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Assessment of the Beneficial Impacts of Water-Induced Gully Erosion in Eastern Nigeria

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Abstract: Water-induced gully erosion, an extreme form of soil erosion, leaves a conspicuous and easily observable mark on the land, representing a significant challenge to the environment and communities worldwide. While its detrimental environmental and socio-economic impacts have been extensively studied, its potential benefits have often been overlooked. Therefore, this study aimed to investigate the beneficial impacts of gully erosion in Eastern Nigeria, a region known for its susceptibility to this phenomenon. The region comprises nine areas at high risk of gully erosion, each located in one of its constituent states, which were purposefully selected for the study. A community located near a large gully was conveniently sampled from each of these nine areas. A total of 399 household heads residing within 0.3km (300m) radius of the gullies' head-scrapes were purposively sampled, out of which 370 completed and returned the questionnaires. The research employed various data collection methods, including questionnaires, interviews, observations, photographs, and satellite imagery. Respondents were asked to indicate their agreement with statements using a five-point Likert scale: strongly agree (5), agree (4), neutral (3), disagree (2), and strongly disagree (1). Data were analyzed using the Chi-square (X^2) test in SPSS, version 22.0. The results revealed that self-employment in sand mining activities, such as loaders, beach owners, food sellers, and buyers and sellers of sand, was the most significant benefit, while the use of sand as a raw material for glass industries was perceived as the least beneficial. There was a significant difference in the mean ratings among the affected people regarding the benefits of gully erosion in the region (X^2 value= 997.933, $p = 0.00$, $p < 0.05$ significant level). The study's recommendations include maximizing the benefits of sand mining businesses and establishing tourist centers around stabilized gullies and lakes created by gullies in the region, among others.

Keywords: *Assessment, Gully erosion, Beneficial impacts, Sand mining, Eastern Nigeria*

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1. Introduction

Water-induced soil erosion is one of the land degradation processes that beset the global environment and its peoples. It occurs in four forms: rain splash; rill; sheet; and gully erosion (Morgan 2005). Gully erosion by water, an extreme form of soil erosion, makes a clear and easily observable footprint in the soil that has the potential to become an irreversible badland, if not mitigated. It is the most impressive of all types of soil erosion (Abdulfatai, Okunlola, Akande, Momoh and Ibrahim, 2014), where runoff cuts into the land surface to a depth greater than 0.3m, usually within a defined area (Wilkinson, Howdson, Hairsine and Austin, 2019). It often indicates extreme land degradation (Afegbua, Uwazuruonye and Jafaru, 2016), a natural process and recognized global scale geomorphic hazard that can be accelerated by human activities (Okuh and Osumgborogwu, 2019). It involves the detachment of top soil along drainage channels by surface water consisting of an open incised and unstable channel generally more than 0.3m deep (Brown, 2020). European Union Soil Observatory (EUSO) (2022) reported that gully erosion is the formation of and subsequent expansion of erosion channels in the soil due to concentrated water flow. Gullies create very noticeable footprints in the soil through the detachment and transportation of soil particles wherever it occurs (Igwe, Ajadike and Ogbu, 2023a and b).

The severity of problems arising from gully erosion by water is manifested in a number of humongous hazards at on-site and off-site levels in communities the world over. This was correctly captured to a large extent by Ayele,

Gessess, Addisie, Tilahun, Tehubu, Tenessa, Landendoen, Nicholsen and Steenhus (2016) in a statement that it created lots of environmental on-site and off-site problems with its attendant huge costs for societies. Soil loss is the first and most critical gully erosion problem that triggers other on-site and off-site problems (Igwe, Ajadike and Ogbu, 2023a). In Eastern Nigeria, Agulu-Nnaka in Anambra State was an area worst hit by gully erosion as up to 250 tons of soils per hectare were lost in severe storms (Kalu, 2001). Grahmann, Rubio, Kenez-Bidegain and Quincke (2022) claimed that yearly average soil losses as an impact of erosion in 2017, 2018 and 2019 were 233, 805 and 139 kg ha-1 respectively in Colonca de Sacramento, Uruguay. In the contention of Belayneh and Tsegaye (2020), soil loss arising from gully erosion was 0.68m ha-1 yr-1, 8.91m2 ha-1yr-1 and 23.34t ha-1 yr-1 respectively, over the period 2001-2018 in the Gumara Watershed, Northwestern Ethiopia.

Agricultural lands are the first victims of gully erosion. In the perspective of Egboka, Akudo and Nwankwoala, (2019), degradation of arable land which translated into low crop productivity was one of the problems of gully erosion in Southeastern Nigeria. In semi-arid Farmland, North Ethiopia, Lemma, Kebede, Mesfin, Fitiwy, Abraha and Norgrove (2017) reported that the average annual loss of nutrient due to erosion was estimated at 41.4 kg ha-1. Ugwulebo and Oku (2021) were of the view that sedimentation of the river was one of the fallouts of a gully erosion site in EFAB (Queens and Varizone) Estate, Federal Capital Territory, Abuja, Nigeria. Udoumoh, Abuchaogu, Ehiomogue, Sam and Anan (2019) identified loss of human lives as a gully erosion problem in Uyo, Akwa Ibom State, Nigeria. Badlands created by gullies were highly susceptible to more erosion, particularly in more humid environment such as in large parts of India (Ranga, Poesen and Pani, 2016). Igwe (2016) noted that the 'eyes' of aquifers of some springs, streams and rivers in Ebonyi State, Nigeria have been permanently closed by sediments arising from gully erosion that one could not notice their existence at all during the dry season, except obviously at the peak of the raining season when water was found in their channels.

Dalil, Babangida and Hassan (2016) posited that destruction of properties was a problem occasioned by a gully in Auchi Town, Southern Nigeria. According to Oluyori and Ojo (2021), gully erosion had damaged roads and was also threatening properties in Gwagwalada Area Council, Abuja. Asuoha, Okafor, Phil-Eze and Ayadiuno (2019) asserted that erosion resulted in the depletion of below-ground biodiversity which included soil micro-organisms in Isiala Ngwa North L.G.A, Southeastern Nigeria. Zhang, Lauerwald, Regneir, Ciais Yuan, Naipal, Cuenet, Van Oost and Camino-Serrano (2020) argued that gully erosion affected biogeochemical cycles and climate change was a problem occasioned by it.

Gully erosion occurs in all parts of Nigeria, but with dominance in Eastern Nigeria, which is a region in the country most threatened by the phenomenon. Numerous small, medium and large gullies dot the environment of the region from the Udi-Nsukka Plateau in the north to the coast of the Atlantic Ocean in the south across her nine contiguous states of Abia, Akwa Ibom, Anambra, Bayelsa, Cross River, Ebonyi, Enugu, Imo and Rivers. According to the National Geo-Hazards Monitoring Centre, Awka (NGHMCA) (2019), the region had 257 large gullies of hazardous nature causing enormous damage to her environment and adversely affecting the socio-economic conditions of the residents living proximal to the gullies. Specific environmental and socio-economic problems arising from gully erosion in the region include soil loss, loss of agricultural lands, destruction of roads and footpaths, siltation of water bodies and low-lands and loss of human lives (Udoumoh et al., 2019; Egboka et al., 2019). In Anambra State of the region, some gullies have coalesced at Agulu-Nanka-Oko area to form an irreversible badland similar to that of Loess Plateau, China. Many gullies like those sampled in the study have the potentials to form other badlands, if urgent steps are not taken to manage them.

Gully erosion is generally well-known for its adverse environmental and socio-economic consequences. In the lips of laymen and even researchers on gully erosion across the globe is that gullies are a risk, nightmare, terror, danger, killer, destroyer, disaster, hazard, monster, devil and other such fearful names, which is a true talk. Nevertheless, only a few researchers (e.g. Igbokwe, Akinyede, Dang, Alaga, Ono, Nnodu and Anike, 2008; Abdulfatai et al., 2014; Igwe, 2016) just noted that gully erosion has sand mining as a benefit, without thorough investigation on its full beneficial impacts. These previous researchers were unable to see beyond sand mining as a single benefit of prominence arising from gully erosion wherever it deposits its sediments at either low-lands or waterbodies. Therefore, the main objective of this study is to assess, in a comprehensive manner, the beneficial impacts of gully erosion in Eastern Nigeria through a survey of the directly affected people who are both victims and beneficiaries so as to fill the foregoing gap created by previous studies and contribute to the body of knowledge on the phenomenon. The outcomes of this study will create awareness among the affected people in the region and indeed the global community on the benefits of gully erosion for them to leverage on the opportunities offered by the phenomenon for survival.

2. Materials and methods

2.1. Study area

The study was carried out in Eastern Nigeria, which is a region in Nigeria (Figure 1) where water-induced gully erosion is dominant, and its nine communities with large gullies located in Mgbarakuma, Ikot Ayan Itam, Oko, Igbogene, Ikot Nkebre, Ocha-Ekoli Edda, Abia, Ozu Urualla and Umuebulu II in Abia, Akwa Ibom, Anambra, Bayelsa, Cross River, Ebonyi, Enugu, Imo and Rivers states respectively. The communities are situated in the nine most gully erosion-risk areas with large gullies in Umuahia (Abia), Itu-Uyo (Akwa Ibom), Agulu-Nanka-

Oko-Ekwulobia (Anambia), Yenagua (Bayelsa), Calabar (Cross River), Ekoli-Nguzu Edda (Ebonyi), Udi-Nsukka (Enugu), Ideato-Orlu (Imo) and Oyigbo-Eteche (Rivers) respectively according to National Geo-Hazards Monitoring Centre, Awka (NGHMCA) (2019). The region has a total land mass of 46,977km2. From the region's base population of 30,092,822 persons in 2006 (National Population Commission [NPC], 2010) and population growth rates for Nigeria ranging from 2.67-2.55% between 2007-2023 according to the United Nations (2023), the number of human beings in the region has been estimated to be 46, 809, 600 in 2023.

The region is located between latitudes 50 0′ 0″ N, 70 0′ 0″ N of the equator and longitudes 60 0′0″E, 90 0′ 0″E). It consists of the contiguous states of Abia, Akwa Ibom, Anambra, Bayelsa, Cross River, Ebonyi, Enugu, Imo and Rivers. It is bounded on the east by the Cameroon Highlands, west by the River Niger, north by Kogi and Benue states and the Atlantic Ocean in the south, along the Gulf of Guinea. It was formerly administered as Eastern Nigeria before the Nigerian-Biafran civil war that erupted in 1967 till 1970. From1967 to 1996, the region had metamorphosed politically, through its balkanization by various military juntas who ruled Nigeria over the years, into its present nine constituent states (Figure 2).

Geologically, it is characterized by several mega structural features, notably the Calabar Flank, the Mamfe Embaymeul, the Anamba Basin, the Afikpo Syncline, the Abakaliki Anticlinorium, the Niger Delta, the Oban Massif and the Obudu Plateau (Bassey, 2012) as indicated in Figure 3. The geology of the area influenced gully formation and expansion as well as massive landslides that happened in several communities because the Ameki Formations, Nanka Sands, Ajali Sands and Coastal Plain Sands in the area are very susceptible to the forces of denudation anywhere they were exposed as sandy outcrops (Egboka and Okoyeh, 2016). The region lies within the tropical rainforest and derived savanna belts, with abundant rainfall ranging from 4000mm on the coastal sea board to below 1700m in the Udi-Nsukka Plateau (United Nations Development Programme [UNDP], 1995), varying land forms, scarcely thick natural vegetation and many natural resources like huge crude oil/natural gas reserves, lead, limestone and gold. According to UNDP, the mean annual maximum temperature ranged between 30^0C in Calabar and Port Harcourt to 33^0C in Enugu whilst the mean annual minimum temperature decreased from the interior to the coast, ranging from 29^0C to 21^0C. However, the global climate change is altering the existing pattern of temperature and rainfall, leaving the area with what is seemingly like one maxima duration of rainfall which is short and heavy, devastating the region with gully erosion.

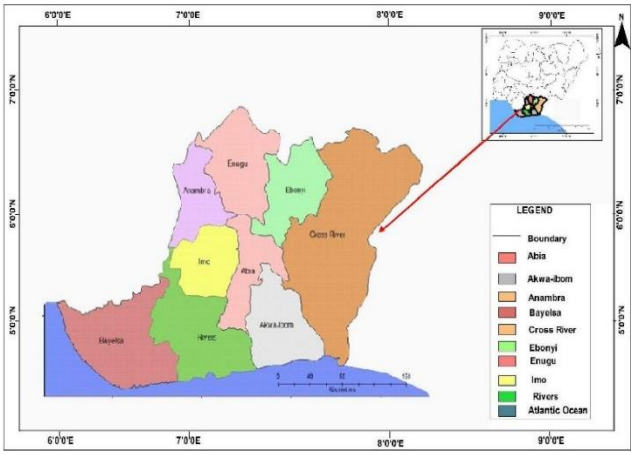

Figure 1: Map of Eastern Nigeria in the map of Nigeria - National Geo-Hazards Monitoring Centre, Awka (NGHMCA), 2020

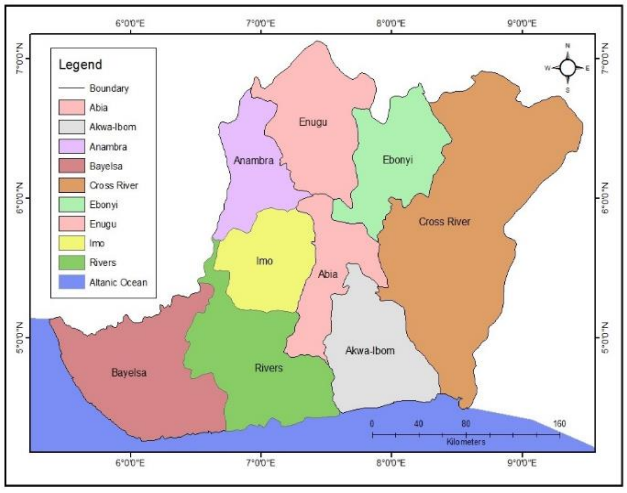

Figure 2: Map of Eastern Nigeria indicating her nine constituent states - National Geo-Hazards Monitoring Centre, Awka (NGHMCA), 2020

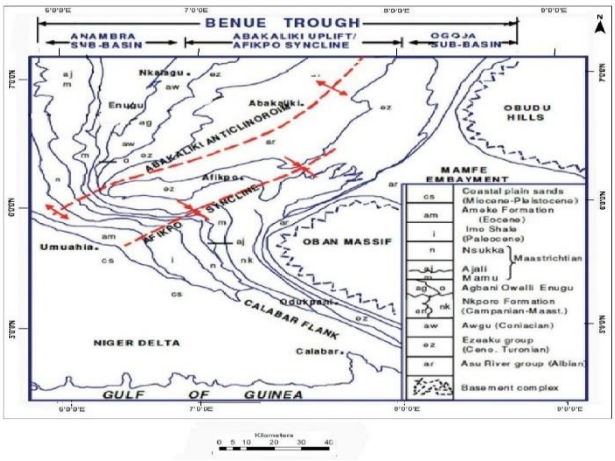

Figure 3: Geological map of Eastern Nigeria indicating the various mega structural features (Adapted from Bassey, 2012)

2.2. Sampling methods and data analysis

The purposive and convenience sampling techniques were employed in the course of the research. Firstly, the nine most gully erosion-risk areas with large gullies were purposively sampled to depict the best gully erosion scenario of Eastern Nigeria. Secondly, the convenience sampling technique was used in selecting a total of nine communities alongside its large gullies, each situated in one of the most gullied area, one in each of the nine states of the region. Reasons for selecting the communities alongside its large gullies were: (i) communities with some residents who constitute the directly affected people living in close proximity to the gullies; (ii) presence of large and active gullies from which sand was being detached and deposited elsewhere at low-lands and waterbodies; (iii) accessibility to the gullies and sand mining sites for easy survey; and (iv) evidence of on-going sand mining activities around which other benefits of gully erosion were pivoted. Thirdly, the purposive sampling technique was also used in selecting 399 household heads as respondents from 399 households situated within 0.3km (300m) radius of the gullies' head-scraps, from which sand is usually detached most because it is the most active part of any gully in its upward movement. The figure was arrived at by counting the number of all the households (399) within the stated distance, out of which one household head was chosen (total: 399) to represent the directly affected people as both victims and beneficiaries. The global locations and elevations of the gullies above the sea level taken at their head-scraps are indicated in Table 1. Unlike the four geographical coordinates used to locate the study area, only two coordinates were used to indicate the point of location of each of the gullies at its head-scrap. The communities sampled bearing the same name with its gullies, the number of household heads and sample sizes are indicated in Table 2. The study employed the survey research design, using observation, questionnaire, interview, photographs and satellite imagery to collect data and information. A total number of 399 copies of questionnaires were administered to the respondents, 370 of them were correctly filled and returned. The Likert Scale used in ranking agreement with statements on the beneficial impacts of gully erosion by the respondents has five levels: strongly agree (5); agree (4); neutral (3); disagree (2); and strongly disagree (1). The Chi-square of SPSS, version 22.0 was used in data analysis. The relationship in the mean rating among the affected people on the beneficial impacts of gully erosion was tested at $p< 0.05$.

Table 1: Locations and elevations of the investigated gullies in the nine studied communities in Eastern Nigeria

S.N.	State	Gully site	Gully location	Elevation (m)
1	Abia	Mgbarakuma	E07º 25' 17" N05º 28' 23"	144.6
2	Akwa Ibom	Ikot Ayan Itam	E07º 59' 07" N05º 07' 17"	37.8
3	Anambra	Oko	E07º 05' 08" N06º 02' 20"	267.6
4	Bayelsa	Igbogene	E06º 24' 10" N05º 02' 41"	10.8
5	Cross River	Ikot Nkebre	E08º 21' 30" N05º 03' 46"	64.2
6	Ebonyi	Ocha-Ekoli Edda	E07º 50' 18" N05º 44' 44"	184.1
7	Enugu	Abia	E07º 24' 53" N06º 20' 04"	428.1
8	Imo	Ozu Urualla	E07º 03' 36" N05º 51' 45"	102.9
9	Rivers	Umuebulu II	E07º 08' 35" N04º 53' 21"	15.5

Source: Researcher's field survey, 2019

Table 2: The population of household heads sampled

S. N.	State	Local Government Area	Community Sampled	Number of Households Sampled	Sample Size
1	Abia	Umuahia South	Mgbarakuma	11	11
2	Akwa Ibom	Itu	Ikot Ayan Itam	22	22
3	Anambra	Orumba North	Oko	78	78
4	Bayelsa	Yenagoa	Igbogene	59	59
5	Cross River	Calabar	Ikot Nkebre	76	76

6	Ebonyi	Afikpo South	Ocha-Ekoli Edda	18	18
7	Enugu	Udi	Abia	33	33
8	Imo	Ideato South	Ozu Urualla	35	35
9	Rivers	Etche	Umuebulu II	67	67
10	9	9	9	399	399

Source: Researcher's Field Survey, 2019.

3. Results and discussion

3.1. Benefits of gully erosion

Like in many parts of the world (e.g. Loess Plateau, China), the enormity of gully erosion problems in Eastern Nigeria appears to be completely sweeping its benefits under the carpet. Igwe et al. (2023a) asserted that the problems occasioned by water-induced gully erosion in the region were: damage to footpaths, roads and properties; soil loss; reduced land productivity and loss of livelihood; nutrient loss upslope, enrichment of low-lands and freshwater bodies; closing of 'eyes' of springs, streams and rivers and sedimentation of low-lands and waterways---impeding navigation. According to the authors, others were: migration of internally displaced persons (IDPs) and loss of human lives; creation of badlands; cause of climate change through destruction of vegetation (a sink for carbon dioxide) and exposure of soil carbon and biodiversity (species of plants and animals) loss. No known study by the researcher has ever investigated this aspect of the phenomenon either in the study area or elsewhere. As a paradigm shift, this study deemed it very necessary to delve into thorough investigation of the beneficial impacts of water-induced gully erosion as these have not been properly harnessed as good windows of opportunities for revenue generation to governments and local authorities as well as a source of livelihood and welfare for the affected people and even beyond. The beneficial impacts of gully erosion investigated in this study were arrived at during the pilot/reconnaissance survey of the region in 2019, when the investigated gullies were critically observed before field survey began in 2020 and ended in 2022.

Gully erosion is not only a tale of environmental and socio-economic woes according to previous researchers (e.g. Tufekcioglu, 2019; Onuoha, Igu and Oluwole, 2020; Olivier, Van De Weil and Clercq, 2021; Dogo, Joseph, and Olatayo, 2023) across the globe. Rather, it is a mixed blessing because it has some benefits noted by some researchers (e.g. Igbokwe et al, 2008; Abdulfatai et al., 2014; Igwe, 2016) who never studied them thoroughly. This study investigated, in a comprehensive manner, the beneficial impacts of gullies and revealed that atop the list of the benefits is self-employment in sand mining activities as loaders (Plate 1), beach owners, food sellers as well as sellers and buyers of sand as a source of livelihood and welfare according to the strong rating by 88% of the respondents (Table 3). It was observed that both residents living proximal to the gullies and outsiders were involved in any of those forms of self-employment opportunities.

This study also revealed sand mining as a core benefit of gully erosion which agrees with the opinions of some previous authors (e.g. Igbokwe, Akinyede, Dang, Alaga, Ono, Nnodu and Anike, 2008; Abdulfatai et al., 2014; Igwe, 2016)) who just note it as a benefit of the phenomenon, strongly rated by 74% of the respondents as a big business that has improved the revenue base of both local authorities and governments through tax payment by miners. The miners confirmed that they were paying tax for their mining activates to the aforementioned bodies. Another finding of the study is bumper harvest of crops cultivated at low-lying areas where sediments containing the nutrient-enriched topsoil are deposited as the third benefit of gully erosion in the strong ranking by 65% of the respondents. The big stems of cassava and luxuriant leaves of yams and vegetables cultivated without chemical fertilizers observed during the field survey at the low-lands were a proof that the crops yields would be very high. Cropping at the low-lands happens mainly during the dry season to avoid heavy damage occasioned by floods during the rains. Harvesting occurs before the peak of the rainy season in July-October, or else floods would swallow the crops. Another beneficial impact of gully erosion found by this study is the removal of sand for use in moulding blocks and road construction which was strongly attested to by 58% of the respondents, who ranked it fourth. It was observed that some of the block moulders established their businesses at the shoreline of rivers where gullies, exemplified by the Ikot Ayan Itam gully in Akwa Ibom State (Plate 2), empty their sediments into.

Yet, another result of this study as strongly rated fifth by 28% of the respondents as a benefit is that sand arising from gullies is a raw material for glass manufacturing industries. For example, it was the use of sand from the Oko gully that prompted the establishment of Alustar Glass Factory in Oko by the former Vice President of Nigeria, late Dr. Alex. Ekwueme. Creation of springs, lakes, streams, rivers as well as exposure of minerals for mining was revealed as the sixth and last benefit of gully erosion by this study according to the strong opinion of 27% of the respondents. For instance, it was observed that the Oko gully erosion site in Anambra State has created the Obubu Ntia and Iyiocha lakes (Plates 3 and 4) as well as the Odo River which is a spring at its headwater in Oko. The gully also exposed kaolin and clay at the gully being mined by the residents, despite the danger of entering the deepest part of the gully and death.

Table 3: Ratings of the benefits of gully erosion.

Benefits of Gully Erosion	SA(%)	A(%)	N(%)	D(%)	SD(%)
Self-employment in sand mining activities as loaders, beach owners, food sellers as well as buyers and sellers of sand as a source of livelihood and welfare	88	9	3	0	0
Sand mining as a big business, improving the revenue base of government and local authorities	74	26	0	0	0
Bumper harvest of crops cultivated at low-lying areas where sediments containing nutrient-enriched topsoil are deposited	65	17	18	0	0
Sand removed for moulding blocks and road construction	58	31	11	0	0
Sand as a raw material used by industries for the production of glasses	28	19	49	0	4
Creation of spring(s) and lake(s) for domestic water supply, by exposing aquifers which are rock-bearing water that exist some metres below the earth's surface and exposure of minerals (e.g. kaolin and clay) for mining	27	13	28	17	15

SA= Strongly Agreed, A = Agree, N = Neutral, D = Disagree, SD = Strongly Disagree
Source: Researcher's field survey, 2020

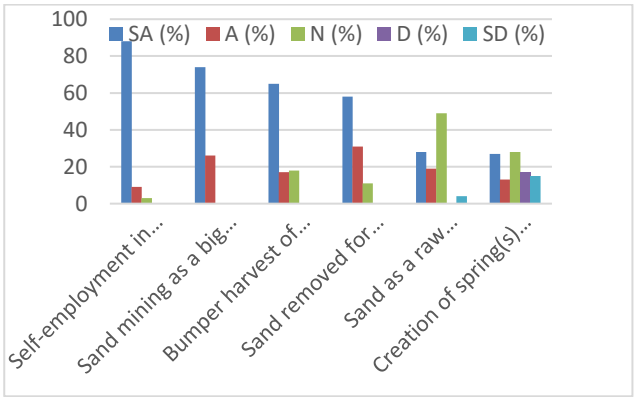

Figure 4: Ratings of the benefits of gully erosion
Source: Researcher's field survey, 2020

3.2. Statistical analysis

The Chi-square ($\mathbf{X^2}$) statistical test summarized in Table 4 which addressed gully erosion benefits suggests that there is a significant difference in the mean rating among the affected people on the beneficial impacts of gully erosion in the region ($\mathbf{X^2}$ = 997.933, p = 0.00 < 0.05 significant level), implying that all the gully erosion benefits are significant enough as to have important effect on the environmental and socio-economic conditions of the affected people and even beyond. For example, sand mining is a big business that has the potential for becoming a reliable source of income for those engaged in it. The self-employment opportunities as beach owners, sellers and buyers of sand, tipper loaders and food sellers as benefits of water-induced gully erosion have important effect on improving the welfare of all those involved in them. If more people engage in the business of sand mining, it would expand the business of food sellers. Essentially, the removal of sand deposited at low-lands and waterbodies in the course of sand mining, would have a remarkable positive effect on the environment of the areas, exemplified by improvement on navigation at rivers. Additionally, the bumper harvest of crops cultivated at the low-lands due to the enrichment of its soils by nutrients detached alongside soil particles upslope, has a very important effect on raising the food security of the communities and indeed the region. Based on the results of this study, government policy on water-induced gully erosion management ought to integrate and emphasize that the phenomenon has benefits that could easily improve the welfare of the affected people in the communities and even beyond. Where the benefits are properly leverage upon, it would lead to remarkable improvement on community development across the region.

Table 4: Summary of the Results of Chi-square Test of Association on Hypothesis that Addressed Gully Erosion Benefits.

	Value	Df	Sig
Pearson Chi-Square	997.933	20	p< 0.01

X^2cal=997.933; X^2tab=37.57; Df = 20, p< 0.01
There is a significant difference in the residents' ratings on the degree of beneficial impacts of gully erosion.

4. Conclusion

This study attempted a paradigm shift in the study of gully erosion which had been extensively focused on its problems (negative impacts) by previous researchers the world over. The study unveiled six benefits of gully erosion, ranging from self-employment in sand mining activities as loaders, beach owners, food sellers as well as buyers and sellers of sand as a source of livelihood and welfare that was rated the highest to the use of sand as a raw material by glass industries which was rated the

lowest by the respondents. No doubt, these six novel outcomes of this study as beneficial impacts of gully erosion would change the perception and narrative about it as a phenomenon that has only adverse environmental impacts to the one that is now a mixed blessing with some benefits that are capable of improving the revenue base of governments and local authorities plus the livelihood and welfare of the directly and adversely affected people and others.

Based on the benefits arising from gully erosion in the region, it is recommended as follows:

a. Maximization of sustainable sand mining activities especially at low-lands, streams and rivers where gullies deposit the sand detached upslope is very important, or else the sand which is always on transit would be conveyed to the Atlantic Ocean, where all rivers, particularly through the major ones: River Niger, Cross River and Imo River in Eastern Nigeria empty their sediments into.

b. Training of youths on sustainable sand mining activities for self-employment is necessary as those who are already engaged in the business in an unsustainable manner are making a good living out of it. Given the large volumes of sand observed to have been deposited at low-lands and highly silted up channels of water bodies in the region, leveraging on this window of opportunity by the youths will lower the high rate of unemployment and crimes amongst them.

c. Government and private enterprises should establish tourist centres around stabilized gullies only and lakes like Obubu Ntia and Iyiocha, which are fall-outs from the large Oko gully, Orumba North Local Government Area, Anambra State.

d. Large quantities of sand arising from gullies in the region which are deposited at low-lands, lakes, rivers and streams should be sustainably mined and used as a raw material for more glass industries to be established by both government and private businesses.

References

Abdulfatai, I. A., Okunlola, I. A., Akande, W. G., Momoh, L. O., and Ibrahim, K. O. (2014). Review of Gully Erosion in Nigeria: Causes, Impacts and Possible Solutions. *Journal of Geosciences and Geomatics*, 2 (3):125-129.

Afegbua, U.K., Uwazuruonye, J., and Jefaru, B. (2016). Investigating the Causes and Impacts of Gully Erosion in Auchi, Nigeria. *Journal of Geography, Environment and Earth Science International*, 4 (4):1-13.

Asuoha, C.C., Okafor, U.P., Phil-Eze, P.O., and Ayadiuno R.U. (2019). The Impact of Soil Erosion on Biodiversity in Isiala Ngwa Local Government Area, Southeastern Nigeria. *Sustainability.* Accessed at: www. mdpi.com/journal/sustainability, 10 05 2020.

Ayele, G.K., Gessess, A.A., Addisie, M.B., Tilahum, S.A., Tebulu, T.Y., Tenessa, D.G., Langendoen, E.J., Nicholsen, C.F., and Steenhius, D.G. (2016). A Biophysical and Economic Assessment of Community-Based Rehabilitated Gully in Ethiopian Highlands. *Land Degradation and Development*, 27: 270-280.

Bassey, E.E (2012). Investigation of the Geochemical Signatures and Conditions of Formations of Metacarbonate Rocks occurring within the Mamfe Embayment of Southeastern Nigeria. *Earth Sciences Research Journal*, 16(2):121-138.

Belayneh, M., and Tsegaye, D. (2020). Current, Extent, Temporal Trends and Rates of Gully Erosion in the Gumara Watershed, Northwestern Ethiopia. *Global Ecology and Conservation.* Accessed at: www. sciencedirect.com, 03 11 2021.

Brown, R. (2020). Gully Erosion, Definition, Causes, Effects and Prevention. Accessed at: www. jotscroll. com, 22 03 2021.

Dalil, M., Ilegueuno, A. A., Babangida, M.S., and Husain, A. (2016). Assessment of the Impacts of Gully Erosion on Auchi Settlement, Southern Nigeria. *Journal of Geography and Regional Planning*. 9 (7): 128 – 138.

Dogo, S., Joseph, W.E., and Olatayo, O.J. (2023). Evaluation of Gully Erosion and Landslides in Southeastern Nigeria.: Causes, Consequences and Control Measures. *International Journal of Innovation Research and Advanced Studies*, 20 (2): 107-118.

Egboka, B.C.E., Akudo, E. O., and Nwankwoala, H.O. (2019). Gully Erosion and Landslides in Southeastern Nigeria: Causes, Consequences and Control Measures. *Global Journal of Engineering Sciences*, 2(4): 1-2.

Egboka, B. C. E., and Okoyeh, E.I. (2016). The Impacts and Implications of Anthropogenic Forces on the Unstable Geological Platform in Parts of Anambra and Imo States, Southeastern Nigeria. *International Journal of Environmental Protection and Policy*, 4 (4): 104-110.

European Union Soil Observatory (EUSO) (2022). Gully Erosion. Accessed at: esdec.jrc.ec.europa.eu, 20 09 2022.

Grahmann, K., Rubio, V., Kenez-Bidegain, M., and Quincke, J.A. (2022). Soil Use Legacy as Driving Factor for Soil Erosion under Conservation Agriculture. *Frontiers in Environmental Science*, 10: 1-15. Accessed at: www.frontiersin. org, 08 02 2022.

Igbokwe, J.I., Akinyede, J.O., Dang, B., Alaga, T., Ono, M.N., Nnodu, V.C., and Anike, L.O. (2008). Mapping and Monitoring of the Impact of Gully Erosion in Southeastern Nigeria with Satellite Remote Sensing and Geographic Information System. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 36:865-872.

Igwe, P.U. (2016). Soil Erosion: Factors, Consequences and Environmental Management Plan. *Book of Proceedings of the 2016 Annual National*

Conference Organized by the Environmental Management Association of Nigeria (EMAN) at Villa Toscana Hotel, Independence Layout, Enugu, Nigeria, pp. 232-243.

Igwe, P.U., Ajadike, J.C., and Ogbu, S.O. (2023a). Assessment of Gully Erosion Problems for its Remediation in Eastern Nigeria. *Journal of Environmental Management and Safety*, 14 (2): 72-88.

Igwe, P.U., Ajadike, J.C., and Ogbu, S.O. (2023b). Assessment of Factors Influencing Gully Erosion for its Remediation in Eastern Nigeria. *African Research Journal of the Environment (Arejoen)*, 6 (1): 8-16.

Kalu, A.C. (2001). Soil Erosion and Landslide: 21st Century Environmental Issues and Challenges to Rural Development in Nigeria. Unpublished MURP Seminar Paper, Department of Urban and Regional Planning, Abia State University, Uturu, Abia State, Nigeria.

Lemma, R., Kebede, F., Mesfin, S., Fitiwy, I., Abraha, Z., and Norgrove, L. (2017). Quantifying Annual Soil and Nutrient Lost by Rill Erosion in Continuously used Semi-arid Farmland, North Ethiopia. *Environ. Earth Sci*., 76: 190-198.

Morgan, R.P.C. (2005). *Soil Erosion and Conservation (3rd Ed.)*. Blackwell Publishing Ltd., Oxford, UK, 304pp.

National Geo-Hazards Monitoring Centre, Awka (NGHMCA) (2019). Mapping of Gully Erosion Sites in Eastern Nigeria. Unpublished Databank on Number of Large Gullies in Eastern Nigeria.

National Population Commission (NPC) (2010). *2006 Population and Housing Census*. Abuja: NPC.

Okuh, D., and Osumgborogwu, I.E. (2019). Adjustments to the Hazards of Gully Erosion in Rural Southeast Nigeria: A Case Study of Amucha Communities. *Applied Ecology and Environmental Sciences*, 7 (1): 11-20.

Olivier, G., Van De Weil, M.J., and Clercq, W.P. (2021). Intersecting Views of Gully Erosion in South Africa. *Earth Science Processes and Landforms*, 48 (1): 119-142.

Oluyori, N.R; Ojo, D.C. (2021). Gully Erosion and its Management in Gwagwalada Area Council, Abuja, Nigeria. *Journal of Architecture and Planning*. Accessed at: www. researchgate.net, 22 12 2021.

Onuoha, D.C., Igu, N.I., and Oluwole, R. (2020). GIS-Based Study of Prioritized Gully Erosion and Flood Locations in Ebonyi State. *Journal of Environmental and Earth Sciences*, 10 (2): 72-114.

Ranga, V., Poesen, J., and Pani, P. (2016). Detection and Analysis of Badlands Dynamics in the Chambal River Valley (India) during the last 40(1971-2010) years. *Environmental Earth Sciences.* Accessed at: www.deepdyve.com, 04 11 2020.

Tufekcioglu, M. (2019). Gully and Streambank Erosion and the Effectiveness of Control Measures in a Semi-arid Watershed. *Fresenius Environmental Bulletin*, 27 (I): 8233-8242.

Udoumoh, U.I., Ahuchaogu, I., Ehiomogue, P.O., Sam, E.N., and Anan, U.A. (2019). Gully Erosion Menace in Uyo; Causes, Effects and Control Measures. *Sapiential Foundation Journal of Education, Sciences and Gender Studies, (SEJESGS)*, 3 (3): 31-45.

United Nations (UN) (2023). World Population Prospects. Accessed at: https: // www.macrotrends.net/countries/NGA/Nigeria/population -growth-rate > Nigeria Population, 10 09 2023.

United Nations Development Programme (UNDP) (1995). Unpublished Documentary Materials on the Environmental Baseline Studies of Eastern Nigeria, Port Harcourt Office.

Ugwulebo, B.A., and Oku, H.B. (2021). Analysis of Temporal Dynamics of Gully Erosion in EFAB Estate (Queens and Varizon Estate), Federal Capital Territory, Nigeria. J*ournal of Research in Environmental and Earth Sciences*, 7 (10): 59-77.

Wilkinson, S., Hawdson, A., Hairsine, P., and Austin, J. (2019). *Gully and Stream Bank Erosion Control Programme, 2nd Edition.* Commonwealth of Australia.

Zhang, H., Lauerwald, R., Regneir, P., Ciais, P., Yuan, W., Naipal, V., Cuenet, B., Van Oost, K., and Camino-Serrano, M. (2020). Stimulating Erosion-Induced Soil and Carbon Delivery from Uplands to Rivers in Global Land Surface Model. *Journal of Advances in Modelling Earth Sciences*. Accessed at: https: //doi.org/10.1029/2020MS002121, 11 11 2021.