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Integrated Flood Hazard and Multidimensional Vulnerability Assessment of Anam Communities in Anambra West Local Government Area, Anambra State, Southeastern Nigeria

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ABSTRACT: Flooding is a recurrent extreme hydrometeorological hazard in many riverine communities. Consequently, the objective of this paper was to assess integrated flood hazard and vulnerability of selected Anam communities in Anambra West Local Government Area of Anambra State, Southeastern Nigeria using appropriate standard methods. Results reveal moderate-to-high composite social vulnerability index (CSVI $\approx$ 1.91) and moderate composite physical vulnerability index (CPVI $\approx$ 2.16), which combined to produce an overall high flood risk classification (FRI $\approx$ 5.18) for the communities. This finding demonstrated that flood risk in the study area is intricately embedded within socio-economic conditions and settlement patterns. To achieve effective flood risk reduction for the affected communities, the study recommended integrating hazard mitigation with vulnerability reduction, diversification of livelihoods, and spatial planning controls. This study provides a multidimensional risk assessment framework that can be applied to manage flooding in similar floodplain communities in developing countries.

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Flooding is one of the most widespread environmental hazards affecting wetland and floodplain communities in many regions of the world. Along the River Niger in Nigeria, recurrent seasonal flooding has intensified in recent decades due to climate variability, land-use changes, and settlement encroachment into natural floodplains (IPCC, 2014). While flooding is a natural hydrological process, its transformation into a disaster is largely determined by human vulnerability

(Birkman, 2007; Rana and Routray, 2018). Vulnerability itself is multidimensional, encompassing social, economic, physical and institutional factors that collectively influence the capacity of communities to anticipate, withstand, and recover from flood events (Cutter *et al.*, 2024). Riverine settlements within the Niger-Benue trough have been identified as particularly susceptible to recurrent flooding due to their geomorphological setting and prevailing socio-economic conditions

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(Ifatimehin *et al.*, 2020). Consequently, disaster risk is increasingly understood not merely as the occurrence of hazardous events, but as the interaction between them and underlying socio-economic vulnerability conditions that shape their severity (Birkman, 2007). The Anam people of Anambra West LGA in Anambra State, Southeastern Nigeria inhabit extensive wetlands and alluvial floodplains of the River Niger that support fishing and floodplain agriculture. However, these same environmental conditions expose them to recurrent flooding, leading to displacement, livelihood disruption, and infrastructure damage. Despite repeated flood events over the past decades, limited empirical attention has been given to the vulnerability characteristics and adaptive capacity of these communities. For example, social vulnerability indicators such as income level, education, household structure, and demographic composition have been shown to significantly influence disaster outcomes and recovery in flooded regions (Tascon-Gonzalez, 2020). This is why integrated flood risk assessment frameworks advocate the aggregation of multiple vulnerability dimensions into composite indices to improve analytical precision and policy relevance (Robielos *et al.*, 2020). Consequently, the objective of this paper was to assess integrated flood hazard and vulnerability of selected Anam communities in Anambra West Local Government Area of Anambra State, Southeastern Nigeria.

MATERIALS AND METHODS

Study area: Anam is located in Anambra West LGA of Anambra State, Southeastern Nigeria, on the eastern floodplains of the River Niger. Anambra West LGA, with headquarters in Nzam, is situated within longitudes $6^{\circ}48'60''\text{E}$, $6^{\circ}51'36''\text{E}$ and latitudes $6^{\circ}21'16''\text{N}$, $6^{\circ}18'48''\text{N}$. The local government area is bounded to the west by the River Niger, to the East by Ayamelum and Anambra East LGAs, to the South by Onitsha North LGA, and to the North by Kogi

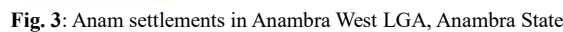
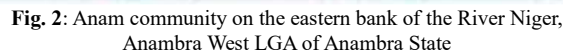
State. The area is characterized by low relief, extensive wetlands, and seasonal flood inundation. Major settlements include Ezi-Anam, Ifite-Anam, Nzam, Olumbanasa, Oroma-etiti, Umueze-Anam and Umuenwelum-Anam. Annual rainfall in the area ranges between 1,400 mm and 2,500 mm, with maximum flood inundation occurring during the peak rainy season.

Data collection and sampling procedure: Anam comprises eight (8) communities within the Anambra West Local Government Area. However, five (5) of these communities were purposively selected for this survey. The selection criteria included degree of historical flood exposure; proximity to the River Niger, settlement density and spatial extent; variation in elevation; and accessibility during survey. Pilot surveys indicated that the selected communities account for the highest seasonal frequency and inundation within Anam. They also represent the required spatial variability in settlement structure, socio-economic characteristics, and proximity to the River Niger channel. Consequently, the selected communities are the main flood-prone areas in Anam. The other three (3) communities that were excluded have comparatively lower flood exposure levels as they are located on higher grounds that make them less critical for the survey.

Sample size determination: To ensure adequacy in household-level representation and also strengthen the generalizability of survey findings, a sample size of 400 respondents was adopted for this study. The 400 questionnaires were proportionally distributed across the five (5) selected Anam communities based on the estimated household population size. A total of 360 questionnaires were successfully recovered, representing 90% recovery, which exceeded the minimum acceptable threshold for a survey of this nature.



Fig.1: Map of Nigeria showing Anambra State



scale of 1 (low vulnerability) to 3 (high vulnerability); a ranking that reflected the relative susceptibility of each category to flood impacts (Ogundolie, *et al.*, 2024). The index for each selected indicator was computed using a weighted proportion approach expressed in equation 1 below:

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Where P_i represents the proportion of respondents in the category i , and R_i represents the assigned vulnerability rank to the indicator.

A Composite Social Vulnerability index (CSVI) was derived as the arithmetic mean of individual indicator indices, as expressed in the equation 2:

$$CSVI = \sum \frac{\text{Indicator Indices}}{2} \quad \text{Equation 2}$$

Where n is the number of social vulnerability indicators considered. By integrating demographic and socio-economic dimensions of vulnerability, a more comprehensive representation of social susceptibility to flooding was achieved in this study.

Composite physical vulnerability assessment: Similarly, the composite physical vulnerability was assessed using structural and locational characteristics of buildings in the study area (Amama *et al.*, 2023). The study considered five (5) indicators which included housing construction material, building elevation above ground level, foundation type, proximity to the river channel, and drainage condition around buildings.

Each category within these five (5) indicators was assigned a vulnerability rank that ranged from 1 (low vulnerability) to 3 (high vulnerability), reflecting the susceptibility of buildings to flood damage (Ogundolie, *et al.*, 2024). Indicator indices were computed using a weighted proportion method expressed in equation 3 below:

$$\text{Indicator Index}(p) = \sum (P_i \times R_i) \quad \text{Equation 3}$$

A Composite Physical Vulnerability Index (CPVI) was derived as the arithmetic mean of the individual indicator indices expressed in equation 4:

$$CPVI = \sum \frac{\text{Physical Indicator Indices}}{n} \quad \text{Equation 4}$$

Where P_i = proportion of buildings in the category i ; R_i = assigned vulnerability rank; n = number of physical indicators

The adopted composite approach integrated both structural and spatial characteristics to provide a multidimensional assessment of the susceptibility of

buildings to flood damage in Anam (Robielos *et al.*, 2020).

Livelihood Sensitivity Index: Livelihood sensitivity was computed as expressed in equation 5:

$$LSI = \sum (P_i \times S_i) \quad \text{Equation 5}$$

Where P_i represents the proportion of households engaged in livelihood i and S_i is its sensitivity rank. See Table 1 below.

Table 1: Livelihood Sensitivity Ranking

Livelihood	Sensitivity Ranking
Fishing	3
Floodplain farming	3
Petty trading	2
Civil service/artisan work	1

Adapted from Rana and Routray, 2018

Integrated Flood Risk Assessment Model: To provide a holistic evaluation of flood impacts in Anam communities, hazard intensity was integrated with both composite social and composite physical vulnerability indices to derive an overall Flood Risk Index (FRI). Flood risk was conceptualized as the interaction between flood hazard and vulnerability assessment components expressed in equation 6:

$$\text{Flood Risk (FRI)} = H \times V \quad \text{Equation 6}$$

Where: H = Flood Hazard Index; V = Overall Vulnerability Index

The overall Vulnerability Index was derived as the mean of the Composite Social Vulnerability Index (CSVI) and the Composite Physical Vulnerability Index (CPVI). See equation 7 below:

$$V = \frac{CSVI + CPVI}{2} \quad \text{Equation 7}$$

Thus:

$$FRI = H \times \left(\frac{CSVI + CPVI}{2} \right) \quad \text{Equation 8}$$

The approach ensures that flood risk for the study area reflects not only the magnitude of the hazard (flood), but also the physical and socio-economic susceptibility of Anam communities.

Hazard Index for Anam communities: This study categorized flood hazard levels based on inundation

depth and recurrence characteristics, with ranking values assigned as follows:

Table 2: Hazard index ranking	
Hazard Level	Rank
Low	1
Medium	2
High	3

Source: Ouma and Tateishi, 2016

Hazard Index (HI) for this study was computed as the weighted average of hazard categories affecting each community (Abubakar *et al.*, 2025).

RESULTS AND DISCUSSION

Table 3 presents the distribution of administered and retrieved questionnaires across the five (5) selected Anam communities. The proportional allocation reflects relative settlement size and ensures balanced representation of household-level characteristics within the study area. The questionnaire retrieval rate of 90% exceeds the minimum acceptable threshold for vulnerability assessment surveys, thereby supporting the validity and reliability of subsequent

composite index computation and flood risk assessment (Robielos *et al.*, 2020). *Derived composite social vulnerability indicator (CSVI) of Anam communities (n = 360)*: Flood vulnerability in the selected Anam communities is shaped by demographic and multiple socio-economic indicators, including age, educational attainment, income status, household dependency levels, and gender of household head. These indicators affect the capacity of individual households to anticipate, withstand, and recover from flood events. While age structure alone provides insight into demographic sensitivity, the integration of other socio-economic variables into a composite social vulnerability index (CSVI) allows for a deeper and more comprehensive assessment of social susceptibility for the studied population. The results indicate that vulnerability to flooding in Anam communities is not solely demographic but is reinforced by these other socio-economic indicators that collectively weaken adaptive capacity. Table 4 presents the distribution of the selected indicators, assigned vulnerability rankings and weighted scores used in computing the composite index, CSVI.

Table 3: Distribution of questionnaires by community (N = 400)

Community	Administered	Retrieved	%Retrieved
Ezi-Anam	70	63	90
Ifite-Anam	60	54	90
Umueze-Anam	55	50	91
Umuenwelum-Anam	55	49	89
Olumbanasa	60	54	90
Total	400	360	90

Table 4: Composite Social Vulnerability Index (CSVI) and Index Scores

Indicator	Category	Frequency	Percentage (%)	Vulnerability Rank (R_i)	Weighted score ($P_i \times R_i$)
Age Structure	<5 years	72	20.0	3	0.60
	5 – 25years	108	30.0	2	0.60
	25 – 60years	135	37.5	1	0.38
	>60years	45	12.5	3	0.38
Education Level	None	90	25.0	3	0.75
	Primary	126	35.0	2	0.70
	Secondary	108	30.0	1	0.30
	Tertiary	36	10.0	1	0.10
Income Level	Low income	162	45.0	3	1.35
	Medium income	126	35.0	2	0.70
	High income	72	20.0	1	0.20
Dependency Ratio	High	144	40.0	3	1.20
	Moderate	126	35.0	2	0.70
	Low	90	25.0	1	0.25
Gender of Household Head	Female-headed	126	35.0	2	0.70
	Male-headed	234	65.0	1	0.65

Source: Nwatu *et al.*, 2026: *Interpretation scale (after Balica *et al.*, 2018): CSVI value 0 – 1.0 = Low; 1.1 – 2.0 = Moderate; 2.1 – 3.0 = High

From Table 4, for each indicator:

$$\text{Indicator Index}(s) = \sum (P_i \times R_i)$$

Then:

$$\text{CSVI} = \frac{\text{Sum of Indicator Indices}}{\text{Number of Indicators}}$$

If we compute from Table 4 above, we have the following indicator values: Age Index = 1.96; Education Index = 1.85; Income Index = 2.25; Dependency Index = 2.15 and Gender Index = 1.35

$$\text{CSVI} = \frac{1.96 + 1.85 + 2.25 + 2.15 + 1.35}{5}$$

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$$CSVI = 1.912$$

With $CSVI \approx 1.91$, Anam communities fall within the upper moderate vulnerability category, approaching high vulnerability.

The derived Composite Social Vulnerability Index ($CSVI \approx 1.91$) indicates that flood vulnerability in Anam communities is multidimensional and structurally embedded within socio-economic conditions. While demographic factors such as age contribute to sensitivity, income level (Index = 2.25) and household dependency ratio (Index = 2.15) emerge as particularly critical determinants of overall population vulnerability. Clearly, the predominance of low-income households and high dependency ratios suggests limited financial capacity within households and the community to prevent or mitigate flood-related losses. The relatively low levels of educational attainment observed amongst respondents may reduce access to early warning

information and adaptive planning for people who need them. Though male-headed households were observed to be in the majority, female-headed households show much higher vulnerability because of their limited asset ownership and income security. Overall, the determined composite index ($CSVI \approx 1.91$) demonstrates that flood risk in Anam communities is exacerbated by prevailing demographic and socio-economic constraints that further limit adaptive capacity and weaken resilience. These findings underscore the necessity to integrate vulnerability reduction strategies into flood risk management to address both structural poverty and hazard exposure.

Derived composite physical vulnerability index (CPVI) of Anam communities: This study developed a composite physical vulnerability index (CPVI) used to quantify the structural predisposition to flood damage of residential buildings within the selected Anam communities.

Table 5: Composite physical vulnerability indicators (n =360)

Indicator	Category	Frequency	Percentage (%)	Vulnerability Rank (R_i)	Weighted score ($P_i \times R_i$)
Housing Material	Durable (Cement/brick)	126	35.0	1	0.35
	Semi-durable	108	30.0	2	0.60
	Non-durable (Mud/Thatch)	126	35.0	3	1.05
Building Elevation	Raised (>1m)	72	20.0	1	0.20
	Moderate (0.5-1m)	126	35.0	2	0.70
	Low (<0.5m)	162	45.0	3	1.35
Foundation Type	Reinforced concrete	90	25.0	1	0.25
	Block foundation	144	40.0	2	0.80
	Mud foundation	126	35.0	3	1.05
Proximity to River	>1 km	72	20.0	1	0.20
	500m – 1 km	108	30.0	2	0.60
	<500 m	180	50.0	3	1.50
Drainage Condition	Functional drainage	90	25.0	1	0.25
	Partial drainage	126	35.0	2	0.70
	No drainage	144	40.0	3	1.20

Source: Nwatu et al., 2026; *Physical Vulnerability Interpretation Scale (after Balica et al., 2018): CPVI value 1 – 1.8 = Very Low; 1.81 – 2.6 = Low to Moderate; 2.61 – 3.40 = Moderate; 3.41 – 4.20 = High; 4.21 – 5.00 = Very High

The five (5) key indicators that were adopted were based on earlier field reconnaissance, established flood vulnerability literature, and contextual relevance to riverine settlements. They include: housing material, building elevation, foundation type, proximity to river channel, and drainage condition. Each physical vulnerability indicator was further categorized and assigned vulnerability rankings and weighted scores. Table 5 above presents the distribution of these indicators, their categories, frequencies observed in the survey, and assigned vulnerability rankings and weighted scores used in computing the composite index (CPVI). From Table 5 above, for each indicator we apply equation 3 restated below:

$$\text{Indicator Index}(p) = \sum (P_i \times R_i)$$

Then equation also restated below:

$$CPVI = \frac{\text{Sum of indicator Indices}}{\text{Number of Indicators}}$$

If we compute from Table 5 above, we get the following indicator values: Housing Material Index = 2.00; Building Elevation Index = 2.25; Foundation Type Index = 2.10; Proximity to River Channel Index = 2.30; Drainage Condition Index = 2.15

$$CPVI = \frac{2.00 + 2.25 + 2.10 + 2.30 + 2.15}{5} = 2.16$$

With CPVI ≈ 2.16 , Anam communities fall within the moderate physical vulnerability category.

The computed CPVI (2.16) indicate moderate physical vulnerability to flood damage. This CPVI value reflects the combined effect of selected indicators, housing material, building elevation, foundation type, proximity to river channel, and drainage condition in the built environment within the studied communities. While it was observed that most residential structures are not constructed with highly fragile materials, moderate vulnerability persists due to the low elevation of houses, with those nearer to the river channel contributing significantly to overall physical exposure to flood inundation. Again, when we compare the CPVI of 2.16 to the derived CSVI (1.91) for this study, we see that though physical/structural conditions present moderate risk, social vulnerability indicators may play an equally important or greater role in shaping disaster outcomes in the selected Anam communities.

Integrated Flood Risk Assessment: To determine the overall flood risk profile for the study area, composite social and physical vulnerability indices were integrated with the flood hazard index.

The Composite Social Vulnerability Index (CSVI) was computed as approximately:

$$CSVI = 1.91$$

The Composite Physical Vulnerability Index (CPVI) was computed as approximately:

$$CPVI = 2.16$$

Thus Overall Vulnerability Index V is determined by applying equation 7 restated below:

$$V = \frac{CSVI + CPVI}{2}$$

$$V = \frac{1.91 + 2.16}{2}$$

$$V = 2.07$$

Assuming a moderate-to-high flood hazard level (H = 2.5 based on hazard classification), the Flood Risk

Index is determined by applying equation 6 restated below:

$$\text{Flood Risk (FRI)} = H \times V$$

$$FRI = 2.5 \times 2.07$$

$$FRI = 5.175 \approx 5.18$$

Table 6: Flood Risk Interpretation Scale

FRI Value	Risk Level
0 – 2	Low
2.1 – 4	Moderate
4.1 – 6	High
>6	Very High

Adapted from Belica *et al.*, 2018

With FRI ≈ 5.18 , the communities fall within the High Flood Risk Category (Table 6).

Livelihood Sensitivity: Livelihood sensitivity to flooding was assessed by examining the dominant economic activities of households and their susceptibility to flood inundation and disruption. A livelihood Sensitivity Index (LSI) was computed to quantify the degree to which household livelihoods are affected by flooding (Table 7).

Table 7: Livelihood sensitivity of Anam communities (n=360)

Livelihood Type	Frequency	Percentage (%)
Fishing	108	30.0
Floodplain farming	144	40.0
Petty trading	72	20.0
Civil service/artisan work	36	10.0
Total	360	100

Source: Nwatu *et al.*, 2026

Fishing and floodplain farming, the dominant livelihoods in the studied communities, account for about 70% of household livelihoods. This indicates high livelihood sensitivity. Prolonged flood inundation in these communities will directly disrupt income, food supply/security, and market access, reinforcing household vulnerability for households engaged in these activities as their source of livelihood.

Adaptive Capacity and Indigenous Coping Strategies: Coping strategies include temporary relocation, raised household platforms, seasonal livelihood adjustment, and reliance on social networks. These measures are largely reactive and insufficient for extreme or prolonged flooding, reflecting low adaptive capacity.

Table 8: Household flood coping strategies in Anam communities (n=360)

Coping strategy	Frequency	Percentage (%)
Temporary relocation to higher ground	126	35.0
Raising household items/platform	90	25.0
Seasonal livelihood adjustment	72	20.0
Dependence on social networks	36	10.0
No identifiable coping strategy	36	10.0
Total	360	100

Source: Nwatu *et al.*, 2026

Floodplain Dependence and the Vulnerability Paradox: Flooding represents a dual process of hazard and livelihood sustenance. Communities remain within flood-prone zones due to dependence on fertile soils and fisheries, creating a floodplain dependence paradox that complicates relocation-based risk reduction strategies.

Adaptive capacity and indigenous coping strategies of selected Anam communities: Despite recurrent flooding, the Anam people have developed a range of indigenous coping strategies aimed at reducing flood impacts on lives and livelihoods. Analysis of household responses indicates that adaptive capacity is largely informal, community-driven, and based on experiential knowledge of the flood regime of the River Niger.

Common coping strategies include temporary relocation to higher grounds during peak flood periods, elevation of household items using raised platforms, seasonal adjustment of livelihood activities, and reliance on extended family and social networks for support. However, these strategies are largely short-term and reactive, providing limited protection against prolonged or extreme flood events.

A significant proportion of households reported the absence of any formal coping mechanism, reflecting limited access to early warning systems, financial resources, and institutional support. This low adaptive capacity amplifies flood vulnerability and contributes to repeated losses after each flood event. The finding underscores the need for community-based flood adaptation initiatives that build upon existing indigenous knowledge while enhancing resilience through institutional support.

The integrated flood risk assessment demonstrates that the Anam communities are exposed to elevated flood risk resulting from the interaction between moderate-to-high hazard intensity and pronounced multidimensional vulnerability. While hazard is primarily influenced by hydrometeorological processes and riverine dynamics, the severity of disaster outcomes is largely mediated by underlying social and structural conditions (Birkman, 2007; Rana and Routray, 2018). This finding reinforces the conceptual understanding that natural flood events translate into disasters when they intersect with vulnerable human systems rather than as a direct consequence of hazard magnitude alone.

The analysis further reveals that vulnerability in Anam is shaped by settlement configuration within low-lying floodplain zones, dependence on climate-

sensitive livelihoods, housing material quality, and limited adaptive and coping capacities. Such multidimensional vulnerability characteristics are consistent with established social vulnerability frameworks, which emphasize the role of demographic, economic, and structural determinants in amplifying disaster impacts (Cutter *et al.*, 2024; Tascon-Gonzalez, 2020).

By integrating both social and physical vulnerability components into the composite flood risk model, the study confirms that flood risk within the Anam floodplain is structurally embedded and spatially reinforced rather than being solely environmentally induced. Similar integrated modelling approaches have demonstrated that risk emerges from the dynamic interaction between hazard intensity and pre-existing vulnerability conditions across space (Rana and Routray, 2018; Belica *et al.*, 2018). The spatial concentration of vulnerability factors within flood-prone settlements further compounds exposure levels and limits recovery potential.

These findings underscore the necessity for flood risk reduction strategies that extend beyond hazard management to include targeted vulnerability reduction measures. Contemporary disaster risk reduction frameworks advocate proactive interventions aimed at strengthening social resilience, improving structural conditions, and addressing systemic vulnerability drivers as a more sustainable alternative to reactive relief-focused approaches (Wen *et al.*, 2023). Accordingly, effective environmental management in the Anam context must integrate hydrometeorological risk mitigation with socio-economic transformation and adaptive capacity enhancement.

Conclusion: This study developed an integrated flood risk assessment framework that combines hazard intensity with multidimensional social and physical vulnerability indicators, providing a more comprehensive approach to understanding flood risk in riverine environments. The framework advances knowledge by demonstrating how vulnerability dimensions can be systematically integrated into flood risk analysis beyond conventional hazard-based models. It highlights the importance of incorporating socio-economic and structural factors into flood risk assessment for improved accuracy and relevance. The study recommends the adoption of vulnerability-based planning approaches, including regulated floodplain development, promotion of resilient housing, and strengthened community-based adaptation strategies. It further suggests the integration of geospatial tools into policy and

decision-making processes for effective flood risk management. This approach offers a scalable model for enhancing resilience in flood-prone communities across Nigeria and similar developing regions.

DECLARATIONS

Ethical Approval: This study involved survey of human participants/respondents via structured questionnaires and formal ethical approval was obtained from the community leaders. All procedures involving data handling and analysis were conducted responsibly and in accordance with standard academic and institutional guidelines.

Disclaimer (Artificial Intelligence): Authors hereby declare that no generative Artificial Intelligence (AI) technologies such as Large Language Models (ChatGPT, COPILOT, XLNet, Ernie 3.0 Titan, etc.) and text-to-image generators have been used during writing or editing of this manuscript.

Declaration of Conflict of Interest: The authors declare that no known conflict of interest or personal relationships have influenced the work reported in this paper.

Declaration of Data Availability: Data are available upon request from the Corresponding Author.

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