Adjustments to Hazards of Gully Erosion in Rural Southeast Nigeria: A Case of Amucha Communities

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Abstract Gully erosion, a natural process that can be accelerated by human activities, is a recognised global scale geomorphic hazard. In the face of hazards, humans adjust, this adjustment is brought about in different ways such as relocation, insurance or self-protection, personal-effort and community-effort. The aim of this study was to ascertain adjustment measures adopted by local population to mitigate hazards of gully erosion in the Amucha area of Imo State. To achieve this aim, questionnaire survey, oral interview and field measurements were used. Results showed two adjustment measures are adopted in Amucha area; personal adjustments and community-led adjustments. Personal adjustment measures adopted by population included relocation (46.8%), use of ridges (23.2%), shifting habitation (17.7%) and intensified cultivation (12.3%). Community-led adjustments comprised construction of drainage channels to reduce flooding; a derived hazard of gully erosion (31.1%), tree planting at community lands (25.5%), and ban on deforestation and soil excavation which accounted for 21.7% of responses each. Chi-square analysis based on responses showed that adjustment measures adopted by local population is significant in reducing hazards of gully erosion, especially, flooding. This Chi-square result was authenticated with oral interview. It is recommended that appropriate farming techniques and insurance against gully hazards be adopted in the study area.

Keywords: adjustment, gully erosion, flooding, hazard, chi-square test

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1. Introduction

Gully erosion is the process whereby runoff water accumulates and often recurs in narrow channels and, over short periods, removes the soil from this narrow area to considerable depths [1]. Surface runoff can lead to significant gully evolution, potentially giving rise to gullies of up to 25–30 m deep and more than 1.5 km long [2,3], such deep and elongated gullies become difficult to manage and pose hazards to both humans and built-infrastructure. Hazard refers to the probability of occurrence of a potentially damaging phenomenon within an area in a given period of time [4], different types of hazards exist, e.g. meteorological, geomorphic, nuclear etc. This paper aims at ascertaining adjustment measures adopted by local population in Amucha area of Imo State, to mitigate hazards of gully erosion; an example of geomorphic hazard. The objectives of the present work are to identify the hazards posed by gully erosion in the study area, ascertain adjustments made by the population in the face of gully hazards and ascertain the effectiveness of adjustments. Gully erosion is one of the most destructive types of water erosion and occurs as a result of different mechanisms such as piping, scouring by rainfall, development of rills and extended through head-cut [5,6].

Hazards accruing from gully erosion can be grouped into offsite and on-site hazards [7].

On-site hazards of gully erosion include reduction in soil fertility and reduction in soil thickness which reduces available water capacity and the depth through which root development can occur [7]. Reduction in fertility of soils has negative effects on food production which can lead to food insecurity and malnutrition especially in less developed economies whose mainstay is agriculture. Off-site effects on the other hand such as silted drainage channels can increase incidences of flooding in affected areas. Studies have documented hazards associated with gully erosion to include loss of homes, destruction of livelihood and property worth several millions of dollars, sedimentation of rivers and subsequent flooding, displacement of families, cause of other hazards such as landslides and loss of lives in extreme cases [2,8,9]. These hazards could be broadly divided into two categories; direct and indirect. Direct hazards are those whose impacts are felt immediately, they include loss of live, damage to built-infrastructure, loss of property among others. On the other hand, indirect hazards are felt over a longer time period, these include loss of soil fertility, reduction in food production and food insecurity.

Hazards associated with gully erosion pose the most powerful ecological and geologic hazards facing the five states of the Southeast geo-political zone of Nigeria

[10,11]. At least 1600 gully erosion sites exist in southeast region [12,13] occupying a 36.4 km^2 area that would otherwise have been used for agriculture. Food security and agricultural productivity within southeastern Nigeria has been adversely affected because of the prevalent occurrence of soil erosion [11]. Amucha area in Imo State, southeast Nigeria is one of the most affected areas by gully erosion. The problem of gully erosion in Amucha has captured the attention of researchers for a long time [14,15,16] however, to the best our knowledge, published work is not readily available on adjustment measures adopted by affected communities as well as effectiveness of these measures in the face of gully erosion. This condition raises the questions of what adjustment/adaptive measures have been adopted by communities to reduce impacts of gully erosion? What is the effectiveness of these adjustments? This present work is an attempt to contribute to knowledge by filling these identified gaps.

1.1. Causes of Gully Erosion

Both anthropogenic and natural factors are thought to cause gully erosion. The importance of excessive rainfall, rainfall intensity and erosivity in gully erosion studies is widely recognised [17]. It has been found that precipitation duration and accumulation were more important than precipitation intensity in initiating and propagating erosion in the humid subtropical climate of the United States [18]. An element of climate not often talked about in erosion studies is wind. However, study shows that wind can affect direction of rain which then produces local windward and leeward effects, in the long run; the windward area receives more rain and is easily more saturated than the leeward [19]. Thus, the possibility of gully erosion initiation can be more pronounced on the windward side that on the leeward side of a local slope. Topography is a key factor for the initiation and development of gully erosion and this is because, topography influences erosive power of flow of surface runoff [20]. Slope angle is usually included in gully erosion studies, for example, [21] found that slope characteristics of gully sites were greater than 15º which encouraged gully initiation in Abia State, Nigeria. The study by [21] contrasts that of [22] who observed that slope angles less than 15º had highest concentration of gully erosion in the Kashkan-Poldokhtar Watershed of Iran. It is plausible that other factors such as land-use change and vegetation cover account for this discrepancy in slope angles. With regard to lithological units, unconsolidated sandstones, mudstones and shales have been observed to show a high occurrence of gully erosion [21,23].

1.2. Gully Erosion Studies in Nigeria

Earliest studies on soil erosion in Nigeria were completed by [24]; he concluded that forest clearing was the main driver of soil erosion. Similar ideas were shared by subsequent researchers including [25] who suggested that the gully erosion in south-eastern Nigeria started with removal of vegetation cover. This favoured exposure of bare soils to direct impacts of raindrops and human influences such as establishment of foot paths on marginally stable lands. The latter discourages growth of

vegetal cover and subjects the soil to crusting and compaction thereby encouraging increased surface runoff [26]. Further, establishment of footpaths mainly for fetching water, or to provide access to farmlands either on the edge of gullies or within them, has the potential to increase pressure on unstable slopes thereby increasing anthropogenic contribution to gully erosion [27]. Other anthropogenic factors that lead to gully erosion include but not limited to housing developments especially on marginally stable lands, customary laws, change in land use, road construction, government policies, farming techniques, mining, demographic pressure and livestock grazing [14,28,29].

It has been suggested that soils of south-eastern Nigeria have high soil erodibility and are classed as structurally unstable, thus making them susceptible to gully erosion [30]. This notion of structural erodibility has been opposed by [15]. The study by [15] suggested that gully initiation and evolution in Southeast Nigeria can be traced back to unplanned diversions of road runoff and not necessarily as a consequence of structurally unstable soils. A relationship exists between road construction and gully erosion; distance from roads has an inverse relationship with susceptibility to gully erosion [9,22]. This inverse relationship can be explained with regard to careless practices of some road contractors who do not construct appropriate drainage channels for runoff. The kinetic energy wielded by such runoff can lead to incision along edges of roads and subsequently increase susceptibility to gully erosion. Demographic pressures can lead to gully erosion, especially in areas with high population density such as southeast Nigeria [11,31,32]. Four phases of transition has been identified in gully evolution in southeast Nigeria as a result of demographic pressure [25] see Figure 1. First, increase in population density. Secondly, increase in population density leads to removal of natural vegetation cover, reduction of fallow period from 15-20 years to as little as one year as a result of demographic and economic pressures on the environment.
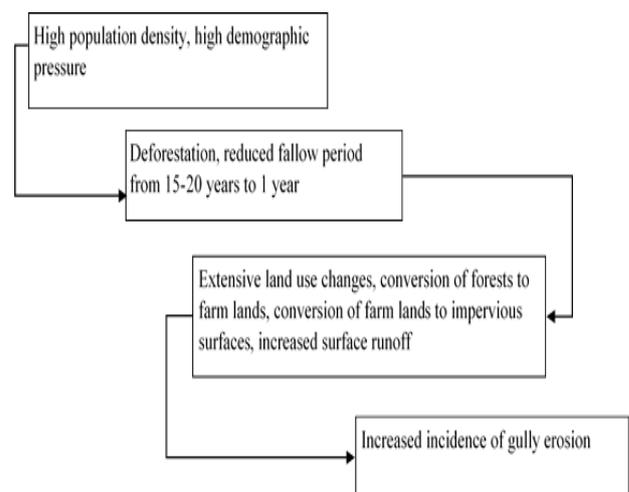

Figure 1. Demographic pressure as a causative factor of gully erosion proposed by [25]

Thirdly, reduced fallow periods in addition to extensive land-use changes over the last century; natural forests were cleared for plantation agriculture and farm lands, subsequently, farms were cleared for hard engineering

constructions, thus, within a short period of time, former forests were converted into paved and impermeable surfaces. A fourth and final stage resulted from increase in volume of storm-water and surface runoff as a product of increase in impermeable surfaces. Increased volume of runoff increases incidence of gully erosion and flooding [33].

Physical factors including geology, hydrogeology, slope angle, topography lithology and tectonic activities have been identified as drivers of gully erosion [8,11,22,27]. For example, [27] studied the Agulu-Nanka gully complex in Anambra State southeast Nigeria, they observed that the primary control of the gullies was the hydrogeological and geotechnical properties of complex aquifer systems in the areas. Aquifers can influence gully erosion especially through their effects on landsliding, pore-water pressure exerted by perched water tables can effect landsliding [34]. This effect is brought about by a reduction of the shear resistance of the regolith, as illustrated by the shear equation;

$$S = c + \left(p - h\gamma_w \right) tan\phi \qquad (1)$$

Where S = shearing resistance per unit area
c = cohesion per unit area (kN/m^2)
p = pressure due to the weight of solids and water (kN/m^3)
h = piezometric head
γ_w = unit weight of water (kN/m^3)
ϕ = angle of internal friction (°)

Increase in piezometric head reduces friction component (p - $h\gamma_w$) tanϕ as well as cohesion, thus resulting in substantial reduction in shear resistance of regolith and subsequent susceptibility to sliding [34]. Landslides could become the dominant process of gully head formation [35]. On regional scales in Nigeria, the southeast is geologically similar to the southwest, yet, the former is more susceptible to gully erosion than the latter. This increase in susceptibility has been explained in terms of tectonic activities that created regional cuestas, joints and faults that now determine the pace of gully erosion in the southeast [8].

Accelerated gully erosion has led to flooding, loss of farmland and ancestral artefacts, destruction of both physical and social infrastructure, degradation of aesthetical values of the environment, distortion of communication utilities, damage of pipelines, loss of property and other resources worth millions of dollars and death in many Nigerian communities including Amucha [2,8]. Previous authors [14,16] have attributed increase in susceptibility to gully hazards in Amucha community to concentrated flow due to topography, poor farming method and poor engineering construction. These papers did not take into account adjustment measures adopted by the community to mitigate gully hazards, hence the justification for the present study.

1.3. Hazard Adjustment

In response to hazards, humans adjust so as to ensure their continued survival. Hazard adjustment is the process wherein characteristics of a hazard, the individual affected and possible adjustments are examined [36]. This examination takes into account risk perception of the hazard, risk perception is guided by information on identified hazard. Information on hazard is usually obtained through information seeking which has been described as the conceptual portal to knowledge of the hazard, its consequences, the availability and effectiveness of protective measures and implementation procedures [36]. Sources of information in times of hazard include the internet, personal networking, public gatherings, mass media, government agencies, published articles as well as social media. Adjustments include cognitive and behavioural responses; the former refers to changes in thinking and the latter to changes in actions [37]. In cognitive adjustments, there are changes in people's awareness of hazards including frequency of occurrence, impacts of hazards as well as changes in preconceived ideas and feelings of such hazards [38]. Behavioural adjustments are seen where affected population take actions to respond to hazards. Several factors including awareness of hazard can influence behavioural adjustment; frequency of occurrence, intensity and impact of hazard are commonly linked to form of behavioural adjustment adopted in places [37].

Adjustments to hazards come in different ways; relocation, insurance or self-protection [39], personal-effort and community-effort. Relocation implies moving out of harms-way. Effectiveness of adjustment by relocation depends on three factors:

1) Risk communication/early warning signals,
2) Willingness of affected population to adhere to warnings and
3) Safe destination.

Risk communication can produce more accurate beliefs about a hazard and also increase adoption of protective actions [40]. Willingness to adhere to early warnings and relocate can be hampered by a few factors, one of which is the affinity to remain close to friends and family who share similar beliefs and social lifestyle. It is well known that demographic groups seek to stay within areas that share common interests and social networks [39], thus if affected population feel they will be far from their social ranks, they could opt to remain within the hazard zone so as to stay close to loved ones. To relocate from hazard-prone environments, affected population must have a safe destination they are relocating to. If one or two of these three conditions (risk communication, willingness to adhere to warning and safe destination) are compromised, relocation may not be effective as an adjustment to hazards. In many parts of the world, built infrastructure is insured against extreme events, thus when such events occur, accruing hazards are minimized on the part of the population. However, insurance against extreme events is only beneficial to those who can afford it. Community-effort is seen in form of community protection works and land use practices aimed at minimizing impacts of hazards on affected population. This type of adjustment has sometimes been referred to as hazard mitigation [41,42].

2. Study Area

Amucha area of Njaba Local Government Area (L.G.A) in Imo State is made up of twelve villages grouped into three autonomous communities namely; Amucha-Ebeise, Amucha and Umuamucha, geographically it is located between latitude 5° 44' 24" North, and Longitude 7° 03'

41" East (see Figure 2). The area is situated within the tropical rainforest belt of Nigeria with mean monthly temperature range of 25°C – 28.5°C and mean rainfall of about 2500 mm; most of which falls between the months of May and October [43]. Due to demographic pressure, original forests have been cleared for agricultural, economic and residential purposes. Agriculture is the mainstay of the local economy in Amucha and environs and major agricultural products include cassava, yam, cashew nuts, banana and palm oil. The study area is underlain by the Benin Formation (a major lithostratigraphic unit in the Niger Delta Basin). The formation which is Pliocene to Miocene in age is made up of friable sands with intercalations of clayey-shale lenses and isolated units of gravels, conglomerates, very coarse sands and sand-stones [43,44].

3. Materials and Methods

This study was based in Amucha area of Imo State, Southeast Nigeria (see Figure 2). Field based reconnaissance survey, fieldwork, oral interviews and distribution of questionnaire took place during the dry season of November 2014 – March 2015. The dry season was chosen to reduce exposure of field enumerators to gully edges which become unstable especially during rainy seasons. This paper uses results obtained from these identified research tools to ascertain hazards of gully erosion and adjustments adopted by population in the face of identified hazards, detailed explanations are provided in the subsequent paragraphs. Simple Chi square statistical technique was used to test significance of effectiveness of adjustments to gully erosion hazards in the study area.

3.1. Primary Data

Primary data were collected using direct field measurement and observation, questionnaire survey and oral interviews. Instruments used for field measurement included ranging poles and measuring tapes; these were used to determine gully depths. One end of a 50m tape was attached to a ranging pole and held on the top of the gullies by a field enumerator, while another field enumerator climbed down into the bottom of measured gullies. This was the method adopted for measuring gully depths. More than 12 gullies were measured in the study area. Direct field observation was guided by expert judgment and this was used to identify gully hazards such as gully-induced landslides in the study area. Questionnaire survey was employed to obtain data from locals on information that were not directly available from fieldwork and direct observation. Such information included length of time gully erosion has been going on in the area, hazards associated with gully erosion and adjustment measures adopted by population among others. The three autonomous communities formed the strata in stratified sampling. In each stratum, one village was sampled using random sampling technique where the names of the villages in each autonomous community were written, folded, put in a bag and shuffled. By lucky dip, one village was selected from each autonomous community thus ensuring all autonomous communities were represented: Umuzikeabom, Duruewuru and Umuorji were the villages selected by this method.
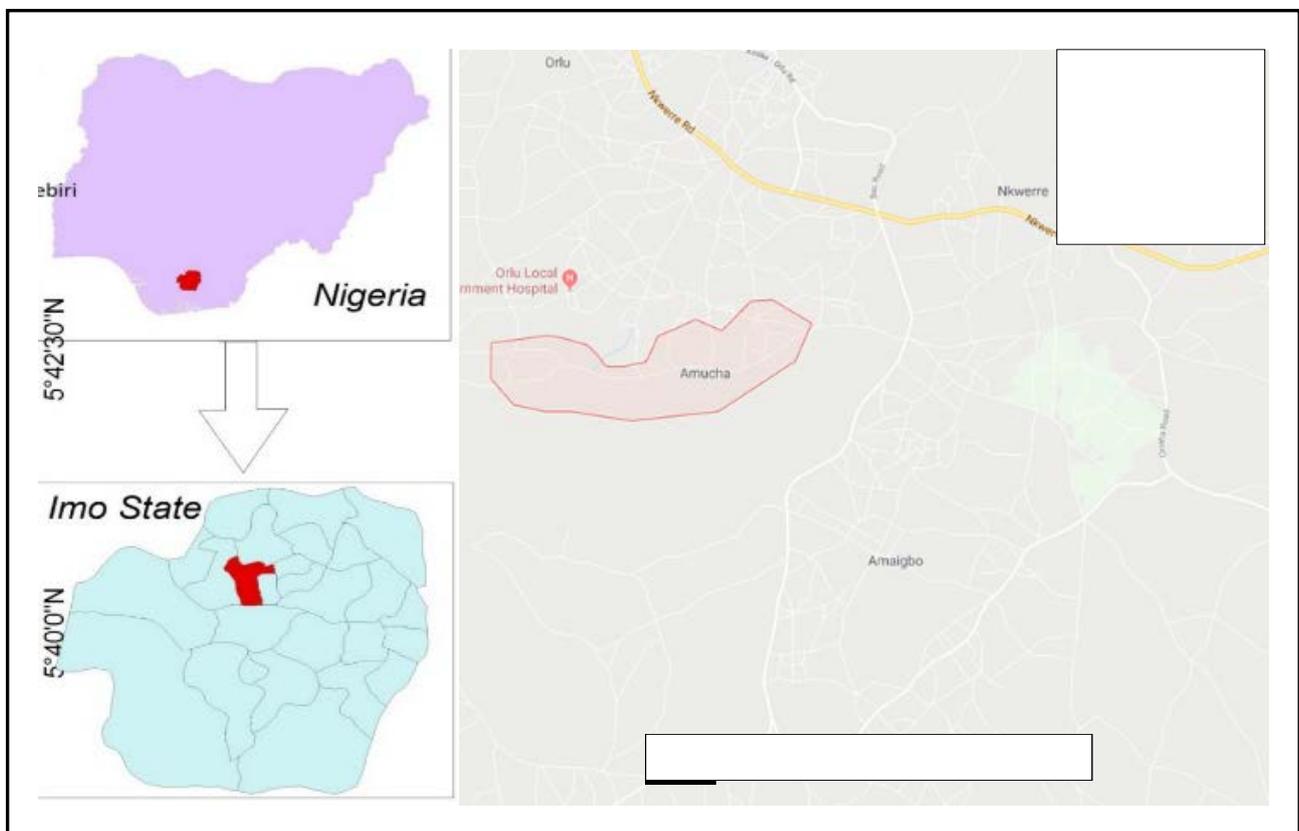

Figure 2. Location of Amucha the study area

A total of 450 copies of structured questionnaire were distributed among the villages, i.e. 150 copies of questionnaire per village. The rationale for using same number of questionnaire per village was that the villages are fairly equal in size. Three trained field enumerators were employed to assist in questionnaire distribution, 372 copies of questionnaire representing 82.7% of respondents were correctly completed and returned. A distinction was made in the questionnaire between threatened homes and destroyed property such as market stores and shops; this distinction was necessitated because people do not spend nights in these other property. Another distinction was made in the questionnaire between shifting habitation as an adjustment measure and permanent relocation within the community. Permanent relocation as the name implies refers to a situation whereby affected individuals have no intention of returning to hazard-prone houses or environments. Shifting habitation on the other hand comes in the form of temporary relocation, for example during rainy season, people whose homes are threatened by gully erosion or flooding may temporarily relocate to stay with family members until the end of the rainy season, they return to their homes after the rainy season. Responses from two questions were lumped together to provide a single percentage answer for food insecurity, these two questions were "have you lost some part of your farm to gully erosion"? The second question about food insecurity related to inaccessibility to farms as a result of gully erosion.

Structured oral interview was carried out in the three selected autonomous communities. This involved selection of 15 elders (five from each community) and the main intention of the interview was to ascertain risk perception of gully erosion in the communities. Questions such as "what season of the year do you feel most vulnerable to gully hazards"? "What aspects of your life are most affected in this season"? Another question included in the structured interview centered on ways in which lives were lost due to gully erosion, i.e. "did they fall into the gullies or were they buried by sliding mass"? Chi-square analysis is often used to analyze data in contingency tables created by crossing two categorical variables, with at least one having three or more categories [45]. Many authors [46,47] have used Chi-square analysis for ecological studies. The present study employed the chi-square analysis to determine significance of effectiveness of adjustment to hazards of gully erosion adopted by local population in Amucha area. Effectiveness was derived from the questionnaire, questions included "in what ways have your adjustment measures reduced gully hazards". To test the significance of adopted adjustment measures, a 4*2 contingency table was developed, results are presented in the following section.

4. Results

Data collected suggests that gully erosion has been taking place in Amucha area for more than 40 years, this environmental hazard captured headlines at the end of the Nigerian civil war in 1970 [15]. The average depth of gullies in the study area was more than 8 m deep, at some locations, gullies have exposed ground water which is seen in the form of spring flowing out of gullies. Plate 1 shows a spring which flows out from a gully up slope,

also shown is a collapsed engineering structure designed to control erosion.

Plate 1. Spring flowing out from a gully in Amucha, plate also shows destroyed engineering structure used for gully control. Gully head situated behing the camera, hence not visible in plate

4.1. Hazards Associated with Gully Erosion in Amucha

Amucha area is prone to both direct and indirect hazards of gully erosion; Table 1 illustrates identified hazards of gully erosion in the area. A total of 115 out of 372 respondents which makes up 30.9% of sampled population agreed that their homes or the home of someone they knew were threatened by gully erosion. This response makes threat to homes and buildings the highest identified hazard posed by gully erosion in the study area. Interviewed respondents whose homes were close to gully edges attributed cracks appearing in their homes to gully erosion, however, it is difficult to attribute such cracks solely to gully erosion as the structural stability of such homes need to be ascertained. It is also possible that other factors such as quality of building materials could lead to cracks in buildings, thus, care must be taken in attributing certain structural defects to natural hazards. Destroyed property accounted for 8.3% of responses, it was easier to identify such property as many of them were not built with sophisticated engineering input, they were mostly temporary structures made of wooden materials.

64 respondents reported that gully erosion has led to loss of life or has the potential to do so in their community, especially during rainy seasons. Oral interview showed that loss of life occurs as a result of landsliding associated with gully erosion especially where unsuspecting commuters or farmers were caught by sliding materials during rainy seasons. Plate 2 shows landslide scar in one of the gullies visited. Interview also suggested that farming activities are especially precarious during rainy seasons, especially around gully edges. For this reason, locals do not go to the farm after heavy rainfalls; this identified behavior of staying away from farm lands during rainy seasons is an adjustment to gully hazards.

Table 1. Identified hazards associated with gully erosion in Amucha

Identified hazard	Frequency	%
Threatened building	115	30.9
Loss of lives	64	17.2
Food insecurity	101	27.2
Possibility of being homeless	61	16.4
Destroyed property	31	8.3
Total	372	100

Plate 2. A: destroyed farm due to extreme gullying. Man was used for scale. B: landslide scar at one of the gully

Food insecurity is an indirect hazard of gully erosion and accounted for 27.2% of responses. Food insecurity as a result of gully erosion can arise from four ways; first, reduction in farm land as shown in Plate 2, increase in workload (i.e. labour necessary to cultivate the land), loss of crop yields and finally, loss of arable land through deterioration in soil quality [48,49]. Reduction in farmland means decrease in space for cultivation and unavailability of extra labour needed to cultivate lands as a result of gully erosion can translate to cultivation of few crops which leads to reduction in farm yields. For an agrarian economy like Amucha, reduction in farm yields as a result of gully erosion has many effects such as increase in food prices, decrease in purchasing power of farmers, drop in seedlings for planting in subsequent farming seasons and malnutrition.

4.2. Adjustments to Gully Erosion Hazards

Two adjustment measures are adopted in Amucha area; personal adjustments and community-led adjustments. Oral interview suggested that personal adjustment measures adopted by local population in Amucha have been influenced by the individual's sense of self-responsibility for protection, this result supports the argument of [50]. Personal adjustment is manifest in different ways as shown in Figure 3; relocation, use of mounds, shifting habitation within the area, and intensified cultivation on available land aimed at cushioning the effect of lost land. Insurance as an adjustment strategy is not adopted by the population, the reason for this is not known, it is likely however that non-adoption of insurance as an adjustment strategy is related to the financial involvement of paying for insurance.

Results from other studies indicate that the wealthy adopt insurance as an adjustment strategy [39] while personal and community-efforts are the adjustment tools of the less-wealthy segment of the population.

Relocation as a personal adjustment measure has the highest percentage, 46.8%, this result on relocation is in contrast with those of [37] who acknowledged that only a small number of sampled population was willing to actually relocate in face of environmental hazard in their study area. Relocation as a behavioural adjustment is followed by use of ridges and mounds with 23.2% response rate. Oral interview revealed that these mounds are used to control flooding which occurs in Amucha area alongside gully erosion. Intensified cultivation has a response of 12.3%, farmers adopt this measure to cushion the effect of loss of arable land due to gully erosion.

Community-led adjustment efforts adopted to reduce hazards of gully erosion include construction/de-silting drainage channels, tree planting campaigns (see Plate 3), stopping deforestation on communal lands and soil excavation (see Figure 4). One of the offsite effects of gully erosion is sedimentation of waterways [51] and drainage channels, in the long-run, this condition leads to a derived hazard, flooding as a result of sedimentation. In Amucha area, the community embarks on de-silting and construction of new drainage channels so as to control flooding (which is a derived hazard of gully erosion) in the community.

To test the significance of effectiveness of the adjustments adopted by population, a 4*2 contingency table was designed for Chi Square analysis based on responses of respondents (see Table 2). Calculated Chi Square value was 265.013, testing at 3 degrees of freedom and at 5% significance level, the critical value was 7.815 while the P-Value was < 0.00001. The result is significant at $p < 0.05$, thus, the data suggests that adjustment measures adopted by the community is significant in reducing hazards posed by gully erosion. In the absence of insurance, local population driven by self-responsibility relies on individual as well as community-led adjustment measures to ensure their continued survival and habitation in their ancestral homes, this explains the significance of the result.
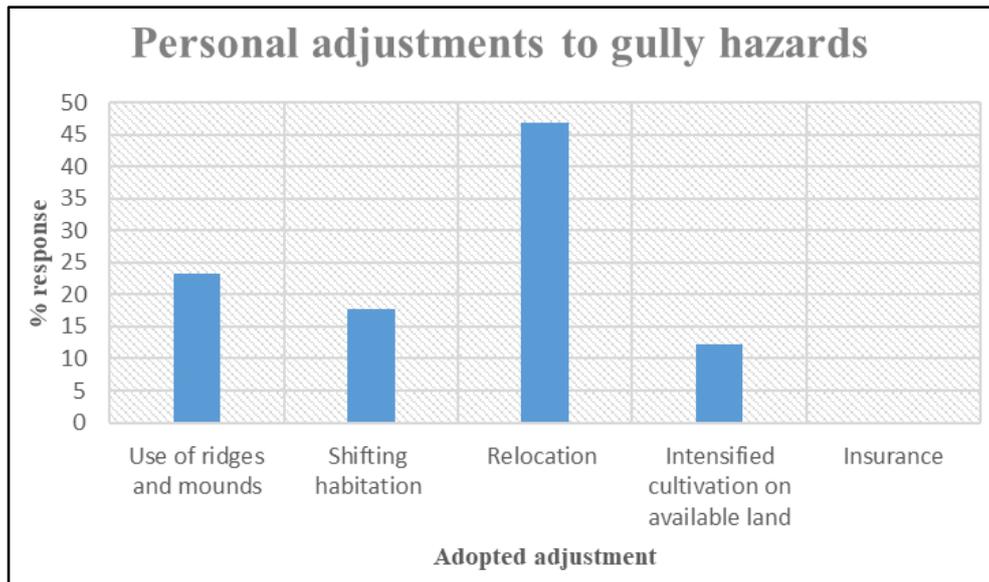
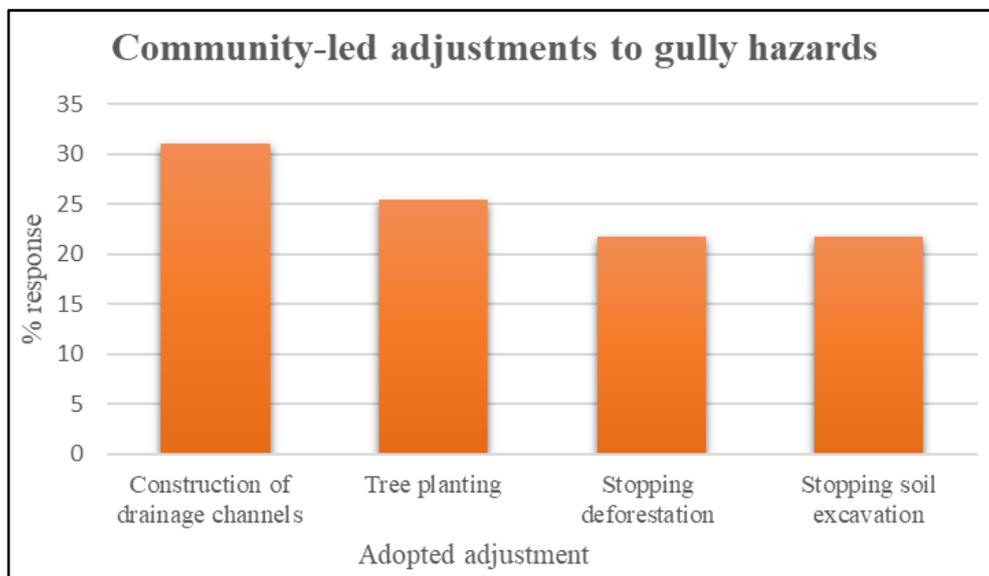**Figure 3.** Personal adjustment measures adopted by local population

Figure 4. Community-led adjustment measures adopted by local population

Plate 3. Tree planting aimed at controlling gully erosion in Amucha

Table 2. Chi Square Table for hypothesis testing

	Category 1	Category 2	Total
Group 1	85(131.5)	173(126.5)	258
Group 2	65(119.8)	170(115.2)	235
Group 3	172(92.8)	10(89.2)	182
Group 4	45(22.9)	0(22.1)	45
Total	367	353	720

5. Discussions

Local population in Amucha is exposed to a variety of hazards as a result of gully erosion, chief among these hazards is danger to built-infrastructure. Other studies e.g. [21] have also identified threat to built-infrastructure as a hazard of gully erosion in the southeast of Nigeria. In an area where there are no insurance policies against gully erosion, everyone is left to protect their vulnerable property. In the course of this study, some residents attributed cracks in their houses to gully erosion, however as observed by [42], estimates of losses to the built environment due to natural hazards are prone to error. Such damage estimates are most accurate when trained damage assessors enter each building to assess the percent of damage to each of the major structural systems (e.g. roof, walls and floors) and the percentage reduction in market valuation due to the damage [42]. Based on this recommendation, this study does not explicitly attribute identified cracks in visited buildings to gully erosion only, however it is upheld here that gully erosion poses substantial risks to the built-environment in Amucha. Owners of homes exposed to gully erosion adopt shifting habitation as an adjustment measure, especially every rainy season when the danger of collapse is most pronounced. Same adjustment measure of shifting habitation is adopted for flooding hazard. Flooding in Amucha is likely to occur as a product of gully erosion which leads to sedimentation of drainage channels. In order to adjust to this derived hazard of gully erosion, local population embarks on community efforts such as construction of new drainage channels as well as de-silting old channels. This type of adjustment adopted by the community has been referred to as hazard mitigation by some authors [42].

During field work, it was observed that gully erosion has exposed groundwater at one of the gully sites, the significance of this exposure can be related to fluctuation of water table around gullies, similar observations were made by [52] who reported extreme water table drawdown around gully edge locations in the South Pennines of northern England. Fluctuations in water table can compromise the ability of such aquifers to provide water to inhabitants, thus, undermining an important ecosystem function of water provision [53]. Secondly, where such springs attain sufficient energy, further erosion and deepening of gullies could occur and this condition can lead to further degradation of the environment.

Due to risk of loss of arable lands to gully erosion, farmers in the study area engage in intensive cultivation and reduction in fallow period on available farm lands.

This intensified cultivation is done to cushion the effect of lost land, however, this action has two implications. First, intensive farming leaves little room for soil recovery, secondly, reduction in fallow period reduces natural vegetation cover and reduces recovery time of soil. These two effects predispose available pieces of lands to a fresh cycle of gully erosion. Thus, actions adopted to cushion the effect of gully erosion on a piece of land can increase susceptibility of another piece of land to gully erosion, thus, creating a positive feedback of gullying as shown in Figure 5.
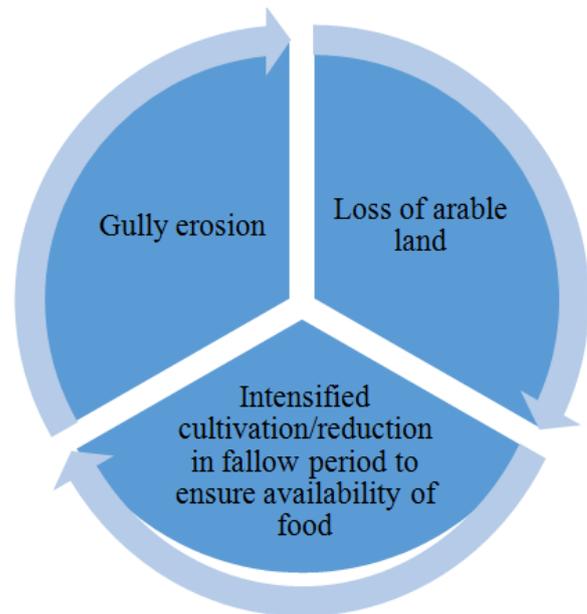

Figure 5. Positive feedback between gully erosion and intensified cultivation as an adjustment measure

In other to reduce exposure to risk of gully-induced landsliding, especially in the farms, a behavioural adjustment of delayed visit to farmlands has been adopted by farmers. Visit to farmlands bothering gully edges has been identified by local population to be particularly hazardous especially during rainy seasons, thus, the population has adjusted by staying away from such farms in rainy season. This behavioural adjustment reduces exposure of farmers to gully edges that become unstable especially after heavy rains.

Chi-square result obtained from this study indicates that effectiveness of adjustment measures adopted by local population is significant in reducing hazards of gully erosion. This result is similar to that of [37] who found that residents had taken actions to reduce impacts of severe environmental problems in Beach Strip area of Ontario Canada. An identified community-led adjustment effort has been to stop soil excavation within the area. This action has economic ramifications, it means members of the community who were soil vendors have been forced to adopt other economic activities so as to reduce impacts of soil erosion and this change in economic activity is a community-led adjustment that has personal ramifications. Despite the cognitive and behavioural adjustments adopted by local population as discussed in this section, gully erosion remains the most significant environmental problem in the area.

6. Recommendations

Results from this study have revealed that people in the study area have adopted some adjustment measures to reduce hazards of gully erosion in their area. Further, this study shows that these measures are statistically significant, however, the study area still suffers from menace of gully erosion. Considering the agrarian nature of the economy, soil conservation methods are recommended for farming activities. Soil conservation and farmer education are needed to reduce farmland susceptibility to gully erosion. Use of insurance was not identified as an adjustment measure in the study area, this is likely due to the financial requirement of paying for insurance. Insurance as an adjustment tool is recommended in this study, this will mean less worry about property loss to local population. Further, use of vegetation as a control of soil erosion is recommended. Vegetation creates friction for surface runoff thereby retarding erosive power of surface runoff, protects the soil from direct impacts of rain, wind and compaction from both humans and grazing animals [54,55]. In selecting vegetation cover, a few points need to be borne in mind, first, native plants will usually increase success of planting program, use of pioneer plants which grow rapidly on degraded lands and gullies and economic value of vegetation for local population [56]. In all, undergrowth is important in the reduction of surface runoff, and hence, outright tree planting without regard to undergrowths may not be an efficient adjustment/mitigation strategy. External aid in the form of extra-community assistance is recommended. This aid could come from both state and federal governments, non-governmental organizations (NGOs') as well as international organisations. The present work has shown that community-efforts aimed at reducing gully hazards are effective, however, if these efforts are complemented with extra-community assistance, susceptibility to hazards of gully erosion in Amucha community will be further reduced.

7. Conclusions

Substantial literature exists on causes, impacts, hazards and control of gully erosion, little is known about adjustment measures adopted by local communities to combat this environmental problem. Also, to our knowledge, effectiveness of efforts aimed at reducing gully hazards have not been fully documented, this study has attempted to fill these identified gaps. Gully erosion is the single most devastating environmental hazard in Amucha area, hazard and risk perception of this problem is high and thus local population adopts many measures to adjust to gully hazards. These adjustments are made in two forms; personal and community-led adjustments. Personal adjustments are borne out of self-responsibility to reduce gully hazards on affected individuals and they include shifting habitation, relocation as well as intensified cultivation on available farms. Community-led efforts such as ban on forest clearing and soil excavation are carried out mainly on communal lands, these community-led efforts have been shown to affect economic activities of inhabitants. Change in economic activities as a result of gully erosion in itself is an adjustment measure. All these adjustments are adopted so as to ensure that local population carry out their day to day activities in their ancestral homes. Despite these measures, local population is exposed to gully hazards thus necessitating the need to external aid. Increased awareness of population on differences between gully erosion and gully hazards such as landsliding is important. Currently, local knowledge perceives both gully erosion and gully-induced landslides as one and same thing, however, this is not the case. This gap in local knowledge could be a factor hindering adoption of a yet-to-be-identified adjustment measure to further reduce gully hazards. The next logical step is to improve understanding of interactions between gully erosion and identified hazards such as landsliding. Improved understanding of gully-landslide interactions will enhance community adjustment to gully hazards and therefore reduce susceptibility to such hazards.

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