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RESEARCH ARTICLE

FLOOD EARLY WARNING SYSTEM AND RISK REDUCTION IN FLOOD-PRONE AREAS OF KOGI STATE, NIGERIA

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ABSTRACT

Flooding is a persistent and escalating hazard globally, with profound socio-economic consequences, particularly in flood-prone regions such as Kogi State, Nigeria. This study aims to assess the effectiveness of a flood early warning system (FEWS) and risk reduction strategies in mitigating flood impacts in flood-prone communities of Kogi State. The research employs a mixed-methods approach, combining Geographic Information Systems (GIS) for flood risk mapping and community-based participatory assessments. The study investigates key factors influencing flood vulnerability, including socio-economic characteristics of residents, community awareness, preparedness, and the role of Flood Vanguards. GIS-based flood vulnerability maps were developed based on factors such as land use, elevation, rainfall, and proximity to water bodies, highlighting significant flood-prone zones. A multi-stage sampling technique was used to select 12 communities across six local government areas (LGAs), with data collected through household surveys, Key Informant Interviews (KIIs), Focus Group Discussions (FGDs), and field observations. The findings indicate a high vulnerability to flooding in low-lying areas with dense human activity and poor drainage systems. Additionally, community-based initiatives, particularly the Flood Vanguards, have shown potential in enhancing preparedness and response. The study concludes that integrating GIS-based risk assessments with community-driven flood management strategies can significantly improve flood resilience in Kogi State. The findings provide insights into the need for targeted flood mitigation measures that address technical and community-based aspects of flood risk management.

Keywords: Flood early warning system, GIS, flood vulnerability, community-based flood management, flood vanguards, risk reduction strategies.

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1.0. INTRODUCTION

Flooding remains one of the most frequent and destructive natural hazards globally, severely disrupting livelihoods, infrastructure, and socio-economic systems (John-Nwagwu et al., 2022; Rentschler & Salhab, 2020; Umar & Gray, 2022; Kaya & Derin, 2023). Globally, floods affect approximately one-third of the Earth's surface and pose risks to about 82% of the global population. Rentschler and Salhab (2020) estimated that 1.47 billion people—about 19% of the world's population—are directly exposed to significant risks from 1-in-100-year flood events.

Climate change has amplified the frequency and severity of flood events due to rising sea levels and extreme rainfall patterns (IPCC, 2014; Kundzewicz *et al*., 2019). This has created enormous challenges for preparedness, especially in vulnerable regions (UNISDR, 2015; Hirabayashi *et al*., 2013; Alfieri **et al.**, 2017). Sub-Saharan Africa, particularly during the peak monsoon months of June to October, regularly experiences intense flooding events (Adefisan, 2018; Balogun et al., 2019, 2021, 2022). West African floods are often driven by the northward movement of the Intertropical Discontinuity and westward-propagating convective systems, which bring moisture inland from the Atlantic Ocean (Pante & Knippertz, 2019).

According to the African Development Bank (AfDB, 2021), climate variability significantly intensifies the severity of flooding across the region. This heightened vulnerability is echoed in reports by the United States Agency for International Development (USAID), (2018) and the International Monetary Fund (IMF), (2020) which document the profound impacts of climate fluctuations. Africa is the second most flood-affected continent, with substantial consequences for human lives, economic infrastructure, and agriculture (Few, 2003; Tschakert et al., 2010; AfDB, 2021).

In Nigeria, flooding has grown in scale and frequency, often causing catastrophic human and economic losses. Between 1969 and 2022, flood events claimed an estimated 21,000 lives and caused damage exceeding US$17 billion (CRED, 2023). The 2022 floods alone resulted in over 603 deaths and displaced more than one million people.

Kogi State, situated at the confluence of the Niger and Benue Rivers, is one of Nigeria's most flood-prone regions. Annual flood events have intensified, particularly in urban centers such as Lokoja, due to rising rainfall intensity and geographic vulnerability (Aladejana & Ebijuoworih, 2024). For instance, in 2019, floods affected over 150 communities in the state. In 2022, nine local government areas were inundated, with massive disruptions to homes, infrastructure, farmlands, and livelihoods. Over 600 hectares of rice farmland were submerged following the release of water from the Lagdo Dam and seasonal downpours (Punch, 2022).

These recurring disasters have inflicted long-term socio-economic impacts, including food insecurity, displacement, infrastructure loss, and increased public expenditure on emergency relief. The financial toll includes damage to roads, healthcare centers, water systems, and educational institutions, with at least 1,380 schools and 5,550 children affected (PREMIUM TIMES, 2022). Moreover, the frequency of flood events is expected to rise due to global climate change trends, threatening the objectives of the UNFCCC, the Paris Agreement, and the SDGs (USAID, 2018).

A hydro-climatological analysis by Ologunorisa et al. (2022, 2023) of the Lower Benue Valley shows consistent flood peaks, mostly in September and October, over a 46-year study period. Additionally, the Standardized Precipitation Index (SPI) for 1980–2017 indicates that 13.5% of years were extremely wet, 54.1% were wet, and only 32.4% were dry, reinforcing the region's susceptibility to hydrological extremes.

Despite decades of investment in flood control infrastructure such as drainage channels, embankments, and dikes, flooding continues to devastate Kogi State. This indicates a significant limitation in the effectiveness of traditional flood mitigation strategies (Jha et al., 2012). Failures of structural measures, including dam breaches and ineffective drainage systems, are becoming increasingly evident, as noted by Ogie, Adam, and Perez (2019).

Kogi State's riparian communities experience recurrent flooding that result in severe destruction. For example, the 2012 floods destroyed over 24,000 houses, displaced more than 100,000 people, and caused nearly 100 deaths in Lokoja alone (Jimoh and Salami, 2019). Over the past decade, the state has experienced at least eight major flood events (1994, 2004, 2010, 2012, 2017, 2018, 2019, and 2020), culminating in roughly 250 deaths and economic damage worth millions of naira.

Given the persistence of these disasters and the evolving nature of flood risks—driven by rising temperatures and erratic rainfall—there is a pressing need to shift toward non-structural, adaptive flood management solutions. One such approach is the implementation of a **Flood Early Warning System (FEWS)** tailored to Kogi State's unique geophysical and socio-economic context. A FEWS integrates climate forecasts, hydrological modeling, GIS-based risk mapping, and community-based monitoring to enhance early response and resilience (GCF, 2022).

Beyond reducing casualties and property loss, a FEWS would significantly lower emergency response costs and allow public funds to be redirected towards long-term development. It would also support the resilience of critical sectors such as agriculture, infrastructure, and education, aligning with both national and global climate adaptation goals.

This project aims to implement effective Flood Early Warning Systems (FEWS) and risk reduction strategies to enhance community resilience and reduce the socio-economic impacts of flooding. Key objectives include assessing residents' socio-economic characteristics,

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developing a GIS-based flood risk map, and evaluating community awareness of FEWS. Additionally, the project will establish community-based response teams, known as Flood Vanguards, to strengthen local preparedness and response efforts.

Recent studies have increasingly emphasized the integration of local community capacities and advanced technologies as a dual strategy to improve the effectiveness of Flood Early Warning Systems (FEWS). Rural communities, in particular, possess distinct social, economic, and environmental structures that form intrinsic resilience capacities. Moises and Kunguma (2023), in their study of FEWS in Kabbe, Namibia, highlighted that these inherent characteristics are essential to the resilience paradigm and must be prioritized during the design and implementation of EWS. Their findings underscore that communities possess embedded capacities that, if identified and enhanced through collaboration with local organizations, can serve as effective conduits for tailoring flood EWS to contextual needs.

Similarly, Gwimbi (2007) demonstrated that leveraging local tools, stakeholders, and knowledge through a participatory framework can bridge the divide between top-down and bottom-up approaches. His study emphasized that empowering beneficiaries to define operational rules improves comprehension and action-taking in response to flood alerts, thereby fostering an inclusive and sustainable warning system. Perera et al. (2019) categorize FEWS globally into basic, intermediate, and advanced levels, with Least Developed Countries (LDCs) largely operating at basic levels due to limited resources. Robson et al. (2017) explored the historical evolution and present dynamics of FEWS. They traced development from manual systems to modern, automated setups that integrate meteorological data, satellite imaging, and real-time monitoring. Three critical success factors were identified: integration with local emergency systems, active community involvement, and robust data management. The review concluded that despite technological advances, FEWS effectiveness hinges on community engagement and adaptability to changing environmental conditions.

Davies et al. (2019) reinforce the value of Community-Based Flood Risk Management (CBFRM), showing that local engagement fosters tailored and sustainable solutions. Technological tools like Geographic Information Systems (GIS) and remote sensing have also played a pivotal role in improving flood prediction accuracy (Chien, Chang, and Lee 2007; Gao & Zhang, 2021). Early applications, such as those by Wiles and Levine (2002) and Gutry-Korycka et al. (2006), demonstrated GIS's role in urban and riverine flood risk mapping. Wiles and Levine (2002) pioneered the integration of GIS with the HEC model to analyze urbanization impacts on flooding, while Gutry-Korycka et al. (2006) used GIS for numerical flood zone estimation along Poland's Vistula River. More recently, Sole, Giosa, and Copertino (2022) applied GIS to map flood-prone areas in Italy's Basilicata region.

The integration of GIS and remote sensing technologies has also shown substantial benefits. Chien et al, (2007), demonstrated that combining spatial data with real-time monitoring significantly improved the accuracy of flood risk assessments in Taiwan. Gao and Zhang (2021) reinforced these findings in their review of urban flood mapping techniques, noting that high-resolution satellite data and aerial imagery offer precise insights into flood-prone zones, enhancing preparedness and mitigation planning.

Machine learning (ML) is emerging as a powerful tool in flood susceptibility mapping. Studies by Liu et al. (2021) and Islam, (2021) show that hybrid and ensemble ML models (e.g., Support Vector Machine (SVM), Artificial Neural Network (ANN), Dagging) provide high predictive accuracy for identifying flood-prone areas. In West Africa, Olowe (2022) confirmed the superiority of hybrid models like DT-IOE over stand-alone techniques. Together, these studies advocate for an integrated FEWS framework combining community-based knowledge with advanced technologies, ensuring locally relevant, accurate, and timely flood risk management.

2.0. THE STUDY AREA

2.1 Geography and Demographics of Kogi State

Kogi State is located in the North-Central region of Nigeria and forms part of the six states in the North-Central geopolitical zone. Established on August 27, 1991, from parts of Kwara and Benue states, Kogi has historical ties to the Kabba Province of Northern Nigeria. The state is home to several ethnic groups, including the Igala (dominant in the Eastern Senatorial District), Okun (predominant in the Western Senatorial District), and Ebira (dominant in the Central Senatorial District). Minority groups, such as Bassa Nge and Bassa Komu, are primarily found in the East, while Kakanda, Nupe, and Egbira Koto are located in the West, and Ogori resides in the Central region (Kogi State, 2024).

The capital city of Kogi State, Lokoja, is strategically situated at the confluence of the Niger and Benue Rivers, giving the state its nickname "Confluence State." The state has coordinates 7°30′N and 6°42′E, covering an area of 29,833 km² (11,519 sq mi), ranking it 13th in land area among Nigeria's 36 states (Kogi State Government, 2020). The state shares borders with nine other states, including the Federal Capital Territory (FCT) to the north, Nasarawa to the northeast, Benue to the east, Enugu to the southeast, Anambra to the south, Edo to the southwest, Ondo and Ekiti to the west, and Kwara to the northwest, making it a central hub for trade and transportation in Nigeria (National Population Commission, 2006).

As of the 2006 National Population Census, Kogi State had a population of 3,278,487—comprising 1,691,737 males and 1,586,750 females—while by 2014, estimates suggested the population had exceeded 5 million, placing it 20th among Nigeria's states in terms of size (National Population Commission, 2006). The state's economy is predominantly agrarian, with key outputs including coffee, cocoa, palm oil, cashews, maize, cassava, yam, and rice (World Bank, 2018). Kogi also boasts significant mineral deposits such as coal, limestone, iron ore, and petroleum, and is home to major industrial facilities like the Ajaokuta Steel

Company and the Obajana Cement Factory (Central Bank of Nigeria, 2019; Obajana Cement, 2019).

2.2. Flood Vulnerability and Management Challenges

Kogi State is highly vulnerable to flooding due to its position at the confluence of the Niger and Benue Rivers, particularly affecting low-lying areas like Lokoja and nearby LGAs (NIMET, 2019; UN-Habitat, 2016). Recurrent floods have caused significant displacement, loss of life, and property damage. Flood management efforts in the state are hindered by limited governmental capacity and a predominantly top-down, reactive approach, which lacks community involvement and contributes to ongoing inefficiencies in managing flood risks (Federal Ministry of Environment, 2017).

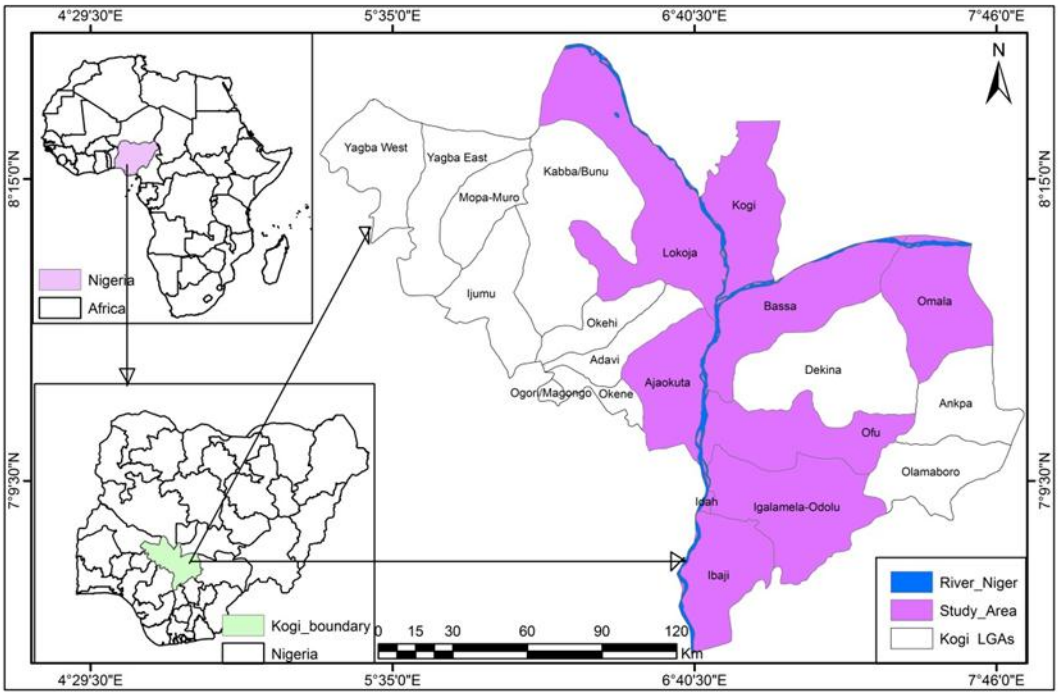

Figure 1.1: Map of Kogi State in the National and Continental Setting

3.0. RESEARCH METHODOLOGY

This section outlines the research methodology used to assess flood risk and develop a Flood Early Warning System (FEWS) for flood-prone areas in Kogi State, Nigeria. The methodology integrates different data sources, research techniques, and analytical tools, providing a comprehensive framework for identifying flood-prone areas and assessing local flood resilience. The research methodology is structured into several key components: data types and sources, field research techniques, and data analysis approaches. These components work together to develop an effective flood risk assessment system and propose solutions for improved flood management.

3.1. Types and Sources of Data

To conduct an effective flood risk assessment and develop a GIS-based risk mapping system in Kogi State, this study utilized a combination of hydrological, topographical, land use, and spatial data from reputable sources, including rainfall data from the WorldClim database to identify precipitation patterns and flash flood-prone areas; Digital Elevation Models (DEMs) from the Shuttle Radar Topography Mission (SRTM) at a 30-meter resolution to analyze terrain and elevation for the identification of low-lying, high-risk zones; Land Use and Land Cover (LULC) data from global monitoring platforms and local sources to evaluate the influence of vegetation, built-up areas, and land use changes on runoff and flood behavior; and GIS data layers, including administrative boundaries, road networks, infrastructure, and settlement locations from OpenStreetMap (OSM), which were integrated into the GIS environment to produce detailed flood risk maps and support spatial analysis of community vulnerability, thereby ensuring a robust, data-driven approach to flood risk assessment and disaster risk reduction in Kogi State.

3.2. Field Research Techniques

To assess the socio-economic impacts of flooding in Kogi State, both qualitative and quantitative methods were used. Structured interviews were conducted with community members, government officials, and flood experts to gather insights on flood experiences and mitigation efforts. Field observations were made during visits to flood-prone areas to document visible damages and community responses. Real-time discussions with residents provided further understanding of local flood preparedness. A structured questionnaire was also administered across selected LGAs. The questionnaire captured data on socio-demographic backgrounds such as age, gender, occupation, and income. It assessed living conditions, including access to amenities and housing quality. Residents' awareness of Flood Early Warning Systems (FEWS) and their preparedness levels were evaluated. The study explored perceived vulnerability and coping strategies. Finally, the impacts of previous floods and residents' perceptions of flood risks were analyzed, and the data collected through these methods provided a comprehensive understanding of the social and economic impacts of floods, community preparedness, and the effectiveness of existing FEWS in Kogi State.

The study adopted a proportionate sampling technique to ensure fair representation of communities across flood-prone areas in Kogi State. Based on the estimated 2024 population of 245,351 in the selected LGAs, a sample size of 384 respondents was determined using Cochran’s formula (Cochran, 1977). Proportional allocations were made to eight key locations across seven LGAs, including Idah (160 respondents), Odeke in Ibaji (86), Wimpey Camp in Ajaokuta (41), Itobe in Ofu (20), Adankolo in Lokoja (18), Atakpa in Bassa (16), Ohinki in Kogi LGA (12), and Bagana in Omala (9). This distribution ensured demographic and spatial balance, aligning with the relative population sizes of each community and enhancing the validity of the data collected.

3.3. Flood Conditioning Factors

Flood susceptibility in Kogi State, Nigeria, is driven by a combination of natural and anthropogenic factors. To effectively assess flood risk, a multi-criteria GIS-based approach was employed, incorporating key environmental variables widely referenced in flood modeling literature. Elevation is a fundamental factor, as lower terrains are more prone to water accumulation and surface runoff; this was assessed using Shuttle Radar Topography Mission (SRTM) Digital Elevation Models (Avand *et al*., 2022). Slope also plays a crucial role—steep slopes promote rapid runoff, while flatter areas encourage water pooling, increasing flood risk (Youssef *et al.*, 2011).

Land Use and Land Cover (LULC) data, derived from ESA Sentinel-2 imagery, provided insight into the hydrological behavior of different surfaces, with urban areas generating more runoff and vegetated areas aiding water infiltration (Waleed & Sajjad, 2022). Rainfall intensity, a major flood driver, was analyzed using data from the WorldClim database, which helps to identify areas vulnerable to precipitation-induced flooding (Tehrany *et al.*, 2015). Drainage density—calculated as the total length of streams per unit area—was another critical factor, as higher drainage density is associated with more rapid runoff and flood susceptibility (Strahler, 1964).
Proximity to rivers and water bodies, analyzed through GIS buffer analysis, also indicates flood risk, especially in locations near major rivers during periods of high rainfall (Tehrany *et al.*, 2015). Similarly, proximity to road networks influences flood behavior by altering natural drainage systems, with roads potentially acting as both barriers and conduits for water (Mahmoud & Gan, 2018).

Beyond physical parameters, socio-economic vulnerabilities were also considered, incorporating indicators such as population density, housing quality, and access to early warning systems. These human dimensions, when combined with environmental data, provide a holistic view of flood risk and support effective mitigation strategies (Khosravi et al., 2018). This study adopted a mixed-methods approach, integrating GIS analysis with community engagement to assess flood risk in Kogi State. Spatial data on rainfall, topography, land use, and river proximity were analyzed using ArcGIS and QGIS, while weighted overlay techniques identified high-risk areas. Community surveys and stakeholder feedback enriched the analysis, guiding the development of a locally responsive Flood Early Warning System (FEWS) within an ethically grounded framework.

4.0. RESULTS' PRESENTATIONS AND DISCUSSIONS

This section presents an analysis of the socio-economic characteristics of residents in Kogi State, Nigeria, focusing on variables such as Local Government Area (LGA) distribution, age, gender, household size, education level, employment status, primary source of income,

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and monthly income. Understanding these characteristics is crucial in assessing the community's vulnerability and resilience to flooding.

4.1 Socio-Economic Characteristics of Respondents

The socio-economic profile of residents in Kogi State presents a population that is largely active in the economy but highly susceptible to flood-related impacts. The majority of the respondents (51.6%) are within the 28–57 age group, indicating a working-age demographic that plays a critical role in local economic productivity and post-flood recovery. Gender distribution is balanced—50.5% male and 49.5% female—implying equal exposure and participation in socio-economic activities. Most households are moderately sized, with 74.3% having fewer than eight members, which may enhance mobility and responsiveness during evacuation or recovery. In terms of geographical representation, flood-prone LGAs like Idah (43.7%), Ibaji (23.5%), and Ajaokuta (14.8%) dominate the study, highlighting regional disparities in exposure. On the other hand, areas like Bassa (3.0%) and Omala (2.2%) report lower flood vulnerability, likely due to their lower population density.

Education levels vary widely across the population, with 35.5% of respondents having secondary education and 25.7% attaining post-secondary qualifications. However, 18.0% of the population has no formal education, posing challenges in the dissemination and comprehension of early warning messages and disaster risk reduction initiatives. Employment trends reveal that 45.1% of respondents are self-employed, and 39.9% are formally employed, suggesting a strong dependence on informal economies that are more vulnerable to flood disruptions. Agriculture remains the dominant source of income for 35.0% of households, followed by manufacturing (30.6%) and services (30.3%). These sectors are highly sensitive to environmental hazards, particularly flooding, which can result in income loss, food insecurity, and livelihood disruptions.

In terms of income, a significant portion (51.4%) of the population earns between ₦33,000 and ₦100,000 monthly, while 28.7% earn less than ₦33,000. This indicates that a large segment of the community may lack the financial capacity to invest in flood preparedness or recovery strategies, further deepening their vulnerability. These socio-economic indicators collectively point to a community with limited adaptive capacity and high exposure to flooding. As emphasized by Epuh et al. (2024), such factors—education, income, employment type, and household structure—are pivotal in determining resilience. Therefore, flood risk management in Kogi State must adopt a people-centered approach that incorporates these socio-economic realities into policy design, ensuring that flood early warning systems, emergency response, and resilience-building interventions are both inclusive and effective.

4.2. Geo-spatial Mapping of Flood Risk and Hazard in Kogi State

The objective 2 of the study focused on developing a Geographic Information System (GIS) database to enhance flood risk mapping and hazard analysis in Kogi State, Nigeria. This GIS

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database integrates various spatial datasets, such as elevation, land use, rainfall, drainage density, and proximity to rivers and roads, to identify flood-prone areas and assess flood risks. By utilizing GIS tools, the study aims to create detailed flood vulnerability maps that inform disaster management strategies and mitigation efforts.

For instance, a study by Epuh et al. (2024) employed GIS and remote sensing techniques to produce flood risk maps for Kogi State, utilizing models like the Analytic Hierarchy Process (AHP) and Multi-Influence Factor (MIF) to analyze factors influencing flooding. Similarly, Aladejana and Ebijuoworih (2024) integrated flood hazard and vulnerability factors using GIS to generate a state-wide flood risk map, identifying high-risk areas such as Kabba, Idah, and Lokoja. These GIS-based approaches provide valuable insights for effective flood risk management, enabling the identification of vulnerable zones and informing policy decisions to mitigate flood impacts in Kogi State.

The study employs Geographic Information System (GIS) and remote sensing techniques to assess flood vulnerability in Kogi State, Nigeria. By integrating spatial data on factors such as land use/land cover, slope, rainfall, drainage density, distance to roads, and elevation, the research generates a comprehensive flood vulnerability map. This map classifies the study area into five vulnerability levels: very low (9.49 percent), low (21.07 percent), moderate (29.22 percent), high (23.26 percent), and very high (16.96 percent). The analysis reveals that areas with dense vegetation, low slope, and proximity to water bodies are more susceptible to flooding. The study's findings underscore the importance of targeted flood mitigation strategies, particularly in high-risk zones, to enhance community resilience and inform disaster management planning.

4.2.1 Spatial distribution of flood conditioning factors

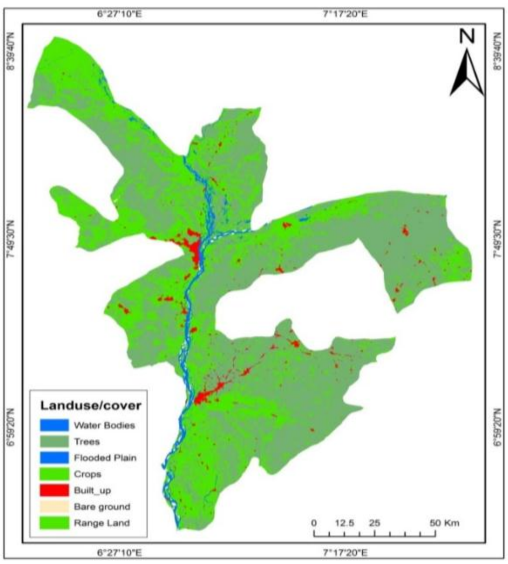

Figure 4.1 Land use/ Landover

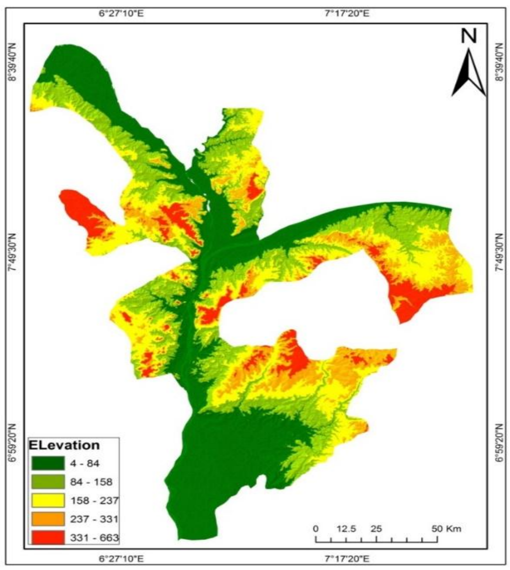

Figure 4.2 Elevation

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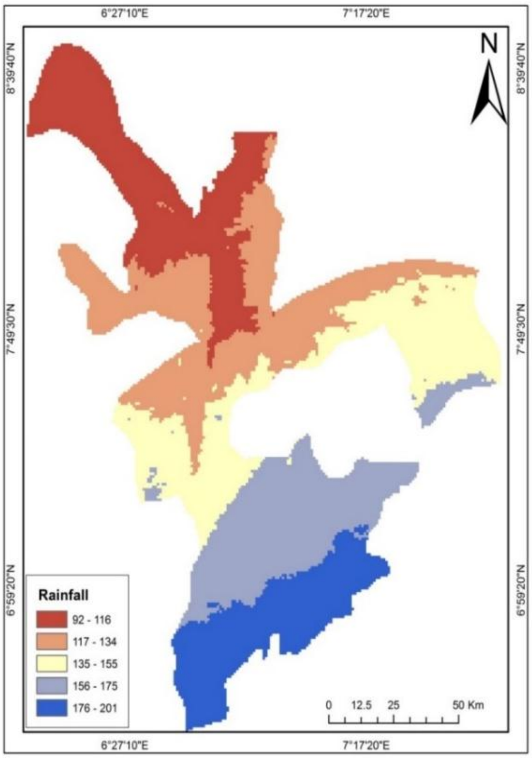

Figure 4.3 Rainfall

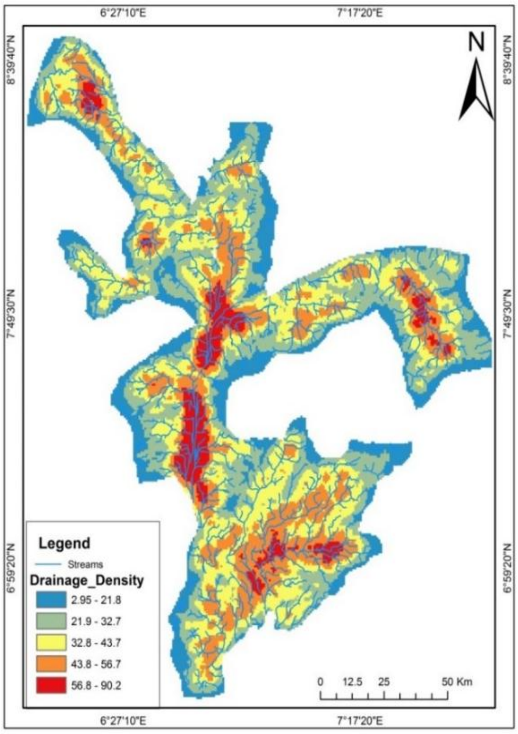

Figure 4.4 Drainage Density

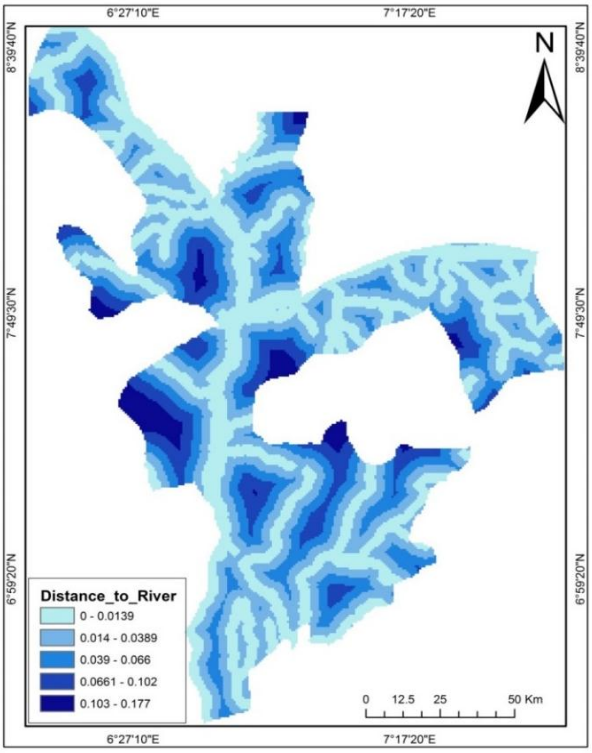

Figure 4.5 Distance to River

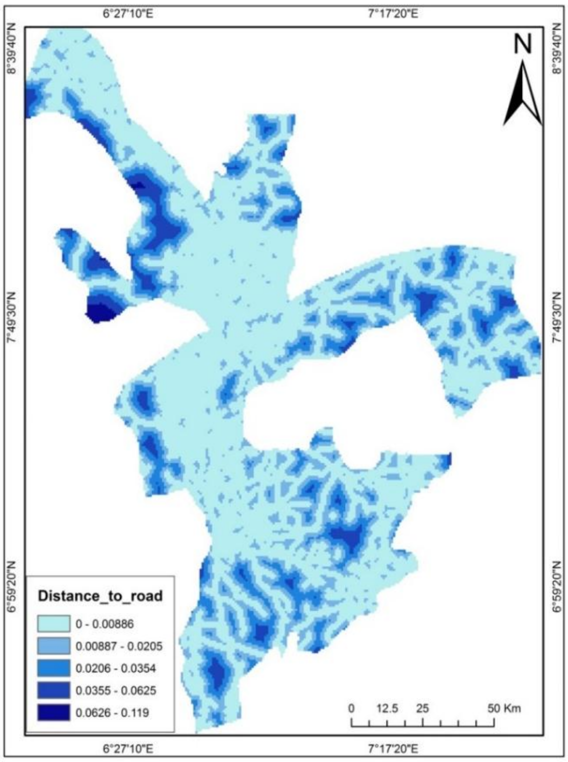

Figure 4.6 Distance to Road

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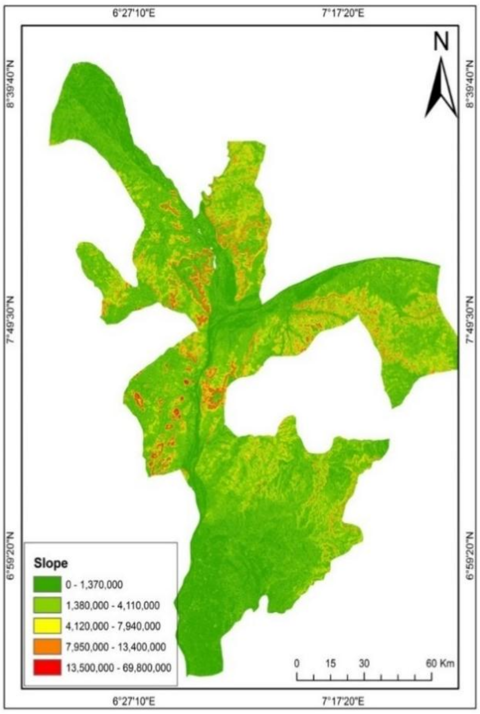

Figure 4.7 slope

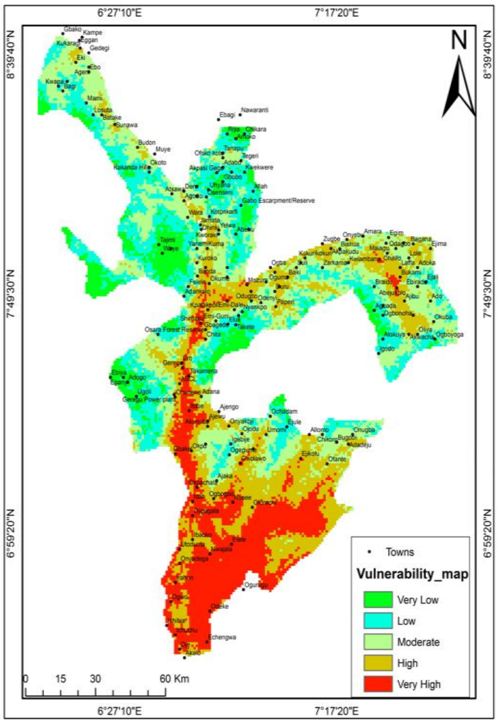

Figure 4.8: Vulnerability Map of Area.

The cross-tabulated analysis of age and income against flood vulnerability factors in Kogi State reveals distinct patterns of exposure. Respondents aged 48–57 were the most exposed across all key risk factors, including poor drainage, proximity to rivers, climate change, and urban planning deficiencies. Younger individuals (18–37) were particularly vulnerable to deforestation and proximity to rivers, while older adults (68+) showed minimal exposure, except to urban planning issues.

Income-based analysis showed that middle-income earners (₦33,000–₦100,000) experienced the highest exposure to environmental risks, especially poor drainage and closeness to water bodies. Lower-income individuals (earning below ₦33,000) were also significantly affected by poor drainage and river proximity. Conversely, higher-income respondents (₦161,000–₦200,000) had the least exposure overall, with poor urban planning being their primary concern. These findings emphasize the role of socio-economic and demographic characteristics in shaping flood vulnerability.

4.3. Community Awareness and Perception of FEWS

Community awareness of the Flood Early Warning System (FEWS) in Kogi State is crucial to effective flood risk management. The study shows that traditional media—particularly radio and television—are the most effective channels for disseminating flood warnings, as most respondents who rated the FEWS as "Good" or "Very Good" accessed the information through these mediums. In contrast, social media has moderate reach but mixed effectiveness, while community meetings and government agencies are more often associated with negative ratings, suggesting limited trust or poor communication through these official channels. Internet and other sources had minimal impact on awareness.

A Chi-square test confirmed a statistically significant association between how respondents rated the FEWS and how they heard about it, though caution is advised due to low expected values in some data cells.

Regarding flood mitigation measures, 40.4% of respondents believe current efforts are effective, though 34.7% remain neutral and 15.6% rate them as ineffective or worse. The most preferred improvement strategy is investment in better infrastructure, followed by support for early warning systems, increased funding, stricter regulation, and improved community awareness—each receiving relatively balanced support.

On the establishment of community flood vanguards, nearly 89% of respondents reported that their communities do not have vanguard structures, and only 2.2% affirmed their existence, with 9% unsure. This reflects very limited community-level engagement in organized flood response, underscoring the need for targeted awareness campaigns and the mobilization of grassroots flood vanguard initiatives.

4.4. Community-Based Flood Mitigation Initiatives

Community involvement is vital for effective flood mitigation and resilience-building. While respondents recognized the importance of improved infrastructure, early warning systems, regulatory enforcement, and public education, there was widespread neutrality regarding the effectiveness of existing flood control measures. Notably, community-based initiatives were largely absent or unknown. Approximately 89% of respondents were unaware of the presence of community flood vanguards, only 2.2% confirmed their existence, and 9% were unsure. This reveals a significant gap in grassroots engagement and indicates limited awareness or implementation of community-led flood mitigation strategies.

4.5. Summary of Key Findings

This study presents an integrated assessment of flood risk and vulnerability across selected Local Government Areas (LGAs) in Kogi State, Nigeria, utilizing a combination of socio-economic survey data, Geographic Information System (GIS)-based hazard mapping, and community-level analysis. The findings reveal that flood susceptibility in the region is multifaceted, influenced by both biophysical and socio-economic factors.

The demographic profile of the study area indicates a predominantly working-age population (28–57 years), with significant reliance on agriculture and informal employment, particularly in flood-prone LGAs such as Idah and Ibaji. This economic dependency on climate-sensitive sectors, coupled with income disparities and varying education levels, exacerbates household vulnerability to flooding. These findings support earlier assertions by Nwafor (2006) and Adelekan (2010) on the role of socio-economic conditions in shaping flood impacts.

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GIS-based risk modeling identified seven critical flood-conditioning factors—land use/land cover, slope, elevation, rainfall intensity, drainage density, road proximity, and river proximity. A weighted overlay analysis classified approximately 40% of the study area into either high or very high flood vulnerability zones. The analysis underscores the role of land cover in modulating flood risk; vegetated and forested areas were found to buffer flood impacts, while bare and built-up zones increased runoff and flood potential (Johnson *et al.*, 2022).

Socio-demographic cross-tabulations further revealed that individuals aged 48–57 and those earning between ₦33,000 and ₦100,000 monthly were disproportionately exposed to flood risk factors, particularly those linked to poor drainage, proximity to rivers, and deforestation. These patterns affirm the importance of disaggregating vulnerability assessments by age and income, as suggested by Ologunorisa et al. (2006).

Community awareness of Flood Early Warning Systems (FEWS) was mixed. Traditional media—particularly radio and television—proved most effective for disseminating flood warnings. Conversely, official communication through government agencies and community meetings was poorly rated, indicating low community trust or outreach efficacy. Additionally, the study uncovered a critical gap in community engagement: nearly 89% of respondents were unaware of the existence of community flood vanguards.

5.0. CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study demonstrates that flood vulnerability in Kogi State is shaped by a complex interplay of physical exposure and socio-economic characteristics. By integrating GIS modeling with household-level survey data and community-based assessments, the research presents a holistic framework for flood risk analysis and mitigation. The findings reveal that while structural factors such as topography and drainage density determine flood exposure, socio-economic variables—such as income, occupation, and access to information—critically mediate community resilience.

Addressing flood risk in Kogi State therefore requires a dual approach: enhancing technical infrastructure and geospatial planning while simultaneously strengthening grassroots engagement, education, and socio-economic support systems. The proposed recommendations offer a roadmap for multi-level flood governance that is inclusive, data-informed, and responsive to local conditions. Effective implementation of these strategies will contribute significantly to reducing disaster risk and enhancing adaptive capacity in one of Nigeria's most flood-prone regions.

5.2. Recommendations

This study recommends as following:

Mainstream GIS-based flood mapping into local planning frameworks

State and local planning authorities should formally adopt GIS-generated flood risk maps to guide spatial development, infrastructure siting, and land use regulation. Prioritizing data-driven planning can mitigate exposure and reduce development in high-risk zones (UNISDR, 2015).

Expand public flood awareness and risk communication campaigns

Flood education initiatives should be intensified using trusted communication channels, especially radio and television. These campaigns should be culturally and linguistically adapted to local contexts to improve comprehension and responsiveness (Adelekan, 2010).

Institutionalize and strengthen community flood vanguards

Local governments should collaborate with civil society organizations and traditional institutions to establish and train community flood vanguards. These grassroots structures can serve as early responders and facilitate two-way communication between residents and authorities during emergencies (IFRC, 2014).

Rehabilitate and upgrade urban drainage infrastructure

Infrastructure investments should focus on LGAs with the highest vulnerability scores. Critical interventions include drainage expansion, river channel desilting, and the construction of embankments in recurrent flood zones to prevent surface water accumulation and overflow.

Support vulnerable households through adaptive livelihood programs

Targeted support mechanisms, such as micro-credit schemes, climate insurance, and agricultural extension services, should be directed at economically disadvantaged households, especially those in the agriculture sector, to accelerate post-disaster recovery (Olanrewaju et al., 2019).

Decentralize and localize flood early warning systems

To improve uptake and effectiveness, FEWS should be localized and responsive, using real-time data dissemination in local dialects. Collaboration with community-based organizations can enhance trust and ensure timely action during flood emergencies.

Competing Interest

The authors have declared that no conflicting interest exist in this manuscript.

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