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# PARTICIPATORY MULTI-CRITERIA FLOOD VULNERABILITY ASSESSMENT IN LOKOJA, KOGI STATE

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## Abstract

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*Lokoja has experienced a recurrent devastating flood event since 1994, causing deaths, displacement, and billions in damages amid climate change and urban growth. Traditional top-down vulnerability assessments often neglect local insights, limiting effective mitigation and adaptation efforts. This study employs the Analytic Hierarchy Process (AHP) within a participatory multi-criteria decision analysis (MCDA) framework that integrates stakeholder inputs with physical attributes (elevation, population density, land use, drainage density, rainfall, slope, road density, and proximity to rivers) to develop a flood vulnerability map of communities in Lokoja, Kogi State. The AHP weighted criteria results revealed order of importance of flood vulnerability as proximity to waterbodies (0.25) > elevation (0.20) > rainfall = (0.15) = Drainage = 0.15) > land used land cover change (0.12) > Road Density (0.07) > (Slope = 0.03) = (Population = 0.03). The reclassified results revealed a low-vulnerability area of 1,164.24 km², a moderate-vulnerability area of 1,462.76 km², and a high-vulnerability area of 534.05 km², based on multi-criteria evaluation. Spatially, the vulnerability map highlights west-to-east disparities, with high-risk zones concentrated near riverine areas. This finding implies that areas near the river are highly vulnerable to flooding. The participatory MCA has demonstrated its capacity to enhance vulnerability mapping, thereby supporting decision-making aimed at reducing long-term vulnerability and livelihood disruption.*

**Keywords:** *Analytic Hierarchy Process, Multi-criteria Decision Analysis, Flooding, Vulnerability, Participatory.*

## 1.1 Introduction

Climate change and rapid urbanization are intensifying the frequency and intensity of floods worldwide, altering hydrological patterns and elevating risks in vulnerable regions (Rentschler *et al.,* 2022; Meresa *et al.,* 2021). As one of the most destructive natural hazards, flooding inflicts massive economic losses, fatalities, infrastructure destruction, and ecological damage, disproportionately burdening developing nations (Merz *et al.,* 2021; Njoku *et al.,* 2021). Global records show that major flood events have doubled over the past two decades, from 1,389 between 1980 and 1999 to 3,245 between 2000 and 2019, a surge affecting over 1.6 billion people and claiming the highest human toll among disasters (Wolff, 2021; UNDRR, 2020). In Africa alone, 763 such events occurred during this period, with profound effects on economies, health systems, and community well-being. Kogi State, particularly Lokoja at the Niger-Benue confluence, has endured eight major floods in the last decade (1994, 2004, 2010, 2012, 2017–2020), killing around 250, displacing 85,000, and inflicting millions in damages (Daniel *et al.,* 2023; FloodList, 2022). Projections signal worsening trends, demanding resilient preparedness strategies (Komolafe *et al.,* 2020; National Bureau of Statistics *et* *al.,* 2023). Last-mile communities (LMCs), often rural and isolated, face heightened threats due to poor infrastructure, weak early warning systems, communication gaps, and limited risk management (Global Disaster Preparedness Center, 2023; Shrestha *et al.,* 2021; Lundgren & Strandh, 2022). Hazards like floods become disasters only when they strike vulnerable populations, defined by exposure, sensitivity, and low adaptive capacity (IPCC, 2023; Quesada, 2022; Iss *et al.,* 2024). Effective flood vulnerability assessments are thus essential, especially in flood-prone Lokoja, where top-down methods that ignore local knowledge yield suboptimal interventions (Daniel et al., 2023). Participatory multi-criteria decision-making (MCDM) addresses this by blending community insights with analytical tools like the Analytical Hierarchy Process (AHP) and Multi-Influence Factor (MIF) to weight factors such as elevation, land use, and river proximity (ATBU, 2024). Non-state actors and communities remain sidelined, despite government efforts (Danhassan *et al.,* 2023; Nazir *et al.,* 2024; Ukoje & Achegbulu, 2022). Current methods often overlook the complex interplay between social, economic, infrastructural and environmental factors, leading to inadequate preparedness and response strategies. A participatory multi-criteria approach that integrates local stakeholders' perspectives and expertise is crucial for developing a comprehensive flood vulnerability assessment framework. This framework must justify the unique socio-economic conditions and geographical characteristics of Lokoja to enhance the accuracy and acceptance of vulnerability models among local policymakers and residents.

## 2.0 Description of the Study Area

Kogi State is one of the states in Nigeria's north-central geopolitical zone, with a total land area of 29,833 km2. projected population of 4,473,500 (City population, 2024). The study area is located in Lokoja, at latitudes 7˚45'0"N to 7˚53'30"N and longitudes 6˚43'0"E to 6˚51'30"E (Nigeria galleria, 2022). Communities located around the channels and at the confluences of these rivers bear the full brunt of flood impacts. These communities are Gadumo, Adankolo, Kabawa, Kpata, Lokongoma, 500 Units, 200 Units, Sarkin Noma, and Ganaja, among the most affected. The study region experiences distinct wet and dry seasons, with the dry season from November to February and the rainy season from March to October. Annual precipitation ranges from 1016 mm to 1524 mm, while temperatures remain consistently warm year-round, averaging 27°C (Date, 2025).

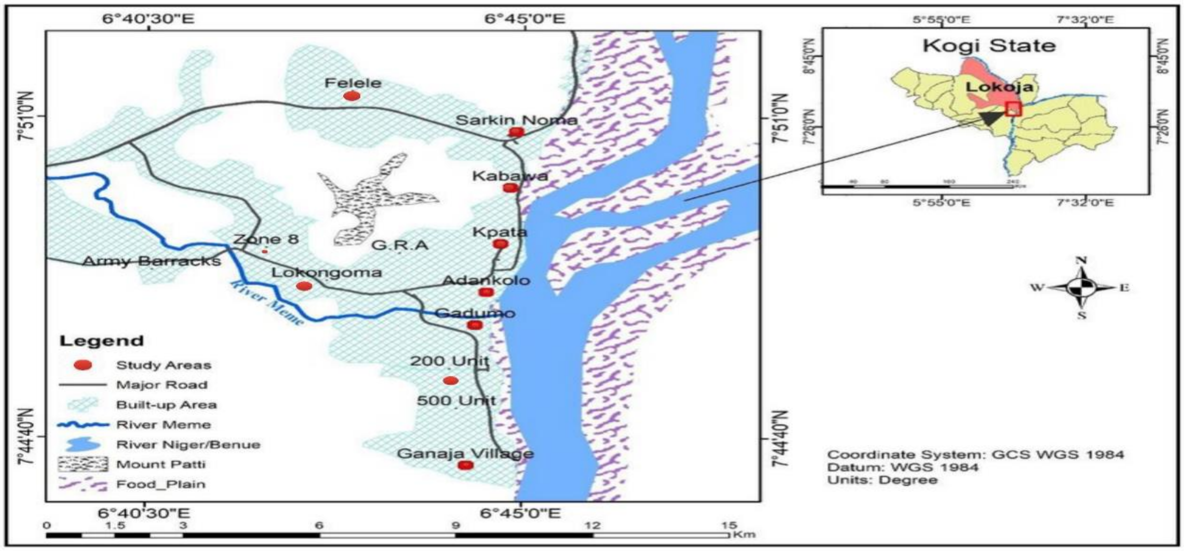

**Figure 1: Map of Lokoja and Sampling Communities (*Source: Kogi State Urban Planning Board, 2025*)**

## 3.0 Materials and Methods

This study employs snowball sampling (also referred to as purposive sampling) to identify participants with direct experience or expertise in flood mitigation strategies, ensuring the relevance and depth of collected data. All residents within the sample area who meet the criteria for flood victims are eligible for selection, minimizing deliberate exclusion. Primary sources are the data obtained to solve a specific problem. A combination of quantitative and qualitative research methods was adopted to collect primary information for the study. For quantitative research, field survey tools and instruments were used to explore the nature of vulnerability and mitigation strategies in flood-prone areas. A detailed field survey was conducted through face-to-face interviews using semi-structured questionnaires and Global Position System (GPS). The target respondents comprise people living in the flood-affected areas of Lokoja. Based on the severity of floods over the last ten years, this study covered the following areas: Adankolo, Felele, Sarkin Noma, Lokongoma, 200 and 500 unit, Ganaja, Kabawa, Lokongoma and Gadumo to provide information on the state of flooding in Lokoja using an existing delineated map obtained from Google Earth. A sample of 180 questionnaires was administered to residents in the study area and to management personnel.

Satellite images (Landsat/Sentinel), topographic map, historic flood records, socio-economic dataset from NEMA, NIMET, Kogi state authorities, Nigerian Institute of Town Planners and Bureau of Land and Urban Development. And also, land-use maps collected from the Ministry of Environment and Physical Development, Lokoja, Kogi State. The base map of Lokoja was obtained from Kogi State Lands and Survey, Lokoja, and overlaid on Google Earth to update the City map and for effective digitizing and georeferencing. Statistical analysis involves collecting and examining data on socio-economic characteristics, environmental and infrastructural factors. Quantitative tools such as surveys and flood vulnerability indices, complemented by qualitative methods like focus group discussions and interviews with key informants, were used to understand how these factors interact and influence vulnerability in the study area.

The multi-criteria decision analysis (MCDA) approach, integrated with Geographic Information Systems (GIS), was used to combine multiple criteria, including elevation, slope, drainage density, rainfall, and infrastructure adequacy, into a composite flood vulnerability index. Parameters were weighted using methods such as the Analytical Hierarchy Process (AHP) to reflect their relative importance, enabling a systematic and spatially explicit assessment of flood risk.

### 3.1 Analytical Hierarchical Process (AHP) Formula

A structured pairwise comparison method that assigns weights to various flood causative factors (e.g., rainfall, slope, drainage, land use and land cover) based on their relative importance. It converts subjective assessments into quantitative weights through a comparison matrix.

$$Aw = \lambda max^{w}$$

Where A is the pairwise comparison matrix, W is the weight vector, and $\lambda max^{w}$ is the maximum eigenvalue.

### 3.2 Weighted Linear Combination (WLC)

This method combines weighted criteria linearly to produce a composite flood vulnerability score. Each factor layer in GIS is multiplied by its weight from AHP and summed to generate vulnerability maps. WLC aggregates weight criteria scores into a single vulnerability score.

$$V = \sum_{i-1}^{n} \mathbf{W_i} \times \mathbf{x_i}$$

Where V is the vulnerability score, $\mathbf{W_i}$ is the weight of criteria i, and $\mathbf{x_i}$ is the standardized score of criterions i. Criteria scores are normalized to a common scale before combination. By combining AHP for weighting, WLC for aggregation and sensitivity analysis for robustness, MCDA frameworks provide a systematic, transparent, and adaptable approach to flood vulnerability assessment.

## 4.0 Results and Discussion

### 4.1 Socioeconomic Vulnerability

Socioeconomic vulnerability is a heightened susceptibility of communities to flood impacts due to economic dependencies, income instability, and limited adaptive capacity. In a participatory multi-criteria flood vulnerability assessment, household size, number of children, main source of income, savings, healthcare facilities, and the main livelihood affected play a significant role in determining the socioeconomic vulnerability of the study area.

**Table 1: Household Size**

| Household Size | Frequency | Percentage |
|---|---|---|
| **4** | 8 | 4.4% |
| **5** | 9 | 5.0% |
| **6** | 20 | 11.1% |
| **7** | 32 | 17.8% |
| **8** | 36 | 20.0% |
| **9** | 37 | 20.6% |
| **10** | 22 | 12.2% |
| **11** | 7 | 3.9% |
| **12** | 9 | 5.0% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

Household size distribution reveals key insights into flood vulnerability in Lokoja. Larger households often face heightened exposure due to greater resource demands during floods, amplifying social vulnerability within communities. The survey captures household sizes: medium-to-large (7-9 members) at 58.4%; smaller (4-5 members) at 9.4%; and very large (11-12 members) at 8.9%. Larger households (8-10 members, 52.8%) exhibit reduced coping capacity during floods. These findings align with Pita *et al.* (2021), who similarly tied larger households to amplified flood impacts, as both highlight coping capacity strains in overcrowded settings.

**Table 2: Children Under 5**

| Children Under 5 | Frequency | Percentage |
|---|---|---|
| **0** | 6 | 3.3% |
| **1** | 47 | 26.1% |
| **2** | 82 | 45.6% |
| **3** | 40 | 22.3% |
| **4** | 4 | 2.2% |
| **9** | 1 | 0.6% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

The frequency distribution shows that 47 households (26.1%) have 1 child under 5, 1 household have 9 children (0.6%) under 5 years, and 82 households have 2 children (45.6%) under 5 years, exacerbating flood sensitivity, as children under 5 face disproportionate risk of disease outbreaks like cholera and post-flooding. This finding is consistent with Ozim et al. (2021), who found floods disproportionately impact family-dependent groups through chi-square tests on livelihood effects, similar to disease outbreak risks for young children.

**Table 3: Main Income Source**

| Income Source | Frequency | Percentage |
|---|---|---|
| **Farming** | 39 | 21.7% |
| **Other** | 4 | 2.2% |
| **Public Service** | 54 | 30.0% |
| **Trading** | 72 | 40.0% |
| **Wage Labour** | 11 | 6.1% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

The study revealed respondents by their main source of income, highlighting the economic activities that sustain households in the study area. Trading leads at 72 households (40.0%), public service at 54 (30.0%), farming at 39 (21.7%), wage labour at 11 (6.1%), and other sources at 4 (2.2%). This distribution mirrors Lokoja's peri-urban economy but highlights an overreliance on flood-sensitive sectors, such as riverbank trading. A clear inference from these findings is that any strategies aimed at reducing flood vulnerability must take into account Lokoja's occupational structure. The findings are consistent with the study by NEMAs (2025), which emphasized the impact of various occupational groups' reliance on flood-exposed locations on vulnerability levels.

**Table 4: Savings**

| Response | Frequency | Percentage |
|---|---|---|
| **No** | 110 | 61.1% |
| **Yes** | 70 | 38.9% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

The table presents the distribution of respondents by their prevalence of Savings: 38.9% of respondents (70 households) reported having savings; 61.1% (110 households) lacked savings, a pattern that clusters in high-vulnerability groups like low-income fisherfolk or recent migrants in informal settlements. The finding aligns with Oyedele *et al*. (2022), which reported low financial buffers (around 35-40% savings rate) elevating vulnerability scores in Kogi flood zones, similar to 38.9% prevalence hindering post-flood recovery.

**Table 5: Healthcare Facility Within 5 km**

| Response | Frequency | Percentage |
|---|---|---|
| **No** | 19 | 10.6% |
| **Yes** | 161 | 89.4% |
| **Total** | **180** | **100.0%** |

**Source: Authors Field Survey (2025)**

The table presents healthcare facilities within 5 km: 89% of respondents report a healthcare facility within 5 km, signalling relatively strong baseline coverage that bolsters adaptive capacity in non-flood scenarios. However, the 10.6% (19 respondents) without access, potentially from peripheral or riverside settlements, highlights pockets of vulnerability. The results of these findings are consistent with Olamilekan *et al*. (2024), who reported comparable 85-90% healthcare access in Nigerian flood-prone cities, attributing it to urban density and PHCs, mirroring Lokoja's Kogi State Specialist Hospital coverage.

**Table 6: Main Livelihood Affected**

| Livelihood Affected | Frequency | Percentage |
|---|---|---|
| **Asset loss** | 45 | 25.0% |
| **Income loss** | 56 | 31.1% |
| **School disruption** | 24 | 13.3% |
| **Work disruption** | 55 | 30.6% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

The research demonstrated a strong relationship between high flood exposure in affected areas and the density of disrupted activities, which is reflected in the diverse livelihood impacts of Lokoja, including asset loss 45 cases (25.0%), income loss 56 cases (31.1%), school disruption 24 cases (13.3%), and work disruption (30.6%) of 55 cases. These findings align with the study by Rudiarto and Pamungkas (2020), which emphasized the impact of livelihood dependencies on vulnerability hotspots.

## 4.2 Environmental Vulnerability

It encompasses the degree to which natural and human systems are exposed to, sensitive to, and unable to cope with adverse climate change and degradation of natural resources (Srinivas, 2022).

**Table 7: Distance to River**

| Distance Band (m) | Frequency | Percentage |
|---|---|---|
| **0–100 m** | 20 | 11.1% |
| **101–300 m** | 51 | 28.3% |
| **301–600 m** | 40 | 22.2% |
| **601–900 m** | 28 | 15.6% |
| **901–1,500 m** | 20 | 11.1% |
| **1,501–5,000 m** | 12 | 6.7% |
| **Above 5,000 m** | 9 | 5.0% |
| **Total** | **180** | **100%** |

**Source: Authors' Field Survey (2025)**

The table presents the distribution of respondents by proximity to the river, highlighting the degree of exposure and potential vulnerability of households living in riverine areas within the study location. The data reveals concentrated vulnerability near rivers, with 20 households (11.1%) within 0–100.m, 51 households (28.3%), falls in 101–300m, 40 (22.2%) at 301–600m, 28 (15.6%) at 601–900m, and fewer beyond, down to 9 (5.0%) above 5,000m. Proximity under 300m affects 71 households (39.4%), amplifying physical vulnerability through direct water contact, erosion, and infrastructure damage. The finding is consistent with Smith and Lee, (2023a), which emphasized the impact of spatial proximity to river bodies on flood vulnerability.

**Plate 1: Poor Proximity to River Channel (*Source: Author's Fieldwork, 2025*)**

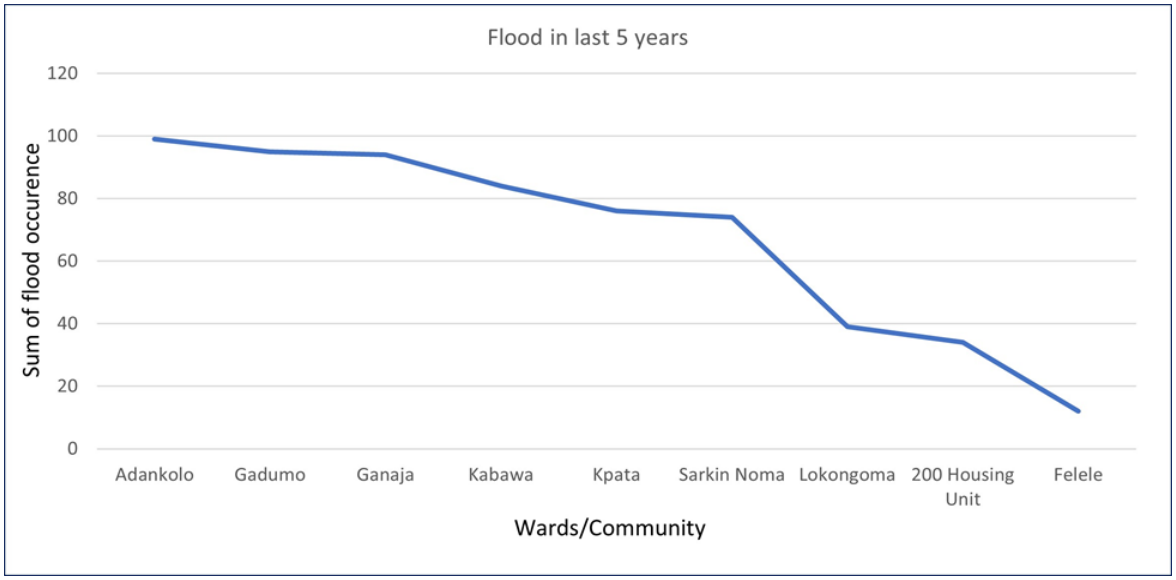

**Figure 2: Flood Events in the Last 5 Years (*Source: Author's Field Survey, 2025*)**

Figure 2 presents the frequency distribution of reported flood events experienced by households over the past five years. The data indicate that most households experienced between 3 and 4 flood events, with 30 households reporting 3 events and 42 reporting 4 events. These findings echo the study of Abdullah *et al.* (2021), who link flood vulnerability to the number of flood occurrences over the years, showing how population density in flood-prone areas heightened risk, as seen in the Lokoja flood event over the years.

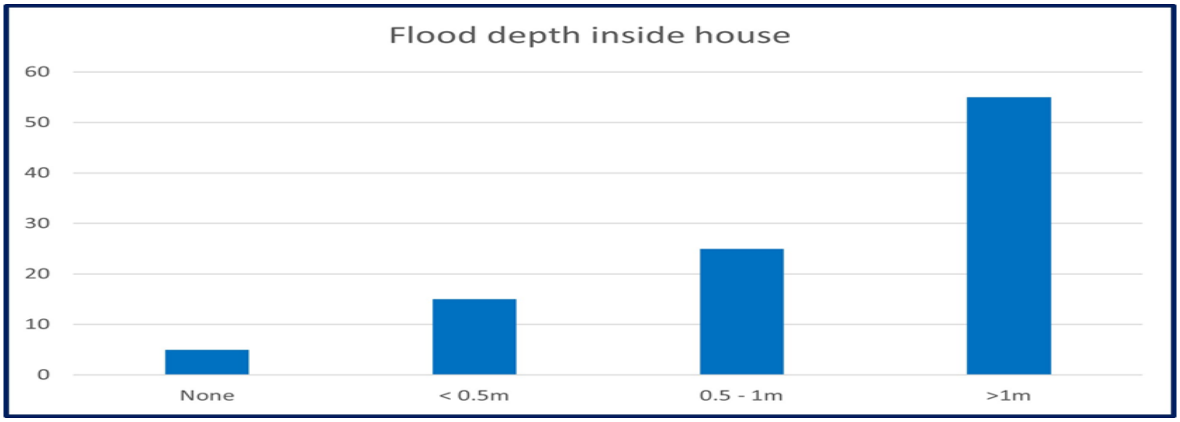

**Figure 3: Flood Depth Inside House (*Source: Author's Field Survey, 2025*)**

The highest incidence occurs in houses with flood depths exceeding 1m, affecting 99 households, which is 55% (0.5–1 m), impacting 45 households, making 25%, followed by minor flooding (<0.5 m) at 27 households (15%). Meanwhile, 9 households (5%) reported no flooding. This underscores the community's vulnerability to flood hazards and the need for flood mitigation measures, improved drainage systems, and emergency preparedness to protect property and livelihoods. It also aligns with Jimoh (2022) which documents spatial flood patterns in Lokoja, highlighting inundation in river-proximal areas.

### 4.3 Infrastructural Vulnerability

Infrastructural vulnerability encompasses essential elements such as roof type, wall materials, drainage, and house type, which are crucial for living and public safety. In participatory multi-criteria flood vulnerability assessment, all these play a significant role in determining infrastructural vulnerability in the study area.

**Table 8: Drainage Present**

| Response | Frequency | Percentage |
|---|---|---|
| **No** | 105 | 58.3% |
| **Yes** | 75 | 41.7% |
| **Total** | **180** | **100.0%** |

**Source: Authors' Field Survey (2025)**

**Plate 2: Poor Drainage System (*Source: Authors' Fieldwork, 2025*)**

The table presents the distribution of respondents based on the presence of drainage systems around their homes, providing insight into the state of local infrastructure and its potential impact on household environmental conditions. A majority of respondents, 105 households (58.3%), indicated that no drainage system is present, while 75 households (41.7%) reported having drainage systems, indicating that a notable proportion of residents benefit from improved water management and reduced exposure to related environmental hazards. These findings is consistent with the study by Paula *et al.* (2022), which emphasized the impact of infrastructure deficiencies on vulnerability hotspots. The research demonstrated a strong correlation between high vulnerability in flood-prone areas and the extent of inadequate drainage, which is reflected in the survey data for Lokoja: 58.3% of respondents (105 out of 180) reported no drainage present, compared to only 41.7% (75 respondents) with drainage available.

### 4.4 Multi-Criteria Decision Analysis (MCDA) Framework for Assessing Flood Vulnerability

Flood vulnerability analysis often involves evaluating multiple environmental, socio-economic and infrastructural factors that influence flood risk. Multi-Criteria Decision Analysis (MCDA) provides a systematic framework for combining these diverse factors into a single assessment. These weights reflect the relative importance of each criterion in determining flood vulnerability. By integrating expert judgment and objective data, AHP ensures that the most critical variables have greater influence on the final vulnerability map.

**Table 9: Pairwise Comparison Matrix Table**

| | C1 | C2 | C3 | C4 | C5 | C6 | C7 | C8 |
|---|---|---|---|---|---|---|---|---|
| C1 | 1.0 | 1.667 | 1.667 | 1.25 | 2.083 | 3.571 | 8.333 | 8.333 |
| C2 | 0.6 | 1.0 | 1.0 | 0.75 | 1.25 | 2.143 | 5.0 | 5.0 |
| C3 | 0.6 | 1.0 | 1.0 | 0.75 | 1.25 | 2.143 | 5.0 | 5.0 |
| C4 | 0.8 | 1.333 | 1.333 | 1.0 | 1.667 | 2.857 | 6.667 | 6.667 |
| C5 | 0.48 | 0.8 | 0.8 | 0.6 | 1.0 | 1.714 | 4.0 | 4.0 |
| C6 | 0.28 | 0.467 | 0.467 | 0.35 | 0.583 | 1.0 | 2.333 | 2.333 |
| C7 | 0.12 | 0.2 | 0.2 | 0.15 | 0.25 | 0.429 | 1.0 | 1.0 |
| C8 | 0.12 | 0.2 | 0.2 | 0.15 | 0.25 | 0.429 | 1.0 | 1.0 |

The consistency of these judgments was evaluated via the principal eigenvalue and related indices. The calculation produced a principal eigenvalue of 8.00.

$$\lambda_{max} = 8$$

The consistency index (CI) was then calculated as $\frac{(\lambda_{\max -n})}{(n-1)} - \frac{(8.000-8)}{(8-1)} = 0$

From the CI, the consistency ratio (CR) was obtained by dividing by the random index for n = 8, yielding: $CR = \frac{0}{1.41} = 0$

### 4.5 Flood Vulnerability Criteria and AHP Weights

Eight criteria were selected for the Lokoja flood vulnerability model, each reflecting a different aspect of flood risk. These criteria and their AHP-derived weights are summarized below. Each criterion's influence on flooding is explained, with emphasis on why it affects vulnerability. The weights (ranging from 0.03 to 0.25) indicate the relative importance of each factor in the combined model.

Table 10: Criteria and Corresponding weight

| **Criteria** | **Features** | **Weight** |
|---|---|---|
| C1 | Proximity to Waterbody | 0.25 |
| C2 | Rainfall Intensity | 0.15 |
| C3 | Drainage Density | 0.15 |
| C4 | Elevation | 0.2 |
| C5 | LULC | 0.12 |
| C6 | Road Density | 0.07 |
| C7 | Slope | 0.03 |
| C8 | Population Density | 0.03 |

#### 4.5.1 Mapping Flood-Prone Area in Lokoja

For each criterion layer, values were reclassified into three vulnerability categories: Low (index = 1), Moderate (index = 2), and High (index = 3). The thresholds for these categories were chosen based on each factor's behavior with respect to flooding. The reclassification scheme and reasoning for each criterion are as follows:

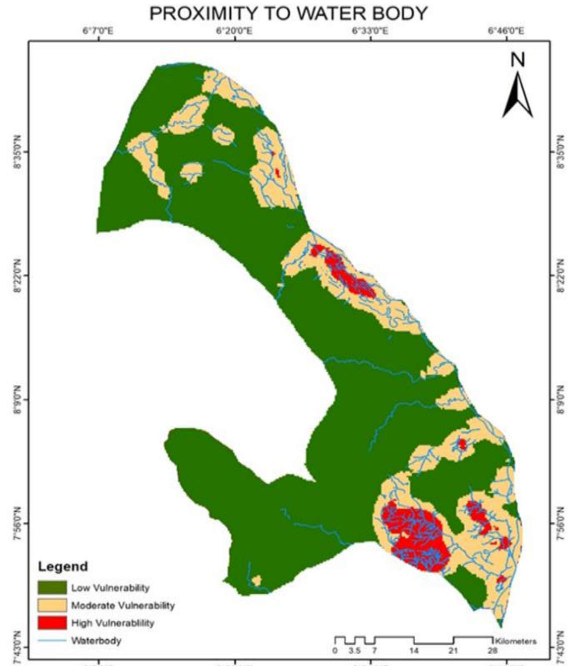

**Figure 3: Proximity to Waterbody**

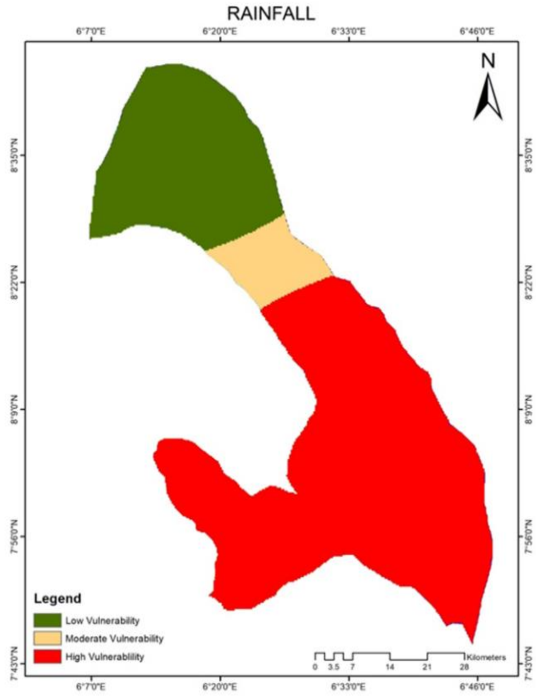

**Figure 4: Rainfall Intensity**

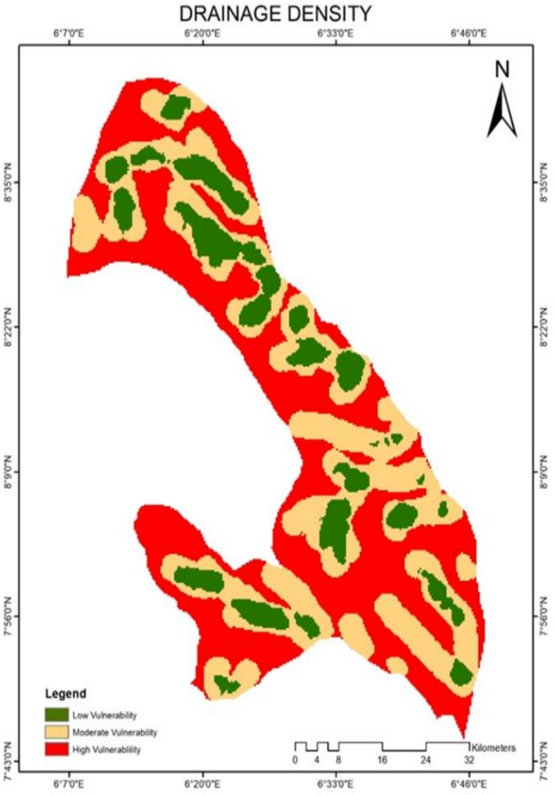

**Figure 5: Drainage Density**

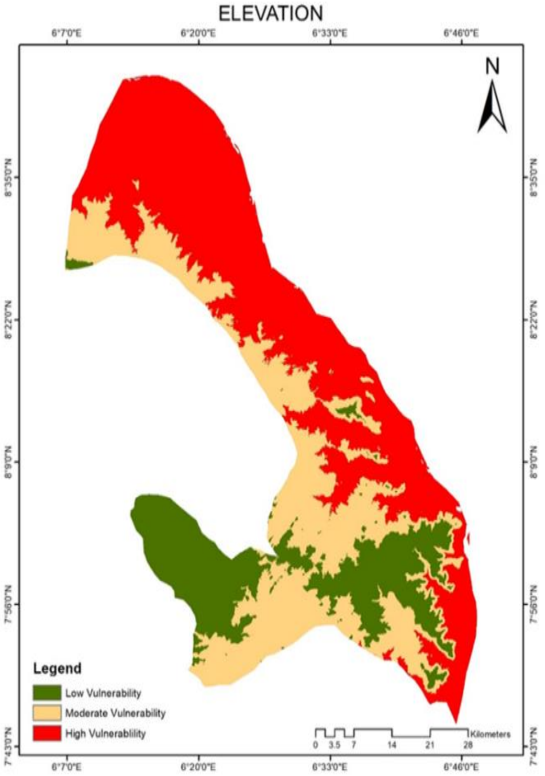

**Figure 6: Elevation**

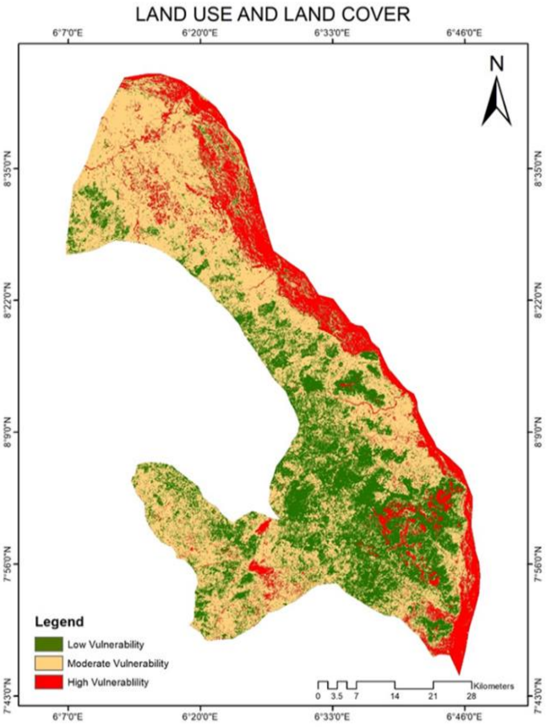

**Figure 7: Land Use and Land Cover**

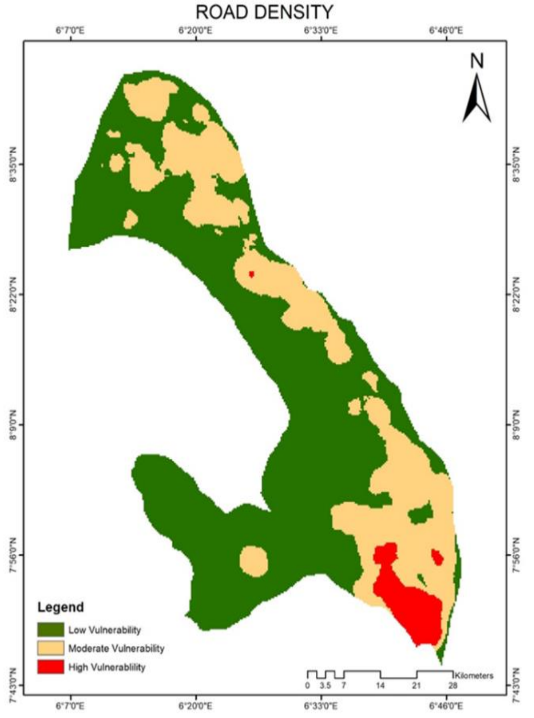

**Figure 8: Road Density**

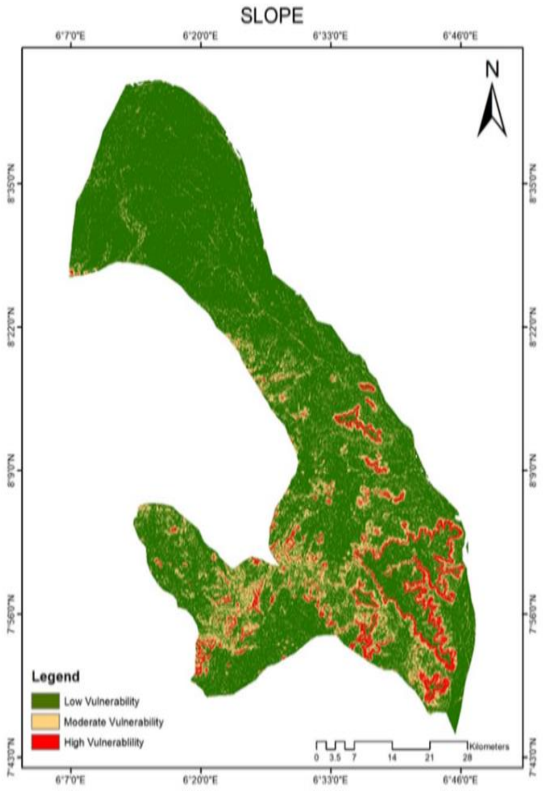

**Figure 9: Slope**

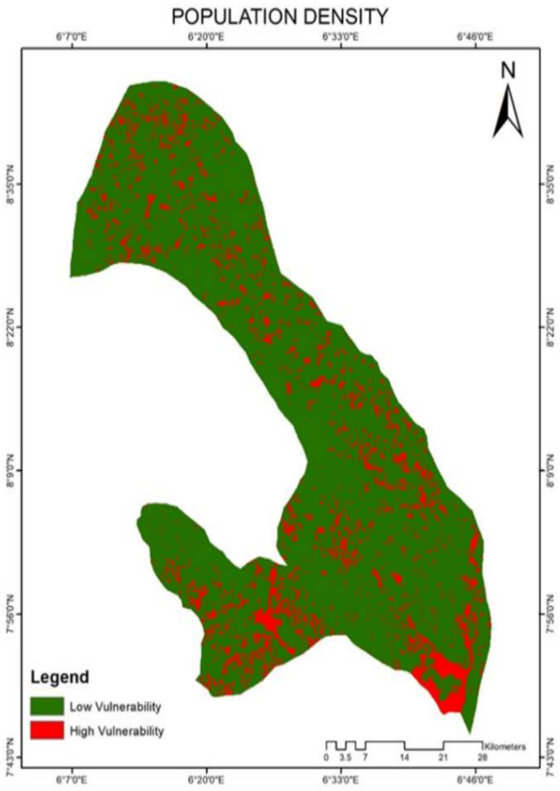

**Figure 10: Population Density**

By reclassifying each layer into the standardized 1–3 scale, all criteria become comparable. The reclassified maps were then combined using the weighted-sum AHP method to produce the final vulnerability index map.

### 4.5.2 Flood Vulnerability Map and Spatial Distribution

The weighted overlay of all reclassified criteria produced the final flood vulnerability map for Lokoja. The composite index was again categorized into three classes: Low (index = 1), Moderate (2), and High (3) vulnerability. The map reveals distinct spatial patterns of flood risk. Low-vulnerability areas cover approximately 1,164.24 km² of the study area, Moderate-vulnerability zones cover 1,462.76 km², and High-vulnerability zones cover 534.05 km². In percentage terms, high-risk areas constitute the smallest share, while moderate-risk areas are the largest.

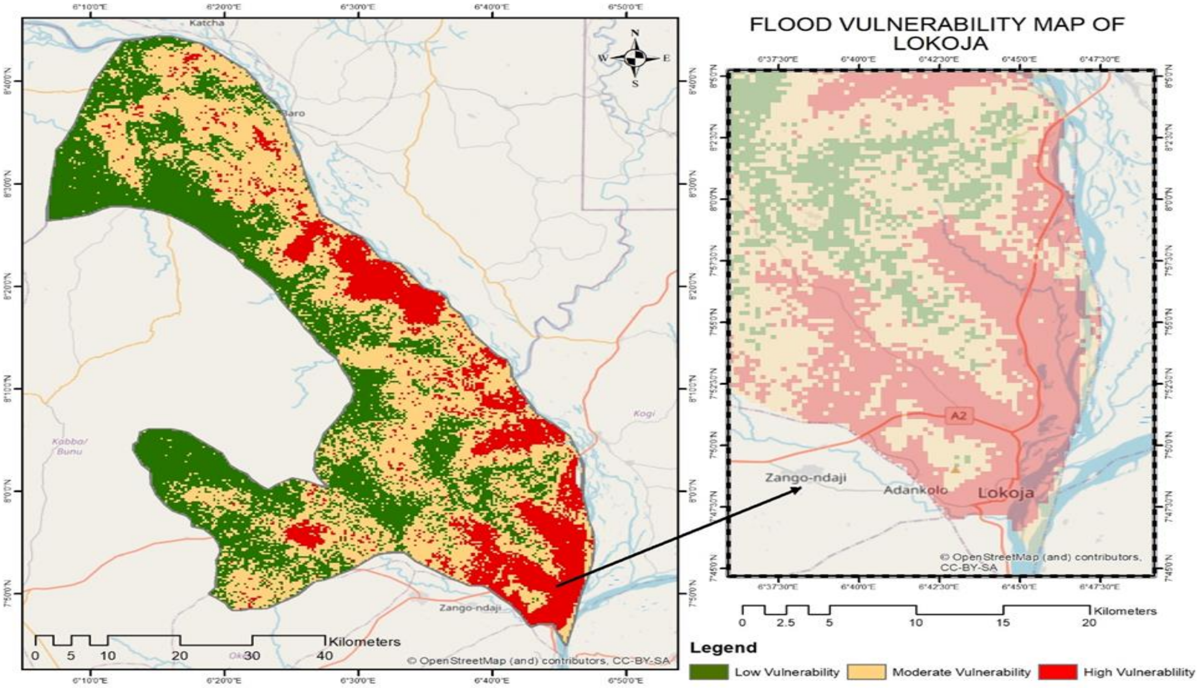

**Figure 10: Flood Vulnerability Map of Lokoja**

## 5.0 Conclusion

This research examined the Participatory Multi-criteria Flood Vulnerability Assessment in Lokoja, Kogi State. The key findings revealed that physical and social factors contribute to flood vulnerability in Lokoja to varying degrees. The spatial vulnerability map showed that Adankolo, Ganaja, and Gadumo are most at risk from the river confluence's overflow. These areas are generally at the eastern flank of the study areas and nearest to the major river. The flood vulnerability map reveals distinct spatial patterns of flood risk: low-vulnerability areas of 1,164.24 km², moderate-vulnerability areas of 1,462.76 km², and high-vulnerability areas of 534.05 km² based on multi-criteria evaluation. Therefore, it is concluded that areas nearest to the major river are most vulnerable to flooding in Lokoja, Kogi State. The findings provide a foundation for policymakers, environmentalists, and town planners to discourage settlement along the riverbank and to consider the possible evacuation of settled communities to promote flood mitigation and contribute to long-term development that fosters overall well-being and sustainable flood resilience in Lokoja.

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