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Assess The Frequency, Intensity, and Spatial Patterns of Flooding and Erosion Hazards Across Ogbaru Local Government Area, Anambra State, Nigeria

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Abstract- Flooding and erosion are major environmental hazards in Ogbaru Local Government Area (LGA), Anambra State. This study assessed their frequency, intensity, severity, and spatial distribution across eight selected communities: Atani, Ossomala, Ogbakuba, Odekpe, Akili-Ogidi, Mputu, Ogwuikpele, and Okpoko. A mixed-methods design combining questionnaire surveys, field observations, GPS mapping, and GIS analysis was adopted. Of 422 questionnaires administered, 377 were retrieved, representing an 89.34% response rate. Data were analysed using descriptive statistics, weighted means, one-way ANOVA, Tukey HSD, and GIS-based spatial analysis. Odekpe recorded the highest annual flood frequency (3.5 ± 1.2 events), longest inundation duration (25 days), greatest flood depth (1.8 m), and highest perceived flood-intensity score (3.17), while Mputu recorded the lowest values. Flood frequency differed significantly among communities, $F(7,369) = 8.64$, $p < 0.001$. Heavy rainfall (92.3%), River Niger overflow (88.6%), and poor drainage (79.8%) were the leading perceived flood drivers. Gully erosion was most prominent in Odekpe (48%), which recorded very high erosion severity. Spatial analysis identified Atani Waterfront and Ossomala Riverbank as very-high flood-risk locations, while Odekpe Gully Site, Ogwuikpele River Margin, and Okpoko Drainage Channel were high-risk areas. The study concludes that flooding and erosion in Ogbaru are recurrent and spatially heterogeneous, requiring community-specific interventions, improved drainage and waterway management, erosion control, environmental restoration, and GIS-supported disaster-risk reduction planning.

Keywords: flooding, erosion, spatial patterns, flood frequency, flood intensity, erosion hazards, climate change, environmental hazards, land degradation

I. INTRODUCTION

Flooding and erosion are among the most significant environmental hazards affecting communities in Nigeria, particularly those in low-lying, riverine, and floodplain areas. Their occurrence is influenced by interacting natural and anthropogenic factors, including intense rainfall, river overflow, inadequate drainage, land-use changes, vegetation removal, and environmental degradation. Beyond direct physical damage, these hazards can lead to the loss of agricultural land, the destruction of buildings and infrastructure, the disruption of economic activities, and the displacement of vulnerable populations. Flooding in Nigeria is characterized by considerable spatial and temporal variability, reflecting differences in environmental conditions, settlement patterns, drainage characteristics, and human activities (Umar & Gray, 2022; Ogboeli et al., 2024).

Ogbaru Local Government Area (LGA) of Anambra State is particularly susceptible to flooding because of its low-lying terrain, extensive floodplains, wetlands, and proximity to the River Niger. Recurrent flooding has consequently become an important environmental and socio-economic concern in the area. Ezeokoli et al. (2019) documented the recurrent nature of flooding in Ogbaru and highlighted stakeholders' concerns regarding its effects on communities and livelihoods. Similarly, Okonkwo and Onyeizugbe (2017) reported substantial flood vulnerability and losses in the LGA and emphasized the importance of effective information dissemination and disaster preparedness. Recurrent inundation also affects land-use practices, particularly agricultural activities, thereby constraining productive use of land and other livelihood resources (Onyeizugbe & Onyejiaka, 2020).

Recent investigations further demonstrate spatial and temporal variations in flood occurrence within Ogbaru and Anambra State. Ubah et al. (2024) applied regression modelling to flood episodes in Ogbaru, highlighting the importance of systematic analysis of flood occurrence for prediction and management. At the state level, Chukwuma et al. (2021) demonstrated substantial spatial variation in flood vulnerability using GIS-based modelling, while Izuegbu and Lay (2024) specifically examined flood vulnerability in Ogbaru LGA. These studies establish that flood risk is spatially heterogeneous and that community-level and location-specific assessments are necessary for effective disaster-risk reduction and land-use planning.

Erosion constitutes another important environmental hazard in the area and may interact with flooding to accelerate land degradation. Across Anambra State, variations in geological, soil, terrain, and related environmental characteristics have been associated with susceptibility to erosion and land instability (Nwazelibe & Egbueri, 2024; Ifeanyi & Nkiru, 2024). Flooding can further intensify erosion through increased surface runoff, riverbank instability, soil saturation, and removal of protective vegetation. The combined effects may consequently alter landscapes, degrade agricultural land, threaten settlements and infrastructure, and increase community vulnerability.
Despite the growing body of research on flooding in Ogbaru, existing studies have largely emphasized flood occurrence, vulnerability, impacts, or mapping, with comparatively limited integration of flood and erosion frequency, intensity, and spatial patterns at the community level. A comprehensive assessment integrating field observations, community-level evidence, and geospatial analysis is therefore necessary to identify areas experiencing recurrent and severe hazards and to characterize their spatial distribution. Such evidence is important for targeted disaster-risk reduction, floodplain management, erosion control, environmental planning, and community resilience.

Aim of the Study
This study aims to assess the frequency, intensity, and spatial patterns of flooding and erosion hazards across Ogbaru Local Government Area, Anambra State, Nigeria, using field-based and geospatial approaches.

Objectives of the Study
The study specifically seeks to:
1. Determine and compare the frequency, duration, and intensity of flooding and erosion hazards across selected communities in Ogbaru Local Government Area.
2. Analyse the spatial distribution and identify hotspots of flooding and erosion hazards in relation to terrain, drainage networks, land use/land cover, and proximity to the River Niger using GIS and remote-sensing techniques.
3. Examine the major environmental and anthropogenic factors associated with the occurrence and severity of flooding and erosion and identify priority areas for integrated disaster-risk reduction and environmental management.

II. THEORETICAL FRAMEWORK

1. Hazard Theory
Burton, Kates, and White (1978) developed the Hazard Theory to explain the relationship between natural hazards and human societies, emphasizing that hazards become disasters when human populations and activities are exposed to potentially destructive environmental processes. Their work highlighted the importance of hazard frequency, magnitude, spatial distribution, human exposure, and societal adjustments in understanding disaster occurrence. The theory is relevant to the present study because flooding and erosion are major environmental hazards affecting Ogbaru LGA. It provides a basis for assessing their frequency, intensity, and spatial patterns and for identifying communities that are particularly exposed to these hazards.

2. Pressure and Release (PAR) Model
Wisner, Blaikie, Cannon, and Davis (2004) developed the Pressure and Release (PAR) Model to explain disasters as the interaction between natural hazards and underlying vulnerability. The model proposes that disasters emerge through a progression from root causes and dynamic pressures to unsafe conditions that increase exposure to hazards. The model is relevant to the present study because flooding and erosion in Ogbaru may be influenced not only by natural processes such as rainfall, river overflow, and terrain but also by human activities, settlement patterns, land-use practices, and environmental degradation. It

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therefore supports the assessment of spatial variations in hazard intensity and vulnerability across communities.

3. Systems Theory
Von Bertalanffy (1968) developed General Systems Theory, which conceptualizes systems as interconnected components whose interactions determine the behaviour and functioning of the whole system. The theory emphasizes that changes in one component can influence other components within the system. This perspective is relevant to the present study because flooding and erosion are influenced by interactions among rainfall, river systems, topography, soil characteristics, vegetation, drainage, land use, and human settlement. Systems Theory therefore provides a basis for examining flooding and erosion as interconnected environmental processes. It also supports the use of GIS to identify spatial relationships and areas where multiple environmental factors combine to increase hazard occurrence.

4. Disaster Risk Reduction Framework
United Nations Office for Disaster Risk Reduction (UNDRR, 2015) developed the Sendai Framework for Disaster Risk Reduction 2015–2030, which emphasizes understanding disaster risk, strengthening disaster-risk governance, investing in resilience, and enhancing preparedness and recovery. The framework recognizes that effective disaster management requires systematic assessment of hazards, exposure, vulnerability, and capacity. It is relevant to the present study because determining the frequency, intensity, and spatial distribution of flooding and erosion in Ogbaru LGA provides essential information for understanding local hazard risks. The findings can support evidence-based land-use planning, early warning, preparedness, mitigation, and community-based disaster risk reduction strategies.

III. MATERIALS AND METHODS

Study Area: The study was conducted in Ogbaru Local Government Area (LGA), Anambra State, southeastern Nigeria, located along the eastern bank of the River Niger within the Lower Niger floodplain. The LGA lies approximately between 5°58′N–6°15′N latitude and 6°40′E–6°55′E longitude and covers about 608 km². It comprises sixteen communities, of which Atani, Ossomala, Ogbakuba, Odekpe, Akili-Ogidi, Mputu, Ogwuikpele, and Okpoko were purposively selected because of their vulnerability to flooding and erosion.

Ogbaru is characterized by flat, low-lying terrain generally below 50 m above sea level, extensive wetlands, seasonal floodplains, and proximity to the River Niger. Annual rainfall ranges from approximately 1,800–2,500 mm, with the rainy season occurring mainly between April and October, while mean annual temperatures range from 27°C to 32°C. Vegetation consists mainly of swamp forests, riparian woodland, and herbaceous wetlands.

The major livelihood activities include rain-fed agriculture, artisanal fishing, and wetland resource extraction. The combination of low elevation, proximity to the River Niger, seasonal rainfall, extensive floodplains, and human activities contributes to recurrent flooding and erosion. The selected communities therefore provide an appropriate setting for assessing the frequency, intensity, and spatial distribution of flooding and erosion hazards across Ogbaru LGA.

Research Design: A mixed-methods research design was adopted, combining geospatial analysis, field observations, and community-based information. The quantitative component focused on determining the frequency and intensity of flooding and erosion and analysing their spatial patterns, while qualitative information from residents and community stakeholders was used to complement the spatial and field-based findings. The design enabled integration of remotely sensed, geographic, environmental, and community-level information for a comprehensive assessment of the hazards.

Data Types and Sources: Both primary and secondary data were used. Primary data comprised field observations, GPS coordinates of identified flood- and erosion-prone locations, photographic documentation, and information obtained from residents and community stakeholders. Secondary data included satellite imagery, digital elevation data, rainfall records, river and drainage information, administrative boundaries, road networks, settlement locations, soil and geological data, and relevant published literature. Satellite imagery for different years was obtained from suitable Earth observation platforms, while rainfall and hydrological information were sourced from relevant meteorological and hydrological agencies. Administrative and other spatial datasets were obtained from authoritative government and open geospatial databases.

Sample Size Determination: For the household survey, the sample size was determined using Cochran's (1977) formula for large populations:

$$n = \frac{Z^2 P(1-P)}{d^2}$$

where is the required sample size, is the standard normal deviate at the 95% confidence level (1.96), is the estimated population proportion (0.50), (0.50), and is the margin of error (0.05). Substitution of the values yielded a minimum sample size of 384 respondents. To account for possible non-response, an additional 10% was included, resulting in a target sample size of 422 household heads.

Accordingly, 422 questionnaires were administered across the eight selected communities. Of these, 377 were successfully retrieved and found suitable for analysis, representing a response rate of 89.34%. Therefore, the 377 retrieved questionnaires constituted the final analytical sample for the household survey.

Sampling Technique: A multistage sampling procedure was employed. Communities within Ogbaru LGA were first identified, after which communities with evidence of recurrent flooding and/or erosion were purposively selected for detailed field investigation. Within the selected communities, affected locations were identified through reconnaissance surveys, consultation with residents and community leaders, and direct field observation.

A handheld Global Positioning System (GPS) was used to record the coordinates of observed flood and erosion locations. Field observations focused on indicators such as flood depth, duration, extent of inundation, recurrence, erosion scars, gully dimensions, bank instability, exposed soil surfaces, damaged infrastructure, and affected agricultural areas. Photographs were taken to provide visual documentation and assist with validation of the spatial analysis.

Assessment of Flood Frequency: Flood frequency was assessed using historical records, community responses, and available rainfall and hydrological information. Respondents were asked to indicate the occurrence of flooding within specified periods, including the number of flood events experienced annually and the months or seasons during which flooding commonly occurred.

The annual flood frequency was calculated using the expression

$$F = \frac{N}{T}$$

where $F$is the annual flood frequency, $N$is the number of recorded flood events, and $T$is the length of the observation period in years.

Flood frequency was subsequently classified into appropriate categories such as low, moderate, and high based on the distribution of observed values.

Assessment of Flood Intensity: Flood intensity was assessed from respondents' classifications of the severity of flooding experienced in their communities. A four-point ordinal scale was used, comprising Low, Moderate, High, and Very High, which were assigned numerical scores of 1, 2, 3, and 4, respectively. Individual responses were aggregated at the community level to obtain the distribution of perceived flood-intensity categories.

The community-level mean flood-intensity score was computed using the weighted mean:

$$FI = \frac{(1 \cdot f_1) + (2 \cdot f_2) + (3 \cdot f_3) + (4 \cdot f_4)}{N}$$

where $FI$is the mean flood-intensity score, $f_1, f_2, f_3,$and $f_4$are the frequencies of respondents reporting low, moderate, high, and very-high intensity, respectively, and $N$is the total number of valid respondents in each community.

The resulting mean scores were interpreted using the following classification:

Mean Score	Flood Intensity Classification
1.00–1.75	Low
1.76–2.50	Moderate
2.51–3.25	High
3.26–4.00	Very High

This approach enabled comparison of perceived flood intensity among the eight selected communities.
Assessment of Erosion Frequency and Intensity: Erosion occurrence was assessed through field observations, historical evidence, community information, and satellite imagery. Locations showing active gullies, bank erosion, exposed soil, loss of agricultural land, road degradation, or damage to buildings and other infrastructure were identified and georeferenced.

Erosion intensity was assessed using indicators including gully dimensions, rate of visible expansion, affected land area, sediment movement, vegetation loss, and damage to infrastructure. Erosion-prone locations were subsequently categorized according to their relative severity.

GIS Analysis: Geographic Information System (GIS) techniques were employed to determine the spatial distribution of flooding and erosion hazards. Spatial datasets were projected into a common coordinate reference system and processed using GIS software.

Spatial Analysis of Hazard Patterns: Spatial patterns were examined using GIS-based overlay and hotspot analysis. Flood and erosion locations were plotted and analysed in relation to elevation, slope, drainage networks, land-use/land-cover, settlements, roads, and other relevant environmental variables.

Kernel density or hotspot analysis was used, where appropriate, to identify areas with concentrations of recorded flood and erosion events. Buffer analysis was also applied around major rivers and drainage channels to determine the proximity of settlements and infrastructure to potential hazard sources.

The resulting spatial patterns were classified into hazard zones and represented cartographically to identify communities with relatively high concentrations of flooding and erosion.

Questionnaire Survey: A structured questionnaire was administered to residents of selected communities to obtain information on flood and erosion occurrence, frequency, duration, perceived intensity, affected locations, impacts, and historical changes. Responses were measured using appropriate categorical and Likert-scale items. The questionnaire was pre-tested in a community outside the final sample, where feasible, to assess clarity, reliability, and suitability before administration.

Data Analysis: Quantitative data obtained from questionnaires and field observations were coded and analysed using SPSS, while spatial data were analysed using GIS software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize flood and erosion characteristics.

Where appropriate, inferential statistical techniques such as chi-square tests, correlation analysis, and regression analysis were employed to examine relationships between hazard occurrence and selected environmental or socio-economic variables. Statistical significance was evaluated at the 0.05 level.

GIS outputs were presented as thematic maps showing the spatial distribution of flood frequency, flood intensity, erosion occurrence, erosion intensity, and combined hazard hotspots.

Data Validation and Quality Control: Quality assurance was maintained throughout data collection and analysis. GPS coordinates were checked for positional accuracy, field observations were cross-validated with photographic evidence and satellite imagery, and questionnaire instruments were reviewed before and after field administration. Spatial datasets were checked for projection consistency, completeness, and geometric errors. Hazard maps were validated by comparing mapped locations with

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observed field conditions and community-reported hazard locations.

Ethical Considerations: Permission was obtained from relevant community leaders and authorities before fieldwork. Respondents were informed about the purpose of the study, and participation was voluntary. Confidentiality and anonymity of respondents were maintained throughout the study. Field activities were conducted with minimal disruption to community activities, while appropriate care was taken to ensure the safety of researchers and participants during visits to flood- and erosion-prone locations.

IV. RESULT

Table 1: Questionnaire Distribution and Retrieval Rate

Community	Questionnaires Distributed	Questionnaires Retrieved	Retrieval Rate (%)
Atani	53	43	81.13 %
Ossomala	53	47	88.68 %
Ogbakuba	53	49	92.45 %
Odekpe	53	41	77.36 %
Akili-Ogidi	53	45	84.91 %
Mputu	52	51	98.08 %
Ogwuikpele	52	50	96.15 %
Okpoko	53	51	96.23 %
Total	422	377	89.34 %

Table 2: Socio-demographic Characteristics of Respondents

Variable	Category	Frequency	Percentage (%)
Age	18–35	98	26.0
	36–50	142	37.7
	51–65	89	23.6
	Above 65	48	12.7
Gender	Male	215	57.0
	Female	162	43.0
Education	No formal education	67	17.8
	Primary	112	29.7
	Secondary	138	36.6
	Tertiary	60	15.9
Occupation	Farming	168	44.6
	Fishing	92	24.4
	Trading	71	18.8
	Civil service/Others	46	12.2
Household size	1–4	89	23.6
	5–8	198	52.5
	Above 8	90	23.9
Years of residence	Less than 10	45	11.9
	10–20	112	29.7
	Above 20	220	58.4

Table 3: Frequency, Duration and Depth of Flooding across Selected Communities

Community	Annual Flood Frequency (Mean ± SD)	Duration (days)	Mean Flood Depth (m)
Atani	2.8 ± 0.9	18	1.2
Ossomala	3.1 ± 1.1	22	1.5
Ogbakuba	2.4 ± 0.8	15	0.9
Odekpe	3.5 ± 1.2	25	1.8
Akili-Ogidi	2.6 ± 0.7	16	1.1
Mputu	2.2 ± 0.6	12	0.8
Ogwuikpele	2.9 ± 1.0	20	1.3
Okpoko	2.7 ± 0.9	17	1.0

Flood frequency represents the mean number of flood events experienced annually. Duration represents the average number of days of inundation, while flood depth represents the mean observed/reported water depth.

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Table 4: One-way ANOVA Comparing Flood Frequency among the Selected Communities

Source of Variation	Sum of Squares	df	Mean Square	F-value	p-value
Between Communities	17.462	7	2.495	8.64	<0.001
Within Communities	106.532	369	0.289		
Total	123.994	376			

Interpretation: There was a statistically significant difference in annual flood frequency among the eight communities, $F(7,369) = 8.64$, $p < 0.001$. This indicates that flood occurrence was not uniform across the study communities.

Table 5: Post Hoc Multiple Comparison (Tukey HSD) for Annual Flood Frequency

Community Comparison	Mean Difference	p-value	Interpretation
Odekpe vs Mputu	1.30	<0.001	Significant
Odekpe vs Ogbakuba	1.10	0.002	Significant
Odekpe vs Akili-Ogidi	0.90	0.006	Significant
Odekpe vs Okpoko	0.80	0.012	Significant
Ossomala vs Mputu	0.90	0.004	Significant
Ossomala vs Ogbakuba	0.70	0.021	Significant
Atani vs Mputu	0.60	0.048	Significant
Other comparisons	—	>0.05	Not Significant

Note: Low = 1, Moderate = 2, High = 3, and Very High = 4. Mean intensity scores were calculated using the weighted mean of the four severity categories.

Table 6: Perceived Causes/Drivers of Flooding

Cause	Yes (%)	No (%)	Mean Score (5-point scale)	Rank
Heavy rainfall	92.3	7.7	4.61	1
River overflow (River Niger)	88.6	11.4	4.48	2
Poor drainage system	79.8	20.2	4.12	3
Deforestation	71.4	28.6	3.85	4
Climate change	68.2	31.8	3.71	5
Blocked waterways	65.5	34.5	3.58	6

Table 7: Flood Intensity Classification across Selected Communities

Community	Low	Moderate	High	Very High	Mean Score	Classification
Atani	8	14	15	6	2.44	Moderate
Ossomala	3	9	18	17	3.04	High
Ogbakuba	12	18	14	5	2.35	Moderate
Odekpe	2	7	14	18	3.17	High
Akili-Ogidi	10	17	13	5	2.34	Moderate
Mputu	16	21	10	4	1.98	Moderate
Ogwuikpele	7	16	18	9	2.55	High
Okpoko	5	15	20	11	2.75	High

The results indicate considerable variation in perceived flood intensity across the selected communities. Odekpe recorded the highest mean flood-intensity score (3.17), followed by Ossomala (3.04), Okpoko (2.75), and Ogwuikpele (2.55), all of which fell within the high-intensity category. Atani (2.44), Ogbakuba (2.35), Akili-Ogidi (2.34), and Mputu (1.98) recorded moderate flood-intensity scores. Mputu had the lowest mean score (1.98),

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indicating comparatively lower perceived flood intensity among the study communities.

The relatively high scores recorded in Odekpe and Ossomala suggest that respondents in these communities' experience more severe flooding than those in the other locations. This pattern is broadly consistent with the flood-frequency and depth results in Table 3, where Odekpe also recorded the highest annual flood frequency (3.5 events/year), longest duration (25 days), and greatest mean flood depth (1.8 m).

Table 8: Distribution and Severity of Erosion Types across Selected Communities

Community	Sheet Erosion (%)	Rill Erosion (%)	Gully Erosion (%)	Riverbank Erosion (%)	Overall Severity
Atani	28	35	22	15	High
Ossomala	18	30	27	25	High
Ogbakuba	36	32	18	14	Moderate
Odekpe	12	25	48	15	Very High
Akili-Ogidi	39	28	17	16	Moderate
Mputu	42	26	14	18	Moderate
Ogwuikpele	21	33	24	22	High
Okpoko	17	29	31	23	High

Percentages represent the distribution of identified/reported erosion types within each community. Overall severity represents the community-level classification based on the adopted erosion-severity assessment procedure.

Table 9: GPS Coordinates and Spatial Distribution of Flood and Erosion Hotspots

Site	Latitude	Longitude	Flood Risk	Erosion Type
Atani Waterfront	6.0123 °N	6.7456° E	Very High	Riverbank
Ossomala Riverbank	5.9987 °N	6.7289° E	Very High	Riverbank
Ogbakuba Floodplain	6.0246 °N	6.7018° E	Moderate	Sheet
Odekpe Gully Site	5.9876 °N	6.7321° E	High	Gully
Akili-Ogidi Wetland	5.9524 °N	6.6845° E	Moderate	Sheet
Mputu Floodplain	5.9418 °N	6.6697° E	Moderate	Rill
Ogwuikpele River Margin	5.9736 °N	6.7184° E	High	Riverbank
Okpoko Drainage Channel	6.1502 °N	6.7945° E	High	Gully

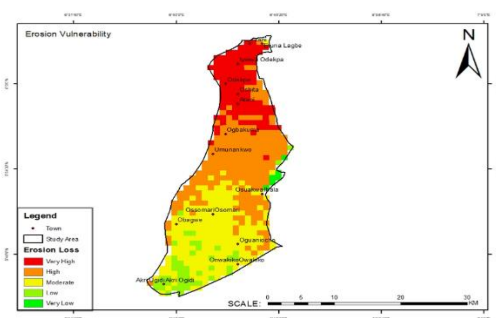

Figure 1: Erosion Vulnerability, Source: Researcher's GIS analysis (2026)

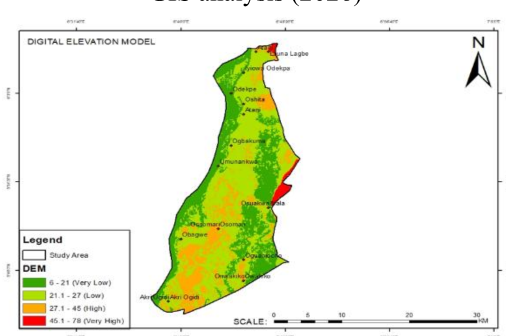

Figure 2: Digital Elevation Model (DEM), Source: Researcher's GIS analysis (2026)

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V. DISCUSSION

The study achieved an overall questionnaire retrieval rate of 89.34%, with 377 of the 422 questionnaires distributed successfully retrieved and found suitable for analysis. Retrieval rates varied across the eight selected communities, ranging from 77.36% in Odekpe to 98.08% in Mputu. The relatively high retrieval rate provides a strong basis for interpreting the household-level findings and suggests good respondent engagement with the study. The lower retrieval rate in Odekpe may reflect difficulties associated with field accessibility or respondent availability, although the available data do not establish a specific cause.

The high level of participation is particularly relevant in a study of recurrent environmental hazards because local residents constitute an important source of information on flood occurrence, duration, intensity, and environmental changes. This is consistent with Ezeokoli et al. (2019), who emphasized stakeholders' perceptions in understanding flooding events in Ogbaru. Their work demonstrates the value of community-level evidence in documenting the characteristics and consequences of flooding in the area.

The socio-demographic results show that the respondents were predominantly within the economically active age groups. Respondents aged 36–50 years constituted the largest group (37.7%), followed by those aged 18–35 years (26.0%) and 51–65 years (23.6%), while those above 65 years accounted for 12.7%. The predominance of middle-aged respondents is important because longer-term residents are likely to possess considerable experience of recurrent flooding and associated environmental changes.

The gender distribution comprised 57.0% males and 43.0% females, indicating relatively broad representation of both sexes. Educational attainment was dominated by secondary education (36.6%), followed by primary education (29.7%), no formal education (17.8%), and tertiary education (15.9%). Occupationally, farming was the dominant livelihood (44.6%), followed by fishing (24.4%) and trading (18.8%). This livelihood structure reinforces the importance of flood and erosion hazards in Ogbaru because agricultural and fishing activities are closely connected with floodplains, wetlands, riverbanks, and other environmentally sensitive areas.

The large proportion of respondents with more than 20 years of residence (58.4%) is particularly significant. Their long-term residence provides a useful basis for reporting recurrent environmental events and changes in hazard characteristics. This finding complements the concerns documented by Ezeokoli et al. (2019) regarding stakeholders' experiences of flooding in Ogbaru and the findings of Onyeizugbe and Onyejiaka (2020), which showed that flooding affects land utilization in the LGA.

The findings demonstrate substantial variation in flood characteristics among the selected communities. Odekpe recorded the highest annual flood frequency (3.5 ± 1.2 events), longest inundation duration (25 days), and greatest mean flood depth (1.8 m). Ossomala ranked second, with 3.1 ± 1.1 annual flood events, 22 days of inundation, and a mean flood depth of 1.5 m. In contrast, Mputu recorded the lowest values, with 2.2 ± 0.6 annual flood events, 12 days of inundation, and a mean flood depth of 0.8 m.

The results indicate that flooding is not uniformly experienced across Ogbaru. Communities experiencing more frequent floods also tended to experience longer inundation and greater water depths. This spatial variability is consistent with Umar and Gray (2022) and Ogboeli et al., (2024) who noted that flooding in Nigeria varies considerably in occurrence and impact according to environmental and spatial characteristics. It also agrees with Ubah et al. (2024), whose regression modelling of flood episodes in Ogbaru underscores the importance of examining flood occurrence systematically for prediction and management.

The particularly high flood characteristics recorded at Odekpe are also consistent with the spatial evidence presented in the study, where Odekpe was associated with a gully site and high flood-risk classification. The findings reinforce the argument that flood risk assessment in Ogbaru requires location-specific analysis rather than treating the LGA as a homogeneous hazard zone.

The one-way ANOVA revealed a statistically significant difference in annual flood frequency among the eight communities, $F(7,369) = 8.64$, $p < 0.001$. This finding provides statistical evidence that flood occurrence varies significantly across Ogbaru rather than being evenly distributed among communities.

The Tukey HSD results further showed significant differences between several pairs of communities. Odekpe recorded significantly higher flood frequency than Mputu, Ogbakuba, Akili-Ogidi, and Okpoko, while Ossomala also differed significantly from Mputu and Ogbakuba. Atani differed significantly from Mputu. These pairwise differences strengthen the descriptive evidence in Table 3 and identify specific communities where flood occurrence is particularly pronounced.

The finding agrees with the broader spatial perspective of Chukwuma et al. (2021), who demonstrated spatial variations in flood vulnerability across Anambra State using GIS-based modelling. It is also consistent with Izuegbu and Lay (2024), whose work specifically addressed flood-vulnerability mapping in Ogbaru. Together, these studies support the interpretation that flood hazard and vulnerability in Ogbaru are spatially heterogeneous and require geographically targeted interventions.

Heavy rainfall emerged as the most strongly perceived driver of flooding, with 92.3% of respondents identifying it and a mean score of 4.61. This was followed by River Niger overflow (88.6%; mean = 4.48) and poor drainage (79.8%; mean = 4.12). Deforestation (71.4%; mean = 3.85), climate change (68.2%; mean = 3.71), and blocked waterways (65.5%; mean = 3.58) were also identified as important contributors.

The prominence of heavy rainfall and River Niger overflow reflects the physical setting of Ogbaru as a low-lying riverine environment. The findings also demonstrate that respondents perceive flooding as resulting from an interaction between natural processes and human activities. Poor drainage, deforestation, and blocked waterways indicate anthropogenic contributions that may increase runoff and reduce the capacity of drainage systems to convey water.

These findings are broadly consistent with Ezeokoli et al. (2019), which documented stakeholder concerns regarding flooding events in Ogbaru, and with Umar and Gray (2022), who identified rainfall and hydrological processes among important factors associated with flooding in Nigeria. The identification of blocked waterways and poor drainage further suggests that flood management should combine structural interventions with improved environmental management and maintenance of drainage channels.

The flood-intensity results reveal considerable variation in perceived severity. Odekpe recorded the highest mean intensity score (3.17), followed by Ossomala (3.04), Okpoko (2.75), and Ogwuikpele (2.55), all classified as high intensity. Atani (2.44), Ogbakuba (2.35), Akili-Ogidi (2.34), and Mputu (1.98) were classified as moderate.

The ranking provides an important complement to the physical flood characteristics reported in Table 3. Odekpe simultaneously recorded the highest flood frequency, longest duration, greatest depth, and highest perceived intensity. Ossomala also showed consistently high flood characteristics. This convergence between physical indicators and community perceptions strengthens the evidence that these locations represent important flood-hazard hotspots.

The findings support the spatial modelling perspective of Chukwuma et al. (2021), who demonstrated that flood vulnerability varies geographically within Anambra State. They are also consistent with the Ogbaru-specific mapping work of Izuegbu and Lay (2024). However, the present findings extend this body of work by combining community-level flood-frequency and intensity information with spatial identification of hazard locations.

The erosion assessment demonstrates substantial differences in the dominant forms of erosion among the communities. Gully erosion was particularly prominent in Odekpe (48%), while Okpoko recorded 31% and Ossomala 27%. In contrast, sheet erosion dominated in Mputu (42%), Akili-Ogidi (39%), and

Ogbakuba (36%). Riverbank erosion was relatively prominent in Ossomala (25%) and Okpoko (23%).

Odekpe was classified as having very high overall erosion severity, while Atani, Ossomala, Ogwuikpele, and Okpoko were classified as high. Ogbakuba, Akili-Ogidi, and Mputu were classified as moderate. The particularly high proportion of gully erosion in Odekpe suggests more concentrated erosional processes in that community compared with locations dominated by sheet erosion.

The findings are consistent with evidence from Anambra State showing that geological, soil, terrain, and related environmental characteristics influence susceptibility to land instability. Nwazelibe and Egbueri (2024) demonstrated the usefulness of geospatial approaches for identifying areas susceptible to land instability, while Ifeanyi and Nkiru (2024) emphasized the role of geological and soil characteristics in landslide susceptibility in Anambra State. Although those studies focus primarily on landslide susceptibility rather than the specific erosion types examined here, they support the broader interpretation that spatial environmental characteristics influence the distribution and severity of land-degradation processes.

The findings also align conceptually with Olorunfemi et al. (2020), who demonstrated the usefulness of GIS-based approaches for identifying soil-erosion and flood-hazard zones. The present study similarly demonstrates the importance of integrating environmental observations with spatial analysis when identifying erosion-prone locations.

The GPS-based observations demonstrate that flood and erosion hazards are spatially distributed across the selected communities, with several locations identified as high or very-high-risk areas. Atani Waterfront and Ossomala Riverbank were classified as very-high flood-risk locations, while Odekpe Gully Site, Ogwuikpele River Margin, and Okpoko Drainage Channel were identified as high-risk locations. Ogbakuba Floodplain, Akili-Ogidi Wetland, and Mputu Floodplain were classified as moderate-risk sites.

The spatial pattern demonstrates the importance of hydrological and landscape characteristics in determining local hazard exposure. Waterfronts, river margins, floodplains, wetlands, and drainage channels appear repeatedly among the identified hazard locations. This is consistent with the GIS-based findings of Chukwuma et al. (2021), which established spatial variability in flood vulnerability across Anambra State, and with Izuegbu and Lay (2024), which specifically mapped flood vulnerability within Ogbaru.

The DEM and erosion-vulnerability maps further provide a spatial basis for understanding how terrain and environmental conditions influence hazard distribution. Such spatial evidence is particularly valuable for disaster-risk reduction because it allows interventions to be prioritized according to location rather than applied uniformly across the LGA.

Overall, the findings demonstrate that flooding and erosion in Ogbaru are spatially heterogeneous, recurrent, and of varying intensity across communities. Odekpe consistently emerged as one of the most affected locations, recording the highest flood frequency, longest inundation duration, greatest flood depth, highest perceived flood-intensity score, and very high erosion severity. Ossomala also exhibited relatively high flood characteristics and erosion severity. Conversely, Mputu generally recorded lower flood frequency, duration, depth, and perceived intensity.

The findings therefore support the central proposition of the study that flooding and erosion hazards across Ogbaru cannot be adequately understood using a uniform LGA-wide assessment. Instead, community-level frequency, intensity, erosion characteristics, and spatial hotspot analysis are necessary to identify priority areas for intervention. This conclusion is consistent with previous research emphasizing spatial flood vulnerability and the need for GIS-supported hazard assessment in Anambra State (Chukwuma et al., 2021; Izuegbu & Lay, 2024; Odoh & Nwokeabia, 2024).

VI. CONCLUSION

The study concludes that flooding and erosion are recurrent and spatially heterogeneous environmental hazards in Ogbaru communities. Significant differences were observed in flood frequency, duration, depth, and intensity, with Odekpe consistently recording the highest levels, while Mputu generally experienced comparatively lower flood characteristics. Heavy rainfall, River Niger overflow, poor drainage, deforestation, climate change, and blocked waterways were identified as major contributing factors.

Erosion also varied considerably across the communities, with gully erosion particularly prominent in Odekpe and sheet erosion more dominant in Mputu, Akili-Ogidi, and Ogbakuba. Spatial assessments further identified Atani Waterfront and Ossomala Riverbank as very-high flood-risk locations, while Odekpe Gully Site, Ogwuikpele River Margin, and Okpoko Drainage Channel were classified as high-risk areas. These findings confirm that environmental hazards in Ogbaru are strongly influenced by local hydrological, terrain, and land-use characteristics.

Overall, the findings demonstrate the need for community-specific and spatially targeted disaster-risk reduction measures in Ogbaru. Priority should be given to high-risk communities through improved drainage, maintenance of waterways, erosion control, flood management, environmental restoration, and strengthened community-based preparedness. Integrating community knowledge with GIS-based hazard mapping can support more effective planning, resource allocation, and long-term resilience to flooding, erosion, and related environmental changes.

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