American Journal of Environmental Sciences

Original Research Paper

Respondent's Perception on Anthropogenic Determinants of Gully Erosion in Upper Imo River Basin (UIRB), Southeastern Nigeria

[1]Chibo Christian Nnamdi and [2]Oluoyin Adeola Fashae

[1]*Department of Geography and Environmental Management, Imo State University Owerri, Owerri, Nigeria*
[2]*Department of Geography, University of Ibadan, Oyo, Nigeria*

Article history
Received: 15-09-2023
Revised: 16-12-2023
Accepted: 10-01-2024

Corresponding Author:
Chibo Christian Nnamdi
Department of Geography and Environmental Management,
Imo State University Owerri,
Owerri, Nigeria
Email: nadeo2k6@yahoo.com

Abstract: Gully erosion has been acknowledged as one of the global environmental issues that affect the region's economy. It is caused by man in his quest to make a living through different economic activities. This research was carried out to investigate the perception of the people in gully-prone areas on the anthropogenic determinants of gully erosion within a headwater. Various economic activities that trigger gully erosion were examined. The various stages and states of gully erosion within the headwater were also investigated, as well as institutions and agencies responsible for control of the environmental problem were also determined. A reconnaissance survey was carried out at the early stage of the research. Both primary and secondary data were also employed. Primary data was obtained through fieldwork and measurement and a structured questionnaire. Field measurement was used to obtain data on gully morphological parameters (length, width, depth, and area). 514 copies of a structured questionnaire obtained by 2% of the study area population were used to generate data on anthropogenic determinants of gully erosion in the study area. 18 gully erosion sites were systematically selected from 67 gully sites identified in the headwaters of the Imo River basin. Data analysis used both descriptive and inferential statistics like frequency tables, percentages, means, standard deviation and analysis of variance as well. The research finds that in the upper Imo Basin, farming activities, sand mining, and failed road construction are the three major anthropogenic determinants of gully erosion within the headwaters of the study area. Agriculture is the most common economic activity observed around the gully sites, while the most common farming system is mixed cropping. The research also found out that most gully sites in UIRB are within the age range of 11-15 years and 94.5% of the gullies are in an advanced stage of development. 92.5% of the gullies within the headwater are not in any form of control, most of the gullies that have any form of control on them were done by the affected communities. Therefore, there is a need for government as well as international agencies' intervention in gully erosion in the study area. Efforts should also be made to stop farming around the gully sites as it triggers its expansion.

Keywords: Gully, Respondents, Upper Imo River Basin, Anthropogenic, Determinants

Introduction

Soil erosion, which manifests in the detachment of the soil by natural agents, can be seen in three forms. These three forms are sheet, rill, and gully. The agents of soil erosion can be categorized into two namely natural and man-made (anthropogenic). The identified natural agents are gravity, moving ice, wind, and running water, while the anthropogenic agents manifest in different types of human economic activities which include but are not limited to urbanization, farming activities, deforestation, sand mining, stone mining, etc. Soil erosion constitutes a threat and hazard to the environment. This results in visible signs of soil destruction. Gully is the most dangerous stage of all the forms of soil erosion development processes (Abdulfatai *et al.*, 2014).

In gully development, man through the alteration of the vegetation cover becomes a significant factor (Okereke *et al*., 2012). Vegetation is removed through logging and cropland expansion in the humid tropics and in the semi-arid areas, it is removed through overgrazing. These two activities favor gullying (De Oliveira, 1990) and the determinants of gully erosion can be traced to them. Generally, sparse vegetation cover results in a reduction in boundary roughness and this is in opposition to a reduced overland flow. The result is an increased runoff capacity which facilitates erosion, while insufficient organic matter in the soil decreases the stability of soil particles. Efforts designed to control gully will be futile until the factors that lead to gully initiation are identified. Genially, several different factors combine to develop gully, though one can agree (Oostwoud Wijdenes and Bryan, 1994). Runoff response and sediment transport on slopes which are natural factors are crucial factors in gully formation. Therefore, there is a need for continuous monitoring of gullies. This can be done through experiments and modeling. These can also act as bases for predicting the effects of global changes caused by land cover and climate changes on gully erosion rate, as well as on the contribution of this soil degradation process to the overall land degradation (Todd, 2010; Okoro *et al*., 2013).

Gully erosion has been associated with soil loss, reduction in agricultural yield, destruction of properties, and forced migration due to making ancestral homes unsafe resulting in abandonment (Igwe, 2012). In UIRB, human economic activities like mineral exploration and resource exploitation have a damaging impact on the environment (Chibo and Onuoha, 2016). Gully erosion has been proven to be caused by factors related to both human and natural phenomena, although the human factor has been found to have a more dominating tendency than the natural factors, especially in developing nations (Noori *et al*., 2016). Some of the direct primary effects of gully erosion in an environment have been inadequacy in water supply, declining productivity in agricultural yield, loss of cultivable arable farmland, vegetation cover loss, as well as facilities and infrastructure destruction (Nwaogu *et al*., 2018). Furthermore, they ranged from climatic, land use/land cover change, topographic, lithological features, and human factors. The variability as well as enormity of these contributing factors has resulted in the complexity in the determination of specific parameters of gully erosion development on the surface of the earth. However, in terms of monitoring, the introduction of a Geographic Information System (GIS) in conjunction with Remote Sensing (RS) in combination with both physical and empirical models has been more reliable and effective (Adediji *et al.*, 2010; Pechanec *et al*., 2015; Seutloali *et al*., 2016; Noori *et al*., 2016).

In Southeastern Nigeria particularly the UIRB, soil erosion has been recognized as a major environmental problem resulting from land degradation and gully erosion which is the most devastating form of soil erosion has affected about 3.975 million hectares of land in India. In India, it was estimated that soil erosion is taking place at an average rate of 16.35 tons ha^{-1} year-^{1} and about 29% of the eroded soil is lost permanently to the sea and 10% of it is deposited in reservoirs (Ghosh and Guchhait, 2016). At this juncture what has not been determined and what this study seeks to achieve is to determine the perceptions of the people living around the gully sites on the determinants of gully erosion in their various localities. The aim of this study is to evaluate the people's perception of the human causes of gully erosion in the upper Imo River Basin so as to expose these factors for specific control mechanisms. Most of the research on gully conducted in the study area has been carried out without integrating the views of the people directly affected by the environmental problem. This research therefore integrates the local inhabitants' perception of gully erosion in UIRB. Based on the background information, the research is geared towards providing answers to the following questions:

1. What are the various economic activities around gully sites in UIRB
2. What are the stages of development of gullies in UIRB
3. What are the gully states in your area
4. What are the agencies responsible for gully control in UIRB

Materials and Methods

Study Area

The upper Imo River Basin, Southeastern Nigeria is the location where the research was conducted. It is located within latitude 4°38-6°01N and longitude 6°40-8°00E of the Greenwich meridian with an area coverage of 9100 km^2 covering two states of the southeastern Nigeria-Imo and Abia (Fig. 1).

Using Koppen's classificatory method, UIRB is within the tropical monsoon (AM). The area is blessed with rich and abundant water resources that come mostly from heavy rainfall. The average rainfall amount yearly is between 2250-2500 mm for areas located between 5°40'-5°49'N. There is a reduction to 2000-2250 mm for locations between 5°49'-5°55'N and further 5°55'-6°03'N, average yearly amount also reduced to 175-2000mm. Seasonality of the rainfall is an important feature that characterizes the rainfall and this is linked to the Inter-Tropical Convergence Zone (ITCZ) and rainfall that comes from conventional storms. Information in Fig. 2 represents 15 years of annual rainfall data for UIRB.

DOI: 10.3844/ajessp.2023.107.117

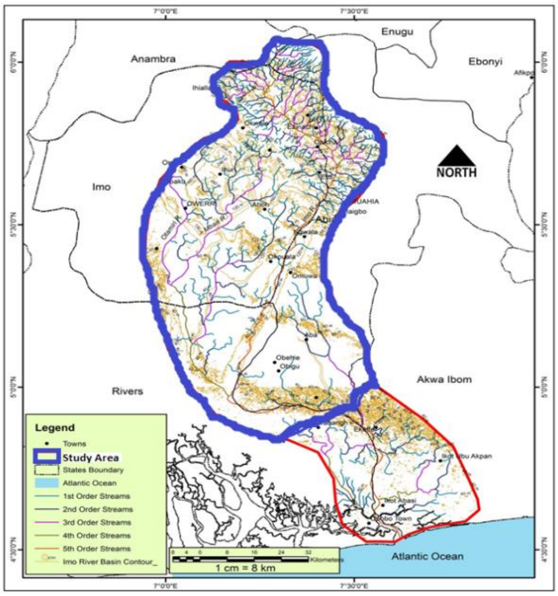

Fig. 1: Map of Imo River Basin showing upper Imo River Basi

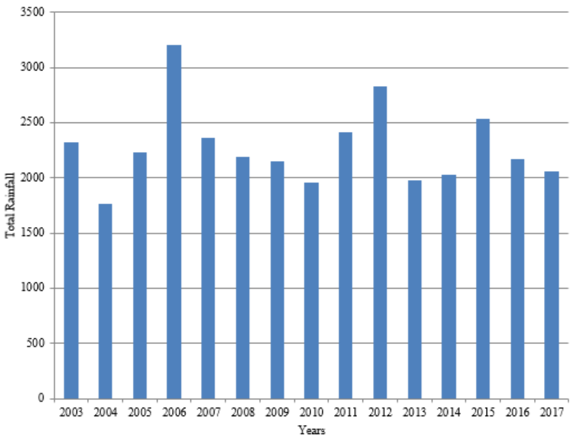

Fig. 2: Total Rainfall in UIRB from 2008-17; Source: Anambra Imo River Basin Development Authority, 2017

Temperature is mainly governed by radiant energy, though some minor influences are felt from other factors. The insolation received on any portion of the earth raises the temperature of the air, plants, and soil. In UIRB the average monthly temperature observed falls between 28 and 35°C, while the annual mean monthly minimum air temperature ranges between 19-24°C between 2017 and 2022. The Imo River is the main river that drains the Imo River Basin. The river has its source in the Nneochi community in Umu-Nneochi LGA of Abia state. It transverses through Imo clay shale to coastal plain sand lithology. The length of the Imo River is about 240 km. The river also flows through many settlements comprising both urban and rural settlements (Fig. 3). The basin area consists of about 29 urban locations and 33 rural areas covering parts of two states of Abia and Imo in Southeastern Nigeria.

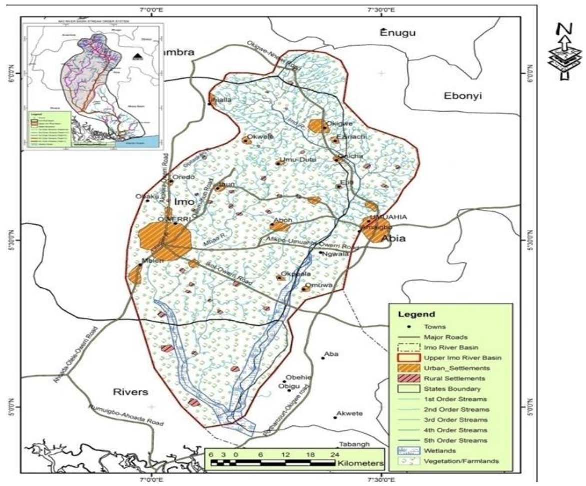

Fig. 3: Settlement map of upper Imo River Basi

Methods

This research is survey research on people's perception of anthropogenic determinants of gully erosion in a basin. The data types for this research fell into two main groups: Primary and secondary (archival) data. Primary data for this research was generated using two methods: Field measurement and observation andquestionnaire distribution. Field measurement was adopted for the measurement of morphological parameters (length L, width W, depth D, and area A) of the selected gullies. This involves the measurement of the morphological parameters of the sampled gullies in different parts of the rural and urban sites. The morphological properties measured were the gully length, width, depth, and area. Field observation and studies were carried out on these gullies and their stages of development were also determined. The sources of primary data also include evidence obtained from direct field measurements. Instruments used for primary data acquisition include global positioning systems (Garmin GPS 60), cameras, measuring tape, leveling staff, measuring tape, and field notes.

Questionnaire administration was also used to generate data on anthropogenic factors on respondents' perception of gully development. Data involved here are data on land use type and vegetation. Well-structured copies of the questionnaire were distributed to individuals living around the sampled gully sites within the basin. A total of 514 respondents were systematically selected from residents of the sites sampled (Table 1). The sample size was obtained by taking a sample of 0.2% of the 2018 population census of the area where the sampled gully sites are located. The information shown in Table 1 represents the sampled locations, their population, and sample size. A total of 512 copies of the questionnaire were distributed to the respondents and at the end, a total of 498 copies were retrieved. The percentage of questionnaire retrieval was 97%. Therefore the 494 copies retrieved formed the sample size of the respondents and the same was used in this study for data collection on anthropogenic factors and people's perception as it relates to gullying in the study area. Secondary data was obtained from existing works on gully from the library, the internet, and government agencies.

A sampling technique was used in the selection of gullies for this research. The sampling technique adopted was randomized systematic sampling. This method of sampling was adopted so as to reduce over-identification and representation of similar gullies. The basin is also made up of rural and urban locations. There are 29 urban locations and 33 rural locations out of which, there are 20 urban and 15 rural areas within the upper Imo River basin (Fig. 3). Monolithic basins were sampled to avoid complications due to lithological heterogeneity within the basin. Second-order basins within UIRB are the target population for the study. This is where channel head cuts and intense gullying initiation and development have been observed. Second-order or lower-order basins are big to be important geomorphological and also produce a statistically significant sample with little effort. The second order was chosen to compare with previous studies. The upper Imo River Basin consists of 112 second-order basins, 80 are gullied while 32 are not gullied. Out of the 162 major gullies within the entire basin through field observation and authenticated with satellite imageries of the study area, 67 gullies were found within the second-order basin. Based on land cover and lithology, 18 gully sites were selected out of the 67 gullies within the second-order basins. The choice was to reduce over-identification and ensure representativeness.

Data presentation made use of frequency tables and charts, while analysis was done using percentages, one-way analysis of variance, games-Howell's post hoc, and Levene's t-test of homogeneity.

Results and Discussion

Anthropogenic Factors of Gully Erosion in Upper Imo River Basin in 2018

Misuse of lands in Southeastern Nigeria has been viewed as an important anthropogenic factor that contributes to gullying in the area (Igwe, 2012). These factors range from poor farming systems which contribute to the collapse of soil structure to uncontrolled overgrazing by nomads which has resulted in deforestation of the land and road construction in addition to uncontrolled infrastructural development has immensely contributed to gullying in both the rural and urban areas of the basin (Igwe, 1999; Chibo, 2022).

The data used in this section were obtained through a questionnaire and it was used to obtain the perceptions of the people on the gullies developed in the UIRB. Information obtained through here was also used to compare, validate, and authenticate some of the information obtained from satellite imageries through remote sensing and laboratory analysis. The information obtained from the respondents through a structured questionnaire distributed to them about gully erosion in their various areas is presented in the various subsections. The information on how the structured questionnaire was distributed is presented in Table 1.

Table 1: Questionnaire distribution table

Gully locations, population and sample size				Gully location, population and sample size				Total	
Urban	2018 pop	No. sampled	No. retrieved	Rural	2018 pop.	No. sampled	No. retrieved	Sampled	Retrieved
Aba 1	38, 139	76	73	Amainyi	10,132	20	16	96	89
Aba 2	12, 210	24	21	AmuzuO kwuohia	6,127	12	12	36	33
Ibeku	12, 548	25	25	Umudurugo Obowo	4,968	10	10	35	35
New Owerri	38,116	76	74	Umueze 2	13,126	26	26	102	100
Okigwe	19, 176	38	37	Emekuku	6,180	26	26	64	63
Amakohia Owerri	14,329	28	28	Umueze-Obizi-Ezala	3,214	6	6	34	34
Umuahia	27,325	55	52	Okohia6,827 Isiama	14	14	49	46	
Nekede	14,665	29	29	Isiebu7,715	15	15	44	44	
				Isinweke	10,082	20	17	17	17
				Umuduru	6,839	14	13	14	13
Total		351	339		163	155	514	494	

Predominant Economic Activities Around Gully Sites in UIRB

The information available in literature from various sources indicates that various human economic activities trigger various forms of soil erosion in different parts of the earth (Adediji *et al*., 2010; Poesen, 2011). To investigate various economic activities going on around various sampled gully sites, the information obtained is presented in Table 2.

The highest economic activity around the gully sites as is seen in Table 2 is agriculture and related activities, mostly farming. This is a result of man's urge and the quest to feed the teeming population in the area. This economy was observed mainly around gully sites located in rural settlements of the study area (Chibo, 2022). This is the view of about 47.37% of the sampled population. This means that about 47.37% of the economic activities around the gully sites in UIRB are agricultural activities. The next highest economic activity after agriculture was sand excavation. This activity was found both in the rural and urban settlements but was more pronounced in the rural settlements. This was the opinion of 192 respondents or about 38.87% of the sampled population. Agricultural activities and sand excavation together account for about 86.14% of the predominant economic activities found around the gully sites. Other identified economic activities around the gully sites can be seen in Table 2. The implication of the finding is that most of the economic activities around sites are the activities that remove vegetation from the soil and these activities encourage gully development (Okereke *et al*., 2012; Chibo, 2022).

Types of Farming Practices Around Gully Sites of UIRB

Since agricultural activity is the predominant economic activity around the gully sites, the investigation was further made to determine the type of agriculture practiced around the gully sites, and the information obtained is presented in Table 3.

Mixed cropping was identified as the most predominant agricultural activity practiced around the gullies in the upper Imo River Basin. This is the system of agriculture where different crops are planted on the same piece of cultivated farmland at the same time. This can be the result of inadequate farmland in the study area compared to the size of the population in the area (Ofomata, 1987). It can be seen in Table 3, that 45.3% stated that mixed cropping is the most visible agricultural practice noticed. Agro-forestry was also observed as the second most predominant agricultural activity practiced around gullies in UIRB. This was observed in the table as indicated by 21.05% of the sampled population. This means that about 21% of agricultural activity practiced around gully locations in UIRB is agro-forestry. Other agricultural activities observed around the gully locations were mixed farming (14.59%) and mono-cropping (4.45%).

Fallow Periods Observed in the Study Area for Farming Activities

The fallow period is an important factor in erosion study because it determines the rate at which soil is exposed for farming activities thereby exposing the soil to various forms of soil erosion including gullying. To obtain information on the fallow periods observed in the study area, questions were asked of the respondents, and the results obtained are presented in Table 4.

Table 2: Predominant economic activities around gully locations

Predominant economic activities	Frequency	Percent	Cumulative percent
Agriculture	234	47.4	47.4
Sand excavation	192	38.9	86.2
Rock mining	49	9.9	96.2
Small scale construction	16	3.2	99.4
Artesian	3	.6	100.0
Total	494	100.0	

Table 3: Types of farming activities around gully sites in UIRB

Types of Farming	Frequency	Percent	Cumulative percent
Plantation	72	14.6	14.6
Agro-forestry	104	21.1	35.6
Mixed cropping	224	45.3	81.0
Mixed farming	72	14.6	95.5
Mono cropping	22	4.5	100.0
Total	494	100.0	

Table 4: Fallow period observed for farming in the upper Imo River Basin

Fallow period	Frequency	Percent	Cumulative percent
1	110	22.3	22.3
2	252	51.0	73.3
3	72	14.6	87.9
4	43	8.7	96.6
5	11	2.2	98.8
More than 5 years	6	1.2	100.0
Total	494	100.0	

Two years was observed to be the highest fallow period observed for farming activities in the study area. The implication is that the land in UIRB is cleared of its vegetation for farming activities every two years. This means that the soil is in constant exposure to agents of soil erosion. This is the response of 252 sampled respondents for the study. The result shows that about 51% of the inhabitants of UIRB observe only a 2-year fallow period. This might not be unconnected to the rapid population explosion in the study area in recent years (Iro, 2020a, Okereke *et al*., 2012; Igwe, 2012). This reduction in the fallow period can be attributed to an increase in the population of the area. This can also be a factor as to why most of the soil of the study area is ravaged by gully erosion since most of the soil is always exposed to various agents of erosion. About 22.27% of the sampled population indicated that they observe only a 1-year fallow period. The information in the table showed that about 73% of the inhabitants of the study area observed 1-2 years fallow period. This means that the majority of the soil of UIRB is always exposed. 8.7% of the sampled population indicated that they observed a 3-year fallow period while 2.23% indicated a 4-year period and only 1.21% observed a 5-year fallow period.

Activities that Initiated Gully Erosion in Upper Imo River Basin

Various factors have been identified to initiate gully erosion in various landscapes. However, it was observed that these factors vary from one part of the earth to the other (Oparaku and Ogbeh, 2018). The information obtained on the factors that initiate gully erosion in UIRB is presented in Table 5.

Sand mining is the greatest activity in the upper Imo River basin that causes gully erosion. This might be unconnected with massive sand mining activities going on in both rural and urban settlements in the study area, resulting from the quest to meet up with the massive infrastructures (buildings and road construction) going in the area (1ro, 2020b). This was the opinion of about 48.49% of the sampled population. The implication is that if indiscriminate sand mining is controlled in the study area, about 48.49% of gully erosion in the study area would have been controlled. The next factor that causes gully erosion as obtained from the respondents is failed road construction. This constitutes about 28.74% of the factors that initiated gully erosion in the study area. This means that sand mining and failed road construction constituted about 76% of the gullies in UIRB. Other factors of gully erosion in the study area are farming (11.74%), Concentration of channel runoff (4.66%), rock mining (3.44%), and urbanization (2.23%). Plate 1 presents a gully that resulted from failed road construction.

Table 5: Activities that initiated gully erosion in UIRB

Activities	Frequency	Percent	Cumulative percent
Poor road Construction	142	28.7	28.7
Farming	58	11.7	40.5
Sand mining	242	49.0	89.5
Stone mining	17	3.4	92.9
The concentration of runoff channel	23	4.7	97.6
Urbanization	12	2.4	100.0
Total	494	100.0	

Plate 1: Gully resulting from failed road construction in Amainyi Ihitte Uboma in UIRB in 2019

Age Range of Gullies in Upper Imo River Basin

The information displayed in Table 6 shows the age of gullies in UIRB as obtained from the respondents through a questionnaire. This information was also used to authenticate the information obtained using remotely sensed data from satellite imagery of the gullies.

From the analysis of the data in Table 6, it was found that 205 sampled gullies fall within the age range of 11-15 years. This showed that about 42% of the gullies in the UIRB fall within the age of 11-15. This information authenticates and confirms the information obtained from the satellite imagery which indicated that about 50% of the gullies fall within the age of 11-15 and also agrees with (Ogbonna and Ijioma, 2010) that the number of gullies in old Imo State has increased in the last 20 years. The next age range of gullies in the study area is those that fall within the age range of 6-10 years. This group has about 36.6% of the sample population. This is interpreted to mean that about 37% of the gullies in the study area fall within the age range of 6-10 years. The oldest gully obtained from the questionnaire has an age of 30 years and above. They have 2 respondents and interpreted to mean that only 0.4% of the gullies in the study area have an age

DOI: 10.3844/ajessp.2023.107.117

greater than 30 years. 6.9% of the gullies fall within the age range of 16-20, while 2.2% have an age range of 26-30 and 1.4% of the gullies have an age ranging from 21-25 years. The mean age of the gullies computed was found to be 10 years and 9 months which is approximately 11 years. This means that the average age of gullies in the upper Imo River Basin is 11 years.

Stages of Gully Development in Upper Imo River Basin

Gully erosion in the UIRB is still at various stages of development. Information obtained during the field reconnaissance survey and from fieldwork is presented in Table 7. Analysis of the information in Table 7 showed that about 94.74 of the gullies have gone into an advanced stage of development. This is an indication that gullies in the study area constitute a major environmental threat as observed by other studies carried out in other parts of South Eastern Nigeria (Iro, 2020b; Igwe, 2012) The findings of this research are all in agreement with the exposure made through this study. The implication of the result is that the gullies in the study area are not given adequate attention at the inception stage and this means that arable lands, infrastructures, human settlements, and public utilities are all at risk of being damaged. The information showed that gullies in the study area are not properly given attention, hence majority of them have advanced into a massive state. This is why some of the gullies have so developed that some of them cover an area as large as 100 km^2. 0.6% of the respondents indicated that the gullies around their area were still at the initiation stage of development. Only 4 respondents indicated that the gullies in UIRB have stabilized. This is interpreted to mean that only 0.81% of gullies in the study area have stabilized. The gullies in their early stage of development have 8 respondents from the sample population meaning that 1.21% of gullies in the study area are still at their early stage of development. The information obtained from the questionnaire presented in Table 7 also showed that some of the gullies are stabilizing. This was the view of 2.43% of the sample population.

Present State of Gullies in Upper Imo River Basin

The study took an investigation to determine the present state of gully erosion in the study area. The result obtained is presented in Table 8.

Analyses of the information in Table 8 showed that the majority of the identified gullies are not under any form of control. This is also why most of the gullies in the study area were left to develop to an advanced stage. From table 92.51% of the sample population indicated that gullies in the area are not under control. This is also interpreted to mean that about 92.51% of the gullies upper Imo River Basin are not under any form of control. Only 37 respondents or about 7.49% of the sample size indicated that the gullies around their area are under control.

Table 6: Age range of gullies in UIRB

Age range	Frequency	Percent	Cumulative percent
0-5	64	13.0	13.0
5-10	171	34.6	47.6
11-15	205	41.5	89.1
16-20	34	6.9	96.0
21-25	7	1.4	97.4
26-30	11	2.2	99.6
More than 30	2	.4	100.0
Total	494	100.0	

Table 7: Stages of gully development in UIRB

Stages of gully development	Frequency	Percent	Cumulative percent
Initiation stage	3	0.6	.6
Early stage	6	1.2	1.8
Advanced	469	94.9	96.8
Stabilizing	12	2.4	99.2
Stabilized	4	0.8	100.0
Total	494	100.0	

Table 8: Present state of gullies in UIRB

Gully state	Frequency	Percent	Cumulative percent
Under control	37	7.5	7.5
Not under control	457	92.5	100.0
Total	494	100.0	

Table 9: Agencies/institutions responsible for gully control in UIRB

Agencies/institutions	Frequency	Percent	Cumulative percent
Affected families	121	24.5	24.5
Affected communities	263	53.2	77.7
Local/state governments	29	5.9	83.6
Federal government	38	7.7	91.3
International agencies	43	8.7	100.0
Total	494	100.0	

Agencies/ Institutions Responsible for Gully Control in Upper Imo River Basin

Information was sought to know various agencies or institutions responsible for gully erosion control in UIRB and information obtained is presented in Table 9.

It was observed from the table that in UIRB, the affected communities are the institution that shows the highest concern in the control of gullies in their various areas. This was the result obtained from the distributed questionnaire as 263 respondents indicated that gully erosion is done by affected communities. This means that about 53.24% of control measures adopted for gullies in the study area are done by the affected communities. Another agency/institution next to the community in ranking order is the affected families. This was the result obtained from the respondents as24.49% of the sampled population agreed that affected families are mostly involved in gully control in the study area. International agencies like the United Nations (UN) through the Nigerian Erosion and Watershed Management Project (NEWPAP) are another agency identified to control gully erosion in the study area. This was the view of 43 respondents or 8.7% of the sample population. Other agencies/institutions as seen from the table are the federal government (7.69%) and state/local government (5.87%).

Measures Adopted to Control Gullies in Upper Imo River Basin

Several measures were adopted to control or at least manage gully erosion. In UIRB, the following measures presented in Table 10 were identified by the respondents as ways to control gullies in the area.

Stopping farming activities around the gully sites is the control measure observed to be mostly adopted by the inhabitants of the study area. This was the view of 39.7% of the sampled population. This revealed that the majority of the people of UIRB see stopping farming activities as a mechanism of gully control that they in their capacity can adopt. Engineering and earthworks is also another measure believed to be effective by the people to control gully in the study area. This is because 26.5% of the sample population views Engineering and earthworks most effective ways to control gully in the study area. 20.6% of the sampled population believed that gully erosion is best controlled when runoff is diverted away from gully sites. 12.1% of the population believed that gully could be controlled by planting vegetation around gully sites, and only 5 respondents or 1.0% of the population believed the gullies stabilized on their own. Further investigation revealed that due to the massive size of the gullies, engineering, and earthworks are the most effective mechanisms of gully control in UIRB, but the local communities resort to the preventive mechanism of stopping farming activities in gully-prone areas because they do not have the financial capacity to carry out engineering and earthworks.

Table 10: Measures adopted to control gully in UIRB

Control measures	Frequency	Percent	Cumulative percent
Stopped on its own	5	1.0	1.0
Stopping farming activities	196	39.7	40.7
Runoff diversion	102	20.6	61.3
Engineering and earthwork	131	26.5	87.9
Planting vegetation	60	12.1	100.0
Total	494	100.0	

Relating and comparing the data on gully morphological data obtained through field measurement to data obtained through a questionnaire, it was observed that field investigation on these gullies showed that there are three major anthropogenic factors that cause gully erosion in the UIRB. These are the major economic activities observed around the gully sites. These major anthropogenic factors are sand mining, farming, and rock quarrying. These three factors remove forest cover of the area before these economic activities could take place.

The summary of descriptive statistics of gully morphological variables on these economic activities is presented in Table 11 analysis of the table shows that the gully length across the major anthropogenic factors ranges from 60.2-980 m, the width of the gullies range from 15.90-441.2 m, gully depth range is from 56-420 m, while the range of gully area in UIRB range from 0.02-100.00 km^2. The mean gully length across the three major anthropogenic activities ranges from 240.87-379.25 m, with a standard deviation range of between 125.56-322.29 m, the mean gully width ranges from 28.25-195.35 m, with a standard deviation range of 16.8-159.12 m. The mean gully depth ranged from 87.38-137.49 m, with a standard deviation range of between 30.19-117.08 m and the mean gully area across the major anthropogenic factors ranges from 0.81-40.15 km^2, with a standard deviation range of from 0.34-4.29 km^2.

The least gully length (60.20 m) was observed in areas associated with sand mining while the highest gully length (980 m) was observed around farming areas. The mean gully length with respect to quarrying was observed to have the lowest value (240.87 m) while the highest value (379.25 m) occurred on farming. With respect to the width of the gullies, the least gully width (4.3 m) was found in areas associated with farming, while the highest (23.6 m) gully was found in rock quarrying areas. The mean gully width with respect to farming was observed to be the least (28.25 m) while the highest (195.35 m) occurred for sand mining. Furthermore, while gully depth values were observed to be the least (45.02 m) in stone quarrying and highest (420 m) in sand mining areas, the mean gully depth value was also least (87.38 m) in stone quarrying areas and highest (137.49 m) around sand mining locations. The least (0.02 km^2) gully area was found around farming areas whereas the highest 100.00 km^2 gully area was located in areas with sand mining activity. It is observed from the table that gully morphological factors (length, width, depth, and area) in UIRB develop faster with sand mining activities than in areas with farming and rock quarrying activities. Hence sand mining is the greatest cause of gullying in the upper Imo River Basin Levene's test of homogeneity of variance for the levels of the anthropogenic factors in UIRB was applied. The result presented in Table 12 shows a non-statistically significant result for gully length and gully area but shows that gully width and gully depth were statistically significantly significant across the three major anthropogenic activities in UIRB.

DOI: 10.3844/ajessp.2023.107.117

Table 11: Summary of descriptive statistics of gully morphological variables under major anthropogenic factors of gully erosion in UIRB

Anthrop ketogenic factor	Gully Morphometric Properties: Length					Width					Depth					Area				
	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std.er	Std dev	M_1	M_2	M_3	Std.Er	Std dev	M_1	M_2	M_3	Std.er	Std dev
Farming	65.80	980.00	379.25	135.66	322.29	4.30	47.00	28.25	6.85	16.8	63.30	144.50	111.38	12.32	30.19	15.80	1538.39	813.76	235.88	577.78
Sand Mining	60.20	609.98	339.88	75.53	213.64	15.90	441.20	195.35	56.26	159.12	64.40	420.00	137.49	41.39	117.08	62.01	100000	40151.1	15178.64	42931.68
Rock Quarrying	99.90	340.70	240.87	72.49	125.56	23.60	112.00	62.85	25.99	45.02	56.00	118.83	87.38	18.14	31.42	528.40	1248.27	865.66	198.79	344.31

Table 12: Levene's test of homogeneity for economic activity for UIRB

Variable	Levene statistic	df1	df2	p-value	Remark
Gully length (m)	1.085	2	14	0.365	Not statistically different
Gully width (m)	6.128	2	14	0.012	Statistically different
Gully depth (m)	15.265	2	14	0.001	Statistically different
Gully area (sq. m)	1.339	2	14	0.294	Not statistically different

Table 13: Spatial variation in gully morphological variables across anthropogenic factors of gully erosion in UIRB

		The sum of squares	Df	Mean square	F	Sig
Length (m)	Between groups	38493.524	20	19246.762	0.298	0.747
	Within groups	903116.801	14	64508.343		
	Total	941610.325	16			
Width (m)	Between groups	104884.982	20	5244.491	4.019	0.042*
	Within groups	187700.505	14	13050.036		
	Total	287585.487	16			
Depth (m)	Between groups	6079.328	20	3039.664	0.415	0,668
	Within groups	102481.830	14	7230.131		
	Total	108561.158	16			
Area (m^2)	Between groups	6548159995	20	3274079997	3.552	0.05*
	Within groups	12900000000	14	921700936		
	Total	19358159995	16			

Table 14: Games-Howell's post-HOC tests for the anthropogenic factors on each morphological variable for UIRB

Variable	Post HOC test: Farming	Rock mining	Sand mining
Gully width	16.78^a	45.02^b	159.12^b
Gully length	379.25^a	240.87^a	339.88^a
Gully depth	111.38^a	87.38	137.49^a
Gully area	813.76^a	864.66^a	40151.10^b

Consequently, a Least Significant Difference (LSD) test was employed to examine the effect of the variables and the Analysis of Variance (ANOVA) score on the variables shows a non-significant result for gully length and gully depth and a significant result for gully width and gully area (Table 12). To further confirm the result of the test, Game-Howell's post-HOC test was also employed to examine the effect of the variables and the ANOVA result shows a significant result for the earlier significant variables and a non-significant result for non-significant results. In other words, the Gully length and Gully depth which are non-significant in Table 13 were further tested using the LSD Post HOC test (Table 14) and their ANOVA table shows them to produce a statistically significant result while the Gully width and Gully area were further tested using Games-Howell's Post HOC test and their one way ANOVA table also presents a significant p-value.

Conclusion

Gullying which manifests in the gradual and continuous degradation of the land is the greatest threat to the landscape of Southeastern Nigeria where this study is conducted. Although at the initial and inception stages, sheet, rill, and inter-rill are easily managed and controlled through recommended soil conservation and tillage operations by the people, once gully erosion has reached a different level and stage, houses, settlement, infrastructures, and agricultural land are under threat. Efforts made towards controlling or at least containing the spread of gully in the area seem not to be yielding any positive result because the effect of gully in UIRB has continued to increase both in severity and spatial spread the study has been able to expose the anthropogenic determinants of gully erosion in UIRB through the perceptions of the people who where directly affected by the environmental problem. This means that the opinions and concerns of the people directly affected were given due consideration in this research. This research is also seen as an addition to available knowledge on gully erosion globally.

The research therefore recommends some measures that will be helpful in at least curtailing the spread of gully together with its negativities. Efforts should be made to stop any form of farming activity around areas prone to gullying. Rainwater harvesting should be encouraged in the study area. This will reduce immensely the amount of rainwater that gets to the surface of the soil to form runoff. Local inhabitants should be mobilized and encouraged to engage in other economic activities that do not have direct contact with the land. They can be given soft loans to engage in trading and other artesian activities. International agencies and federal and state governments should prioritize efforts to control massive gullies since it has gone out of the capacity of the local communities.

Acknowledgment

We wish to thank and appreciate some individuals who in one way or another other contributed immensely to the success of this research. Our appreciations go to Mr. Philip Okoronkwo and Lazarus Chikwendu both of Imo State University, Owerri who are our field research attendantsduring the course of fieldwork. We also wish to thank Miss Peace Ukoha of the Forestry Research Institute of Nigeria (FRIN), Ibadan for the production of various maps used in this research. Your support and commitment were so immeasurable for the successful completion of this research.

Funding Information

All the funds used for the successful completion of this research were provided by the authors.

Author’s Contributions

Chibo Christian Nnamdi: Designed the study, ensured the accuracy of the data, and contributed to the manuscript.

Oluoyin Adeola Fashae: Corrected the manuscript, produced the maps used, performed GIS analysis, and contributed to other aspects of the project.

Ethics

This study was carried out by the authors without funding or grants from any institution, government agencies, or any organization. The funding for this research was provided entirely by the researchers.

Conflict of Interest

The author declares no conflict of interest.

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. http://pubs.sciepub.com/jgg/2/3/8

Adediji, A., Tukur, A. M., & Adepoju, K. A. (2010). Assessment of Revised Universal Soil Loss Equation (RUSLE) in Katsina area, Katsina state of Nigeria using Remote Sensing (RS) and Geographic Information System (GIS). *Iranian (Iranica) Journal of Energy and Environment*, *1*(3). https://www.ijee.net/article_64305_97fadb63863cba3ec4ee113ecb60d930.pdf

Chibo, C. N. (2022). Gully morphological assessment and anthropogenic determinants in urban and rural settlements of upper Imo River basin, South Eastern Nigeria. *American Journal of Environmental Sciences*, *18*(6): 135-144. https://thescipub.com/abstract/10.3844/ajessp.2022.135.144

Chibo, C. N., & Onuoha, T. N (2016). Natural resources exploitation and utilization in Imo State, Nigeria: The economic and environmental perspective. Asian *Research Journal of Arts and Social Sciences*, *1*(5), 1-15. https://doi.org/10.9734/ARJASS/2016/28448

De Oliveira, M. A. T. (1990). Slope geometry and gully erosion development: Bananal, São Paulo, Brazil. *Zeitschrift für Geomorphologie*, *34*(4), 423-434. https://www.cabidigitallibrary.org/doi/full/10.5555/19911954794

Ghosh, S., & Guchhait, S. K. (2016). Geomorphic threshold estimation for gully erosion in the lateritic soil of Birbhum, West Bengal, India. *Soil Discussions*, *2016*, 1-29. https://doi.org/10.5194/soil-2016-48

Iro, S. (2020a). Land-Cover Removal and Gully Development in Southeast Nigeria: A 30-year analysis with pixel and OBIA Approaches in Juxtaposition. *Am. J. Environ. Sci*, *16*(2).

Iro, S. I. (2020b). Determining causes of gully erosion and associated rates of change in South-East Nigeria, using a remote sensing and GIS methodology. https://doi.org/10.21203/rs.3.rs-33441/v1

Igwe, C. A. (1999). Land use and soil conservation strategies for potentially highly erodible soils of central-eastern Nigeria. *Land Degradation and Development*, *10*(5), 425-434. https://doi.org/10.1002/(SICI)1099-145X(199909/10)10:5<425::AID-LDR338>3.0.CO;2-5

Igwe, C. A. (2012). Gully erosion in southeastern Nigeria: Role of soil properties and environmental factors. *Research on Soil Erosion*, *10*, 51020. ISBN-10: 9789535108399.

Noori, H., Siadatmousavi, S. M., & Mojaradi, B. (2016). Assessment of sediment yield using RS and GIS at two sub-basins of Dez Watershed, Iran. *International Soil and Water Conservation Research*, *4*(3), 199-206. https://doi.org/10.1016/j.iswcr.2016.06.001

Nwaogu, C., Okeke, O. J., Assuah Adu, S., Babine, E., & Pechanec, V. (2018). Land use-land cover change and soil-gully erosion relationships: A study of Nanka, South-Eastern Nigeria using geoinformatics. *In Dynamics in GIscience 4* (305-319).

Ofomata, G. E. K. (1987). *Soil Erosion in Nigeria: The Views of a Geomorphologist* (*42*). Ibadan: University of Nigeria Press.

Ogbonna, J. U., & Ijioma, M. A. (2010). Mapping gully erosion susceptibility in old Imo State, Nigeria using probability and statistics model. *American Journal of Geographic Information Systems*, *3*(3), 45-50. https://doi.org/10.5923/j.ajgis.20120103.0

Okereke, C. N., Onu, N. N., Akaolisa, C. Z., Ikoro, D. O., Ibeneme, S. I., Ubechu, B., ... & Amadikwa, L. O. (2012). Mapping gully erosion using remote sensing technique: A case study of Okigwe area, southeastern Nigeria. *International Journal of Engineering Research and Applications*, *2*(3), 1955-1967. ISSN: 2248-9622.

Okoro, B. C., Ibearugbulem, O. H., & Agunwamba, J. C. (2013). Gully erosion control along NWORIE River in Owerri, Imo State-a deterministic model approach. *Int J Mod Eng Res*, *3*, 1774-1782. ISSN: 2249-6645.

Oparaku, L. A., & Ogbeh, G. O. (2018). Comparing gully length and average gully width relationships on two geological sediments of varying vulnerability to erosion in the north central Nigeria. *Nigerian Journal of Technology*, *37*(2), 554-561.

Oostwoud Wijdenes, D. J., & Bryan, R. B. (1994). Gully headcuts as sediment sources on the Njemps flats and initial low-cost gully control measures. *Catena Verlag: Advances in Geoecology*, (27), 205-229. ISBN-10: 3-923881-36-0.

Pechanec, V., Brus, J., Kilianová, H., & Machar, I. (2015). Decision support tool for the evaluation of landscapes. *Ecological Informatics*, *30*, 305-308. https://doi.org/10.1016/j.ecoinf.2015.06.006

Poesen, J. (2011). Challenges in gully erosion research. *Landform analysis*, *17*, 5-9. https://doi.org/10.1016/S0341-8162(02)00143-1

Seutloali, K. E., Dube, T., & Mutanga, O. (2016). Assessing and mapping the severity of soil erosion using the 30-m Landsat multispectral satellite data in the former South African homelands of Transkei. *Physics and Chemistry of the Earth, Parts A/B/C*, *100*, 296-304. https://doi.org/10.1016/j.pce.2016.10.001

Todd, M. (2010). Advisory and regulatory services natural resources management: Balancing conservation and development. Altec spring, NT08. http://www.nreta.nt.gov.au/advis/