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INTEGRATED PERSPECTIVES ON URBAN FLOOD VULNERABILITY IN MINNA, NIGER STATE: A CRITICAL REVIEW

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Abstract

Flooding remains a recurrent and devastating natural hazard in sub-Saharan Africa, with Nigeria among the most severely impacted nations. This study examines flood vulnerability in Minna, Niger State, focusing on Bosso and Chanchaga Local Government Areas (LGAs), through the lens of the Pressure and Release (PAR) framework. The PAR model posits that flood risk is a product of the interaction between physically vulnerable conditions and socially constructed vulnerabilities. Despite extensive research on flood risk, a gap persists in integrating hydrological, geomorphological, and socio-economic dimensions in a comprehensive assessment framework, particularly in the Nigerian context. This paper presents a systematic literature review on flood vulnerability in Minna, synthesizing current research and identifying key drivers of flood risk, including informal settlements, rapid urban expansion, poor drainage networks, and weak institutional structures. The review reveals that previous studies have employed methods such as Geographic Information Systems (GIS) and Analytical Hierarchy Process (AHP), but often focus on a single aspect of flood risk, neglecting the complex interplay between physical and social factors. This study argues for an integrated assessment framework, incorporating multi-criteria modelling, participatory flood risk mapping, and governance reforms to enhance resilience in Minna's urban environment.

Keywords: Flood Vulnerability Assessment, Minna, Socio-Economic and Institutional Drivers, Urban Flood Risk

INTRODUCTION

Flooding is the most pervasive natural disaster in Nigeria, contributing to over 70% of the nation's recorded natural catastrophes each year (National Emergency Management Agency [NEMA], 2024). The frequency and severity of these events have escalated due to rapid urbanization, uncontrolled land-use change, and rainfall variability associated with climate change (Abubakar *et al*., 2022; Adesina *et al.,* 2023). The 2022 and 2024 flood disasters displaced more than 1.4 million Nigerians and resulted in an estimated ₦600 billion in economic losses (Reuters, 2024).

Minna, the capital of Niger State, is one of Nigeria's fastest-growing secondary cities. Geographically located between latitudes 9°30′to 9°45′N and longitudes 6°30′to 6°45′E, Minna's topography and drainage configuration render it susceptible to flash and riverine

flooding. The hydrological network of the city is primarily shaped by the Bosso and Chanchaga river systems, which flow through the urban core, serving as natural conduits for runoff (Dalil *et al.,* 2015; Ibrahim *et al.,* 2017).

Several studies have addressed aspects of flood hazard in Minna, including flood risk mapping (Adeoye *et al.,* 2021), flood vulnerability assessment (Ibrahim et al., 2017), and flood mitigation strategies (Dalil *et al.,* 2015; Usman *et al.,* 2020). However, many of these studies remain spatially fragmented, methodologically inconsistent, or outdated (Geomorphic Assessment, 2021). Bosso and Chanchaga LGAs, home to most of Minna's population, are especially vulnerable but underrepresented in integrated flood vulnerability research.

Theoretical Framing

This study adopts the IPCC risk framework, which conceptualizes flood risk as a function of hazard, exposure, and vulnerability (IPCC, 2014). This framework recognizes that flood risk is not solely a product of physical processes, but also of social and economic factors that shape the vulnerability of communities.

LITERATURE REVIEW:

Flood Risks, Drivers, Consequences, and Solutions

Flood risks in Minna are driven by a combination of physical and socio-economic factors, including rapid urbanization, poor drainage networks, and inadequate institutional capacity (Abubakar *et al*., 2022; Adesina *et al.,* 2023). The consequences of flooding in Minna are severe, with impacts on human lives, livelihoods, and physical infrastructure (Dalil *et al.,* 2015; Ibrahim *et al.,* 2017;). Previous studies have proposed various solutions, including flood risk mapping, early warning systems, and flood mitigation infrastructure (Adeoye *et al.,* 2012; Usman *et al.,* 2020). However, there is a need for an integrated approach that addresses the complex interplay between physical and social factors driving flood vulnerability in Minna.

Therefore, this review aims to (1) identify major drivers of flood vulnerability in Minna; (2) assess the methods applied in existing studies; (3) highlight research gaps; and (4) justify the need for an integrated flood vulnerability assessment in Bosso and Chanchaga.

The Study Area: Minna, Bosso, And Chanchaga (LGAs)

Minna lies in Nigeria’s north-central region and experiences a tropical continental climate with an average annual rainfall of 1,200–1,400 mm (NIMET, 2023). The terrain is gently undulating, ranging from 200 to 400 m above sea level. (Dalil *et al.,* 2015). Bosso LGA occupies the northern section, while Chanchaga extends toward the south and east, encompassing the floodplains of River Chanchaga.

These LGAs host a mix of formal and informal settlements, educational institutions, markets, and key infrastructure. Rapid urban growth along drainage corridors has altered the city’s natural hydrological balance (Adeleye *et al.,* 2022). The steep slopes in the northern catchments and low-lying terrain downstream contribute to high surface runoff during heavy

rains, making Bosso and Chanchaga flood-prone zones (Dalil *et al.,* 2015). Figure 1 shows map of Nigeria depicting Niger Stae (Minna, Bosso and Chachanga LGAs).

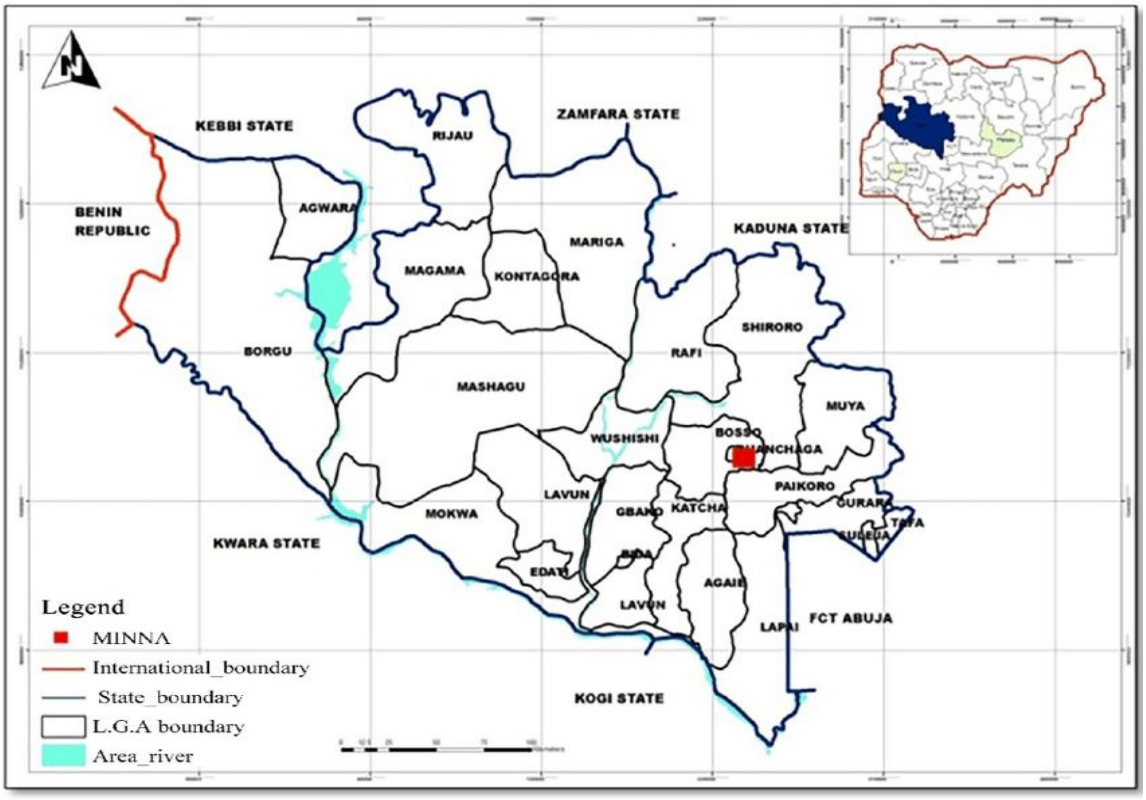

Figure 1: Map of Niger State, showing Bosso and Chanchaga LGAs, of Minna, Nigeria
Source: Adapted from Dalil et al., 2015

METHODOLOGY

A systematic literature review was conducted to synthesize existing research on flood vulnerability in Minna, Niger State, Nigeria. The review followed a structured approach to identify, screen, and select relevant studies.

Search Strategy

Scientific databases including Google Scholar, ScienceDirect, Scopus, and African Journals Online (AJOL) were searched using keywords such as "Minna flood vulnerability", "Bosso flood risk", "Chanchaga hydrology", "urban flood Nigeria", "GIS flood mapping", and database searches were limited to publications between 2015 and 2025.

Inclusion and Exclusion Criteria

Studies were included if they met the following criteria:

a) Published in peer-reviewed journals, technical reports, or theses

b) Empirical relevance to Minna or Niger State

c) Focus on flood vulnerability, risk, or mitigation

Studies were excluded if they: (a) were not written in English, (b) did not provide sufficient data or relevance to the study area ,(c)were duplicates or secondary sources

Screening Process

The screening process is outlined below:

1. Initial search: 120 studies identified through database searches
2. Title and abstract screening: 80 studies retained after removing duplicates and irrelevant studies
3. Full-text screening: 42 studies selected for review based on inclusion criteria

Data Extraction and Analysis

Data were extracted from the selected studies, including research objectives, datasets, analytical approaches, and key findings. Thematic analysis was used to classify information into hydro-climatic, infrastructural, and socio-economic drivers of flood vulnerability, alongside methodological trends and identified research gaps.

Quality Assessment: The quality of the selected studies was assessed based on criteria such as study design, data collection methods, and relevance to the study area (Moher *et al.,* 2009).

Limitations: The review was limited to studies published between 2010 and 2025, and may not capture more recent or unpublished research. Additionally, the search was limited to English-language publications, which may exclude relevant studies published in other languages.

RESULTS AND DISCUSSION

Hydro-Climatic and Topographic Drivers

Flooding in Minna is strongly influenced by intense monsoonal rainfall, high runoff generation, and limited infiltration capacity of lateritic soils. Peak rainfall from July to September often exceeds infiltration rates, leading to flash floods across Bosso and Chanchaga valleys (Adeoye, *et al.,* 2021 Abubakar *et al.,* 2022). The convex topography accelerates overland flow, while low-lying depressions serve as flood accumulation basins (Adesina *et al.,* 2023).

Urbanization and Land Use Transformation

Rapid population growth and urban expansion have increased impervious surfaces and disrupted natural drainage systems. Between 1990 and 2020, built-up areas in Minna expanded by over 240%, with significant encroachment into flood-prone corridors (Ibrahim *et al.,* 2017). Informal settlements along River Bosso and River Chanchaga exhibit weak infrastructure, poor drainage, and inadequate sanitation, heightening vulnerability (Abdullahi, 2022). Figure 3 depicts the flood vulnerability map and drainage network of the study area as reported.

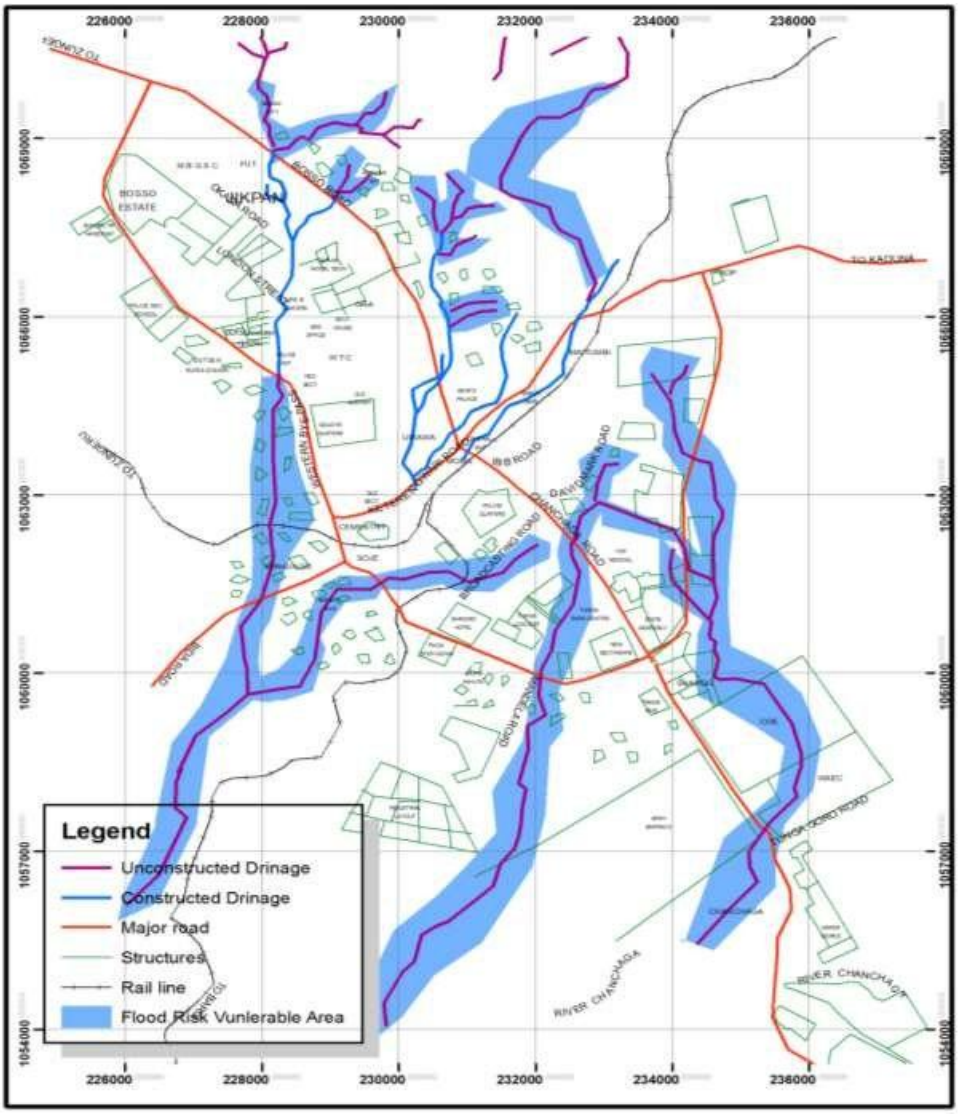

Figure 3: Flood vulnerability/ drainage network, and flood hotspots in the study area

Source: Adapted from Dalil et al., 2015)

Drainage Inadequacy and Waste Management

Drainage systems in Minna are either poorly designed or poorly maintained. Siltation, solid waste dumping, and undersized channels frequently cause blockages, resulting in backflow during storms (Dalil *et al.,* 2015). These conditions amplify flood hazards in densely populated neighbourhoods such as Kpakungu, Tayi, and Sabon-Gari.. Figur

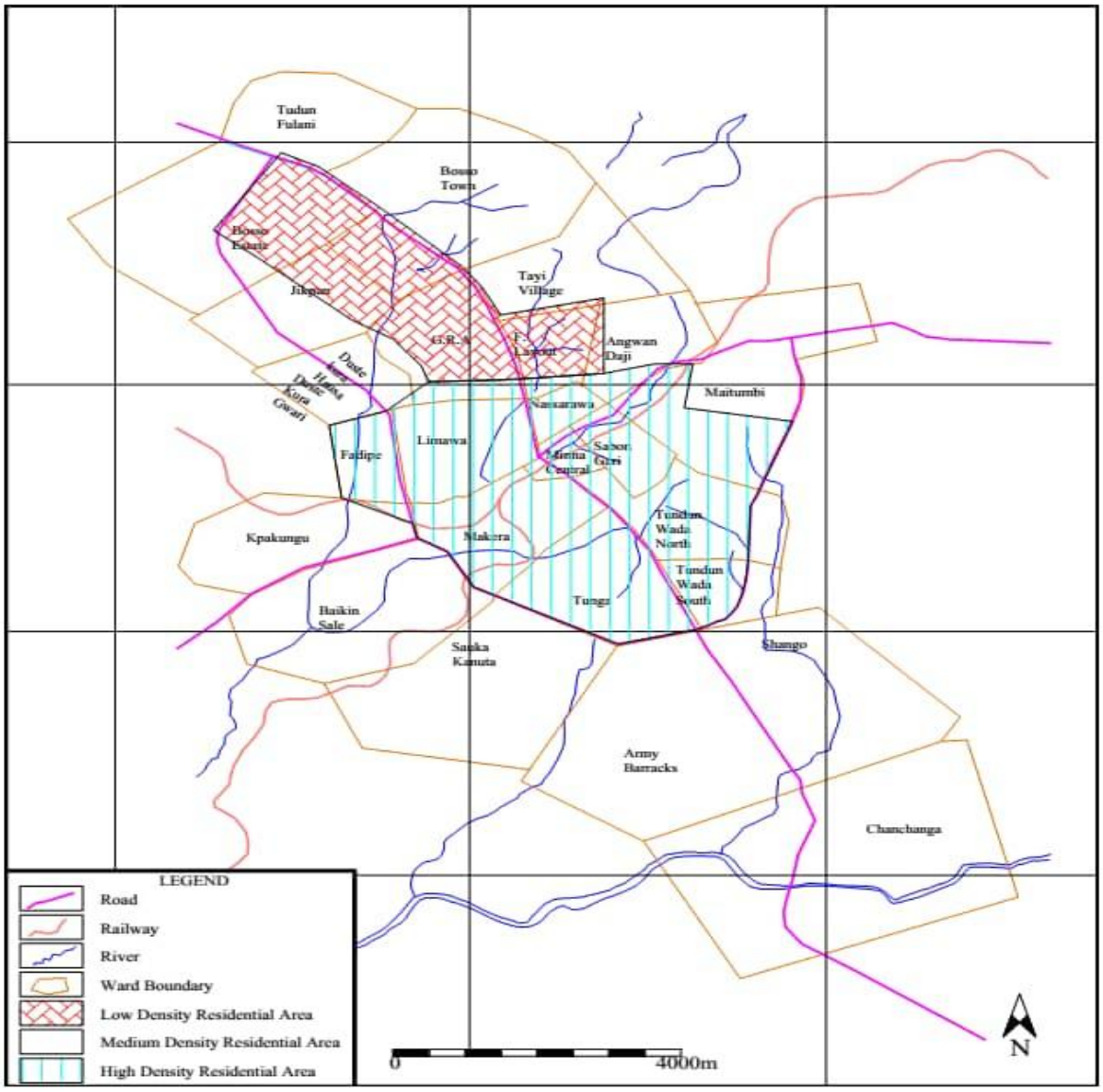

Figure 4: Flood hazards in densely populated neighborhoods of Kpakungu, Gbeganu, Tayi, and Bosso

Socio-Economic and Institutional Factors

Socio-economic conditions strongly mediate flood vulnerability. High poverty levels and limited public awareness compel residents to occupy floodplains due to cheaper housing costs (Adeleye *et al.,* 2022). Weak institutional coordination among agencies such as the Niger State Urban Development Board, Ministry of Environment, and NEMA further undermines flood preparedness and policy enforcement.

Analytical Methods In Previous Studies

GIS and Remote Sensing

GIS-based models dominate Minna's flood studies. Dalil et al. (2015) used multi-layer overlays of land use, slope, and drainage proximity to map high-risk zones, while Ibrahim et al. (2017) utilized Digital Elevation Models (DEMs) to delineate flood plains around Gidan Kwano.

Analytical Hierarchy Process (AHP)

AHP approaches have been applied to weigh flood-conditioning parameters—such as slope, drainage density, and land use—to produce composite hazard maps with improved accuracy (Geomorphic Assessment, Adeoye *et al.,* 2021).

Flood Vulnerability Index (FVI)

Recent Nigerian studies (Akindejoye *et al.,* 2025) integrated physical and socio-economic indicators into composite indices, but such approaches remain scarce in Minna's research landscape.

Hydrodynamic and Simulation Models

Few studies in Minna have applied advanced hydrodynamic tools such as HEC-RAS 2D or SWAT to model flood dynamics. Most outputs remain static susceptibility maps, which limit predictive capacity and early warning applications (Adesina *et al.,* 2023).

Synthesis of Findings

Flood hotspots in Minna align predominantly along the River Bosso and River Chanchaga corridors, encompassing floodplain settlements in Bosso and Chanchaga LGAs. Informal housing, lack of engineered drainage, and low adaptive capacity collectively drive the city's flood vulnerability. However, existing research remains skewed toward physical hazard mapping, with limited incorporation of socio-economic, sustained Methodological and institutional strengthening.

Methodological Strengths and Weaknesses

Studies employing AHP for flood vulnerability assessment demonstrate strengths in integrating multiple criteria but face limitations in subjective weight assignment (Adeoye *et al.,* 2012; Usman *et al.,* 2020). Validation of model accuracy and sensitivity analysis of weighting schemes are often lacking, undermining robustness. Future research should incorporate objective weighting methods and validate models using historical flood data.

Institutional Analysis Depth

Governance gaps in Minna's flood management include inadequate enforcement of land use regulations, insufficient budget allocation for drainage maintenance, and fragmented institutional responsibilities (Dalil *et al.,* 2015). Policy instruments such as the Niger State Flood Act (2018) exist but lack implementation mechanisms. Budgetary constraints limit infrastructure upgrades, and overlapping roles between agencies hinder effective response.

Strengthening institutional coordination, increasing budget allocation, and community engagement are critical for enhancing resilience.

Futhermore, the review highlights several critical gaps: (a) Integration Gap: Most studies focus on either hazard mapping or social vulnerability rather than a holistic integration of both, (b) Data and Resolution Gap: Many analyses rely on outdated or low-resolution datasets such as 30 m SRTM DEMs, (c) Temporal Gap: Climate change projections and land-use evolution are rarely modelled for future flood scenarios.

Addressing these gaps demands a multidisciplinary framework integrating hydrological modelling, socio-economic surveys, and governance analysis.

Implications For Urban Flood Management

Flood vulnerability in Minna poses major implications for urban sustainability and resilience. Strengthening institutional frameworks, rehabilitating drainage networks, enforcing urban planning regulations, and embedding flood risk data into state development policies are critical interventions. Community-based early warning systems and participatory mapping can enhance local preparedness and response capacity (Abubakar *et al.,* 2022).

CONCLUSION

Flooding in Minna results from complex interactions among hydrological, geomorphological, and socio-economic systems. Based on reviewed evidence, Bosso and Chanchaga LGAs are particularly at risk due to poor drainage, unplanned urban growth, and institutional weaknesses. While studies to date highlight these drivers, they often lack integration of temporal modelling and institutional analysis, limiting their application in dynamic risk management. Future research should adopt high-resolution, multidisciplinary approaches combining hydrodynamic simulations, vulnerability indices, and participatory mapping to guide evidence-based policy and strengthen urban resilience. Strengthening institutional frameworks and integrating flood risk into urban planning are critical for reducing vulnerability and enhancing adaptive capacity in Minna.

RECOMMENDATIONS

This review highlights several gaps in current research on flood vulnerability in Minna, Niger State. Addressing these gaps has significant implications for research and policy.

Research Implications:

1. Develop high-resolution, integrated models combining LiDAR or ALOS DEM data with hydrodynamic simulations (e.g., HEC-RAS 2D) to improve spatial accuracy and scenario planning.
2. Construct a comprehensive vulnerability index incorporating physical, social, and institutional indicators through GIS-based multi-criteria analysis.

3. Engage communities in data collection and validation to capture local knowledge and enhance model reliability.

Policy Implications:

4. Strengthen enforcement of land-use and building regulations within identified flood risk zones, informed by robust spatial analysis.
5. Enhance technical capacity of local authorities in GIS, hydrological modelling, and disaster preparedness to support evidence-based decision-making.

These recommendations aim to guide future research and policy efforts towards reducing flood vulnerability and enhancing resilience in Minna.

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