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GIS BASED GULLY IDENTIFICATION AND SOCIOECONOMIC IMPLICATIONS IN THREE LOCAL GOVERNMENT AREAS OF IMO STATE, NIGERIA.

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Abstract

Gully erosion is a serious issue in Imo state, Nigeria with unimaginable negative impacts. Study is aimed at remotely identifying gully erosion sites and assessing socio-economic implications of gullies on impacted communities in three LGAs of Imo State. Ground truthing to distinguish remotely identified gullies from other open cavities and characterization of the gullies based on sizes and activities were carried out. Remote Sensing and Geographic Information Systems were used in identifying the gullies and mapping out their areas. Statistical Package for Social Science (SPSS) was used for descriptive statistics on gully areas and ANOVA estimations. Twenty-eight (28) active gully erosion sites were identified, fifteen (15) out of the twenty-eight gullies making up 53.6% are matured classic gullies measuring above 3000 m^2 in size. Ideato North LGA had twelve gully erosion sites and the biggest in size, followed by Mbaitolu (10) and Ehime Mbano (6). ANOVA result showed significant variation in mean areas of gully sizes across the three LGAs with an F value of 2.859 and a P value of .046 justifying a strong significance ($p< 0.05$) in variation of gully sizes found in the study area. Gullies were caused by impact of poor road construction and surface runoff on sloped ground. Communities suffered most from damages to roads and other infrastructures, loss of land use (farmland, properties *etc*), displacement of indigenous population, among other socioeconomic and environmental impacts. It is recommended that Government should ensure that proper engineering design, integrating watershed management characteristics, are carried out before road construction.

Key words: Geographic information system, ground truthing, gullies, mapping, remote sensing.

1.0. Introduction

Erosion as it affects man and his environment is natural and as old as the earth itself (Omafra 2003). Gully erosion is a natural phenomenon enhanced by human activities and occurs in all landscapes and under different land uses (Ibimilua, 2011) and has been identified as a serious environmental problem with multiplicity of social and economic impacts. The socio-economic consequences are unbearable. Gully erosion destroys public and private infrastructures such as, roads, buildings as well as agricultural land and its productivity (Jeje, 2005; Adegboyega, 2006). In spite of different approaches deployed in solving gully erosion problem in Nigeria, its threat to man and his environment remains as pertinent as ever through rapid growth and expansion once initiated (Okorondu, 2021).

Joel, Paul and Jennifer (2006), defined gully erosion as watercourses marked by steep channel walls, a steeped longitudinal profile, and commonly an abrupt channel head that exist in many settings, but are prevalent in dry lands and are often considered a signal of disturbance and accelerated erosion, brought about by climate or land-use change. It is associated with soil removal along drainage lines by erosive agents (mostly precipitation/run-off) on unprotected land. Major causes of erosion in southeastern Nigeria are linked to poor engineering practices on road projects leading to abrupt termination of drainages and in extreme case, abandonment of road projects or execution halfway (Amangabara, 2014; Nwachukwu & Owette, 2015; Okorondu 2021). Also, deforestation, unsustainable farming practices and urbanization without regard to conservation and environmental protection has been observed to be significant contributing factors to gully erosion development in Imo State (Onu, 2001; Okorondu, 2021)

The impact of gully erosion to man in Imo State is unimaginable ranging from destruction of properties (private and public), loss of soil fertility for agriculture, water pollution due to sediment transport, and on rare cases loss of life. Ofamata (2010), reported 50% of annual rainfall in the tropics can be lost from eroded slopes due to decrease infiltration and high surface runoff. Egboka (2010) noted that the greatest impact of erosion in Nigeria lies in the outright volumetric loss of soil and decrease in nutrient capacity, moisture retention capacity, organic matter content & the depth of soil. Each rainy season is associated with nightmares, particularly for inhabitants living at near proximity to erosion sites through gully progressions and widening by landslides. The cumulative effect is that the affected inhabitants are left homeless and unable to farm or exploit resources from their lands. The threats posed by classic gullies to farmlands, settlements, roads and human are enormous. Most communities in Imo State have been ravaged by gully erosion at different dimensions. For instance, communities such as Urualla, Okwudor, Ihioma, Ogberuru, Ihitteowerri, Obibiochasi, Urualla, Awara, Ndiawa, Umueshi, Umunumu-Ibeafor, Obizi, Awo-Omamma, Mgbidi, Amaigbo, Amandugba, Amucha, Okwudor and Umuaka etc have been suffering from varying degrees of gully erosion ranging from two-four gullies per community (Okorondu *et al*., 2019). These gullies are allowed to advance without adequate control efforts by the government, hence, the affected people watch helplessly while their farmlands and homes are destroyed.

In view of the observed increasing number of gully erosion profiles and associated negative impacts in Imo State, study aimed at utilizing GIS and questionnaire survey to investigate, identify, characterize existing gullies and assess the socio-economic implications of gullies in three LGAs of Imo State was carried out.

2.0. Materials and methods

2.1. Study area

The study area is Imo State. The state is one of the Southeastern States in Nigeria bordered by the states of Anambra to the north, Abia to the east, and Rivers to the south and west, with its capital in Owerri**.** Imo consists of high lands to the North and coastal lowlands to the west of the Niger River. Most of the state's original tropical rain forest vegetation has been replaced by more open areas of urbanization and agricultural activities including oil-palm plantation. Imo State is also one of the chief onshore petroleum-producing areas in the country.

Imo State has twenty-seven local government areas making up for the three zones (Imo west or Orlu zone, Imo East or Okigwe zone and Imo Central or Owerri zone). The study was carried out in many gully impacted communities from three local government areas of the state namely Ideato North, Ehime Mbano and Mbaitolu LGAs (Fig 1) which represented the three zones (Orlu Zone, Okigwe Zone and Owerri Zones respectively).

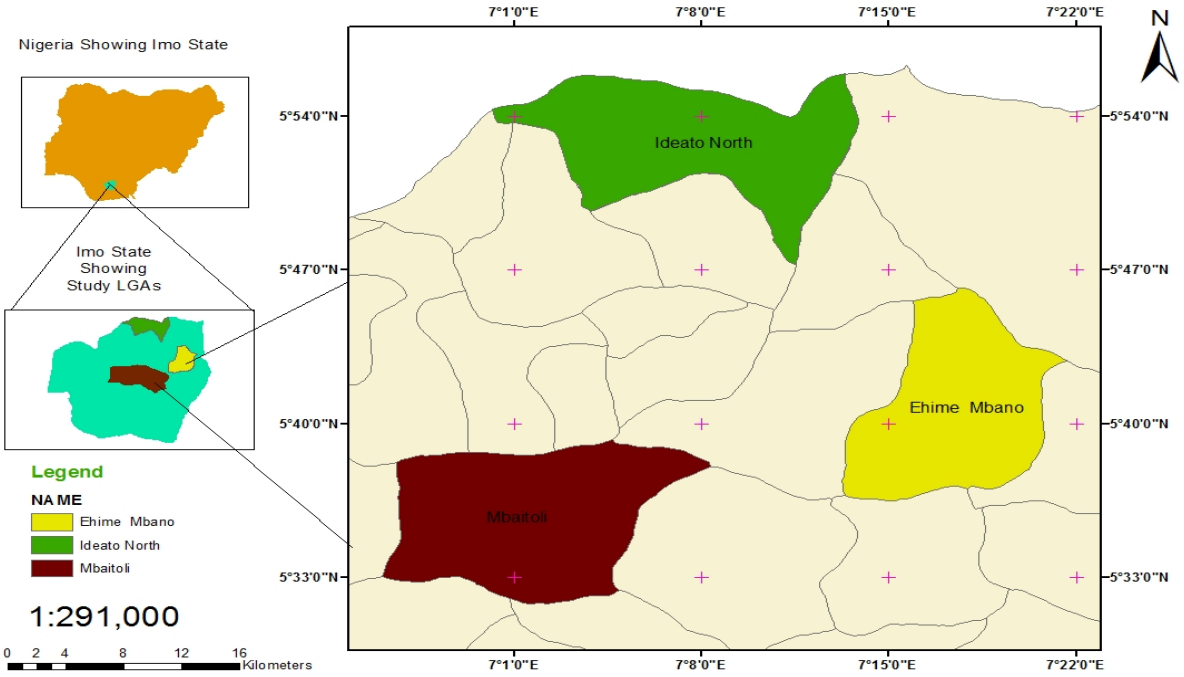

Fig 1 study area map

2.2 Methods

2.2.1 Remotely Gully Identification

Gullies were identified through integration of Bing satellite imagery of Sas Planet and Google Earth Pro software through spatial referenced and digitized LGA shape file of the study area. Ground truthing was also carried out to distinguish identified gullies from other open cavities like burrow pits. Identified gullies were characterized based on their activities (active and inactive) during ground truthing survey and sizes measured using ArcGIS software (Fig 2).

2.2.1 Questionnaire Survey Using Mobile GIS Technique

Mobile GIS is the expansion of GIS technology from the office into the field, enabling field-based personnel to capture, store, update, manipulate, analyze, and display geographic information using mobile and smart phones. It integrates one or more of the following technologies: Mobile devices, Global positioning system (GPS) and Wireless communications

for Internet GIS access (Fig 3). Simplified mobile GIS tool uses smart android phone as a device for field data collection through integration of data web (kobotoolbox.org) platform with Andriod (ODK collect) software. Kobotoolbox platform is used to design questionnaires and create a server for processing of transmitted questionnaire survey. ODK is a software that is downloaded on android play store and configured through its server setting to accept mobile survey created kobotoolbox.

A typical mobile GIS device has three major modules: the location module, the input module, and the transmission module. The location module is used for retrieving the location data from the deployed built-in GPS and camera chip. This location will be sent along with other types of data to the server, and it can be used to pinpoint the current location of the device when displaying a map. The second module is the input module. This module takes care of getting the information from the field data collector depending on the nature of task at hand or the type of the report to be described. Transmission module is used to send collected data to the server where it is processed and stored as database.

A chosen smart (Samsung galaxy and Infinix android) phone with a functional play store capable of downloading designed questionnaire in a cloud via other built-in devices on the questionnaire such as GPS and Camera for purpose of obtaining real ground information in line with other desired questions requiring answers from the respondent were deployed.

Designed questionnaire for understanding of the Socio-economic implication of gully erosion on the three study LGAs were inputted to kobotoolbox.org after creating and validating account, thereafter, redeployed to android for mobile field survey using Kobo collect app on smart phone play store. Configurations and server settings were made after download of kobo collect app to envisage saved and redeployed questionnaire from kobotoolbox.org thus the necessary button on the smart phone were used to capture coordinates and tick respondent's feedback, after which the

saved form on the smart phone is sent back to the server for processing via maps and descriptive statistics production.

To understand, assess and document people's perspective on the socio-economic implications of gully erosion in the three study LGAs of Imo State, respondent's answers from questionnaire survey on gully impacted communities were transmitted to cloud, analyzed using the descriptive statistics and analysis of variance.

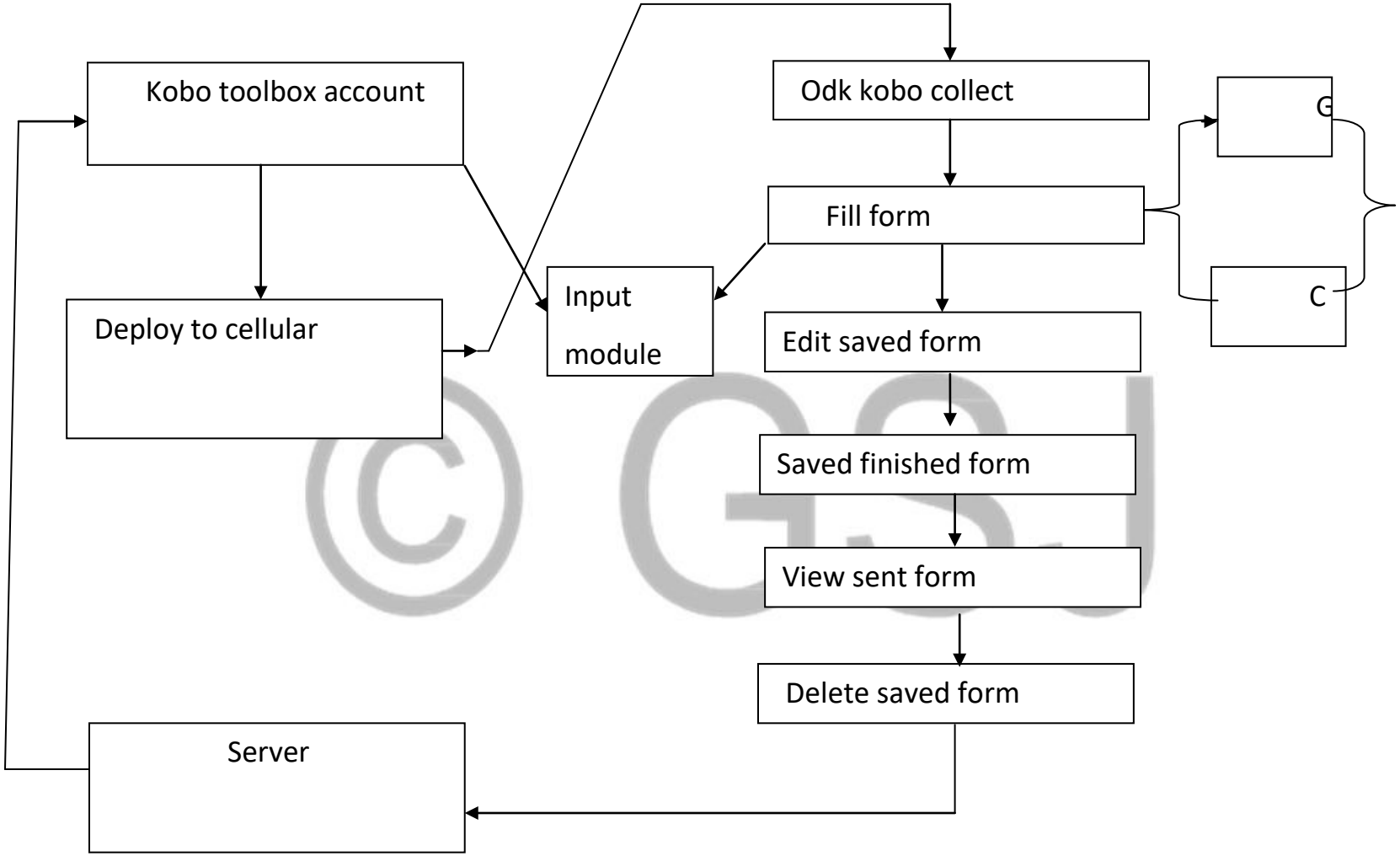

Fig 3. Flow chart of mobile GIS technique

3 Results and Discussion

3.1 Gully Identification

A total of twenty-eight (28) active gully erosion sites (Table 4.1 and Figures 4-6) were identified in the three Local Government Areas of study using remote sensing technique.

Result of gully identification of the three selected LGAs (Table 1) for the three zones in Imo State showed that Ideato North was most predominated by gully erosion sites. A total of twenty-eight (28) active gully erosion sites were identified. Twelve (12) out of twenty-eight gullies, being the highest number of gullies per LGA were identified in Ideato North LGA, representing about 42.86% of total gullies. It is followed by Mbaitolu (35.71%) and Ehime Mbano (21.43%).

Gully areas measurement above 2000 sqm showed that ten (10) out of the twelve (12) gullies representing about 83.3% of Ideato North total gullies (Table 1) are matured active classic gully erosion sites posing serious threats to the communities. Meanwhile, two of six gullies and four of ten gullies (Table 1) translated to 33.3% and 40% of total gullies in Ehime Mbano and Mbaitolu respectively are matured active gullies. This finding shows significant measure of agreement with earlier studies by Nwilo *et al*, (2011); Ogbonna, (2012); Mayowa & Ademola (2013) and Amangabara, Njoku and Obenade (2014), that matured gullies dominated northern part of the study area, characterized with many fingers and oval shape.

Table 1 Identified gully erosion profile

S/N	Name	Community	Area (SqM)	Activity	LGA
1	Uzii Osina	Osina	1987	active	Ideato North
2	Obodoukwu	Obodoukwu	9375	active	Ideato North
3	Umunkwukwa	Obodoukwu	10949	active	Ideato North
4	Ikpezie	Ikpezie	6808	active	Ideato North
5	Ndiawa	Ndiawa	1592	active	Ideato North
6	Umuago Ndada	Ururalla	53338	active	Ideato North
7	Okpu Akpulu	Akpulu	54094	active	Ideato North
8	Isiokpo	Isiokpo	2438	active	Ideato North
9	Osina sec gully	Osina	32194	active	Ideato North
10	Umuezemezu Urualla 1	Urualla	162605	active	Ideato North
11	Umuezemezu Urualla 2	Urualla	41953	active	Ideato North
12	Eleuama	urualla	6762	active	Ideato North
13	Ebom	Mbiery	5259	Active	Mbaitolu
14	Amankuta	Mbiery	2563	Active	Mbaitolu
15	Amaike	Mbiery	793	Active	Mbaitolu
16	Umuonyeali	Mbiery	382	Active	Mbaitolu
17	Alaenyi	Ogwa	1995	Active	Mbaitolu
18	Alaenyi2	Ogwa	788	Active	Mbaitolu
19	Ochi	Ogwa	1247	Active	Mbaitolu
20	Nkalu	Ifekalla	831	Active	Mbaitolu
21	Egbeada	Egbeada	4685	Active	Mbaitolu
22	Umueze Obazu	Obazu Mbieri	14193	Active	Mbaitolu
23	Umueze	Umueze	1844	active	Ehime Mbano
24	Umuanunu Nsu	Nsu	166	active	Ehime Mbano
25	Umuchioke	Umuchioke	382	active	Ehime Mbano
26	Umuezealla Oparamadu	Umuezealla	446	active	Ehime Mbano
27	Nkwo Umuezealla	Umuezealla	16769	active	Ehime Mbano
28	Umunumu Ibeafor	Umunumu	12912	active	Ehime Mbano
					Ehime Mbano

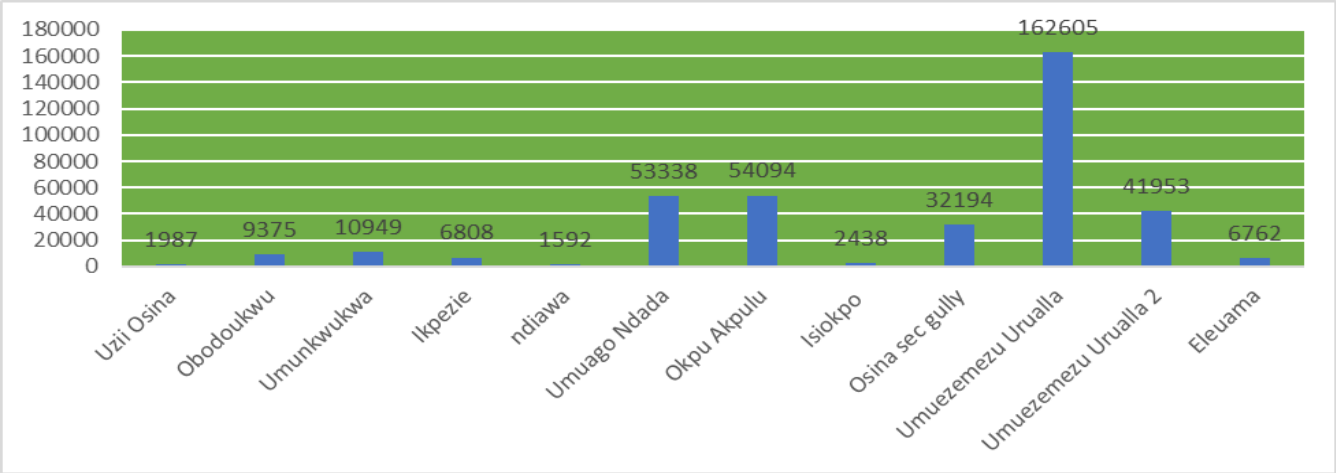

Fig 4. Chart of Ideato North LGA gullies

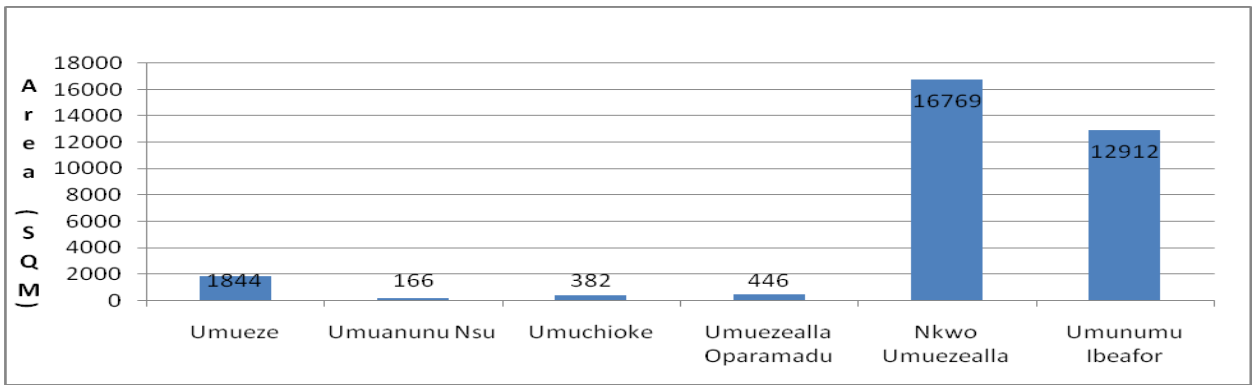

Fig 5. chart of Ehime Mbano LGAgully area

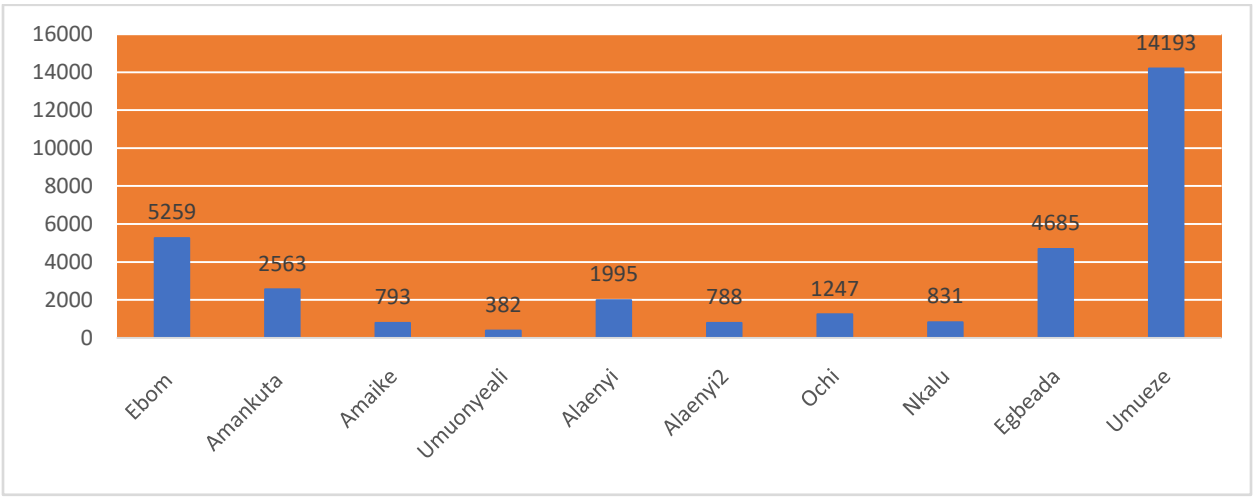

Fig 6. Chart of Mbaitolu LGA gully profile

Gully area descriptive statistics (Table 2) was tested for homogeneity of variance (Table 3) to ascertain if there are strong statistical significance of the variations of gully mean and standard deviations across the three (3) LGAs of study. The test result showed that there is strong statistical significance of variance for gully means and standard deviations across the LGAs at 0.013 level of significance, which is less than 0.05 benchmark. Thus, justifies that gully mean area of 32000sqm for Ideato North is significantly different from that of Mbaitolu (3273.6sqm) and Ehime Mbano (5419.83sqm). Similarly, the standard deviation of gully area in Ideato North 45752.5 is significantly different from that of Mbaitolu (4190.9) and Ehime Mbano (7422.2).

Table 2 Descriptive statistics of gully areas

Area								
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Ideato North	12	3.20E4	45752.484	1.321E4	2938.18	61077.66	1592	162605
Mbaitolu	10	3273.60	4190.906	1325.281	275.61	6271.59	382	14193
Ehime Mbano	6	5419.83	7422.187	3030.095	-2369.27	13208.94	166	16769
Total	28	1.60E4	32674.564	6174.912	3378.34	28718.09	166	162605

Table 3 Test of Homogeneity of Variances

Area

Levene Statistic	df 1	df 2	Sig.
5.149	2	25	.013

Analysis of variance (Table 4) was employed to predict as a group the significance of the variations in the means of the gully sizes across the three local government areas. An F value of 2.859 and p value of .046 was obtained showing a strong statistically significant variation among gully areas in the three LGAs at less than 0.05. The P value of.046 is less than the level of significance at $p \leq 0.05$ (5%), therefore, it indicates that gully sizes vary across the three local government areas sampled from the three senatorial zones of Imo State.

Table 4 ANOVA gully sizes

Area					
	Sum of Squares	df	Mean Square	F	Sig.
between Groups	5.366E9	2	2.683E9	2.859	.046
within Groups	2.346E10	25	9.384E8		
Total	2.883E10	27			

3.2. Socio-Economic Implications of Gullies

Perception of the people on the presence of gully erosion (Table 5) as an environmental hazard with serious socio-economic implications across the three sampled LGAs (Ideato North, Mbaitolu and Ehime Mbano) showed that two hundred and sixty-eight (268) of the three hundred and sixty (360) respondents representing about 74.4% of total respondents accepted the presence of gully erosion in their communities. Ninety-seven (97) respondents from Ideato North translated to 26.9%, ninety (90) persons from Mbaitolu (25%) and eighty-one (81) respondents from Ehime Mbano (22.5%) making a total of 74.4% accepted gully erosion as a serious environmental hazard. Highest respondents were from the northern part (Ideato North) of the study area. Similar observations were noted by Amangabara (2014) and Okorondu (2021) that northern part of Imo State is predominantly occupied by gully erosion profile than its southern part. This is a clear indication that gully erosion is a serious environmental hazard in Imo State, demanding urgent action to curb and reduce increasing negative socio-economic implications suffered by communities through direct impact of gully erosion.

Table 5 Perception of presence of gully erosion in the three LGAs

LGA	Gully Presence	Gully presence (%) from total sampled questionnaire	No gully presence	total
Ideato North	97	26.9	23	120
Mbaitolu	90	25	30	120
Ehime Mbano	81	22.5	39	120
Total	268	74.4	92	360

Surface runoff, terrain slope (undulations) and poor road construction (Table 6) were observed significant causes of gully erosion across the three LGAs from a total of six outlined options (surface runoff, terrain slope, poor road construction, deforestation, farm practice and Sand

mining/Burrow pit). They contributed about 82.7% of total gully causes in the study area from two hundred and ninety-eight (298) respondents out of three hundred and sixty (360). Surface runoff had one hundred and thirteen maintaining about 31.4% of total gully causes, poor road construction (29.5%) from one hundred and six (106) respondents and terrain slope (21.9%) from seventy-nine (79) respondents. Hence, surface runoff was a major observed cause of gully erosion in Ehime Mbano (Table 6), terrain slope by undulations was a major contributory factor to gullies in Ideato (Table 6) and poor road construction either by abrupt termination of drainages or poor engineering concepts contributed majorly to gully formation in Mbaitolu (Table 6).

However, studies by earlier researchers have highlighted poor engineering practices in road construction either through abrupt termination of drainages or abandonment of road projects halfway as major causes of gully erosion in the study area. A few of the studies are reports by Hudec *et al* (2006), and Onu and Opara (2010) in Imo State; contributing NEWMAP (2013) in Ideato North and NEWMAP (2014) in Orlu observed that classic gully erosion sites in the two LGAs were caused by impact of surface runoff on sloped area causing most abandoned road constructions projects to develop into matured gullies rapidly. Most places where roads are constructed with a drainage channel, gully erupts because of poor termination of the drainage lines. Typical examples are Umuezemazu gully erosion in Ideato North, Umuojisi Isiekenesi in Ideato South, Acharaba and Mgbe gully erosion in Orlu, Umueze Obazu gully site Mbieri Mbbaitolu, Umunumu gully site in Ehime Mbano and Umuaka gully erosion in Njaba. Surface runoff generated especially in Orlu, Njaba, Ideato North and South on high relief areas have lesser gutters to properly channel surface runoff to nearby streams, thus, causing concentration of runoff at high velocities leading to gullying.

Table 6 causes of gully erosion

Causes of gully erosion	Ideato North Frequency	Percentage (%)	Mbaitolu Frequency	Percentage (%)	Ehime Mbano Frequency	Percentage (%)
Surface Runoff	31	25.83	39	32.5	43	35.83
Farm practice	12	10	8	6.67	9	7.5
Terrain slope	39	32.5	19	15.83	21	17.5
Poor road construction	29	24.17	42	35	35	29.17
Sand mining/Burrow pit	5	4.17	11	9.17	7	5.83
deforestation	4	3.33	1	0.83	5	4.17
Total	120	100	120	100	120	100

There appeared to be significant and strong measure agreement on severity of gully erosion among the three LGAs sampled (Tables;7). Gullies had existed for over two decades, but their severity became worsened in the recent 10 years. More gullies came up from lack of engineering practices on massive road projects executed simultaneously at various LGAs in Imo State by previous administration that saw none being completed and commissioned. Two hundred and sixty-four (264) respondents translated to 73.3% of total respondents across the LGAs agreed to it. One hundred and forty-five (145) of them maintaining 40.2% of total respondents believed gullies became severe between 0-3 years while one hundred and nineteen (119) maintaining 33.1% claimed that gullies became severe from 4-10 years and its negative impacts keep to the communities kept increasing to the recent time.

Table 7. Severity of gully erosion

Severity of gully erosion (years)	Ideato North Frequency	Mbaitolu Frequency	Ehime Mbano Frequency	Total	Percentage (%)
0-3	41	56	48	145	40.2
4 - 10	39	35	45	119	33.1
11- 20	25	20	20	65	18.1
above 20	15	9	7	31	8.6
Total	120	120	120	360	100

Environmental impacts of gully erosion in the communities (Tables 8) across the three LGAs showed thattwo hundred and seventy-six (276) respondents translated to 76.7% of total respondents agreed that they were majorly affected by three of the five environmental impacts highlighted on the questionnaire. Destruction of properties both private and public appeared to be the major environmental impact as ninety-eight respondents translated to 27.2% claimed they suffered from it, it is followed by land degradation/soil infertility at 25.3% by ninety-one respondents and loss of land uses such as farmlands at 24.2% by eighty-seven respondents. Though, in Ehime Mbano LGA (Table 8), many people claimed surface streams/river which served as a major source of water for drinking and use for domestic purposes were polluted through sediment deposition, water pollution wasn't selected as major environmental impact because it didn't significantly cut across other LGAs as environmental impact suffered by people in their communities.

Table 8. Environmental impact of gully erosion

Environmental impacts of gullies	Ideato North Frequency	Mbaitolu Frequency	Ehime Frequency	Total	Percentage (%)
soil quality/land degradation	29	27	35	91	25.3
surface water pollution	15	10	28	53	14.7
loss of land use (farmland, vegetation, grassland etc.)	24	33	30	87	24.2
destruction of private/public properties (buildings, roads)	41	35	22	98	27.2
Others	11	15	5	31	8.6
Total	120	120	120	360	100

Similarly, on socio-economic impacts of gully erosion in the community (Table9), result showed that communities suffered most from four (loss of farmlands, loss of private properties, destruction of public properties and leavy on gully control) of the five highlighted options. Three hundred and twenty-five (325) translated to 90.2% of total respondents stated that they suffered four major socio-economic impacts by the presence of gully erosion in their communities. One hundred and sixteen (116) of them covering about 32.2% suffered from loss of farmland for agriculture, eighty respondents occupying 22.2% suffered from loss of private properties, seventy-two of the respondents (20%) claimed they suffered from destruction of public utilities while fifty-seven of them said unending community levy on gully erosion control have serious socioeconomic implications on them. Corroborating report on socioeconomic and environmental impacts of gully erosion highlighted on ESMP (2015; 2016 and 2019) for Iyiuzo-Ihioma-Ogberuru-ObibiOchasi, Obizi and Urualla gully erosion sites respectively in Imo state, showed

that gullies erosion posed a serious threat to inhabitants in different communities of the study area, requiring urgent action in management and control to avert further negative impacts.

Control measures applied to curtail severe socioeconomic implications of gully erosion (Tables; 17, 29 and 40) showed that channelization of runoff to stable discharge area through construction of drainages mainly by community effort was leading at 29.2%, when they could not sustain budget for construction of drainages, turned to public awareness and biotechnical approaches at 23.6% and 19.4% respectively as control measures to reduce human induced gully erosion while appealing to government and other bodies for engineering/mechanical bulldozing approach (19.4%) for sustainable control of gully erosion in their communities.

Table 9. Socio-economic impact of gully erosion

Socio-economic impacts of gullies	Ideato North Frequency	Mbaitolu Frequency	Ehime Mbano Frequency	Total	Percentage (%)
migration to other areas	9	19	7	35	9.7
destruction of public utilities (markets, buildings, roads)	24	31	17	72	20
loss of private properties	29	21	30	80	22.2
loss of farmlands	43	28	45	116	32.2
community levy on gully control	15	21	21	57	15.9
Total	120	120	120	360	100

Community input was significantly leading on effort made to control gullies in the study area

(Tables 10), of the total of two hundred and seventeen (217) respondents who agreed that gullies were found in their communities, community effort maintained 39.2% of total effort, Government (28.1%), world bank/NGO (12.9%) and abandonment of gully sites (19.8%). This shows a clear picture of why gullies kept increasing in numbers and kept advancing in development once formed due to unsustainable control. Where community budget fails to sustain

drainage diversion of runoff or discharge to stable grounds, they rely on government assistance which usually deploys poor engineering approaches, gully sites continue to grow as abandoned site, causing migration of people to other communities as no other remedy is visible.

Table 10. Effort made at controlling gully erosion in the study area

Effort to control gully	Ideato north Frequency	Mbaitolu Frequency	Ehime Mbano Frequency	Total	Percentage (%)
community effort/levy payment	31	27	27	85	39.2
intervention of government	19	23	19	61	28.1
World bank/NGOs	14	9	5	28	12.9
abandonment of the gully affected area	17	11	15	43	19.8
Total	81	70	66	217	100

3. Conclusion

Remote sensing, GIS and mobile GIS technique were used as tools in identifying gully erosion sites and assessing socio-economic implications of gully erosion in three local government areas of Imo State. Gully erosion has remained a major environmental hazard in the state, causing destruction of farmlands and properties worth millions of naira. It has been observed in this study that the impact of gully erosion on inhabitants of Imo State are unimaginable with severe environmental and socio-economic implications. Hence government policies should be directed towards creating awareness on gully control measures while helping communities combat the increasing number of gullies observed.

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