Gully Erosion Assessment and Management in Anambra State Nigeria

EGBUNA, ONYINYECHI. K.[1], UNACHUKWU, SOMKENECHI SOPHIA2, ALOM, ANSELEM CHUKWUMA[3]

[1, 2, 3] *Department of Urban and Regional Planning, Nnamdi Azikiwe University Awka, Anambra State, Nigeria.*

Abstract- ***Gully erosion presents a significant environmental challenge in Anambra State, Nigeria, affecting land use, infrastructure, and socio-economic activities. This study focuses on the comprehensive assessment and management of gully erosion sites within the state. Through a combination of field surveys, remote sensing, and GIS analysis, the extent, severity, and underlying causes of gully erosion were evaluated. Various control measures, including re-vegetation, better agricultural practices, drainage management, proper land use management, and early response, were recommended as measures in mitigation of the erosion problem. The findings underscore the critical implications for urban planning, highlighting the need for integrated land use planning and sustainable development strategies to address the erosion problem effectively. This study provides a framework for policymakers and planners in Anambra State to enhance environmental resilience and protect valuable land resources.***

Indexed Terms- ***Erosion Control Measures, Gully Erosion, Land Use Planning, Site Assessment***

I. INTRODUCTION

Soil erosion is a naturally occurring weather process caused by water, wind, or ice. It includes the activities of soil separation, development, and affidavit. It very well may be a sluggish cycle that proceeds somewhat inconspicuously or can happen at a disturbing rate, causing the loss of dirt (Pimentel and Burgess, 2013). Free soil, low natural matter, loss of soil structure, poor inside seepage, salination, and soil corrosiveness issues are other soil corruption conditions that can speed up the course of soil disintegration. As indicated by Pereira, Brevik, Muñoz-Rojas, et. al. (2017), soil disintegration is one of the reasons for land corruption. Exorbitant disintegration can cause biological system harm and the loss of soil and water sedimentation. Gorge disintegration is an overall peculiarity that prompts the loss of significant land utilized for horticultural, homegrown, modern, and tasteful purposes, as well as the loss of property and, surprisingly, living souls. Today, soil disintegration has turned into an endemic worldwide issue in south-eastern Nigeria, in Anambra Express; the word disintegration is inseparable from death and obliteration. More than 75% of the places that are known for Anambra State are assaulted or undermined by delicate or hazardous locales that are at different degrees of advancement and phases of development (Igwe, Ajadike, and Ogbu, 2023). Inside the South Eastern Zone, Anambra State was recognized as the most terrible hit of 1,000 dynamic disintegration destinations in its area (Ike, 2017). A few projects, for example, water system plans, significant street organization, country improvement, urbanization programs designing developments across floodways, and so on, are executed every day of the week without legitimate investigations of the idea of climate change (Uzoma, 2022). Hence, lives and properties are routinely lost. Houses are frequently gulped via avalanches in Nanka, Agulu, Nnewi, Ekwulumili, Obosi, and so on. Antiquated and ongoing normal flood/stream/waterway channels are frequently obstructed with structures supported by town organizers without leaving sufficient well-being flood stream measures. Touchy waste regions, wetlands, and stream channels are infringed upon by hungry land engineers. Unapproved and spontaneous structures spring up in Anambra State inside and across these naturally touchy regions and later block them. The unearthing of red earth, laterite, and sands is completed anywhere and at any rate, frequently without legitimate preparation or consent from important government specialists. The unsafe

deforestation exercises have brought about the loss of the rainforest belt and the resulting savannization of parts of Anambra State. The hazard has negatively affected the financial prosperity of the occupants, to such an extent that terrains utilized for rural purposes, tribal homes, and other foundations are lost at a disturbing rate (Eyankware, Eyankwere, and Effian, 2015). The propriety of a specific variation system is profoundly subject to time, place, social and native perceptions, and practices (Obert and Owen, 2016); furthermore, getting the right areas of these locales and the size of the issue would empower legitimate needs to be set concerning the adaptative methodology. A few versatile methodologies diminish the impacts of soil disintegration: moving development, ridging across inclines, establishing on raised hills, and profound furrowing (Bukari, 2013). His work additionally uncovered that ranchers who effectively applied the conventional strategies further developed their result levels per land region and the way of life of their families. In light of this reason, this study surveyed the systems involved by individuals to control soil disintegration previously and new versatile measures that will assist with diminishing or checking soil disintegration nearby.

II. THE STUDY AREA

With a population estimate of 6,953,500 million people spread over a land mass of 44,116 km^2, Anambra State in the Federal Republic of Nigeria is the most densely populated state in the south-eastern part of the country. The state lies between latitude 5˚ 42′ N and 6˚ 47′N and longitude 6˚ 37′ E and 7˚ 23′ E, being made up of 179 towns divided into 21 local government areas. The study area lies within the tropical region, and its boundaries are formed by Delta State and Edo State to the west for about 97 km across the River Niger, Imo State and Rivers State for 4 km to the south, Enugu State to the east for 139 km, and Kogi State to the north for about 40 km (see Figure 1). The area is influenced by two climatic seasons: the dry and wet seasons. The wet season starts around May and ends in November, with a break in August, and the average annual rainfall is about 1800 mm. The dry season lasts for about 4-5 months, spanning the period from December to April (Anambra State of Nigeria, 2022).

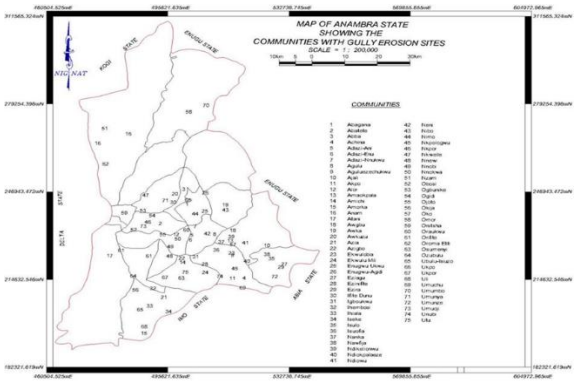

Figure 1: Map of Anambra State showing the communities with gully erosion sites and affected by gully erosion problems.

Erosion in the form of leaf wash, rill/channel erosion, and other factors has severely damaged the soil, especially in the lower reaches of the Awka-Orlu River, which runs through much of central Anambra State. Most soils are lateritic in nature, either from the underlying geology or from adjacent areas. Some soils have been cemented into thin to dense ironstone gravels or fibers, with very coarse soils ranging in thickness from a few centimeters to more than 20 meters (Ofomata, 2000).

III. RESEARCH METHOD

A comprehensive review of previous works was carried out with the aim of identifying sites, causes, and extent of gully erosion in Anambra State, as well as the control measures put in place to check the advancement of the devastating phenomenon. Field work was thereafter embarked upon to examine the gully site, measure its magnitude by way of its depth, length, and width through the use of a global positioning system (GPS) and digital photographs of the gully erosion sites., and assess its impact on the socio-economic wellbeing of the people in the locality, identify causative factors, and appraise the effects of control measures already in place. Where there are no control measures in place, appropriate ways of mitigating the menace are suggested, taking into consideration the physical, geological, and anthropogenic factors at play in the system. Different symbols were used to depict four different categories of gully erosion. The categories are:

Category One: Must severely gully sites.

Category Two: severely gullied sites.

Category Three: moderately gullied sites.
Category Four: Slightly Gullied Site.

IV. DISCUSSION OF RESULT

A. Gully Erosion Menace in Anambra State

The most common cause of erosion is the relatively uniform loss of the soil surface by excess runoff, which is facilitated by steeply sloping terrain, different types of soil and rocks, the removal of vegetative cover, and shoddy construction work. It concentrates over time, creating rills and channels, and if left unchecked, it may spread into the enormous gullies that are strewn over the study area and other regions of southeast Nigeria. The monster has continued to elude efforts to stop it from spreading and damaging more valuable land and properties, as well as occasionally human lives, making it extremely difficult to control the growth of gullies. In certain instances, the action of gullies carries away dams, embankments, culverts, and other engineering construction works, along with trees planted to prevent the development of gullies. These tools are then utilized to further wreak havoc on the nearby soils and rocks (Francisca, Oshim, Ayajuru, Anumaka, & Olayemi, 2023). This necessitates a methodical approach to Anambra State's gully erosion control that integrates and takes into account the causal variables responsible for the emergence of the environmental threat.

Instead of using broad corrective methods, the goal is to provide proper and targeted management measures for the different types of gullies. The Ameki Formation is the primary geological formation in the study region. It is overlain by the Ogwashi-Asaba Formation, which contains lignite and clay, and under it is the dark gray plastic Imo Shale. According to Ocheli, Ogbe, and Aigbadon (2021), the Ameki Formation is mostly sandy with thin bands or laminations of siltstone and clay stone. The sand has medium-to-fine grains and is not well separated. These units are divided by strata of fine sand, shale, and quartzite that may be as thick as 30 meters in certain areas. Additionally, the deposits have well-developed patterns of dark-grey shales layers and alternating cross-bedded sand layers. Usually found in 40–50 cm-thick strata, the shale units alternate with fine sand and siltstone. Between 70 and 90 feet is the typical low dip for the units (Anthony, Ekine, & Onuoha 2008). In general, the sands have thin shaley layers and are loose, friable, and weakly cemented. Its strength is further affected by the fact that the sands are wet and very porous beneath the water table. The water table's depth changes seasonally and geographically. The region experiences heavy rainfall and an increase in the water table during the rainy season. Hydraulic head degradation is the reason for the water table dropping throughout the dry season. As a result, the saturated zone's depth increases and flow rates fall. Gulling activities are thus reduced during the dry season (Anthony, Ekine, & Onuoha 2008). The high pore pressure facilitates the formation and extension of the gully complex, especially during the rainy season's peak recharge periods.

The unconsolidated sands effective strength is decreased by this high pore pressure. Runoff progressively erodes and loosens the sands. The formation of gully erosion is facilitated by the behaviour of the interbedded shales and clay, which experience significant volume fluctuations due to alternating wetting and drying. When the shale becomes wet during the rain, its volume increases, and it turns plastic and sticky. They accumulate into a cake-like, dry mass throughout the dry season. Widespread tension fractures are formed when the clay and shale shrink as a result of drying. With time, these fissures enlarge, and when it rains, they act as pathways for water to go vertically toward the underlying sand and shale borders. After many days of rain, the shales and clays are completely saturated, swell, and start to slide. Deep into the gully, large amounts of sand slip beneath this flexible shale and clay, the shale serving as a lubricant. The sliding mass has taken away the trees, embankments, and dams that were initially intended to manage the threat and protect local residents' houses in the gullies.

Through chemical weathering, the hydro-geochemical features of the region play a significant role in the gully's formation and expansion (Anthony, Ekine, & Onuoha 2008). Because the groundwater and surface water have a small acidity, the cements that hold the rock particles together break down more easily, leaving the particles more susceptible to erosion from excess runoff and mass wasting. Dams and other civil engineering projects installed to mitigate the danger

are attacked and disintegrated by the same acidic water (Nich & Okekeogbu 2017). Complications have also been made worse by human meddling with the natural geologic system. The majority of erosion areas are located close to densely populated small towns and villages. The land that is available is used for farming and development, the majority of which is poorly designed. This results in eroding potential, concentration of surplus runoff at high velocity, and obstruction or alteration of the natural water channel ways. Anambra State's widespread habit of deforestation exposes the rocks and soils to extreme gulling (Figure 2). Despite efforts by the federal government, state governments, local governments, towns and community unions, and individual citizens, gulling has continued. The ravine stretches kilometers in length and has widths and depths measured in tens and hundreds of meters in places like Agulu, Agulu-Ezechukwu, Nanka, and Nkpologwu (table 1). In general, despite the management measures already in place, the majority of the gully sites surveyed is still quite active. For instance, at Ekwulobia, the culvert, pavement, and bamboo trees that were employed to control the gully were visible directly at the base of the channel that had been moved by sliding. At the location and other locations visited, extensive civil construction is being done to mitigate the threat (Figure 4).

B. Assessment of the gully erosion site

The positional data (coordinates) of the different categories of gully erosion were used to plot the positions of the erosion. Different symbols were used to depict four different categories of gully erosion. Three factors were considered as the criteria for the categorization of gully sites. They are the depth of the gully site, the length of the gully site, and the level of destruction of lives and property so far. For most severely gullied sites, the depths are 90 m and above. Severely gullied vary from 70 m to 90 m. Moderately gullied ranges from 40 m to 70 m, while slightly gullied ranges from 5 m to 40 m. With respect to the length of gully sites, the most severely gullied sites were estimated at 500 m and above. Severely gullied, between 250m to 400m; moderately gullied sites, between 150m to 250m while slightly gullied, between 50m to 150m. On the level of destruction of lives and properties, nearby residents of the gully sites were interviewed to obtain the level of destruction that has taken place so far as a result of the gully effects.

Table 1: Analysis of some stage 4 gully erosion site

Gully site	*Coordinate*	*Elevation*	*Trend*	*Depth (m)*	*Length (m)*	*Width (m)*	*Stage/ Geometry*
Achina	N5^{0}57.2’ E7^{0}7.3’	275	143^0	10	155	2	Active/V-shaped
Agulu	N6^{0}6.5’ E7^{0}3’	190	330^0	20	2100	86	Active/U-shaped
Agulu-Ezechukwu	N6^{0}0.1’ E7^{0}6.6’	144	152^0	12	1200	23	Active/V-shaped
Akpo	N5^{0}57.2’ E7^{0}6.4’	200	300^0	17	25	18	Active/V-shaped
Ekwulobia	N6^{0}1.8’ E7^{0}5.6’	748		60	1010	42	Active/V-shaped
Ezinifite	N5^{0}58’ E7^{0}3.3’	260	165^0	3	900	8	Active/V-shaped
Nanka	N6^{0}2.4’ E7^{0}4.6’	249	275^0	66	2900	349	Active/U-shaped
Nkpologwu	N5^{0}59.1’ E7^{0}5.5’	210	105^0	25	1800	73	Active/U-shaped
Umuchiana	N6^{0}1.34’ E7^{0}4.5’	278	160^0	18	1010	70	Active/U-shaped
Umuchu (A)	N5^{0}56.6’ E7^{0}8.1’	222	252^0	10	1500	12	Active/V-shaped

Umuchu (B)	N5^{0}56.6' E7^{0}8.1'	200	28 0^0	12	165	12	Active/V-shaped

There are 179 communities in Anambra State; 75 communities are affected by gully erosion. This ranks Anambra State highest in the entire Eastern States of Nigeria in terms of gully erosion-affected states. The gully sites were assigned names according to the communities in which they exist. Category-one gully erosion sites are the most severe gully sites. The depths of the gullies are over 90 m, with lengths of 500 m and above (Figure 4). With respect to the length of gully sites, the most severely gullied sites were estimated at 500 m and above. Severely gullied sites are between 250 and 400 m; moderately gullied sites are between 50 and 150 m. On the level of destruction of lives and properties, gully effects range from one degree of destruction to another. Such as devastating roads, buildings, farmlands, springs, and streams, as well as threatening homesteads. Others are the loss of human and animal lives, markets, schools, etc. Category-one gully erosion sites are the most severe gully sites. The depths of the gullies are over 90 m, with lengths of 500 m and above. These most severe gullies have destroyed several lives, homesteads, buildings, lands, streams, roads, etc. They require a lot of funds to be controlled. These gully sites are located in Nanka, Oko, Ekwulobia, Ozubulu, and Agulu-Ezechukwu.

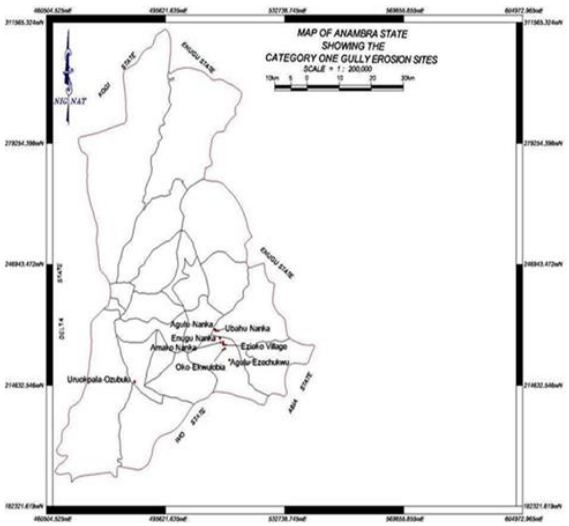

Figure 4: Map of Anambra State showing the category one gully erosion sites

Category two gully erosion sites are the severely gully sites. The depth of the gullies varies from 70 m to 90 m, with a length of between 250 m and 400 m. These are severely damaged sites. The communities affected are shown.

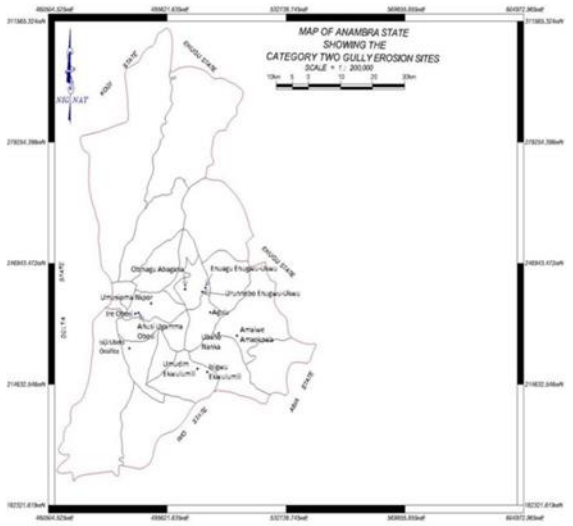

Figure 5: Map of Anambra State showing the category two gully erosion sites

The category three sites are the moderately gully sites, ranging from 150 m to 250 m. The map (Figure 6) shows there are 30 moderately gully erosion sites in Anambra State.

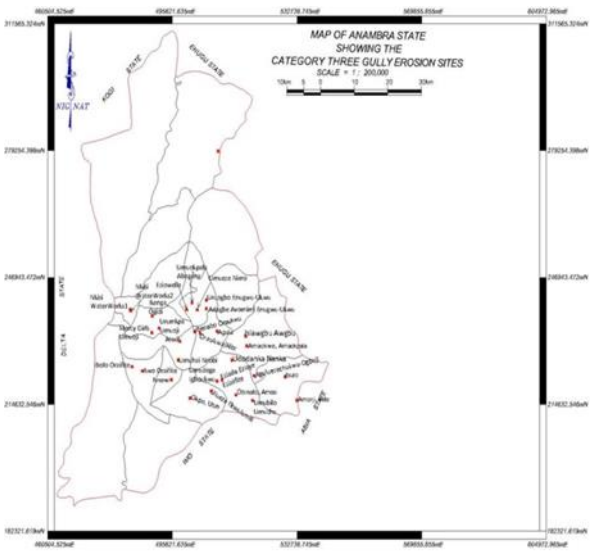

Figure 6: Map of Anambra State showing the category three gully erosion sites

Category four gully erosion sites are the slightly gully sites. The depth of the gullies varies from 5 m to 30 m, with a length of between 50 m and 150 m. The map (Figure 7) shows that Anambra State has 85 slightly gullied sites. These are slightly gully sites. Many of them are under control through the use of trees, especially bamboos. Furthermore, more effort is needed to ensure that they are permanently checked.

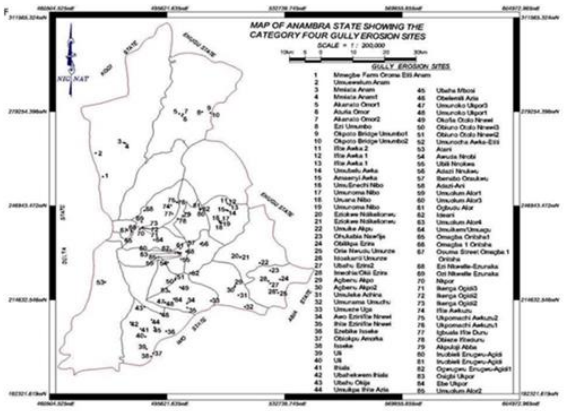

Figure 7: Map of Anambra State showing category four gully erosion sites

C. Factors Responsible for Gully Erosion in Anambra State.

Gully erosion in Anambra State, Nigeria, is driven by a combination of natural and human-induced factors. These factors contribute to the severity and frequency of gully formation, posing significant environmental, economic, and social challenges. Anambra State's soil composition is predominantly sandy, making it highly susceptible to erosion due to its loose structure and low cohesion. The underlying geology of sedimentary rock formations, which are less resistant to erosion, exacerbates the problem. The state's varied topography with steep slopes accelerates water runoff, enhancing the erosive power of flowing water, which contributes to gully formation. The region experiences intense and frequent rainfall, especially during the rainy season, leading to significant surface runoff. Short, intense bursts of rain have a higher erosive potential compared to longer, less intense rainfall. The clearing of forests for agriculture, urban development, and other purposes reduces the protective cover over the soil, making it more prone to erosion. The removal of trees and shrubs decreases the root systems that stabilize the soil, thus increasing erosion risks. Agricultural practices such as slash and burn, which involve clearing large tracts of land, leave soil exposed and vulnerable to erosion. Rapid urbanization leads to increased impervious surfaces (e.g., pavements and roof tops), which enhance surface runoff and contribute to gully formation. Construction activities, including road building and housing projects, without proper planning and erosion control measures disrupt natural water flow and soil stability. Inadequate or poorly maintained drainage systems fail to manage runoff effectively, leading to water accumulation and concentrated flow that initiates gullies. Debris and siltation can block drainage channels, causing overflow and erosion in the surrounding soil.

Limited knowledge and awareness about soil conservation techniques among local communities exacerbate the problem. Insufficient funding and resources for implementing effective erosion control measures hinder progress in addressing the issue. Changes in land use and hydrological dynamics, including increased runoff from impermeable surfaces, contribute to the formation and expansion of gullies.

D. Gully Erosion Mitigation in Anambra State

The control of the erosion disaster should be scientifically and systematically implemented rather than the common and general practice of channelization and embankment construction. Nich & Okekeogbu (2017) attempted a genetic classification of gullies and proposed specific control measures and methods for the different classifications. Obiadi, Ajaegwu, Anakwuba, & Onuigbo (2011) are of the opinion that detailed pedological, geological, hydrogeological, geotechnical, and hydrogeotechnical characterization of the region threatened by gullies should be done as a prerequisite for the adoption and design of the most efficient control method to be employed. Gully walls can be stabilized through civil engineering works such as the construction of embankments and grouting. Most gullies are associated with tension cracks, which aggravate the devastation. Simple grouting and stabilization can arrest the progress of gullies, especially when applied at a very early stage of development (Liu, Zhang, Zhu, & Hu, 2022). Excess runoff can be channelled to a local base-level stream or river by the construction of drainage. These drainages must get to the local base stream or river level; otherwise, they form triggers at

their discharge points. Materials to be used for the construction work should be acid-resistant, especially where hydro-geochemical analysis of the surface and groundwater in the vicinity of the gully shows acidity. Groundwater level influences the development and growth of gullies; therefore, controlling groundwater level through the installation of wells and dewatering facilities at strategic locations is necessary to check this. The pumped water can be put to other domestic and industrial uses. An extensive afforestation program can be very effective in controlling gully erosion, especially when well applied (Ocheli, Ogbe, & Aigbadon, 2021). This helps to protect the soil from the direct impact of raindrops and runoff, as well as maintain the moisture content of the soil at a responsible level during the dry season. Stability in moisture content is important to avoid the formation of tension cracks, which trigger erosion. Gully-prone areas should be delineated and human activities such as agriculture and civil works should be controlled, as these act as gully triggers and catalysts (Singh & Singh, 2017). The most effective control measure, when identified through scientific studies, should be extensively applied and monitored to achieve the desired objective.

E. Implications for Urban Planning

The urban planners that shall be involved must show the highest degree of commitment, expertise, and morality. There is a need for genuine and good conscience that shall encourage the management of whatever meager financial resources are made available. The urban and rural problems of floods, soil and gully erosion, and landslides that have assumed disastrous consequences in Anambra State demand carefully planned and executed multi-objective but integrated study and control programs that shall become permanent. Landuse and environmental planners must engage in a sub-catchment management strategy for floods, gully erosion, and landslide control with an implementable design. There must be continuous development control strategies that will avert illegal development that tampers with existing flood channels. Urban planners must insist on erosion control measures being adopted in any development unit. There must be the agro-forestry aspect, which includes the use of an alley cropping system, the use of multi-purpose and ornamental trees and shrubs, the use of vetiver and bahama grasses, the use of bamboo plants, etc. The role of forest vegetation in contributing to healthy living and preventing flood menaces must be well understood. Drainage and drainage channels must be an important factor and consideration in any development project, including road construction. Conservation and maintenance of existing water bodies in land use plans must be a major priority. Landuse and environmental planners should be updated on the measures to handle floods and erosion problems in development projects as a result of climate change effects.

CONCLUSION

Anambra State, in east Nigeria, can be said to have an unfair share of gully erosion. Field studies show that this environmental hazard has remained active and has continued to defy control measures put in place to checkmate it, thanks to the peculiar geological, hydro-geological, geotechnical, hydro-geochemical, climate, and anthropogenic factors at play in the area. The effects of this menace on the indigence have been enormous, ranging from the loss of access roads to neighbouring communities, farmland, and crops to ancestral homes, livestock and properties, and even human lives. The government, communities, and individuals have continued to combat this monster with little or no success. This is attributed to the peculiar geology of the area and the generalized and non-specific control methods employed in combating gully erosion. A scientific and systematic approach that integrates the influence of all factors responsible for gully development and growth should be adopted for the control of gullies within the state and region. These control measures should be extensively applied and monitored for effectiveness.

REFERENCES

[1] Anambra State of Nigeria (2022). Nigeria Information & Guide. www.nigeriagalleria.com. Retrieved 20 May 2022.

[2] Anthony.S. Ekine; & K. M. Onuoha (2008). Burial History Analysis and Subsidence in the Anambra Basin, Nigeria. *Department of Physics University of Port Harcourt, Nigeria; Department of Geology University of Nigeria, Nsukka, Nigeria*. www.ajol.info.

[3] Bukari; F.I.M. (2013). Indigenous Perceptions of Soil Ero-sion, Adaptations and Livelihood Implications. The case of maize farmers in the Zampe Community of Bole, Ghana. *Journal of Natural Resources and Developments*, 3. 114-120.

[4] Eyankware, R. O., Eyankwere, M. O., & Effian, S. C (2015). Soil Erodibility Assessment in selected part of Ekwusigo Local Government Area Anambra State South-Eastern Nigeria. *International Journal of Innovation and Scientific Research*, 13(1). 50-62

[5] Francisca, O., Oshim, C., Ayajuru Nelson, C., Anumaka Collins, & S. Olayemi Opeyemi. (2023). Review of Gully Erosion in Anambra State: Geology, Causes, Effects, Control Measures and Challenges Associated with Its Mitigation. *Journal of Geography, Environment and Earth Science International* 27(9).102-16. https://doi.org/10.9734/jgeesi/ 2023/v27i9709.

[6] 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). 72-88

[7] Ike P.C. (2017). Impact of Climate Change and Mitigation Measures: The Case of Gully Erosion in South Eastern Nigeria, Nigerian Agricultural Policy Research Journal. 2(1). http://aprnetworkng.org 31

[8] Liu W., Zhang H., Zhu J., and Hu A (2022). Strategies for Gully Stabilization and Highland Protection in Chinese Loess Plateau. Front. Earth Sci. 10:812609. doi: 10.3389/feart.2022. 812609

[9] Nich, I. O., & Okekeogbu, C. J. (2017). Erosion Problems and their Impacts in Anambra State of Nigeria: (A case of Nanka Community). *International Journal of Environment and Pollution Research*, 5(1). 24-37

[10] Obert, P. C. and Owen, M. (2016). Seasonal Climate Prediction and Adaptation Using Indigenous Knowledge Systems in Agriculture Systems in Southern African: A Review. *Journal of Agriculture Science*, 2(1). 23-27.

[11] Obiadi I.I., N. E. Ajaegwu, E. K. Anakwuba, & E. N. Onuigbo (2011). Gully Erosion in Anambra State, South East Nigeria: Issues and Solution. *International Journal of Environmental Sciences.* 796-806.

[12] Ofomata, G. E. K. (2000). Classification of Soil Erosion with specific reference to Anambra State. Environmental Review, 3(2). 14-23

[13] Ocheli, A., Ogbe, O.B., & Aigbadon, G.O. (2021). Geology and geotechnical investigations of part of the Anambra Basin, South-eastern Nigeria: implication for gully erosion hazards. *Environ Syst Res* 10, 23. https://doi.org/10.1186/s40068-021-00228-2

[14] Pereira, P., Brevik, E. C., Muñoz-Rojas, M., Miller, B. A., Smetanova, A., Depellegrin, D., & Cerdà, A. (2017). Soil mapping and processes modelling for sustainable land management. In *Soil mapping and process model-ing for sustainable land use management*. 29-60

[15] Pimentel, D., & Burgess, M. (2013). Soil Erosion Threatens Food Production. *Agriculture*. 3(3). 443-463. https://doi.org/10.3390/agriculture3030443

[16] Singh, R., and Singh, G.S. (2017). Traditional agriculture: a climate-smart approach forsustainable food produc-tion. *Energ. Ecol. Environ.* 2. 296–316

[17] Uzoma Nzeagwu (2022). Gully erosion destroys 70% of Anambra land area says commissioner. The Guardian, guardian.ng/news/gully-erosion-destroys-70-of Anambra –land-area-says-commissioner/