Book of Proceedings, 14th Nigeria Association of Hydrological Sciences Conference (Okitipupa 2024) held at Olusegun Agagu University of Science and Technology, Okitipupa, Ondo State, Nigeria, November 5 - 8, 2024

Characteristics of Soils of Iwogban Gully in Edo State and their Implications for Household Food Security

Adegun, Olubunmi, Eremen, Patience Enefuwa, Odunuga, Shakirudeen.
Department of Geography, University of Lagos, Nigeria.
Tel: +2348051581057; +2348037232665; +2348038172104
E-mail: ebeneremen@gmail.com , odushak@yahoo.co.uk, oadegun@unilag.edu.ng
Corresponding Author: Tel: +2348051581057 E-mail: ebeneremen@gmail.com

ABSTRACT

Land degradation through soil erosion which is a global threat has negatively affected the functioning of the ecosystem through various means such as provision of food. Soil erosion is one of the major causes of land degradation in Edo State particularly in Ikpoba Okha LGA. This study characterizes the soils of Iwogban catchment, a major gully erosion site, and how it has impacted home gardening which is way of maintaining household food security.Using different hydrologic and edaphic parameters such as rainfall intensity, soil erodibility and soil physical properties, the rate of land degradation within the catchment between April and November, 2023 were determined. The summary of the results show that the soil of the catchment is mainly characterized by sand (59.5%), silt (19.61%), clay (20%) and occasional gravel (1%), with the soil lyingbelow the "A line" in the plasticity index chart, based on the unified soil classification system. This indicates that the soil has a tendency to be eroded by water which is a major agent of weathering. Based on the results of the study, it is recommended that control measures such as the use of sandbags, local drainage channelization and cover crop planting can be adopted. This will help to prevent further gully expansion and loss of land that can be used for agricultural productivity in the study area.

Keywords: Rainfall intensity; Soil erosion; Soil erodibility; Land degradation; Food security

1.0 Introduction

Nigeria is one of the countries most affected by gully erosion, a severe form of land degradation caused by the rapid removal of soil from water flow. Human activities, such as deforestation, agriculture, and urbanization, have been identified as significant contributors to gully erosion, leading to loss of arable land, infrastructure damage, and environmental degradation. Significantly in Edo State, Nigeria, this problem has affected the livelihoods of local communities and causing environmental degradation and food insecurity.

Soil erosion is exacerbated dueto the decrease in the erosional resistance of the land surface or increase in the erosivity factors acting onthe land (Ofomata, 2000). The lost land resources are at thedetriment of the local people (peasant farmers) who dependon them for sustainability and livelihood (Odunuga et al, 2018).

Erosion can be classified according to its cause; whether geologic or accelerated, geologic erosion is a normal process of weathering that generally occurs at lowrates in all soils as part of the natural soil forming processes. In contrast, soil erosion becomes a major concern when the rate of erosion exceeds a certain threshold level and becomes rapid, known as accelerated erosion. (Humberto and Rattan, 2008).Uncontrolled progress of gullies results in 'bad land' topography and destroys the ecology and economy of the affected areas, (Cavey, 2006).Gully erosion is defined as the erosion process whereby runoff water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths, (J Poesen, et al 2003).Gully erosion as a form of soil erosion that affects soil productivity, deprives proper land use and can threaten infrastructures ranging such as roads,buildings, drainageand human life. Gully erosion enthrones deprivation inits process and this affects soils in many parts of the world (Le Roux et al. 2012). Multiple onsite and off-site effects of gully erosion threaten sustainable development, which is especially evident in the tropical climate environments (Franklet al,2014).According to Eseigbe and Ojeifo (2012), gully erosion is a serious form of soil degradation often involving an initial incision in to the subsurface, by concentrated runoff along lines or zones of weakness such as tension and desiccation fractures.

The surface geology, soil cover and prevailing environmental surface processes of an area greatly influence mechanism of gully erosion (Abdulfatai et al, 2004). The efficacy of soils to function as a filter from polluting substances largely depends on the behavior of pollutants in the soil and the hydrological transport processes as demonstrated by (Keesstra et al,2012).

The effect gully erosion and danger have posed to lives and property in some towns and villages in Edo state are at an alarming rate that some occupants have abandoned their buildings for safer locations. Most worrisome is the recent gully along Iwogban quarters in Ikpoba Okha local government which is one of the prioritized gully erosion sites identified by Edo- State Flood, Erosion, and Watershed Management Agency (Edo- State FEWMA). The untended and devastating effects of gully development in many communities across the state have done so much damage to both tangible and intangible human values.

Soil is the basis for crop production because about 99% of food is produced from the soil (Pimentel, 2006). Thus, food security depends directly on soil productivity. Accelerated soil erosion is among principal causes of the decrease in soil productivity and increase in risks of global food insecurity

Soil erosion is one of the major challenges leading to land degradation (Koch et al., 2013) and mostly affect the fertile topsoil layer, which plays an essential role in productivity of (agro) ecosystems which is fundamental for the provision of food security (Amundson et al., 2015).

Food insecurity is a serious problem at the global, national and household levels. (FAO, IFAD, UNICEF, WFP and WHO, 2017) showed that one in ten people in the world (9.3 percent) suffered from severe food insecurity equivalent to about 689 million people. However, the problem of food insecurity is rising and highest in Africa reaching 27.4 % equivalent to almost four times that of any other region. In West African sub-region, about 16% of the population is undernourished (Oluyole and Lawal, 2008). In Nigeria specifically, the percentage of food insecure households was 18% in 1986 and this increased to over 40% in 2005 (Sanusi et al., 2006).

The formation and propagation of gullies in Iwogban catchment has contributed to the high rate of soil erosion experienced in the community. This has contributed to loss and abandonment of arable land for household gardening and food insecurity. The continuous propagation of gullies due to loosed soil properties and rainfall intensity during peak period will worsen food insecurity, especially during this period of economic downturn.

Soil is the basis for crop production because about 99% of food is produced fromthe soil (Pimentel, 2006). Thus, food security depends directly on soil productivity.Accelerated soil erosion is among the principal causes of the decrease in soil productivity and increase in risks of global food insecurity.

2.0 Study Area

Iwogban town in Fig.(a) is located in Ikpoba Okha local government area of Edo State Iwogban Catchment is located at Latitude: 6.383818- Lat: 6.364275 and Long:5.665506- Long:5.655318 on the Ikpoba slope road, to the east of the Ikpoba River. The catchment covers an area of about 4.39 km2 (439 ha.) and is enclosed by four major roads: Upper Mission Road (North), Ikpoba Hill road (South), Lucky way road (East), and Temboga road (West). In this catchment, there are different quarters including Uteh, Temboga, and Iwogban.Development of large gullies within Iwogban catchment were found along boundary road, Ekhaguere street, St. Jude Street and Omoriege-Uteh street. These gullies particularly have resulted in the collapse 28 buildings including buildings along St. Jude gully. There is also an imminent threat to a 750 million Naira worth structures and as such requiring urgent intervention to safeguard lives and property. (Edo-FEWMA,2023)

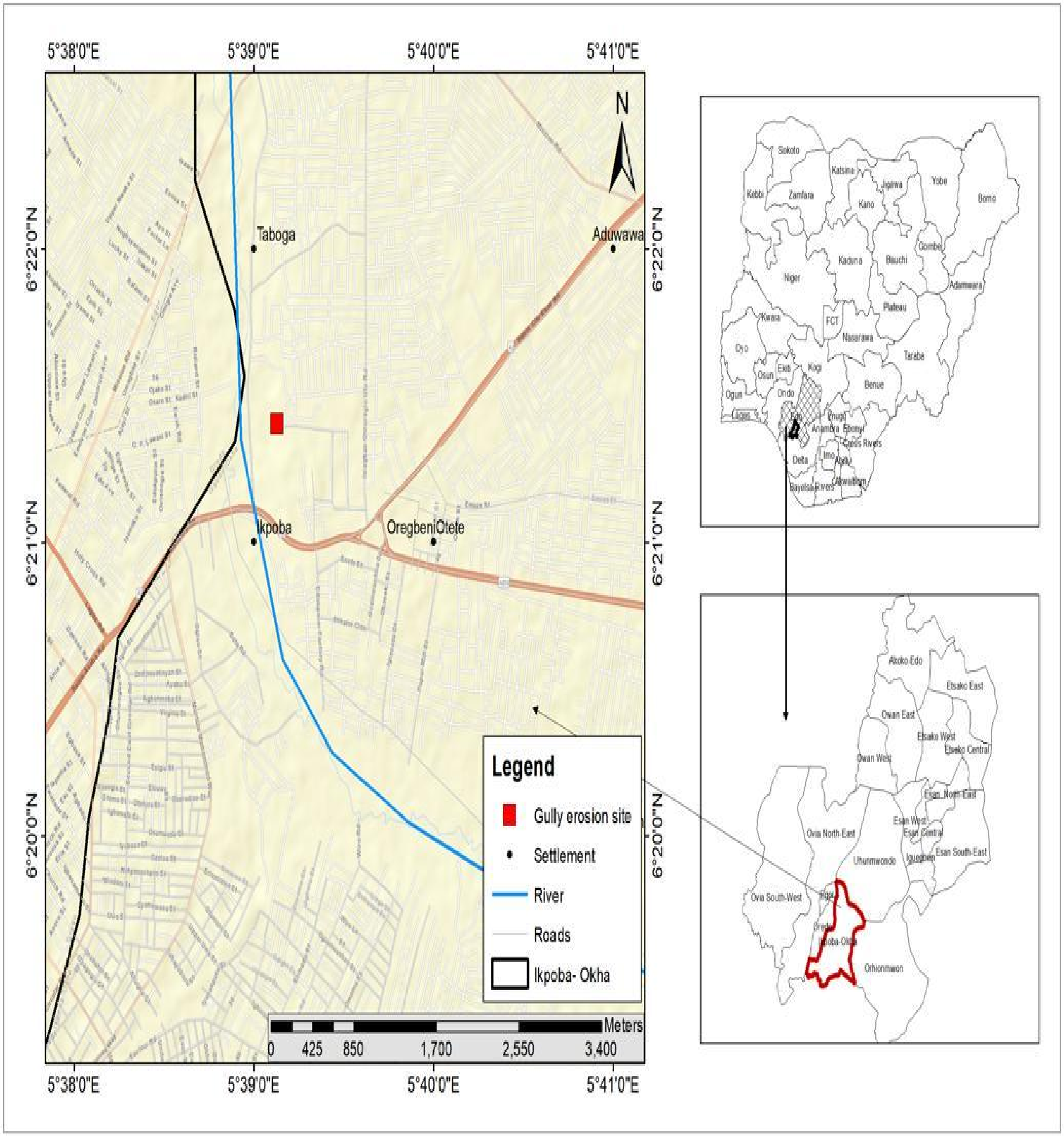

Fig.1 (a) Location of study area, Nigeria and Edo State map inset

Source: Authors, 2024

Fig. 2(b)Google Earth Imagery of Catchment Area
Source: Edo-FEWMA,2023

Fig. 2(c)View of gully erosion in the study catchment   Fig. 2(d)Gully scar used as waste dumpsite

3.0 Materials and methods

Evaluation of topographical maps, satellite images and other data collected from Edo State- Flood, Gully and Watershed Management Agency (Edo-FEWMA, 2023)were used to determine the soil erosionprone areasalong the flood routes and direction of storm runoff. Field reconnaissance and in-depth site appraisal was also conducted to assess the current state of the gullies.Field studies revealed inadequate drainage system in the catchment and some few available channels were terminated abruptly, which has led to gully formation within the catchment. The catchment is also characterized with a slopy topography and several poorly constructed drains alongside their inadequate sizes.

3.1 Topographical survey

Ground survey was carried out to determine thefollowing. Gully elevation, profile, longitudinal and transverse sections at a regular interval not more than 25m. A total of 16 bench marks (BM1-BM16) were established from the gully head to gully mouth.This was done using a Total Station which involves the following stages. i. Establishment and marking of point of reference. ii. Setting the tripod at the refence point, iii. Attaching the tribrach to the tripod and adjusting as necessary, iv. Setting the total station on the tripod with connected cables.v. Necessary setup information was imputed into the total station, such as the known coordinates of the setup point and the instrument height before the ground survey data were acquired. The gully longitudinal profile and site plot is shown in Fig. Fig 4.1 (a) and (b)

Fig.3(a)Total station set up Fig.3(b)Site Survey

3.2 Soil test investigations

Soil test was carried out to determinethe soil properties. Soil samples were collected from the gully head, gully bed and gully mouth at 5cm, 15cm and 30 cm respectively. The soil analysisconducted were Particle Size Analysis, Specific Gravity Test, Natural Moisture Content, Atterberg Limit Test, Compaction and falling head permeability test. All the laboratory tests were conducted in accordance with the general specification given in the British Standard Specifications B.S 1377.

4.0 Results and Discussions

4.1: Topographic Survey result

The gully horizontal profile and site plot in Fig 4.1 (a) and (b) from the topographic survey result reveals a slopy terrain from the gully head at BM1 to the gully mouth at BM16 implying that the topography of the study area is a gentle slope. Since slope has agreatinfluence on erosion, the presence of heavy run-off and high rainfall intensity can result in increasedsoil erodibility and gully expansion in the study area.

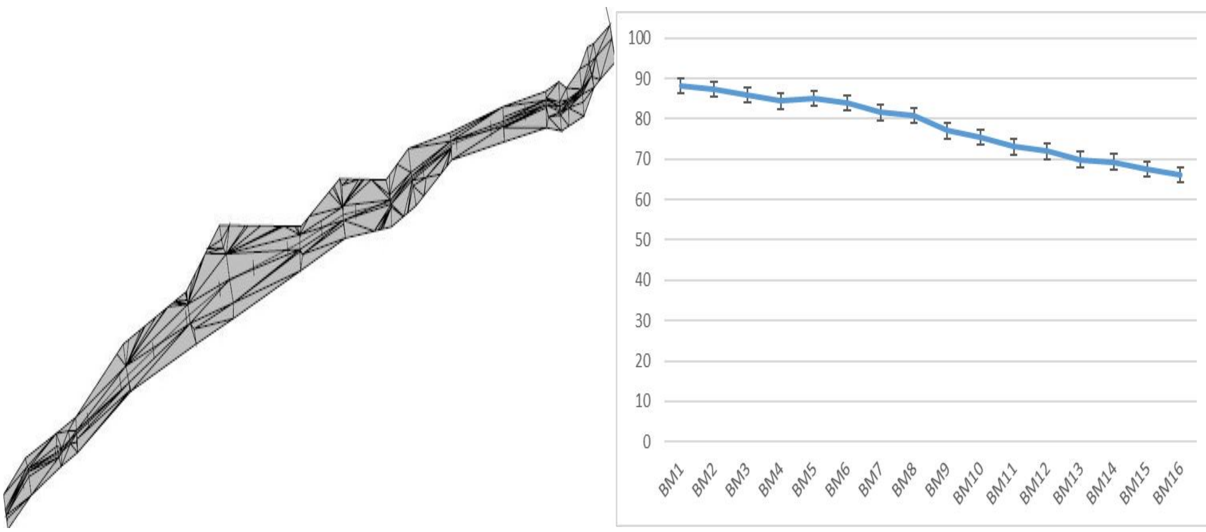

Fig 4.1(a) and (b) Gully Longitudinal profile and site plot of Iwogban

Source: Author: 2024

4.1 Description of Soil sample and gully dimension and shape

The soil sample in the study area falls under Munsell soil color charts falls value 5 ranging from 4/6, 4/8 and 5/6-5/8 respectively. Physical observation of the gully cuts shows that the material is a dry, reddish silty lateritic sandy clay soil.The gully can be described as a very small gully in relations to Suresh 2006 gully classification. The depth of the gully is slightly above4 meters and width of about 2.5meters with length of 600meters. In gully dimension, the gully is a u-shaped active gully.

4.2: The soil investigation result is summarized the tablesbelow

Table 1 Summary of Specific Gravity (SG), Natural Moisture Content (NMC) Atterberg limit test (Liquid limit (LL), Plastic limit (PL)and Plasticity Index (PI)) andCompaction test (Optimum Moisture Content (OMC) and Maximum Dry Density (MDD))

Sample No	Sample Point	Specific Gravity	Natural Moisture Content	Atterberg Limit test LL	PL	PI	Compaction OMC (%)	MDD (g/cm3)
A	GH	2.63	16%	44	16	28	10.9	1.495
B	GB	2.68	18.6%	47	16	31	11.0	1.511
C	GM	2.71	22%	50	17	33	11.2	1.516
Ave.		2.67	**18.67%**	**47**	16.3	30	11.03	**1.510**

Source: Authors (2023)

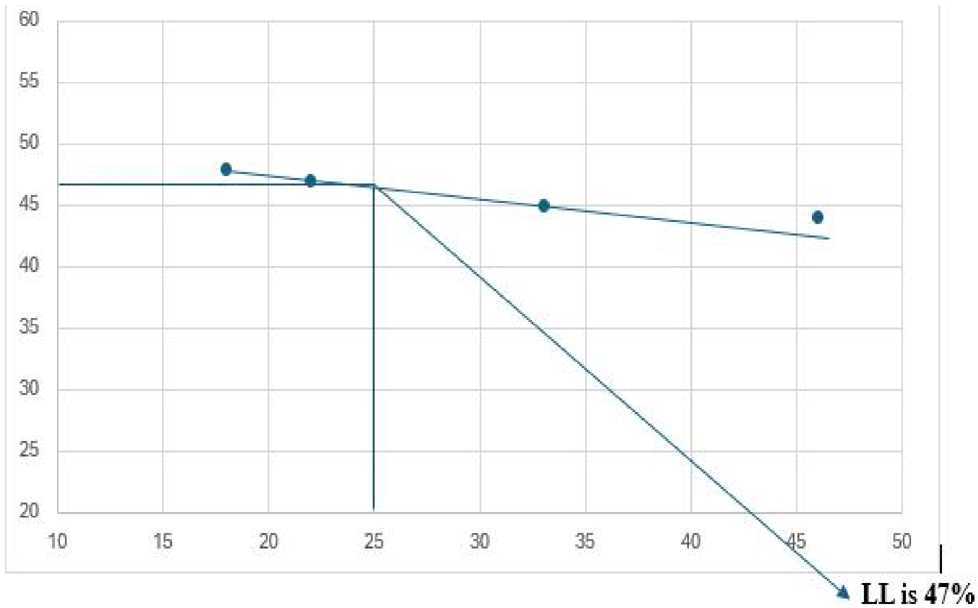

Fig 4.1 Sample plot of Atterberg limit test

Table 2: Falling head Permeability Test

Average Permeability Test						
Natural Moisture Content (NMC)	Moisture content (MC)	Specific Gravity (GS)	Bulk Density (Mg/m^3)	Porosity (n)=Vv/V	Void ratio (e)= Vv/Vs	Coefficient of permeability K(cm/sec)
18.87	20.6	2.67	1.520	31.82	0.4667	$1.783x10^{-4}$

Source: Authors (2023)

Table 3: Grain size analysis

Percentage Passing Sieve										
Sample number	Sample point	3.35 mm	2.0 mm	1.18 mm	0.600 mm	0.625 mm	0.300 mm	0.212 mm	0.150 mm	0.075 mm
	Gully head	99.9	99.1	95.21	74.07	75	58	50	46	39.2
	Gully bed	99.93	99.89	93	79	72	55	49	45	39.5
	Gully mouth	99.6	99.2	94.98	73	77	59	54	48	40.1

Average		99.71	99.10	94.45	75.40	74.67	57.3	51	46	39.6

Source: Authors (2023)

Table 4: Percentage of sand, silt and clay

Average Percentage of sand, silt and clay (%)		
Sand	Silt	clay
59.5	19.6	20.0

Source: Authors (2023)

4.3: Analysis of soil test

From the summary test sheet, the soil of the catchment is mainly characterized by sand (59.5%), silt (19.61%), clay (20%) and occasional gravel (1%), it is deduced that the soil is loose and can be easily eroded.From the compaction properties of the soil conducted,the average optimum moisture contentis 11.03% while the average dry density of the location is 1.510g/cm3. The average moisture content is 20.6 gotten from thepermeability test conducted. The average natural moisture and average specific gravity 18.67 and 2.67 respectively which indicates the presence of porous materials and sandy soil. From the sieve analysis test conducted, see Table 3, the percentage passing sieve No 3.35mm shows a tiny proportion of 1% occasional gravel, The average percentage passing sieve No 2.0mm is 99.1% while the average percentage passing sieve 0.075mm is 39.6 which indicates that the soilisa silty-clay sandy soil with fine grain. Figure 4.1is the sample plot of the Atterberg limit test with an average liquid limit of 47% and average plastic limit of 16.3%, indicating that the soil is non-plastic. This is an indication that during the periods of the rainy season, the soil in the study area is likely to be eroded. Using the unified soilclassification system, the soil lies below the “A line” in the plasticity index chart. Therefore, the soil sample can be classified as under Soil Group SM with the name, silty sands, sand silt mixtures.

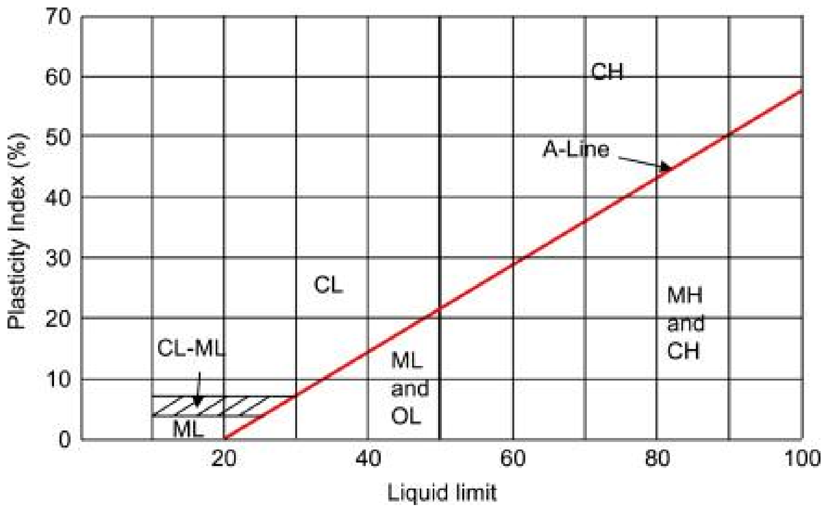

Fig:4.2 Unified Soil Classification System
Source: Howard and Amster (1986)

The soil permeability testing of the sample carried out assesses how effectively the soil allows water to travel through it.In general, water travels quickly through highly permeable soils and slowly through soils with low permeability. The result of the coefficient of permeability of the soil in the catchment which is 1.783×10^{-4} in relation to the Coefficient of Permeability k (cm/s)) and drainage characteristics of soils according to Casagrande and Fadum (1940) revealed that the measured coefficient of permeability value (10^{-4}) lie within the typical ranges for sands and silty sands. This indicates that the soils of Iwogban are characterized with very fine sands with a mixture of silt and clay.

Table5: Coefficient of Permeability k (cm/s)) anddrainagecharacteristicsofsoils

	Coefficientofpermeability*k*(cm/s)(logscale)			
	10^{2} 10^{1} 1.0	10^{-1} 10^{-2} 10^{-3}	10^{-4} 10^{-5} 10^{-6}	10^{-7} 10^{-8} 10^{-9}
Drainage	Good	Good	Poor	PracticallyImpervious
Soiltypes	Cleangravel	Clean sands, cleansand andgravel mixtures	Very fine sands,organicand inorganicsilts, mixturesofsandsilt andclay,glacialtill, stratifiedclay deposits,etc.	"Impervious" soils, e.g.,homogeneousclaysbelow zoneofweathering
			"Impervious"soilsmodified byeffectsofvegetationand weathering	

Source: CasagrandeandFadum(1940)

The result of the above assertions is that the soil has a tendency to be eroded by weathering agent mostly by water. Therefore, adequate control measures such as the use of sandbags, local drainage channelization and cover crop planting should be adopted to prevent further expansion of the gully.

4.3 Influence of Soil Erodibility in Iwogban Catchment

The erodibility of the soil is defined as the vulnerability or susceptibility of the soil to erosion. It is a measure of a soil's susceptibility to particle detachment and transport by agents of erosion. Igwe (2003) remarked that a number of factors such as the physical and the chemical properties of the soil influence. The gully area in the watershed falls around the lower plains of the watershed where surface and sub-surface soil are easily erodible as a result of which the gully bank collapses resulting in a vertical sidewall forming a u-shaped gully. because the contributing runoff is large, the discharge passing through the gully is also large, the run-off enters the gully from the head and from the sides at points where adjacent land is slightly lower anddrains into Ikpoba River which is the major river that runs through the watershederodibility.

4.4 Analysis of Hydrological parameters

Studies of rainfall characteristics which includes the rainfall amount, intensity and its distribution pattern from April to November 2023 for Benin City as well as the watershed characteristics such as shape and size and how it affects the affects the runoff rate were done. Erosivity which consists of amount of rainfall and precipitation intensity is the most important climatic factors affecting the amount and rate of soil erosion. The intensity and amount of rainfall in recent times has resulted in some of the most significant erosion experienced within Benin City in the last years. With climate change, heavy and damaging storms will continue to increase in frequency and gully processes will keep occurring.The hydrological data obtained from Nigerian Meteorological Agency was used for this analysis. The result shows the rainfall intensity at the peak of raining season June and September where visible maxima is evident. During this period, the rate of soil erosion and erodibility is high which also contributes to land degradation resulting in loss of fertile land for household food production.

Table 6: Rainfall date for Benin city April-November, 2023

Station	April	May	June	July	August	September	October	November
Rainfall	3.543229	5.233636	12.98479	11.84409	11.67759	13.78097	8.968924	3.040729

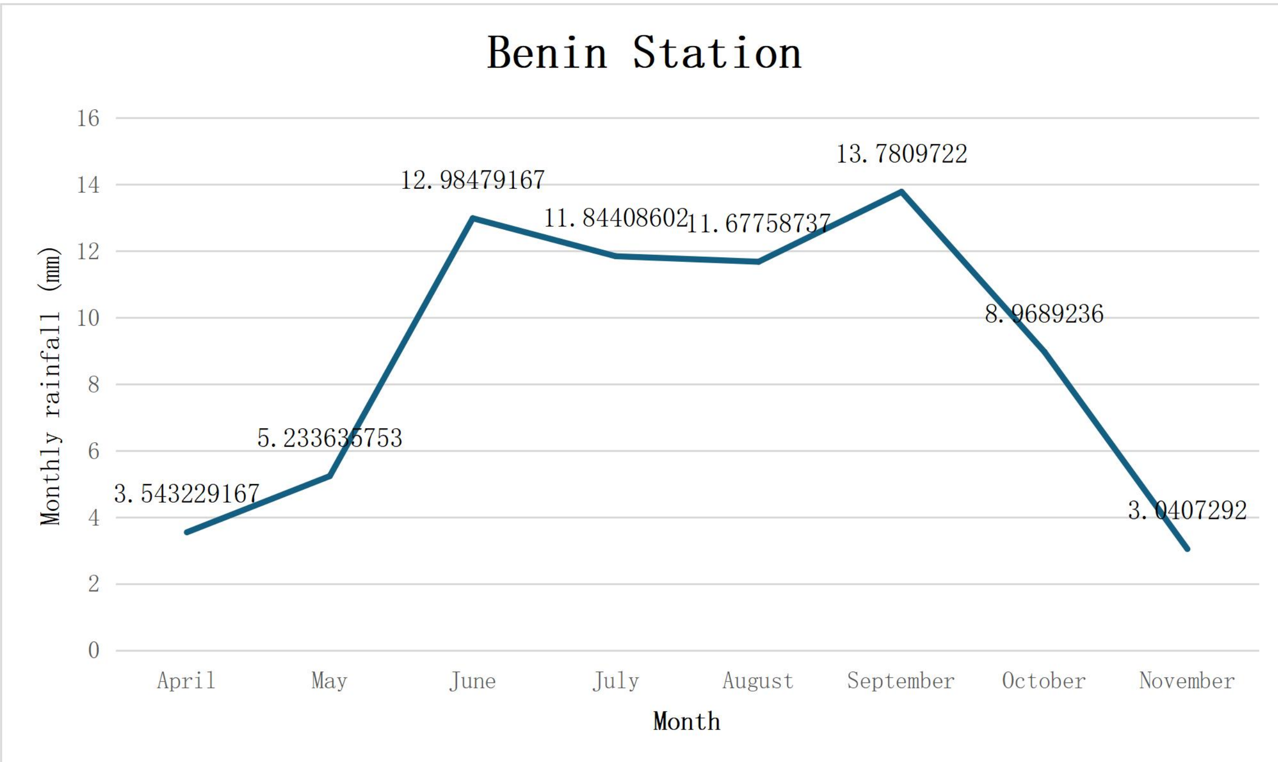

Fig. 4.4 Rainfall graph for Benin city April-November, 2023
Source: Nigerian Meteorological Agency (NiMet)

4.5 The Impact of Gully Erosion on Household Gardening and Food Security

The effects of soil erosion and the propagation of gully in Iwogban catchment has resulted in loss of arable land. The topsoil, which lies closest to the surface of the land that contains essential nutrients for crop growth is endangered by erosion. This has resulted in loss fertile soil, reducing agricultural productivity and food security in affected communities. Some occupants have abandoned their buildings and household gardening for safer locations due to threat posed by the presence of the gully and can no longer practice their subsistence farming for food production as well as generating income for them. As seen in Fig 4.5 (b) sidewalls and demarcations was done along the erosion route as means of controlling erosion to protect household gardening for food production.

Fig 4.5 (a)Abandoned farmland in the study area (b)Coping mechanism for household gardening

4.5 Impacts of Anthropogenic Activities on Gully Formation and Propagation

Anthropogenic influence from land mismanagement contributes significantly to soil erosion problem in the study area.These includes poor drainage and discharge channels, abruptly termination of drainage, Poor urban planning, dumping of solid waste into drainage channels as seen in Fig2(a),Topography and terrain, deforestation, construction and poor farming systems and land use change have also contributed to soil erosion within the catchment resulting in gully formation, The impacts of anthropogenic activities include:

1. **Infrastructure Damage:** The erosion of the soils can undermine roads, bridges, buildings, and other infrastructure, leading to costly repairs and disruptions in transportation and communication networks in the communities.
2. **Impacts on Water Quality and Quantity:** There are possibilitiesof increased sedimentation and contamination of household reservoirs, wells and boreholes which can adversely affect the water quality and water quantity for domestic, agricultural, and industrial use.
3. **Disruption of livelihood:**Most of the communities in the study area who depend on agriculture for their livelihoods can be severely affected by gully erosion, as loss of arable land and reduced crop yields can lead to poverty, food insecurity, and displacement.

4. **Health Risks:** The disruption of natural drainage systems and increased exposure to contaminated water sources can lead to outbreaks of waterborne diseases, such as cholera, diarrhea, and malaria, posing significant health risks to affected communities in the study area

5.0 Conclusions and Recommendations.

Soil erosion is global environmental threat that needs serious and immediate as it can negatively impact agricultural productivity and household food security because when the soil erodes, it loses its fertility and can no longer support plant growth, which can lead to reduced crop yields and food shortages. This can be particularly devastating for households that rely on agriculture as their primary source of income and food. In order to combat soil erosion and ensure household food security, it is important to implement sustainable agricultural practices that promote soil conservation, such as crop rotation, terracing, and the use of cover crops. The study critically examined how soil of Iwogban catchment contributes to loss of agricultural productivity. The study reveals that soil properties, as well as the length and gradient of its slopes have an effect on the run-off rate and amount of surface water. The gully is on a steep slope in terms of topography, where velocity and erosive power of the run-off is high initiating gully erosion before depositing to the main adjoined river (Ikpoba River). Also, the inadequate drainage system in this catchment contributes to soil erosion and some of the available open channels were terminated abruptly and this has led to gully formation within the catchment.Following the conclusion of the field observation and the corresponding soil test,soil erosion and the presence of gullies in Iwogban catchment poses imminent danger to the community in terms of loss of lives/properties, loss of agricultural lands, food insecurity and economic loss to the state. The following are however recommended as a control measures and adaptation strategies.

1. Integrated Watershed Management: This approach involves the implementation of policies, practices, and incentives that protect and improve the health of watersheds, including reforestation, terracing, conservation tillage, and buffer strips along waterways.
2. Sustainable Land Use Planning: Effective land-use planning and zoning can minimize the impact of human activities on sensitive ecosystems and promote sustainable land management practices that prevent gully erosion.
3. Planting of Native Grasses and Trees: The planting of native grasses and trees in the eroded areas can help stabilize the soil, improve water infiltration, and increase biodiversity.

4. Rainwater Harvesting and Storage: The collection and storage of rainwater can also reduce surface runoff that can lead to increased erosion in the catchment and also provide a source of water for irrigation purposes by reducing the need for groundwater extraction and supporting sustainable agriculture practices.
5. Environmental AwarenessEducation and: Enlightening the communities with basic information and education on the causes and impacts of gully erosion can help build community resilience and support for adaptation strategies.
6. Local Water Infrastructure such as the use of sandbags, local drainage channelization can help to reduce the rate of erosion. This will help to prevent further gully expansion and loss of land that can be used for agricultural productivity in the study area

REFERENCES

Abdulfatai, I. A., Okunlola, A. I., Akande, W. G., Momoh, L. O., & Ibrahim, K. O. (2014). Review of gully erosion in Nigeria: causes, impacts and possible solutions.

Amundson, R., Berhe, A. A., Hopmans, J. W., Olson, C., Sztein, A. E., & Sparks, D. L. (2015). Soil and human security in the 21st century. *Science*, 348(6235), 1261071.

BS 1377, B. S. (2019). Methods of test for soils for civil engineering purposes. *British Standards Institution. London. UK*.

Casagrande, A. and Fadum, R.E. (1940), "Notes on soil testing for engineering purposes", Soil Mech. Series No. 8, Harvard Graduate School of Engineering, Cambridge, MA, USA.

Cavey (2006).Cavey, B (2006) Gully erosion, Deparment of Natural Resources and Water Fact sheets L 81 P1-4.

Edo- State Flood, Erosion, and Watershed Management Agency (Edo- State FEWMA, 2023).

Eseigbe, J.O. and Ojeifo, M.O. (2012) Aspects of Gully Erosion in Benin City Edo State, Nigeria. Research on Humanities and Social Sciences, 2, 22-26.

Frankl, A., Deckers, J., Moulaert, L., Van Damme, A., Haile, M., Poesen, J., & Nyssen, J. (2016). Integrated solutions for combating gully erosion in areas prone to soil piping: innovations from the drylands of Northern Ethiopia. *Land Degradation & Development*, *27*(8), 1797-1804.

Food and Agriculture Organization (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (UNICEF), World Food Programme (WFP) and World Health Organization (WHO). (2017). The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

Humberto, B. C., & Rattan, L. (2008). Water erosion. *Principles of soil conservation and management. Springer, New York*, 21-53.

Howard, Amster K. (1986). Soil classification handbook: unified soil classification system. Denver, Colo.: Geotechnical Branch, Division of Research and Laboratory Services, Engineering and Research Center, Bureau of Reclamation.

Igwe, P. U., Ajadike, J. C., & Ogbu, S. O. (2023). Assessment of gully erosion problems for its remediation in eastern Nigeria. *Journal of Environmental Management and Safety*, *14*(2), 17-17.

Keesstra, S. D., Geissen, V., Mosse, K., Piiranen, S., Scudiero, E., Leistra, M., & van Schaik, L. (2012). Soil as a filter for groundwater quality. *Current Opinion in Environmental Sustainability*, *4*(5), 507-516.

Koch, A., McBratney, A., Adams, M., Field, D., Hill, R., Crawford, J., and Zimmermann, M. (2013). Soil security: solving the global soil crisis. *Global Policy*, *4*(4), 434-441.

Odunuga, S., Ajijola, A., Igwetu, N., & Adegun, O. (2018). Land susceptibility to soil erosion in orashi catchment, Nnewi south, Anambra state, Nigeria. *Proceedings of the International Association of Hydrological Sciences*, *376*, 87-95.

Ofomata, G. E. K.: Classification of Soil Erosion with Specific reference to Anambra State of Nigeria, Environ. Rev., 3, 252–2551, 2000.

Oluyole, K.A. and Lawal, J.O. (2008). An Appraisal of the Impact of Agro-services Co-operation. Proceedings of the 9th International Conference on Precision Agriculture, 20 – 23 July, 2008.

Pimentel, D. (2006). Soil erosion: a food and environmental threat. *Environment, development and sustainability*, *8*, 119-137.

Poesen, J., Nachtergaele, J., Verstraeten, G., & Valentin, C. (2003). Gully erosion and environmental change: importance and research needs. *Catena*, *50*(2-4), 91-133.Le Roux, J. J. (2012). Gully location mapping at a national scale for South Africa. *South African Geographical Journal= Suid-Afrikaanse Geografiese Tydskrif*, *94*(2), 208-218.

Sanusi, R.A., Badejo, C.A. and Yusuf, B.O. (2006). Measuring household food insecurity selected local Government Areas of Lagos and Ibadan, Nigeria. *Pakistan Journal of Nutrition*, 5:62-67.