the volume of soil loss in the study area was 24200.39 tones/ha in all the gullies in the study area. The mean values of large gullies length was 154.77, depth was 11.86 and that of very small gullies was length 55.16, depth was 6.66. Gullies in the area are long-narrow linear to rectangular shaped. 54.6% of gullies are at their continuous stage of development while 64.4% of gullies were at their discontinuous stage of development. This study finally concludes that gullies in the study area were initiated by a combination of steep slope, high rainfall, soil characteristics and human activities. Precaution measures and self-control methods are recommended.*

Keywords: *Gullies, Morphometric, Morphology, Parameters, Effects.*

1.1 Introduction

Erosion, a peculiar physical problem and process known to man, is therefore, defined as the gradual wearing of the land surface mainly through the detachment and transport of mineral grains through the action of geologic agents which may be mechanical or chemical (Fairbridge, 2010). This is evident by numerous records of conservation works in different countries particularly in the developed countries. These attempts at conserving the soil are aimed mainly at preventing accelerated soil loss by surface runoff and to some extent by wind (Faniran & Ojo, 1980). Soil erosion is basically classified into two; the geological soil erosion and the accelerated soil erosion. Geological soil erosion is a natural process of the modification of the earth surface which to a large extent is governed by the nature of soil itself, topography, climate and vegetation. While accelerated soil erosion on the other hand, is the abnormal and hazardous destruction of the outermost layer of the earth mainly by anthropogenic factors which include deforestation, construction, mining, over cultivation and overgrazing (Faniran & Ojo, 1980).

Soil erosion is among the most endemic environmental problems of modern times. During the past three decades, numerous studies have been carried out on the different processes of soil erosion as splash (Morgan, 1978; Bryan, 1979; and Luk, 1979) sheet (Kesel, 1977; Bryan & Armon 1984; and Jeje, 1987); and rill erosion by Young and Onstad (1978) Odemerho (1987) and Bryan (1987). Overall, gully erosion is the most widely studied because of the remarkable impression it leaves on the surface of the earth. In Nigeria, accelerated erosion manifesting in the form of severe gullying has been confirmed in Zaria area by Ologe, (1972, 1973, 1987); in Jos area by Grove (1952); in Kano area by Olofin (1987); in south western Nigeria by Areola and Faniran 1974; and Jeje (1988, 1391); in parts of Gongola basin (Ologe, 1988); and in Auchi and Ikpoba slope in Benin City by Jeje (1988:82). The problem of gully erosion in south eastern Nigeria is not new; it was first documented by late Sir Dudly Stamp in 1938. Stamp's review was followed by the special study of the phenomenon by Grove (1951).

In recent times, intense gullying has been reported from different parts of south-eastern Nigeria (see for instance Niger Techno, 1979; Ofomata, 1988 and 2000; Okagbue, 1988; Okoye 1988; Udosen, 1991, 2000, 2002, 2004, and 2006; Udosen & Akintola, 2007; and Igbokwe, 2004). The extent of damage to land by severe gully erosion is documented in the numerous studies by Ofomata (1964, 1965, 1973, 1978, 1981, 1984, 1985, and 1988), Igbokwe (2004), and Ofomata (2000). In fact, gullies of various sizes, appear to be among the most striking geomorphic features on the landscape of eastern Nigeria. Typical examples of gullies in the area include those of Aguiu-Nanka, Orlu, Ozuitem, Abriba, Ohafia, Onitsha, Amucha, Uyo, Itu, Aba Obotme, Arochukwu, Owerri, Aguata, Idemili North and South LGA and Orumba North.

InTaraba State, gully erosion studies were reported in the work of Anzaku (2015), Shitu 2017, Bulus (2013) and Saheed (2016). Majority of studies in gully erosion in Nigeria focused on human activities as the primary cause of gully development. These studies point to misuse of land resources, in appropriate agricultural practice, ill-aligned road network, sand mining, unplanned and uncontrolled urbanization among others as possible causes of gully erosion. In Taraba state, gullies have caused the loss of urban residential lands and have also hampered other land uses. Wukari Local Government Area are some of the areas in Taraba State where the menace of gully erosion is very glaring, despite the attempts by government to control the problem. However, no similar study has focused on the morphometric and morphological analysis of gullies in the area. It is therefore against this backdrop that the study assessed the Morphometry of gullies in Wukari, Taraba State.

2.1 Materials and Methods

The Study Area

Location and Position

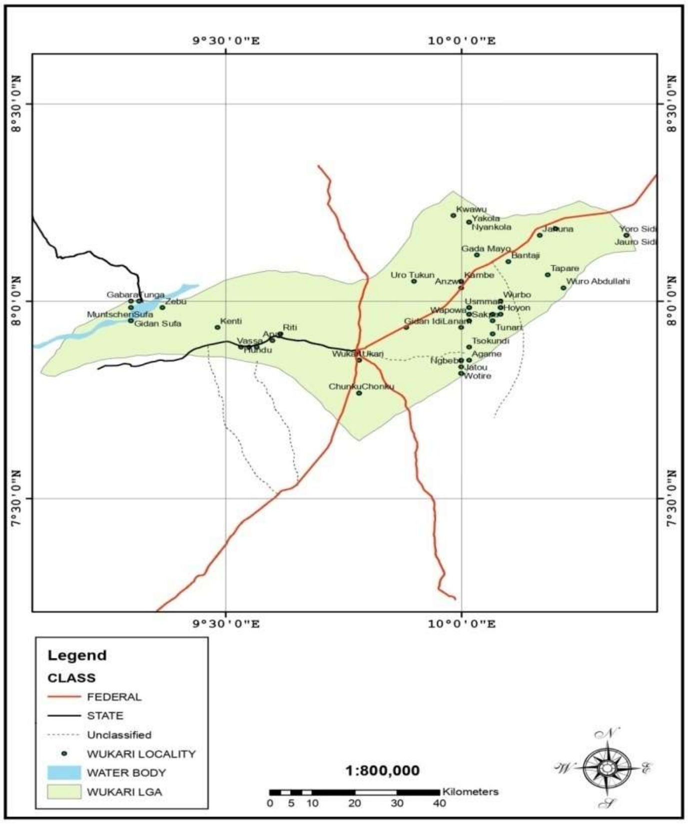

Fig 1: Map of the study area

Source: AGIS, 2024

Taraba State is located in the North-East geographical zone of the country, with its head-quarters in Jalingo. It has sixteen (16) Local Government Areas (LGAs). The State has a total land mass of 51,000-kilometre square. It lies roughly between latitude $6^0 30^1$ and $9^o 36^1$N and longitude $9^0 10^1$ and $11^0 5^1$E. It is bounded on the North-East by Adamawa State and the West and South-East by Plateau and Benue States respectively. On its east border is the Republic of Cameroun. According to the 2006 Census figures released by the National Population Commission (NPC), Taraba State has a population of 2, 294, 800 people (NPC, 2006). Wukari Local Government is situated in the southern part of Taraba state. It is bordered to the north by Ibi Local Government Area, east by Gassol Local Government Area, from the south by Donga Local Government Area of Taraba State, and to the west by Ukum Local Government Area of Benue State. The Local Government Area has a total area of 4,308km^2 (1,663 square mile), located at 7°51′N 9°47′E. According to 2006 National population Census figures, Wukari has a population of 241,546 people (NPC, 2006).

3.2 Methods

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. Topographical maps, existing geological map of the study area were also sourced. Similarly, rainfall distribution data of Taraba State were obtained from the Nigeria Meteorological Services Department, Jalingo.

A reconnaissance survey was carried out before the field work in the study area. The purpose was to study the general characteristics of gullies in in the study area, in order to ascertain those area that are more vulnerable to gully erosion in the State, and to also know the various vegetation types in the State. Each village were selected from each electoral wards, to represent the study area. These areas were selected because they were more vulnerable to gully erosion, based on the reconnaissance survey carried out in the Local Government Area. Wukari Local Government Area has undulating tropology, and Furley (1996) observed that variation in tropology could modify occurrences of land degradation. In this research, the sampling design selected was dependent upon the objectives of the study. Two sampling frames were employed in the study. The first was for pilot survey while the second sampling frame was used to determine the morphology 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 in the study. The revised university soil loss equation (RUSLE) empirical 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, and 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).

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.
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. Rainfall data were collected from NIMET, Jalingo centre, to determine the extent of rainfall factors as one of the causative factors of erosion in the state. Pilot survey was also done to know the different anthropogenic factors causing gully erosion in the study area. The data extracted from (i) field work (ii) laboratory analysis of particle size was processed using SPSS statistical software package (version 17.0). Descriptive statistics such as range, mean, standard deviation, variance and coefficient of variation were used to determine the variability of gullies morphometric properties and the variability of rainfall in the study area.

Results and Discussion

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 3.1 and 3.1.1 were obtained from Wukari Local Government Area of Taraba state. Generally, the gullies in these areas are characterized by streams, dense vegetation and terrain-steep slopes. From the data presented in the Table 3.1 and Table 3.1.1, it will be observed that gullies in Taraba 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 the study area 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 the study area.

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 (%) Sand	Silt	clay
	Wukari LGA								
1	Bantaje	154	277.84	15.1	17	V-Shape	88.2	4.4	9.4
2	Chonku	65	525.4	7.1	6.9	V-Shape	87.2	3.4	9.4
3	Gidan Idi	92	66.4	8	8	V-Shape	84.2	5.4	10.4
4	Kente	36	396.9	6	5	U-Shape	84.0	5.4	12.6
5	Agbarike	70	26.0	5.2	4	V-Shape	86.2	5.4	8.4
6	Akwana	92	65.6	8	6.3	U-Shape	87.2	3.4	9.4
7	Anyam	82	26.0	5	5.2	U and V Shape	84.2	3.4	12.4
8	Arufu	134	68.4	6	8	U and V Shape	86.2	5.4	8.4
9	Ityogbedia	84	65.8	7	5	U and V Shape	84.2	3.4	12.4
10	Jibo	57	277.3	5.9	5	V-Shape	84.2	4.4	11.4
11	Kenke	32	280.8	5.4	4	V-Shape	86.2	5.4	8.4
12	Kuyu	78	68.6	7	7.2	U-Shape	86.2	4.4	9.4

Source: Field and laboratory work, 2024.

Table 2: General Characteristics of Gully System in the Study Area

S/N	Gully Site	Latitude			Longitude			Magnitude
		Degree	Minutes	Seconds	Degree	Minutes	Seconds	
Sites in Wukari LGA								
1	Bantaje	7	53	38.2656	9	52	19.063	Large gully
2	Chonku	7	2	10.266	9	37	34.374	Small gully
3	Gidan Idi	7	53	51.4788	9	43	21.313	Medium gully
4	Kente	7	53	53.6532	9	43	0.257	Small gully
5	Agbarike	7	2	1.6728	9	37	35.324	Very small gully
6	Akwana	7	53	37.1724	9	42	39.1	Small gully
7	Anyam	7	53	57.9948	9	42	45.346	Small gully
8	Arufu	7	0	10.026	9	37	3.23	Medium gully
9	Ityogbedia	7	53	32.5716	9	42	35.975	Medium gully
10	Jibo	7	54	1.1196	9	42	44.91	Very small gully
11	Kenke	7	54	11.3076	9	42	43.988	Versy small gully
12	Kuyu	7	1	43.6944	9	36	58.19	Medium gully

Source: Field and laboratory work, 2024.

From the data presented in Table 1 and 2, it can be observed that in Jibo Area, Kenke 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.

Plate 1: A typical gully cross-section in Kenke gully site
Source: Field work, 2024

Plate 2: A typical gully cross-section in Arufu, Wukari LGA
Source: Field work, 2024.

Gullies found in both Gidan Idi and Kenke Village were both medium gullies, with a cross section of V and U-shape. in terms of particle size distribution, Gidan Idi recorded; clay 12.4%, silt 3.4% and sand 84.2%, while Kenke Village recorded clay 27.4, silt 29.9% and sand 43%. Furthermore, gullies found in Kenke 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 Gidan Idi covered and area of $65.8m^2$, with a depth of 5m, width of 6m and a length coverage of 94m.

Plate 3: A typical gully cross-section in Jibo, Wukari LGA
Source: Field work, 2024.

The findings also reviewed that in respect to the general characteristics of gullies in the study area 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.

The Trend of Rainfall in the Study Area

Figure 1: Trend of Rainfall

Figure 1: Trend Chart of Monthly Rainfall Distribution in the Study Area

Source: Author's computation, 2024.

Table 1: Monthly and Average Monthly Rainfall Distribution in the Study Area (mm)

Years	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	0.0	0.0	10.2	98.6	189.8	144.4	451.1	205.5	147.0	108.0	0.0	0.0
2014	0.0	0.0	0.0	90.2	100.2	202.0	231.0	240.9	215.0	70.2	0.5	0.0
2015	0.0	0.0	0.0	40.0	190.0	60.1	190.6	80.0	205.3	96.1	0.0	0.0
2016	0.0	0.0	0.0	60.3	88.4	196.2	160.2	270.0	176.9	129.6	5.0	19.6
2017	0.0	0.0	10.5	30.6	89.0	33.1	250.0	120.0	199.1	170.4	0.9	0.9
2018	0.0	0.0	2.0	0.4	82.1	132.1	190.2	150.3	112.0	38.1	0.0	0.0
2019	0.0	0.0	12.6	82.4	175.6	210.2	268.2	240.6	208.0	110.1	0.0	0.0
2020	0.0	0.0	0.8	62.1	100.5	172.5	165.6	260.8	132.6	140.6	0.8	0.0
2021	0.0	0.0	0.0	46.2	120.0	62.1	190.4	120.8	175.6	40.7	0.0	0.0
2022	0.0	0.0	0.9	121.0	227.5	410.2	201.0	291.8	193.2	102.8	1.8	0.0
2023	0.0	0.0	2.2	142.6	208.1	223.3	271.0	261.0	172.5	116.4	0.0	0.0
2024	0.0	0.0	5.0	107.2	142.0	191.7	148.2	310.3	106.6	96.5	0.8	0.0
Average Monthly Rainfall	**0.0**	**0.3**	**3.8**	**84.8**	**150.9**	**194.2**	**224.2**	**198.2**	**170.7**	**104.5**	**1.4**	**1.1**

Source: *Nigeria Meteorological Agency (NIMET), Jalingo, Taraba State, 2024.*

The data presented in Table 1 depicts the distribution of rainfall in the study area over a spread of twenty years on a monthly basis. The data also shows the average monthly rainfall distribution in the study area as well. The data presented in the table is a true representation of the pattern of rainfall in Wukari Local Government Area of Taraba State and thus shows the level of variability of rainfall in the study area as a result of the impact of climate change over the years. Looking at the results presented in the table, it can be observed that the month of January over the past twenty years has never experienced rainfall in the study area. While other part of Nigeria does experience what is considered unlikely rainfall during this month, Wukari Local Government Area is an exception, usually because it is located at the North-east part of the country, and because the month of January is considered the peak period of harmattan/dry season.

Beside the month of January that did not experience rainfall in the study area, the months of February through December recorded rainfall in the study area at a fluctuating rate. However, it is important to note that the months of February, December, November and March recorded the lowest drop of rainfall in the study area across the entire time frame under consideration. As depicted in the table, the month of February experienced rainfall only in the year 2013 and 2018, recording an average rainfall of 0.3mm, while the month of December experienced rainfall in the year 2015, 2016, and the year 2017, recording an average rainfall of 1.1mm during these periods. In the same vein, the study area experienced rainfall in the month of November in the year 2000, 2002, 2003, 2006, 2008, 2013, 2014, 2015, 2018, and the year 2020, recording an average rainfall of 1.4mm across these years. Unlike the month of February, December and November, the month of March in the study area experience more frequent rainfall over the time frame under consideration. it is however important to state that the frequent rainfall experienced during this month was less significant, as an average rainfall of only 3.8mm was recorded for across the entire years under consideration. The trend chart depicted in Figure 1 depicts and provides a vivid e picture of the nature of rainfall variability on a monthly basis in the study area across the entire years under consideration in the study. From the trend chart, it can be observed that the peak periods of rainfall in the study area occurs in the months of June, July, August, and the month of September respectively. From the data presented in Table 1, it can be observed that the month of June recorded an average rainfall of 194.2mm, while the month of July recorded an average rainfall of 224.2mm. Furthermore, the month of August and September recorded and average rainfall of 198.2mm and 170.7mm respectively. It however important to explicitly state that the month of July is the most peak period of rainfall in Wukari Local Government Area of Taraba State.

From the scattered plot in the trend chart, it can be observed that highest drop of rainfall in a singular month was experience on the month on July, in the 2013 and 2024 respectively. During these periods, total rainfall for the month in question was recorded at 451.1mm (in the year 2013) and rainfall was recorded at 462.2mm (in the year 2024) respectively. Close to these figures for total rainfall for a singular month, is the month of June, 2014. During this period, rainfall was recorded at 410.2mm. For non-peak periods of rainfall, on the month of December recorded significant rainfall for a singular month, at 19.6mm in the year 2015.

Table 2: Total and Average Annual Rainfall Distribution in the Study Area.

S/N	Years	Total Annual Rainfall (mm)	Average Annual Rainfall (mm)
1	2013	1354.6	112.9
2	2014	1150.0	95.8
3	2015	862.1	71.8
4	2016	1106.2	92.2
5	2017	904.5	75.4
6	2018	707.2	58.9
7	2019	1307.7	109.0
8	2020	1036.3	86.4
9	2021	755.8	63.0
10	2022	1550.2	129.2
11	2023	1397.1	116.4
12	2024	1108.3	92.4
Total		**13240.5**	**1346.7**

Source: Nigeria Meteorological Agency (NIMET), Jalingo, Taraba State, 2024.

Table 2 gives a detailed account of the rainfall trend rainfall variability in Wukari Local Government Area of Taraba State. Depicted in Figure 2, the trend plot in the chart shows a fluctuating trend mean rainfall in the study area. From the trend chart, it can be observed that from the period of 1999 to 2021 recorded decreasing trends in average rainfall at 112.9mm for the year 1999, 95.8mm for the year 2020, and 71.8mm for the year 2021. The year 2002 experienced a slight increase in the average annual rainfall in the study area, recorded at 92.2mm. In the year 2013 and 2014, a decrease in the average annual rainfall was experienced. Within these two years, average annual rainfall was recorded at; 75.4mm, and 58.9mm respectively. From the trend chart, it can be observed that a significant increase in average annual rainfall in the year 2015 coursed and upward shift in the trend plot, as the average annual rainfall for this year was recorded at 109.0mm.This increase was however temporal as a decline in average annual rainfall was experienced in the year 2016 and 2017. During these years, average annual rainfall was recorded at 86.4mm and 63.0mm respectively.

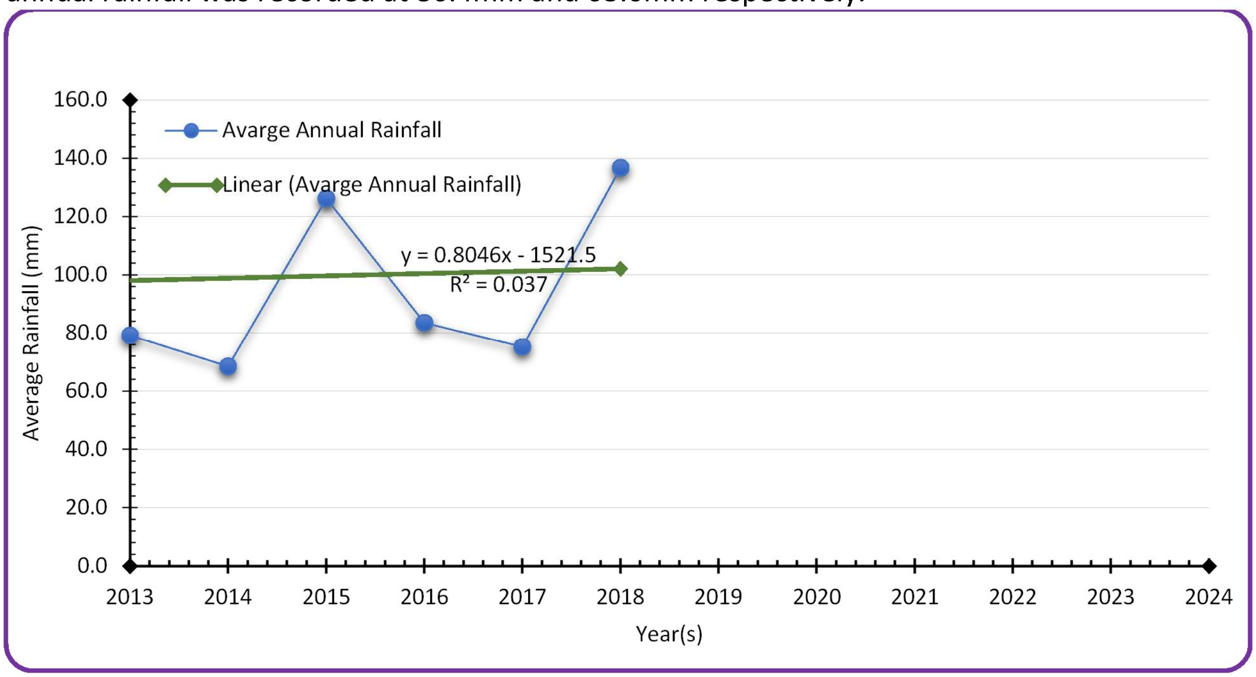

Figure 2: Trend Chart of Annual Average Rainfall
Source: Author's computation, 2024.

While the improvement in average annual rainfall was experienced in the year 2018 and 2019, it is important to note that this improvement can be said to be a remarkable increase compared to the preceding three years, as the average annual rainfall recorded these were; 129.2mm and 116.4mm.The year 2020 and 2021 recorded a steady decline in the average annual rainfall of the study area. This decline is made vivid, as depicted by the downward slope of trend plot in the figure above. During these periods, the following the following amount of average annual rainfall was recorded; 92.4mm, and 80.5mmrespectively. A look at the trend plot shows that an upward movement occurred in the year 2022. This upward movement by interpretation signify an increase in the average annual rainfall in the year concerned. The year 2023 and 2024 recorded a significant decline in the average annual rainfall of the study area. This decline is made vivid by significant downward shift in the trend plot presented in the figure above. In this years, average annual rainfall was recorded at 79.2mm and 68.5mm. It Compared to preceding year (2023 and 2024), the year2015recorded an increase in average annual rainfall at; 126.3mm, while the year 2016 and 2017 experienced a decrease in average annual rainfall at 83.6mm and 75.2mm. Worthy of note here is that that the year 2018 recorded the highest average annual rainfall in Wukari Local Government Area of Taraba State across the period of 2013 to 2024, recording rainfall of 136.8mm. The value of r^2 in the trend equation indicates a variation in trend of annual rainfall at 37 percent.

The data presented in Table 4.2.3 shows the volume of soil loss in various sampled gully sites in Wukari Local Government Area of Taraba State. The data as presented in the table shows that Ado site recorded soil loss of 7364.6tons, while City College site recorded a total of 1148.3tons of soil loss due to the occurrence of gully erosion in the area. In Gidan Idi, a total of 12960.7tons of soil loss was recorded, while Jibo and Arufu sites recorded soil loss of 2726.7ton and 6242.6ton respectively. In the same vein, NTA quarters recorded soil loss of 5124.2tons of soil loss, while Kenke Village gully site recorded soil loss of 9128.2tons. Furthermore, Chonku and Sharp-corner gully sites recorded a total volume of soil loss of 9168.6tons and 8848.2tons respectively, while Arufu site recorded a total volume of soil loss of 15137.7ton, and Gidan Idi, a total volume of soil loss of 8713.4tons respectively. The mean (average) volume of soil loss experienced in the sampled gully sites in Wukari Local Government Area of Taraba State due to gully erosion was 14222.6tons with a standard deviation of 17361.8. The coefficient of variation of the volume of soil loss of the entire sampled gully sites in Wukari Local Government Area of Taraba State was recorded at 226.7tons. From the results in Table 4.2.3 it can be observed that Kenke and Jibo suffered more soil loss due as a result of gully erosion in the area. The relative implication here is that urban settlements in this area exposed to high risk of building and structure collapse, in which in its even, lives and properties will be lost.

Table 4.2.3: Volume of soil loss in Gully Sites Located in Wukari local Government Area

S/N	Gully Site	R	K	LS	Volume of Soil Loss (tons)
1	Bantaje	265.86	124.1	10	7364.6
2	Chonku	265.86	194.6	8	11548.3
3	Gidan Idi	265.86	218.4	7	12960.7
4	Kente	265.86	110.0	10	65278.1
5	Agbarike	265.86	96.5	20	5726.7
6	Akwana	265.86	105.7	20	6272.6
7	Anyam	265.86	136.9	10	8124.2
8	Arufu	265.86	152.1	10	9028.2
9	Ityogbedia	265.86	154.5	20	9168.6
10	Jibo	265.86	149.1	6	8848.2
11	Kenke	265.86	253.4	10	15037.7
12	Kuyu	265.86	150.2	20	8913.4
Mean Value of Soil Loss					**1422.6**
Std. Deviation					**16361.8**
CV of soil loss in Wukari LGA					**116.7**

Source: Field and Laboratory work, 2024.

On an aggregate level, the data presented in Table 4.2.4 shows the average (mean) volume of soil loss in Taraba State, the standard deviation, as well as the coefficient of variation of the volume of soil loss in Taraba State. From the data presented in the table, it can be observed that the average volume of soil loss in Taraba State due to gully erosion was recorded at 14200.39ton, with a standard deviation of 16340.12. The coefficient of variation of the volume of soil loss was recorded at 115.07tons.

	Sites in Wukari LGA			
1	Bantaje	Long-narrow	Discontinuous gullies	Stable
2	Chonku	Long-narrow	Continuous gullies	Unstable
3	Gidan Idi	Long-narrow	Continuous gullies	Stable
4	Kente	Linear	Continuous gullies	Unstable
5	Agbarike	Long-narrow	Continuous gullies	Stable
6	Akwana	Rectangular	Continuous gullies	Unstable
7	Anyam	Long-narrow	Continuous gullies	Stable
8	Arufu	Linear	Discontinuous gullies	Unstable
9	Ityogbedia	Linear	Continuous gullies	Stable
10	Jibo	Long-narrow	Continuous gullies	table
11	Kenke	Linear	Continuous gullies	Stable
12	Kuyu	Rectangular	Continuous gullies	Stable

Source: Field and laboratory work, 2024.

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 4.4 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.* (2014) and Leopol and Miller (1956) were employed. From the results presented in the Table 4.4, it can be observed that 54.4% of the gullies in the study area are discontinuous gullies, while 54.6% 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 4.4, 50.3% of the sampled gullies were at a stable state of development, while 51.7% 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), 48.9% of the sampled gullies were long-narrow gullies, while 32.2% were linear shaped gullies. In the same vein, rectangular shaped gullies found in the study area consisted of 23.2% of the sampled gullies in the study area, while 23.9% of the sampled gullies in the study area were trapezoidal shaped gullies. Long-narrow and rectangular shaped gullies consisted of 8.8% of the sampled gullies in the study area.

Plate 4.13: Long-narrow shaped gully in Akwana site, Wukari LGA
Source: Field work, 2024.

Conclusion

This study analyzed the Morphometric and Morphology of gullies in Wukari, Taraba State, Nigeria. Taraba 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.

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