Sustainable Geo-Textile, Gully Rehabilitation and Environmental Monitoring in Uyo Urban, Akwa Ibom State, Nigeria

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Abstract
The study focused on ‘’ Sustainable Geo-Textile, Gully Rehabilitation, Environmental Monitoring in Uyo Urban, Akwa Ibom State, Nigeria’ was aimed at investigating the level of gully monitoring and rehabilitation in Uyo urban, the challenges facing monitoring and how such knowledge can translate into mitigating the level of risk residents within gully degraded environment faces from unprepared disaster eruption owing to poor environmental monitoring. 400 copies of questionnaires were distributed to the sampled communities and the result of the data was further subjected to empirical analysis using chi-square. The results of findings indicated a calculated value of 259.4 and a table value of 19.532, which by implication shows that there is a significant effect of gully erosion on livelihood of residents in Uyo LGA. Methods of rehabilitation were identified in the study and they included the use of vigilante, planting of trees/grasses, routine visiting and many others. In terms of the effect of gullies on livelihood, it was noted that gully erosion has a significant effect on the livelihood of local communities especially affecting food production through degradation of the land and decline in soil fertility. It has been revealed in the work that gully erosion pose a significant negative impacts on agricultural farmland, residential buildings, soil fertility, crop yield, environmental quality as well as socio-economic development. The author identified the challenges facing gully rehabilitation and monitoring and they included low funding, low interest on monitoring, lack of awareness, high cost of gully infrastructure and 40 respondents and weak policy implementation. Further findings revealed that the failure in monitoring newly formed and passive gullies have led to the proliferation and structural deformation in gullies parameter which ended up threatening human livelihood and infrastructures. However, recommendations were made to promote effective monitoring and rehabilitation for disaster occurrence such as sustainable farming, compensation of victims, routine visiting, the use of satellite remote sensing for monitoring, community vigilante, increment in allocation of ecological funds, integration of educationist, researchers and expertise in environmental project implementation.
Keynotes: *Sustainable Geo-Textile, Gully Rehabilitation, Environmental Monitoring, Uyo Urban, Akwa Ibom State, Nigeria*

1.1 Introduction

Nigeria's environment is under increasing threat from natural disasters, such as drought, and anthropogenic (human) activities (Abraham et al 2018; Ofomata, 2000). There are already certain ominous problems with the environment and visible scars associated with the destruction of the natural resource base (land, water and air) upon which all life depends (Abraham et al 2017). The country's large population and its rapid growth rate are putting serious pressure on its environmental resources. The key environmental issues facing Nigeria can be captured broadly in terms of land degradation and air and water pollution. Much of Nigeria's arable land is being sapped insidiously of its productive potential through overuse and inappropriate technologies. Rapid deforestation, resulting from unsustainable use of forest resources for human survival (e.g. fuel wood and energy, housing etc.) is a major contributing factor to land degradation. The end result of deforestation and other agricultural activities, including intensive grazing, over-ploughing and over-cultivation, is severe land degradation, usually resulting to gullies (Abraham , Rogers and John 2018).

Following the extent of land degradation, environmental remediation or rehabilitation becomes necessary so as to promote further land use in degraded landscape. Environmental remediation and restoration focus on the development and implementation of strategies geared to reverse negative environmental impacts.

Geo-textile being a new coinage is concerned with the landscaping (the earth's blanket) using ecological measures including trees, shrubs and ornamental plants. The idea behind geo-textile is to put another clothing to the earth surface where it has been torn.

Geo-textile was first used in the field of engineering for erosion control and road construction before other disciplines began to show interest and applying the approach to other life's problem (Abraham et al, 2023; Kacorzyk, 2021).

The history of geotextiles in landscape design and engineering is closely tied to the development of materials used for soil stabilization, drainage, erosion control, and structural support in civil engineering projects. Geotextiles are synthetic fabrics or textiles used in construction and landscape applications for reinforcement, filtration, separation, and drainage (Shin, 2018).

Geotextiles have evolved significantly from their humble beginnings using natural fibers to the modern-day synthetic fabrics that are crucial in landscape architecture and civil engineering. Their role in stabilizing soil, controlling erosion, improving drainage, and enhancing landscape design continues to grow as sustainable materials and eco-friendly practices gain importance in modern construction and landscaping. Today, geotextiles remain a key component in managing natural resources, improving infrastructure longevity, and promoting environmental sustainability.

Before the widespread use of synthetic materials, natural fibers such as jute, coir (coconut fibers), and hemp were commonly used for erosion control and stabilization in agricultural and landscape projects. These materials helped improve soil retention, reduce erosion, and support plant growth along riverbanks and coastal areas. However, their durability was limited compared to modern geotextiles.

The first significant development in geotextiles came in the mid-20th century. In the 1950s, synthetic materials such as polypropylene and polyester became widely available. These materials were stronger, more durable, and resistant to decay compared to natural fibers, which made them more suitable for large-scale landscape and engineering projects (Erickson, 2021).

The use of geotextiles in civil engineering began to grow, especially in road construction, drainage, and erosion control projects. The ability of synthetic geotextiles to separate layers of soil, allow water flow, and prevent soil mixing was quickly recognized as beneficial in improving the longevity and stability of infrastructure.

Geotextiles were used primarily in road construction to improve subgrade stabilization and increase the lifespan of roads and highways. In the 1970s, research and development efforts led to a greater understanding of the benefits of geotextiles (Shao, 2020). This period saw the expansion of their use in various landscape and civil engineering applications, such as erosion control, drainage systems, and even in landscaping projects like green roofs and retaining walls.

Geotextiles started to gain traction in drainage systems. Their ability to filter and separate soil from gravel or other drainage materials made them essential in managing stormwater runoff and preventing clogging of drainage systems. The use of geotextiles spread further into erosion control in 1980s, especially in coastal areas and along rivers. Geotextile tubes and mats were introduced to help stabilize shorelines and prevent soil erosion in areas vulnerable to wave action and heavy rainfall.

By the 1990s, geotextiles were widely used in landscape architecture, stormwater management, and civil engineering for their strength, versatility, and environmental benefits. The focus shifted toward sustainable and eco-friendly practices. The design of geotextiles evolved to include biodegradable options, which offered a more environmentally friendly solution for short-term erosion control and planting support in landscape designs. Nonwoven geotextiles became popular for their superior filtration and drainage properties.

The use of geotextiles continued to grow in applications such as green infrastructure (e.g., green roofs, bioswales, and permeable pavements (Shao, 2020). Geotextiles were also used to support vegetation in areas prone to erosion, acting as a protective layer while allowing for the natural growth of plants.

Sustainable geotextiles made from recycled materials or biodegradable fibers have gained popularity as part of green building and landscaping practices. There is a growing focus on using geotextiles in urban landscapes, stormwater management systems, and landscape reclamation projects.

Anthropogenic activities often perturb earth landscape and severely limit its capacity for regeneration (Udosen, 2013). After the degraded environment is restored or rehabilitated, monitoring becomes essential in ensuring that the recovered environment is not further degraded by human activities. Sarminah (2014) suggested that the choice of plant species for land rehabilitation and water and soil conservation program must be carefully taken into consideration. In general, ground cover plants are vine-type legumes that are planted in between the annual crops, grown alternatively with the annual crops, or raised as pioneer crops in degraded land rehabilitation (Idjudin 2011). The merit of sengon (*Falcatariamoluccana*) as forest tree species for agroforestry has been reported by Sudomo (2007) and Wahyudi and Panjaitan (2013).

In addition to the suitable plant species, the success of land rehabilitation project is determined by the proper combination of the plants constituting the agroforestry system. The combination must not only satisfy the biogeophysical condition of the land but also be compatible with the social, economic, and cultural aspect of the local community. Karmini et al. (2017) reported that sengon peanut- based agroforestry system in East Kalimantan made a profit of Rp 3,015,000.00/ha/season (226.96 USD/ha/season). As an alternative land rehabilitation policy, agroforestry system is viable to be applied on a degraded land.

Agroforestry offers ample benefits, it is a relatively simple technology greater output for household. Environmental monitoring is one of the measures in carrying out environmental management. It involves a process of obtaining repeated measurement or observation of environmental phenomena for the purpose of understanding the internal structure and working of the phenomena (Ayele, 2019; Ikenna, 2019; Igbokwe, et al 2009; Chikwendu, & Uchendu, 2019). This provides an avenue to judge the current state of the environment and its impact thereof. This is done by evaluating sets of impact indicators in line with its corresponding environmental components such as air, water, soil, wildlife, vegetation, socio-economic livelihood, etc. It is the condition of these impact indicators that gives an insight to the actual state of the environment. Environmental monitoring calls for regular evaluation of these impact indicators within specified intervals. Environmental Monitoring is the series of processes, procedures and activities undertaken with a view to ascertaining the quality of the environment (Neville et al ***2017)***. Environmental monitoring is usually characterized by ascertainable strategies and programmes and it usually end up with reports and outcomes with justifications that are often more than not intended to ascertain the existing condition or status of a particular environment or to establish trends in environmental parameters. The results of such monitoring are reviewed, analysed and published. Environmental monitoring can be in relation to air quality, soil and water quality monitoring as the case may be. Its parameters incorporate five elements, namely: chemical, biological, radiological, microbiological and finally, populations (Oliver, Franz, and Wolf-Fritz, 2010). Monitoring is concerned with identification and measurement of impacts from development. It is a process of repetitive observation of one or more elements or indicators of the environment according to pre-arranged schedules in time and space in order to test or postulates about man's impact on the environments (Tibebu, et al 2014; Jones, 2017; Kerenku & Iorkyar, 2017).

Monitoring is an important tool for gaining insight into understanding the performance of a given environmental project including gullies and flood. Development of environmental monitoring has generally relied on research aiming at improving monitoring methodology, technique or practice within a particular management tool (Jones, 2017). Environmental Performance Monitoring (EPM) involves gathering and evaluating data to determine whether the gully rehabilitated site is sustainable, perturb, modified and the need for emergency attention in the case of intrusion by man. Environmental monitoring programmes are targeted towards variables identified as important for the specific local ecological system. Variables monitored must be environmental, socially and economically important. A typical monitoring programme will describe the techniques commonly used and also state clearly why monitoring of the environment is important. The necessity for monitoring rehabilitated gully sites becomes more demanding most especially in the post-covid era whereby the poor masses in rural communities are vulnerable to intrude gully degraded areas for one economic activity and the other.

1.2 Statement of the Problem

In many part of the developing country, the problem of managing an environmental project most especially gully rehabilitated site has generated enormous constraint to policy makers and community involved. Cases of rehabilitated sites relapsing to its initial degraded status have been noted in some communities across Nigeria. This scenario calls for effective monitoring among relevant stakeholders. In Akwa Ibom State for instance, there are some rehabilitated sites that acts as either tourist centre, forest reserve and many other essential purposes, while there are others that have been rehabilitated and further degraded due to poor monitoring. Climatic factor like extreme rainfall can play a

significant role for a re-degradation of a gully site apart from human-induced factors. Harun (2019) who carried out a study to examine the relationship between rainfall and slope failure at South Bound, New Jersey and the effect of rainfall toward the stability of the slope, at initial and after rehabilitation works, noted that rain contributed to slope failure events. In his study, intensity of rain as well as period of rain contributed to slope instability in that the longer the slope is exposed to the rain, the higher the risk of the slope to fail. Ehiorobo and Izinyon (2011) studied Monitoring Gully Formation and Development for Effective Remediation and Control in Nigeria and revealed that floodstorm influence the re-degradation of a gully rehabilitated site in such a manner that slumping and widening of gully cross sections occurs only in the section where flood water discharge are in appropriately terminated. From these literatures, the need for monitoring gully rehabilitated sites is very important given the huge expenditure involved in gully rehabilitation and the need for effective land use planning. Such a scenario motivates the researcher to undertake studies on environmental monitoring on gully rehabilitated sites in Uyo so as to facilitate effective land use planning and sustainable livelihood. The aim of the study is to examine Sustainable Geo-Textile, Gully Rehabilitation and Environmental Monitoring in Uyo Urban, Akwa Ibom State, Nigeria through the following objectives:
i. To identify the major gully rehabilitated sites that need monitoring in Uyo LGA.
ii. To assess the various methods of monitoring gully rehabilitated sites in Uyo LGA.
iii. To examine the effect of monitoring gully rehabilitated sites on community livelihood in Uyo LGA
iv. To assess the challenges facing gully rehabilitation and monitoring and measures for improvement.

1.3 Study Area

Uyo LGA lies within latitude 5' 02" N and longitude 7' 50" E. It is bounded in the north by Ikono, Ibiono Ibom and Itu Local Government Area, in the south by Ibesikpo Asutan, Nsit Ibom and Etinan Local Government Areas, in the east by Uruan Local Government Area and in the west by Abak Local Government Area. It covers a total land mass of 155.856 square kilometers. The Local Government is made up of four clans namely Oku, Etoi, Offot and Ikono Ibom.

Uyo LGA falls within the sub equatorial region, the climate is made up of two seasons; the dry and rainy seasons. The rainy season begins in March to November and is characterized by heavy flooding and several erosion. The frequency of rainfall and its intensity influence gully development in this humid tropical terrain.

Uyo is characterized by a gentle undulating terrain. According to Usoro and Akpan(2010), Sandstone hills and ravine are attributed to parts of Uyo. The area is believed to have been submerged by the Atlantic Ocean during the Cenozoic area. The soil type of Uyo is typically ferrasol/ tertiary plain sands, generally referred to as acid sands, which are fragile and susceptible to erosion; the loose, friable and unconsolidated ferralistic soils are deficient in weatherable mineral reserve (Udosen, 2008). Erodibility of the soil explain why gullies encroaches faster in Uyo urban and its environment. The are fewer gully rehabilitated sites: Gully site at Brooks Street, Gully site at Midwifery, Gully site at University of Uyo as well as the non-rehabilitated sites are Etim Umana, Ekpri Nsukara, Etoi and CCC.

Research Hypothesis

Ho: There is no significant impact of Environmental Monitoring on sustainable geotextile management in the study area

2.1 Literature Review

Landscape restoration or gully rehabilitation entails to the act of returning an area/landscape to its original state. Leaving terms like natural or pristine, we can have different original states of landscape to which we will be able to restore it. Likewise the restoration activities will be determined by the kind of landscape characteristics and local practices (Allison, 2004a). The success of restoration efforts can vary among sites because of sites‘ variation in hydrology, microclimate, and movement of plants, animals, and disturbance regimes (Holl et al., 2003). On the other hand, in order to bring back the productivity of landscapes which are now lying barren and less productive to more productive and sustainable or to take back the existing natural landscape in its intact state, three types of interventions such as complete restoration, limited restoration or protections of landscape could be applied (Zhang et al., 2011).

Different studies (for example, Hurni, 1993; Gao et al., 2011; Nyssen et al., 2007; Mengistu, 2011; Wendwessen, 2019) have described the successes and benefits gained from landscape restoration or area exclosure as described hereafter. Gao et al. (2011) described that in the Tibetan Plateau, exclusion of livestock grazing from degraded landscape for 10-years enhanced vegetation recovery (increased biomass production and growth of the perennial grass); improved soil organic carbon, and nutrient (total N, and P) contents; and improved soil physical properties (for example, soil structure and soil moisture holding capacity). The recent coordinated efforts of administrators and farmers on natural resources conservation in Tigray, Ethiopia has led to tangible enhancements in soil conservation, infiltration, crop yield, biomass production, groundwater recharge, and prevention of flood hazard (Nyssen et al., 2017; Wolde et al., 2017; Wolde & Ermias, 2017; Haile, 2019).

It is very important for a degraded environment to be either rehabilitated and the rehabilitated sites to be monitored using various techniques. Rehabilitation of the gullies will improve and stabilise the soil for effective plant growth and sequestrate carbon (Alisher et al, 2015; Jones, 2017). Environmental remediation and restoration activities involve contributions from earth scientist such as engineers, soil and water analyst, hydrologists, geologists and geomorphologist. To develop and implement effective environmental monitoring and restoration programs, it is necessary to understand the major physical, chemical, and biological processes operative at the site and to characterize the nature and extent of the problem. This information is gathered with environmental monitoring activities. A study was done by Sarminah *et al (2018) in their attempt to rehabilitated and conserve a degraded land using sengon (*Falcatariamoluccana*) and peanut (*Arachishypogaea*).*

Gachene and Joseph (2019) used low-cost measures to rehabilitate a degraded gullies at Gatanga division, Kenya. Various methods are being used in South Africa to rehabilitate gullies in places like Okhombe area of KwaZulu-Natal. These techniques used are different combinations of swales, tree planting, vetiver grass, stone line, indigenous grass plagues and kikuyu grass. In

Oqolweni, South Africa, 28% less runoff was observed after the re-vegetation of the affected land due to an increase in basal cover that increases infiltration and reduces surface flow (Everson et al 2021). A similar trend was observed in Enhlanokhombe in Okhombe, South Africa, where a period October 2003 to January 2004 re-vegetation saw an increase of surface cover from 55% to 71 %. Re-vegetation and stone checks or gabions were used in combination and most of the transported sediments were trapped behind the stone checks or gabions (Everson et al., 2017).

There are many challenges associated with gully rehabilitation in Africa, which range from human or and animal interference and lack of adequate resources. Poor construction of rehabilitation structure will subsequently result in low trapping efficiency of the structure (Mekonnen et al 2015). Regular maintenance of the gully rehabilitation structures makes them more efficient for a longer time (Zhang et al 2019b). Interference from livestock will also reduce the ability of the gully rehabilitation structure fencing off the remediated area until it is fully rehabilitated. Modelling the area of interest is also essential in order to allocate resources more efficiently and choosing the appropriate location for the rehabilitation is essential to maximise the sediment trap efficiency (Igbokwe et al 2009).

Another problem that can affect the effectiveness of gully rehabilitation is the general application of rehabilitation techniques without taking into consideration soil chemical and physical characteristics. For instance, sodic and dispersive soils will need extra attention compared to non-sodic and non-dispersive soil. In South Africa, it was concluded that no single technique can be recommended for rehabilitation but the use of rehabilitation techniques in combination will increase the effectiveness of the gully stabilisation (Water Research Commission, 2020). The effectiveness and success of the rehabilitation method or methods depends on extent of the gully erosion and construction of the rehabilitation structure.

There are numerous mechanism of rehabilitating a degraded land environment and this is but not limited to ecological approach, engineering approach and many others. All over the world many rehabilitation techniques are used and the most used strategies in South Africa are physical and vegetative techniques. The physical techniques include check dams, logs, stone checks, gully reshaping, refilling and gabions, while afforestation and re-vegetation also contribute.

Check dams are constructed across gully channels that intercept runoff reducing the flow velocity of water and impounding sediments. By reducing the flow velocity, the runoff energy that detaches and transports sediments is reduced (Marsh, 2019). The ability of check dams to trap sediments has been confirmed by numerous studies (Xuemin et al 2018). Check dams have relatively high sediment trapping efficiencies ranging from 51% to 92.8% from a study done by XuMingquan, (2000). In a study by Wand et al (2011) more than 100 000 check dams in the Loess Plateau of China have accumulate approximately 21 billion m3 of sediments over 50 years.

On the other hand, the use of vegetation in gully rehabilitation such as grass, which can be grown in shallow and less fertile soil is common (Addis., 2015). The use of vetiver grass as contour in areas with a slope gradient of 1.7% reduced runoff 7.8% and soil loss by 10.5 t ha-1 which resulted in less soil loss due to erosion in the India (Indian Ministry of Lands, 2021). While planting of vetiver grass in Queensland Australia trapped more than 85% of the bed load and also reduced suspended sediments by between 25-65% (McKergow et al., 2004). In Nigeria the use of vetiver grass resulted in sediment being reduced to 6 kg ha-1 from 29 kg ha-1 in the control plot (Eden et al 2012). While in another observation by Robinson et al (1996) in Lowa USA brome grass trapped between 70-85% of sediments in silty loam soils. Shiono et al (2007) in Japan found that centipede grass trapped 24%-73% of sediments. In an experiment in Iowa USA, both under simulated and natural condition, switch grass had a sediment trap efficiency of 90-95% and 70-92% respectively (Lee et al 2000., 2003). Planting of shrub as tree buffers in Shaanxi province in China resulted in 22-32% in reduction in runoff and by 45-61% reduction in sediment concentration and a further 64-79% in sediment yield compared to the control (Zhang et al., 2010). Leguedois et al. (2008) reported a 94% sediment trap efficiency from acacia in New South Wales, Australia. Vegetative rehabilitation of gullies is most successful and effective in humid area where extended period of plant growth is available. Use of vegetation as a rehabilitation technique is effectively utilised in combination with other techniques; for example physical techniques such as the check dams. Vegetation of gully beds and adjacent areas using a check dam traps sediment and reduces erosion power due to runoff (Addis et al., 2015).

3.0 Materials and methods

The survey research design was used for this study involving the collection of data using observational method such as questionnaire to accurately and objectively describes variables as related to the Environmental Monitoring of Gully Rehabilitated Sites in Uyo Urban: Challenges and Prospects. The study intends to randomly sample nine (9) gully sites in Uyo Urban. The Taro Yamane (1973) formula for finite population was employed to statistically determine the minimum sample size for the study which was put at 400.

The survey covered areas around Uyo LGA where gully erosion is mostly affected. The gully sites to be monitored were identified including Etim Umana, Ikot Oku Idio, Afaha Oku and others. Population of the research area would be mainly resident of Uyo LGA who are directly or indirectly affected by sand mining both positively and negatively.

Both descriptive and inferential statistical techniques were used in data analysis. The descriptive statistical technique includes the use of tables, figure as well as simple percentages in analysing the data. The inferential statistic includes the use of chi-square analysis to test the two (2) hypotheses formulated for this research.

Results and discussions

4.1.1 Demographic Characteristics of Respondents

Table 4.1 Sex Composition of Respondents

Sex	Frequency	Percentage (%)
Male	250	62.5
Female	150	37.5
Total	400	100

Source: Researcher’s Field work, 2024

Table 4.1 showed that 250 respondents (62.5%) were female, while 150 (37.5%) were male. The population of male dominated the study area.

Table 4.2: Age Composition of Respondents

Characteristics	Frequency	Percentage (%)
15-20	40	10.0
21-25	100	25
26-30	60	15
31-35	90	22.5
35 and above	110	27.5
Total	400	100

Source: Researcher's Field work, 2024

The table 4.2 showed that 40 respondents were between 21-25 age brackets, 100 respondents were between 21-25 age brackets, 60 respondents were between 26-30 age brackets, 90 respondents were between 31-35 age bracket and 110 respondents were above 35 age brackets. Besides, majority of the respondents were between 21-25 age brackets.

Table 4.3: Anthropogenic Causes of Gully Erosion

Causes	Frequency	Percentage (%)
Farming	140	35
Sand mining	60	15
Deforestation	120	30
Road construction	40	10
Physical development	40	10
Total	400	100

Source: Researcher's Field work, 2024

Table 4.3 reflected the causes of gully erosion and the responses of respondents showed that 140 respondents with 35% agreed that the causes of gully erosion is traceable to farming, 60 respondents with 15% agreed on sand mining, 120 respondents with 30% agreed on deforestation, while 40 respondents with 10.0% agreed on road construction and 10% on physical development.

Table 4.3 : Gully Sites monitored and vulnerability status

Sites	Coordinates	Vulnerability status
Uyo village road	N 04° 45′ 9.36” E 006° 05′ 56.76”	Emergency actions
Etim umana	N 04° 44′ 37.98” E 007° 05′ 52.44”	Emergency actions
Afaha Oku	N 04° 45′ 23.16” E 006° 04′ 38.76”	Moderate risk
Nwaniba (by Uniuyo Perm site)	N 04° 45′ 53.7” E 006° 05′ 51.12”	Emergency actions
Gully by Ikpa Road	N 04° 44′ 32.94” E 008° 04′ 38.94”	Low risk
Gully Brook Street	N 04° 45′ 20.1” E 007° 02′ 24.0”	Emergency actions
Ikot Oku Idio	N 04° 44′ 34.86”	Emergency actions

	E 007° 05′ 15.6”	

Source: Researcher’s Field work, 2024

Table 4.4: Dimension of Gullies at the Study Area Recorded

Sites	**Gully length**	**Gully depth**	**Areal coverage**
Uyo village road	75.40m	12.3m	$60m^2$
Ifa Etoi	60.1m	7.5m	105m
Afaha Oku	54.2m	8.9m	$140m^2$
Nwaniba (by Uniuyo Perm site)	78.6m	6.6m	$110.5m^2$
Gully by Ikpa Road	49.4m	10.4m	$160m^2$
Gully Brook Street	71.8m	8.8m	$240m^2$
Ikot Oku Idio	50.5m	13.6m	$144m^2$

Source: Researcher’s Field work, 2024

Table 4.5: Forms of monitoring Gully Erosion Sites

Forms of monitoring	**Frequency**	**Percentage**
Field observation	25	6.3
Routine visiting	30	7.6
Planting of vegetative cover	86	21.9
Community vigilante	65	16.25
Satellite remote sensing	5	1.25
Observation and Planting	20	5.1
Regulate human activities on gully site, Planting of vegetative cover	45	11.4
Stop encroachment and Planting of vegetative cover	62	15.8
Control of gully from landslide	54	13.7
Total	**400**	**100**

Fieldwork, 2024

Table 4.5 represented the forms of monitoring for gully erosion and the responses of respondents showed that the majority of the respondents 25 (6.3%) in the study choose field observation as one of the ways of monitoring gully erosion sites in Uyo urban, 30 (7.6%) on routine visiting, 86 respondents (21.9%) on vegetative cover, 65 respondents (16.25%) on community vigilante, 35 respondents (1.25%) on satellite remote sensing, 20 respondents (7.6%) on observation and planning , 45 respondents (11.4%) on regulate human activities on gully site, 62 respondents (15.8%) on stop encroachment while 54 respondents (13.7%) on control of gullies from landslide were the major mitigation strategies to address challenges of gully development in the study area.

Table 4.6: Environmental Component monitored

Components	Frequency	Percentage
Vegetative status of gully site	5	1.25
Soil/ sediment component	10	2.50
Drainage component/Rainfall data	15	3.75
Land pollution assessment	25	6.25
Consultation for ecological restoration	20	50.0
Levels of stakeholders involvement	11	2.6
Funding	30	6.75
Demography	16	4.0
Soil remediation	100	25.0
River restoration	12	2.90
Execution of rules	45	11.25
Implementation of rules	3	1.19
Stakeholders for rules implementation	4	1.20
Performance Assessment of policy implemented	14	3.70
Gully infrastructure	50	12.5
Geomorphic asset affected	40	10.0
Total	400	100

Source: Researcher's Field work, 2024

Table 4.6 showed the various environmental components for gully erosion. From the study, 1.25% agreed that the component of environmental monitoring in the study area is mainly Vegetative status of gully site, 2.5% on Soil/ sediment component, 3.755 on Drainage component/Rainfall data, 6.25% on Land pollution assessment, 5.0% on Consultation for ecological restoration, 2.6% on Levels of stakeholders involvement, 6.75% on Funding, 4% on Demography, 25% on Soil remediation, 2.9% on River restoration, 11.25% on Execution of rules, 1.19% on Implementation of rules, 1.20% on Stakeholders for rules implementation, 3.7% on Performance Assessment of policy implemented, 3.7% agreed on Ministry of Environment engagement, whereas 1.05% agreed on Gully infrastructure.

Table 4.7: Effect of Gully Erosion on the Environment

Effects	**Frequency**	**Percentage**
Loss of crop yield	50	12.7
Destruction of community road	44	11.2
Residential houses destroyed	66	16.8
environmental refugees	36	9.1
biodiversity lost	50	12.7
Land degraded	40	10.2
Economic distress of casualties	46	11.7
businesses disrupted	28	7.1
Poverty	32	8.1

Total	**400**	**100**

Source: Researcher, 2024

Table 4.7 showed the effect of gully erosion on the Environment and majority of the respondents in the study choose loss of crop yield as the main effect of gully erosion on livelihood in the study area with 50 (12.7%), loss of farmland, 44 (11.2%) agreed on destruction of roads, 66 (16.8%) loss of settlement, 36 (9.1%) environmental refugee, 50 (12.7%) on loss of biodiversity, 40 (10.2%) on land degradation, 46 (11.7%) on economic distress, 28 respondents (7.1%) on business disrupted while 32 (8.1%) on poverty were the major effects of gully erosion in the study area.

Table 4.8: Stakeholders involved in gully erosion monitoring

Stakeholders	**Frequency**	**Percentage (%)**
Federal government	70	17.5
State government	70	17.5
Local government	60	15
International agencies	60	15
NGOs	30	7.5
Research Institutes	40	10
Private organisations	40	10
Council of chiefs	10	2.50
Farmer's union	15	3.25
Others	5	1.25
Total	400	100

Source: Researcher's Field work, 2024

Table 4.8 showed the various stakeholder involved in Gully Erosion and from the study 70 respondents with 17.5% agreed that stakeholders involved in gully erosion is federal government, 70 respondents agreed on 17.5%, 60 respondents with 15% agreed on local government, 60 respondents with 15% agreed on international agencies, 30 respondents agreed on NGOs, 40 respondents with 10.0% agreed on research institutes and 10% on private organization. 10 respondents agreed on council of chiefs, 15 respondents agreed on farmers union while 5 respondents were from other profession.

Table 4.9: Effectiveness of gully rehabilitation/monitoring Operation

Level	**Frequency**	**Percentage (%)**
Not effective	60	15
Moderate	100	25
Partly effective	98	24.5
Highly	142	35.5
Total	400	100

Source: Researcher, 2024

From table 4.9 which showed the effectiveness of gully rehabilitation/monitoring Operation at the study area noted that 15 respondents with 3.7 % agreed that it is not effective, 157 respondents with 39.3% agreed that it is moderately effective, 168 respondents which makes up 42% agreed that it is partly effective and 60 respondents which makes up 15% agreed that the level of effectiveness of gully rehabilitation is very high.

Table 4.10: Challenges facing gully rehabilitation/monitoring

Challenges	Frequency	Percentage (%)
Resources exploitation at gully sites	95	23.75
Low funding	100	25
Low interest on monitoring	105	26.25
Lack of awareness	120	30
High cost of gully infrastructure	40	10
Weak policy implementation	40	10
Total	400	100

Source: Researcher, 2024

From table 4.10, 95 respondents with 23.75% agreed that resource exploitation is a great challenge facing gully erosion control, 100 respondents with 25% on low funding, 105 respondents with 26.25% on low interest on monitoring, 120 respondents with 30% on lack of awareness, 40 (10%) on high cost of gully infrastructure and 40 respondents with 10% agreed on weak policy implementation.

Table 4.11: Mitigation strategies for Gully Erosion Control

Mitigation measures	Frequency	Percentage
Provision of baseline data	25	6.3
Effective technological application	30	7.6
Effective funding	86	21.9
Encouraging afforestation	40	10.2
Reliable climatic data	30	7.6
Sustainable agricultural practice	28	5.1
Strengthening capacity in gully management	45	11.4
Effective technology for gully erosion modelling, prediction and monitoring	62	15.8
Adequate funding for researchers in gully erosion studies	54	13.7
Total	**400**	**100**

Source: Researcher, 2024

From the analysis above in table 4.11, it shows that the majority of the respondents 25 (6.3%) in the study choose adequate baseline data as the main mitigation strategies to address challenges of gully erosion in Uyo urban, 30(7.6%) on effective technological application, 86respondents (21.9%) on effective funding, 40 respondents (10.2%) on afforestation, 30 respondents (7.6%) on reliable climatic data, 28 respondents (7.6%) on sustainable agricultural practice, 45 respondents (11.4%) on strengthening of capacity in gully management, 62 respondents (15.8%) on effective technology for gully erosion modelling, prediction and monitoring while 54 respondents (13.7%) on adequate funding for researchers in gully erosion studieswere the major mitigation strategies to address challenges of gully development in the study area.

Ho: There is no significant impact of Environmental Monitoring on sustainable geotextile management in the study area

Analysis of Hypothesis

Chi-square would be used to test for the impact of Environmental Monitoring on sustainable geotextile management in Uyo Urban, Akwa Ibom State

Impacts	SA	A	U	D	SD	TOTAL
Reduce foot trampling	169	100	41	60	30	400
All year-round green landscaping	139	135	26	70	30	400
Reduce post-management coast	125	200	35	30	10	400
Improve soil and water conservation	152	118	40	50	40	400

$X^2 = 259.4$

D/F =(Number of rows-1) X (Number of column-1)

(4-1) X (4-1) = 9

9 at 0.05 = 16.919

Decision: Since the calculated value of 259.4 is greater than the table value of 16.919, H_O is rejected and H_1 is accepted. The result shown that there is a significant impact of Environmental Monitoring on sustainable geotextile management in Uyo Urban, Akwa Ibom State

4.3 Discussion of Findings

Gullies have been considered a serious ecological threat in the study area. The manifestation of gullies tended to trigger other landform modification such as landslide and many others. From personal observation, some of the degraded sites were undergoing one form of rehabilitation and the others so as to prevent total submergence of geomorphic assets. The rehabilitation sites were clearly outlined so as to conduct further investigation on the level of effectiveness for such intervention measures and to compare with other techniques used by others in similar ecological scenario. Gully sites that need physical monitoring after the intervention were outlined as well as those that required monitoring through the agency of geo-spatial were equally spelt-out in the study.

In line with objective two which assessed the various methods of monitoring and rehabilitation were carefully dealt with by the researcher. These methods were the use of vigilante, planting of trees/grasses, routine visiting and many others. From the analysis, majority of the respondents 25 (6.3%) in the study choose field observation as one of the ways of monitoring gully erosion sites in Uyo urban, 30 (7.6%) on routine visiting, 86 respondents (21.9%) on vegetative cover, 40 respondents (10.2%) on community vigilante, 30 respondents (7.6%) on satellite remote sensing, 20 respondents (7.6%) on observation and planning , 45 respondents (11.4%) on regulate human activities on gully site, 62 respondents (15.8%) on stop encroachment while 54 respondents (13.7%) on control of gullies from landslide were the major mitigation strategies to address challenges of gully development in the study area. This affirmed the findings made by other authors such as Gacheneand (2019) in his study on Gully control and reclamation activities using low-cost measures at Gatanga division, Kenya. The project's aimed at introducing green manure legume species that perform well in different agro ecological zones of Kenya mainly for the purpose of soil fertility improvement and erosion control in smallholder farms. At the end of the research, their study focused on the use of locally available vegetative materials, namely green manure and shrubby legumes, grasses and trees, for gully control and rehabilitation. In Uyo urban, the adoption of ecological principles like planting of grasses, green canopy and green open space at places of critical condition were spotted at Brook Street, University of Uyo and Nwaniba Axis. During reconnaissance study, gully rehabilitated sites served multiple functions ranging from livelihood support, promotion of ecosystem integrity, recreational, social and economic purposes (see plate 1-11).

PLATE 1: Landscaping Protects Gully Control Structures in Uyo

PLATE II: Green Space with Coconut Trees for Food in Uyo

PLATE III: Gully rehabilitated site for Shade in Uyo

PLATE IV: Green Space for Gym in Uyo

PLATE V: Green Space for Flood Control and Relaxation in Uyo

PLATE VII: Open Space for Ceremonies in Uyo

PLATE VIII: Area under Intensive monitoring in Uyo

PLATE IX: Barb Wire to Reduce Encroachment in UNIUYO

PLATE X: Vegetation belt in a monitored Zone in Uyo

PLATE XI: Rehabilitation through Engineering Structures in Uyo

The following pictorial illustration (plate I-XI) shows gully rehabilitated sites, status of monitoring and multipurpose utility of the terrain in Uyo LGA as observed during field work. Field observation made it known that gullies that were not rehabilitated had little utility and value, but on the other hand, rehabilitation of gully sites increase the economic value. Apart from the ecological functions, some livelihood opportunities were open likewise existing ones strengthened around the sites, including restaurants, shops, hotel, photographic studio and bar.

In line with objective three which examined the effect of gullies on livelihood, it was noted that gully erosion has a significant effect on the livelihood of local communities especially affecting food production through degradation of the land and decline in soil fertility. In the study, majority of the respondents identified loss of crop yield as the main effect of gully erosion on livelihood in the study area with 50 (12.7%), loss of farmland, 44 (11.2%) agreed on destruction of roads, 66 (16.8%) loss of settlement, 36 (9.1%) environmental refugee, 50 (12.7%) on loss of biodiversity, 40 (10.2%) on land degradation, 46 (11.7%) on economic distress, 28 respondents (7.1%) on business disrupted while 32 (8.1%) on poverty were the major effects of gully erosion in the study area.

At the end of the study, it corroborated findings made by Ayele (2019) who studied the Impacts of Landscape Restoration on the Environment and Farmers' Livelihood in Hita-Borkena Watershed, Northeastern Ethiopia. His study revealed that attempt to restore the degraded landed resulted to loss of essential soil nutrient needed by farmers to cultivate their crops. Though this findings cannot be generalized for all conditions due to the fact that some of the rehabilitation processes seeks to restore the organic manure content of the soil especially planting of legumes and trees/grasses. The farmer may not lose out in the long run depending on the technique used by stakeholders in their intervention process. At Ikot Obong Edong, I spotted a protected zone where no farming was tolerated as well as zone for peasant farmers so as to create a balance between livelihood and conservation. Lastly, for objectives four which examined the challenges facing gully rehabilitation and monitoring. Findings revealed that among all the challenges faced by stakeholders, the issue of poor awareness by local actors affected the maintenance of rehabilitation/monitoring infrastructures at some of the gully sites. From the analysis, 95 respondents with 23.75% agreed that resource exploitation is a great challenge facing gully erosion control, 100 respondents with 25% on low funding, 105 respondents with 26.25% on low interest on monitoring, 120 respondents with 30% on lack of awareness, 40 (10%) on high cost of gully infrastructure and 40 respondents with 10% agreed on weak policy implementation.

5.2 Conclusion

Gully monitoring and rehabilitation is one of the key element of managing ecological disaster in contemporary era. The essence of monitoring is to ensure that protected gully sites are not further destroyed through human actions and those ones which are yet to be rehabilitated be guard against human-induced damage. Some of the identified method of monitoring and rehabilitation in gully erosion studies are community vigilante, forest planting, the use of digital technology and multi stakeholders' involvement. Since the geological structure of Uyo urban is friable and easily washed by intense rainstorm, the need for appropriate monitoring becomes a necessity. Some sites such as Ikot Oku Idio, Ifa Etoi and Afaha Oku are seriously threatened by human activities and it requires that human activities be checked and sanctions be made to mitigate impending full blown disaster. Among the human activities that played a pivotal role in gully encroachment in Uyo includes farming, mining, poor road construction, lumbering, erection of building on vulnerable areas and many others. The terrain in the area coupled with intense rainfall and soil has accelerated the rate of gully initiation and development. Several attempts aimed at mitigating the effects of gullies are most times unsuccessful given poor policy execution. The Federal and State Government as well as community intervention groups are seriously concerned with the mitigation mechanism to be adopted in this region for environmental sustainability. Moreover, the study has notice the commitment of World Bank via NEWMAP seeking to rehabilitate some dreadful gully sites but the capacity and will power to completely rehabilitate all the degraded gullies seemed negligible. As a result, there is need for incorporation of multiple stakeholders coupled with both local knowledge to ensure that gully erosion menace is suppressed through effective monitoring.

5.3 Recommendations

Given the loss of agricultural land and other geomorphic assets in gully-degraded communities, there is need for Enactment and enforcement of laws towards the mitigation of gully erosion in the area. Appropriate monitoring tools such as sanctions against intruders at gully sites, open mining, farming and bush burning at active gully sites should be checked. In addition, the use of satellite remote sensing to capture data and analyse the land use changes experienced at different years is very needful. Government should be more commitment to gully monitoring by setting up

committee to review the level of changes at individual gully sites and also engages local institutions to assist in the monitoring process.
Geospatial technology incorporation in gully management has the ability to capture useful data that can be a reliable tool for future planning. The use of remote sensing and GIS should be encouraged. Another effective approach is the use of local initiative in gully erosion control. Indigenous approaches aimed at controlling gullies encroachment should be promoted in the area. In the affected communities, environmental managers should employ some ecological management technique such as terracing, reforestation, cover cropping, fallowing, rotational grazing, mixed cropping and contour ploughing. Local initiatives have been successful in some studies as reflected in this research due to the fact that it is affordable, less stressful, does not require excessive external support and trainings.
Also, there is need for sensitization by all actors to enlighten the stakeholders on their various roles that can collectively bring about success in gully rehabilitation and goal-oriented monitoring. Lastly, deliberate integration of the various interventions tools have the capacity to moderate the intensity of gully expansion in Uyo Urban. As such collaborative gully erosion initiative involving local communities, state government, NGOs, Research Institutes and Donor Organisations would be a useful opportunity to tame the wildness of gully development especially in Uyo Urban where there are over ten (10) gully sites that needs monitoring and rehabilitation. Therefore, stakeholders need to understand that gully erosion development is systemic in such a manner that failure to successfully manage a particular non-rehabilitated sites can have an adverse effects on other sites even as sediments and other loads trickles down manifesting series of landform evolution process.

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