Flood Risk and Resilience: Evidence from the 2024 Flood in Maiduguri, Nigeria

Abstract

Flooding poses a critical threat to rapidly urbanizing areas in the Global South, where climate variability and inadequate infrastructure intensify vulnerability. Maiduguri, Nigeria, offers a salient case study, as demonstrated by the 2024 flood, one of the most severe in the city's recorded history. This study triangulates qualitative interviews and quantitative rainfall data (1992–2024) to examine three dimensions of the disaster: (1) repercussions on infrastructure, livelihoods, and marginalized populations; (2) the influence of shifting rainfall patterns on flood severity; and (3) the efficacy of preparedness and response strategies. Results highlight an upward trend in seasonal rainfall (Sen's Slope: 10.27 mm/year) and a Rainfall Anomaly Index of 3.07 2024, confirming the intensification of extreme precipitation events. The flood displaced over 157,000 residents, disproportionately disrupting lives of women, children, and the elderly, highlighting systemic inequalities. Delayed infrastructure maintenance and suboptimal early warning systems were key amplifiers of flood impact. These findings emphasize the need for climate-informed urban planning, reinforced infrastructure resilience, and comprehensive disaster-management protocols. This study enriches scholarly discourse on adapting to and mitigating climate-induced disasters in rapidly expanding urban contexts throughout the Global South.

Keywords: Climate resilience, urban flooding, governance, social capital, Global South, Maiduguri.

1. Introduction

Climate change has led to a marked increase in the frequency, intensity, and variability of heavy precipitation events (Adelekan 2011; Li et al. 2016; Tazen et al. 2018; Rodrigues 2019; Okafor 2020). Rising temperatures, coupled with sea-level rise, have heightened the risk of flooding, particularly in developing countries, where it remains a major hydrometeorological hazard. Many of these countries require robust adaptive capacity, rendering them particularly vulnerable to recurrent extreme weather events (Adelekan, 2016; Williams et al., 2018; Tellman et al., 2021). The intensification of flooding is not solely attributable to climate change; rapid urbanization, unplanned land-use transformations, and population growth further compound the existing risks (Cirella, 2019; Tellman et al., 2021). Nigeria is emblematic of these challenges as one of the most flood-prone nations in Africa. Flooding in Nigerian cities stems from the complex interplay of climatic, hydrological, and anthropogenic factors, including deficient drainage systems, weak waste management, and inadequate enforcement of urban planning regulations (Oladokun & Proverbs, 2016; Cirella & Iyalomhe, 2018; Echendu, 2020). Although academic and policy attention often centers on coastal and riverine flood risks, inland urban settlements face escalating threats that remain insufficiently examined.

Maiduguri, the capital of Borno State in northeastern Nigeria, illustrates the multifaceted vulnerabilities of the rapidly growing inland cities. Previous research has examined the city's physical and geospatial factors, such as its physiography (Sambo & Ikusemoran, 2022) and flood-prone areas along major waterways (Obroh & Sambo, 2022). Gully development in the Ngaddabul River floodplain also stresses how geomorphological and anthropogenic processes interact to exacerbate erosion and flooding (Mala et al., 2012). While these studies contributed to Maiduguri's environmental and spatial challenges, they devoted comparatively less attention to socio-economic disparities and the role of climate variability factors widely recognized in theoretical frameworks on vulnerability and resilience (Blaikie et al., 1994; Adger, 2006). Similarly, although geospatial analyses by Kaka et al. (2019) and Jimme et al. (2016) identified terrain-related determinants of flood risk, there remains a gap in exploring how shifting rainfall patterns and socioeconomic inequalities intersect to produce heightened flood impacts. To address these gaps, this study investigated three critical dimensions of the 2024 Maiduguri flood. First, it assesses the immediate and long-term consequences on infrastructure, livelihoods, and vulnerable populations. Second, it evaluates how recent shifts in rainfall intensity and variability contribute to the flood severity. Third, it examines the local preparedness and response mechanisms, elucidating both the strengths and deficiencies of the city's existing flood management strategies. By emphasizing the interaction of environmental, socioeconomic and institutional factors, this study aligns with broader theoretical frameworks on urban resilience and climate adaptation, providing policy-relevant insights into mitigating future flood risks.

2. Climate Crises, Urban Resilience and Vulnerabilities in the Developing World

Urban centers in the Global South face increasing exposure to climate-related hazards due to rapid urbanization, fragile infrastructure, and heightened socio-environmental vulnerability (Berkes & Song, 2021; Berkes & Ross, 2016; Salimi et al., 2020). Rapid urban growth introduces challenges, such as extreme weather events, pollution, and habitat destruction, which are particularly severe in developing regions where infrastructure fails to keep pace with population growth (Wang et al., 2019; UNDP & UN-Habitat, 2013). These gaps leave cities ill-prepared for climate-induced disasters. Heavy rainfall-induced flooding is one of the most devastating consequences of climate change in the Global South. Inadequate disaster preparedness in these regions exacerbates damage and affects governance, communities, and ecosystems (Morrison et al., 2018). Climate change is projected to increase the frequency and severity of heavy rainfall events and the risk of recurring floods (Fatti & Patel, 2013; Waghwala et al., 2019). Beyond physical destruction, floods impose significant psychological burdens, as seen in Durban, South Africa, where residents endure trauma from repeated extreme flooding (Ebhuoma, Nene, & Leonard, 2024).

In Africa, the impacts of flooding are magnified by limited adaptive capacity and preparedness (Cobbinah 2021). Increasing rainfall variability increases the risk of extreme floods and associated hazards such as droughts (Gizaw & Gan, 2016; Williams & Funk, 2011). Low-income urban households often resort to makeshift flood management measures such as sandbags and clearing drains, which provide minimal protection (Ajibade and McBean, 2014; Barau and Wada, 2021; Twum and Abubakari, 2019). These measures highlight the need for sustainable community-focused flood management solutions to protect vulnerable populations. Rapidly urbanizing African cities face heightened risks as infrastructure development and governance struggle to keep pace with population growth (World Economic Forum 2018). Africa's infrastructure gap exacerbates climate risks, while inconsistent policies and insufficient resources hinder efforts to build resilience (Addaney and Cobbinah 2019). Marginalized communities, which contribute minimally to global emissions, bear the greatest burden of climate risk, highlighting the need for equitable adaptive strategies (Füssel, 2010; Sultana, 2022). Beyond governance and infrastructure, community-level adaptation and social capital are crucial for resilience. Local knowledge enhances risk assessment and disaster response, making community engagement vital (Kasperson & Kasperson, 1996; Dodman et al., 2019). The Social Amplification of Risk Framework (SARF) highlights how risk perceptions are shaped by social and cultural factors, reinforcing the importance of participatory planning (Paton & Johnston, 2003; Paton & Johnston, 2017). Social capital networks of trust and cooperation bolster community resilience by enabling resource mobilization and effective communication during crises (Aldrich & Meyer, 2008; Aldrich & Meyer, 2015).

This study examined the interplay of governance, infrastructure resilience, community engagement, and social capital to understand how these factors collectively shape urban flood resilience. Using Maiduguri, Nigeria, as a case study, this study explores the socio-environmental vulnerabilities influencing resilience potential and identifies adaptive measures to withstand intensifying climate risks. The following section presents the methods and study area.

3. Materials and Methods

3.1 Study Area

Maiduguri, the capital of Borno State in northeastern Nigeria (11.8310° N, 13.1500° E), faces substantial socio-environmental challenges owing to rapid urbanization, inadequate infrastructure, and complex climatic conditions. Located in the Chad Basin, Maiduguri's quaternary alluvial soils of sandy loam and clay are prone to erosion and have low permeability, increasing the flood risk during the rainy season (Aliyu & Zubairu, 2020). Annual rainfall, ranging from 500 to 600 mm, is concentrated between June and September, and sparse Sahelian vegetation and deforestation exacerbate runoff and soil erosion (NIMET, 2023; Abatcha, 2024). The Alau Dam, built in 1986, provides irrigation, water supply, and flood control, but has suffered from neglect, resulting in vulnerabilities that contribute to flood risk (IOM, 2024). These factors underline the need for resilient urban planning and infrastructure to manage the effects of increasing climatic variability (Schlef et al., 2023; Wang et al., 2023).

3.2 Data Collection and Analysis

This study combines qualitative and quantitative methods to evaluate the 2024 Maiduguri flood and its effects on climate resilience (Creswell & Plano Clark, 2018).

Qualitative data were collected via key informant interviews twenty-five purposively selected participants including government officials, community leaders, emergency responders, and residents affected by the flood. Semi-structured interviews lasting approximately 60 minutes allowed for an in-depth exploration of resilience themes (Patton, 2015). The interviews were conducted in person, translated, and transcribed. Thematic analysis was applied to the coded transcripts, highlighting patterns related to infrastructure, urban planning, and emergency response. To ensure validity, the qualitative findings were triangulated with quantitative data and secondary reports, including those from NEMA and IOM on flood damage and population impacts (Yin, 2018). Complementary data from the National Bureau of Statistics contextualized the vulnerabilities of the affected population and examined broader infrastructure challenges. Informed consent was obtained from all participants after thorough briefing on the objectives and procedures of the study. Confidentiality and voluntary participation were upheld throughout.

Rainfall data (1992–2024) were sourced from the Tropical Application of Meteorology Using Satellite Data (TAMSAT) and validated with ground-based data from the Nigerian Meteorological Agency (NiMet).

The dataset included monthly and annual rainfall records. Key statistical analyses included the following.

$$\mathbf{CV\ (\%)} = \frac{\sigma}{\mu}\ x\ 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{(1)}$$

where is the standard deviation, and is the mean rainfall. CV values were interpreted as low (<20%), moderate (20–30%), or high (>30%) variability (Asfaw et al., 2018).

Rainfall Anomaly Index (RAI): This index quantifies annual deviations from the mean rainfall to assess wet and dry conditions as follows:

$$\mathbf{RAI} = \frac{R_{observed} - R_{reference}}{\sigma} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \mathbf{(2)}$$

Where:

$R_{observed}$ is the observed rainfall value for a specific period (e.g.,month orseason).

$R_{reference}$ is the reference rainfall value, which is typically the long-term average or median rainfall for the corresponding period.

σ is the standard deviation of the historical rainfall data for the same period.

Trend analysis: The Mann-Kendall test and Sen's slope were applied to identify trends. The Mann-Kendall test is a non-parametric test that assesses monotonic trends over time, with significance tested at the 95% confidence level. Sen's slope, a robust estimator of the trend magnitude, was computed as the median of all pairwise slopes, β\betaβ, calculated as follows:

$$\boldsymbol{S} = \sum_{i-1}^{n-1} . \sum_{i-1}^{n-1} \mathbf{sgn}\,(\boldsymbol{xj} - \boldsymbol{xi}) \text{ ....}\textbf{(3)}$$

Where xj and xi are the annual values in years j and I, j>I, respectively, and

$$\textbf{sgn (xj- xi)} = \begin{cases} \mathbf{1}\ \boldsymbol{if}\ \boldsymbol{xj} - \boldsymbol{xi} > \mathbf{0} \\ \mathbf{0}\ \boldsymbol{if}\ \boldsymbol{xj} - \boldsymbol{xi} = \mathbf{0} \\ -\mathbf{1}\ \boldsymbol{if}\ \boldsymbol{xj} - \boldsymbol{xi} < \mathbf{0} \end{cases} \text{ ....}\textbf{(4)}$$

A positive S value indicates an upward trend (increasing rainfall), whereas a negative value indicates a downward trend (decreasing rainfall). It is necessary to compute the probability associated with S and sample size n to statistically quantify the significance of the trend. The variance associated with S is calculated as follows (Mann, 1945; Kendall, 1975):

$$\textbf{Var (S) Var (S)} = \frac{\mathbf{n(n-1)(2n+5)} - \sum_{k=1}^{n} \boldsymbol{tk}(\boldsymbol{tk}-\mathbf{1}(\mathbf{2}\boldsymbol{tk}+\mathbf{5}).}{\mathbf{18}} \text{ ....}\textbf{(5)}$$

Where m is the number of tied groups and tk is the number of data points in group k. in cases where the sample size n>10, the statistics Z(S) is calculated from

$$\boldsymbol{Z} = \frac{\boldsymbol{S}-\mathbf{1}}{\sqrt{\boldsymbol{var}(\boldsymbol{s})}} \ \ \textbf{if S} > \mathbf{0}, \mathbf{Z} = \textbf{Oi f S} = \mathbf{0} \text{ ....}\textbf{(6)}$$

$$\boldsymbol{Z} = \frac{\boldsymbol{S}-\mathbf{1}}{\sqrt{\boldsymbol{var}(\boldsymbol{s})}} \ \ \textbf{if S} < \mathbf{0}, \mathbf{Z} = \textbf{Oi f S} = \mathbf{0} \text{ ....}\textbf{(7)}$$

The trend is said to decrease if Z is negative and the absolute value is greater than the level of significance, whereas it increases if Z is positive and greater than the level of significance. If the absolute value of Z was less than the significance level, there was no trend. In this study, the desired alpha value was 0.05, which indicates the level of confidence (Birhan, 2017). The trend is considered to decrease if Z is negative and greater than the level of significance, increase if Z is positive and greater than the level of significance, and no trend if the absolute value of Z is less than the level of significance.

The Sen's Slope Estimator

Sen's slope is a robust and nonparametric estimate of the slope of a time-series. The magnitude of the trend in a time series was estimated using a slope estimator, denoted by β (Hirsch et al., 1982). β provides a reliable estimate of the trend and is the median of all possible combinations of pairs for the entire dataset. A positive value of β indicates an "upward trend" (increasing values with time), while a negative value of β indicates a "downward trend" (Xu *et al.,* 2007; Karpouzos *et al.,* 2007). In the calculation of Sen's slope, all sets of slopes (dk) are computed using each pair of Xi d Xj, as per Eq. (8). The Sen Slope (β1) was then calculated as the median of all slopes, dk, using Eq. (9) (Pohlert, 2018). Each set of slopes, dk, is calculated by

$$dk = \frac{xj - xi}{j - i} \quad \text{..........(8)}$$

The sen slope (β1) is calculated by

$$\beta 1 = \text{median (dk)} = \text{median} = \left(\frac{xj - xi}{j - i}\right) \quad \text{..........(9)}$$

where i and j are indices for the values of variable X for all 1 _ i < j _ n.

A positive value of β indicates an upward trend (increasing rainfall), whereas a negative value indicates a downward trend.

This integrated approach enabled the assessment of Maiduguri's flood dynamics and resilience challenges by combining rainfall analysis with qualitative insights into the socio-environmental factors influencing flood vulnerability.

4.0 Results

This section synthesizes findings from key informant interviews, official reports and relevant scholarly literature to analyse the 2024 Maiduguri flooding event. The disaster is examined through the lens of critical factors, such as infrastructure resilience, governance, community engagement, early warning systems, emergency response capacity, impact on vulnerable populations, community resilience, and external support.

4.1 Analysis of Rainfall Trends and Anomalies in Maiduguri: Context for the 2024 Flood

To understand the conditions leading up to the flood in Maiduguri in 2024, an analysis of historical rainfall patterns was conducted, focusing on the cumulative rainfall from

June to October. This period, typically characterized by the heaviest rainfall, is critical for assessing flood risks.

Cumulative rainfall analysis for June to October in Maiduguri from 1992 to 2024 revealed significant interannual variability, with notable peaks in 1994, 2018, 2019, and 2024 (Figure 1). Both 1994 and 2024 experienced major flood events, marked by rainfall well above the long-term average of 517.84 mm, with 2024 reaching unprecedented levels of nearly 1000 mm. This elevated rainfall suggests that extreme seasonal accumulation during this period correlates with an increased flood risk. Notably, despite high rainfall in 2018 and 2019, flooding was only observed in certain years, indicating that other factors, possibly related to infrastructure or drainage resilience, may also play a role in flood occurrence.

The coefficient of variation for the June-October rainfall was calculated to be 0.34, indicating moderate interannual variability around the mean. This suggests that while rainfall fluctuates from year to year, these fluctuations are generally within a predictable range, with occasional extreme years. This moderate variability stresses the importance of a resilient flood management system, as small deviations from the mean can significantly impact the flood risk.

The Rainfall Anomaly Index was computed to identify specific years with rainfall anomalies (see Figure 1). The analysis revealed that 2024 had an RAI of 3.07, marking it as one of the wettest years on the record. Other high RAI values in recent years, such as 2019 (RAI = 1.75) and 2020 (RAI = 1.64), indicate a pattern of above-average rainfall over the past decade. This trend highlights a period of increasingly wet conditions, which likely stresses the existing flood infrastructure and contributes to the severity of the 2024 flood event. Sen's slope was calculated to assess the overall trend in the June-October rainfall from 1992 to 2024. A slope estimate of 10.27 mm per year suggests a significant upward trend in seasonal rainfall. The 95% confidence interval for this increase ([4.98, 15.77] mm per year) further reinforces the observation that rainfall has been steadily increasing, which may have compounded flood risks over time. This trend indicates that the region is experiencing a shift towards wetter conditions during the critical flood-prone months, potentially overwhelming drainage and dam systems designed for lower rainfall levels. The Mann-Kendall Trend Test confirmed the statistical significance of this increasing trend in rainfall, with a

Kendall's tau of 0.39 and a p-value of 0.0015. This statistically significant upward trend strongly suggests that the observed increase in rainfall is not due to random variability but rather part of a sustained climatic pattern. This trend warrants attention for flood preparedness and infrastructure planning, as it indicates an ongoing increase in seasonal rainfall intensity.

The flood event of 2024 can be attributed in part to an unusually high rainfall anomaly, coupled with a long-term upward trend in the June-October rainfall. The statistically significant findings from Sen's slope and the Mann-Kendall test point to a systematic increase in rainfall, which may strain flood prevention systems not built for these heightened levels.

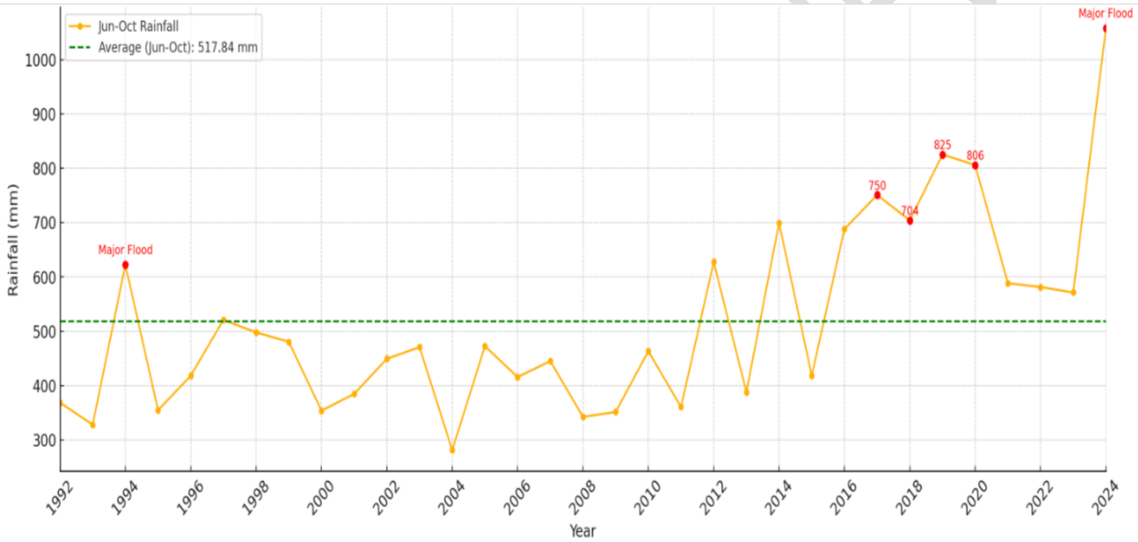

Figure 1: Cumulative Rainfall for June to October in Maiduguri, from 1992 to 2024
Source: Authors Computation, 2024

4.2 Uncovering the paradox and Blackbox of the Flood Incidence

Infrastructure resilience is a major determinant of the flood impact. The Alau Dam, a critical piece of infrastructure, had been neglected, with sedimentation reducing its capacity to regulate water flow effectively. Despite significant funding allocations for rehabilitation between 2018 and 2024, essential repairs have been delayed (NEMA, 2024). Respondents pointed out that "*poor drainage systems and inadequate maintenance of key infrastructures such as bridges worsened the situation, leading to market areas and neighborhoods being quickly submerged*' (R1, R2). Traders at the Monday Market, for instance, lost substantial stock due to the rapid accumulation of water in their stalls. Table 1 shows the damage caused by flooding, including the destruction of over 10,000 houses and 74 water points (IOM 2024).

Governance and accountability issues have emerged as central factors exacerbating the impact of floods. Respondents expressed "*frustration over ignored warnings from local communities about the dam's deteriorating condition, stating that official negligence led to the flood's devastation"* (R3, R4).

Community engagement was insufficient for disaster preparedness and response. Although local communities rely on indigenous methods to predict floods, the unprecedented scale of 2024 flooding surpassed these methods. Many respondents indicated that they had not received any formal warnings that would have allowed them to safeguard their properties and livelihoods (R5). The efforts of communities such as Gwange and Budum to form flood response committees were hindered by a lack of resources and official support (R11). This reflects the need for a stronger integration of local knowledge into disaster planning, emphasizing the role of community engagement in effective disaster risk reduction. Table 1 highlights the total number of displaced individuals 157,274 in total stressing the need for community-based disaster strategies (IOM, 2024). The effectiveness of early warning systems is critically undermined by communication strategies. Although NiMet issued warnings about impending heavy rainfall, these messages failed to reach many at-risk populations (NEMA, 2024). Respondents noted that warnings were either delivered too late or communicated through channels not commonly used by vulnerable communities, leaving them unprepared (R6 and R7).

The flood disproportionately affected vulnerable populations, including women, children, the elderly, and individuals with disabilities. According to the International Organization for Migration (IOM, 2024), among the 320,791 affected individuals, pregnant women, unaccompanied children, and the elderly require specialized care and attention. Table 1 presents a breakdown of the impact, showing that 45,138 pregnant and breastfeeding women, 1,828 unaccompanied children, and 14,837 elderly people needed assistance (IOM, 2024). Respondents emphasized that these groups struggled with access to health services and other basic needs (R10). This reflects a broader global understanding that vulnerable populations bear the brunt of climate-induced disasters. The destruction of farmlands, waterpoints, and sanitation facilities further compounded these vulnerabilities, making it difficult for communities to recover without targeted intervention. Similarly, the environmental impact of flooding extends beyond human displacement and affects local wildlife. Floodwaters from Sanda Kyarimi Park carried dangerous animals, such as crocodiles and snakes, into populated areas, further complicating the response efforts (IOM, 2024). This aspect of the disaster reflects the often-overlooked environmental repercussions of urban flooding, indicating the need for integrated environmental and urban resilience planning.

Table 1: Impact of the 2024 Maiduguri Flooding on Vulnerable Populations

S/No.	Category	Description	Figures
1.	Total flood-affected population	Total number of individuals affected by the flood in Borno State	320,791
2.	Displaced population	Number of people displaced from their homes due to the flood	157,274
3.	Completely damaged houses	Houses completely destroyed and uninhabitable due to flood damage	10,534
4.	Partially damaged houses	Houses partially damaged but still standing, requiring repairs	38,025
5.	Number of farmlands affected	Farmlands that were submerged or destroyed, impacting food production	9,768
6.	Completely damaged water points	Water points that were completely destroyed, impacting water supply	74

7.	Partially damaged water points	Water points that were partially damaged but still operational	105
8.	Toilets/latrines affected	Sanitation facilities damaged by the flood, increasing health risks	7,383
9.	Pregnant women and breastfeeding mothers	Women requiring healthcare and support due to pregnancy or breastfeeding	45,138
10.	Elderly persons	Elderly individuals needing special assistance and care post-flood	14,837
11.	Unaccompanied children and orphaned minors	Children without guardians, requiring protection and support services	1,828
12.	Persons with serious medical conditions	Individuals with severe health conditions needing immediate medical care	447
13.	Functional health facilities after flooding	Number of health facilities remaining operational post-flood	110
14.	Schools affected by the flood	Number of schools damaged or disrupted by the flood, impacting education	24
15.	Access to education facilities after flood	Percentage of population with access to education facilities post-flood	

16.	Education facilities within 30 min walk	Percentage of education facilities accessible within a 30-minute walk

Source: IOM, 2024

4.3 The Response Mechanisms

The emergency response during the 2024 Maiduguri flood was hampered by significant resource limitations, infrastructure failures, and logistical challenges. Key roadways and bridges have collapsed, making it nearly impossible for emergency teams to reach the most affected areas (NEMA, 2024). Respondents (R8, R9) noted "*delays in relief efforts, exacerbating the hardships of displaced populations*." Overcrowded shelters lacking basic amenities, such as clean water and sanitation, also heighten health risks (IOM, 2024). Coordination with local authorities faced difficulties, further complicating response efforts (R9). The Borno State Government (BSG) established an Emergency Operations Center (EOC) to coordinate efforts, working alongside the NEMA and SEMA. However, logistical challenges such as shortages of essential supplies and overcrowded camps remain a barrier. NEMA also plays a central role in managing search and rescue operations, deploying water purification equipment, and evacuating at-risk populations. The agency's efforts extended to supporting states in relocating displaced people and conducting damage assessment. Despite these efforts, the scale of displacement, particularly in large camps such as Bakasi and Muna, which hosted over 57,000 people, overwhelmed the resources (see Table 2 for camp details). Coordination issues and communication gaps further delay aid delivery. This highlights the need for improved logistical planning, the pre-positioning of supplies, and capacity building to enhance urban disaster preparedness in Maiduguri.

Table 2: List of Climate Induced Displaced Person's Camps

S/No.	LGA	Ward	Camp Name

1	Maiduguri	Maisandari	Bakkasi Camp
2	Konduga	Dalori	Dalori Camp
3	Jere	Mashamari	Dikwa Lowcost (Al Habib)
4	Maiduguri	Galtimari	Galtimari Primary School
5	Jere	Ngomari	Gcc Girl Acedamy
6	Maiduguri	Bolori II	Govt Day Sec Bulabulin
7	Konduga	Chabbal	Gubio Camp
8	Maiduguri	Gwange	Gwange I Primary School
9	Maiduguri	Gwange	Gwange Ii Primary School
10	Maiduguri	Bolori I	Kamselem Primary School
11	Jere	Mairi	Maimusari 2 Primary School Tashen Bama
12	Maiduguri	Bolori I	Mega School Opp Maimalari
13	Maiduguri	Bolori II	Ngarnam Primar Scl
14	Jere	Ngomari	Ngomari School
15	Maiduguri	Gwange	Sheikh Sheriff Ibrahim Saleh
16	Maiduguri	Maisandari	Teachers Village
17	Jere	Dusuman	Vocational Enterprise Institute Muna
18	Maiduguri	Bolori II	Zajiri Primary & Secondary School
19	Maiduguri	Bolori II	Modu Fannami School Opp.Maimalari

20	Maiduguri	Bolori II	Bulabulin Ngarnam
21	Maiduguri	Bolori II	Bulabulin Alajiri
22	Jere	Gwange	Aisha Buhari
23	Jere	Mairi	Mega School Tashan Bama

Source: Compiled by Author from various government reports

Despite overwhelming challenges, community resilience and social capital play a crucial role in disaster response. Local volunteers and grassroots organizations mobilized quickly to assist with evacuation efforts, distribute relief materials, and support vulnerable neighbours (R11). Communities have pooled resources and provided immediate relief in the absence of timely official assistance. However, these grassroots initiatives were limited by their lack of integration into formal response systems, which reduced their scalability (Aldrich & Meyer, 2015). Strengthening social ties and community-led initiatives while integrating them into broader disaster management frameworks would significantly enhance disaster response efforts.

External support from non-governmental organizations, international agencies, and other stakeholders played a significant role in bolstering local disaster response capacities. Contributions included both financial aid and material support such as the provision of water purification equipment and medical supplies (NEMA, 2024). While these external partnerships helped alleviate immediate needs, challenges in coordination and resource allocation limited the effectiveness of the relief efforts. Multiple respondents from relief organizations mentioned communication gaps and overlapping responsibilities as key obstacles that hindered smooth operation (R9). These coordination challenges suggest the need for clearer frameworks to optimize resource utilization and enhance interorganizational collaboration during disasters.

Table 3: Donations as Disaster Relief

Contributor Category	Type of Contribution	Description	Amount (₦)

Individuals (Philanthropists)	Financial	Provided substantial financial support for flood relief efforts and emergency response.	Over 6 billion
Organizations (Private Sector)	Financial and Material Aid	Contributed financial assistance and material support (e.g., fertilizer, foodstuff) to aid flood response.	Over 500 million
State Governments	Financial and Material Aid	Several state governments contributed both financial aid and food supplies to support flood-affected populations.	Over 1.8 billion
Federal Agencies and Commissions	Financial and Technical Support	Federal government agencies, including the North East Development Commission (NEDC), provided financial aid and logistical support.	3 billion (NEDC)
International Organizations	Material and Technical Aid	Provided relief materials, food supplies, and logistical coordination for flood recovery and displacement camps.	Not specified

Source: Borno State Government, 2024

The 2024 Maiduguri flood illustrates a profound climate justice challenge as the most vulnerable population, especially women, children, and low-income residents, who suffered disproportionately from the disaster's impact. The aftermath of the flood revealed how socioeconomic disparities and governance failures exacerbated the vulnerability of marginalized groups. For example, the interviews conducted with affected residents, emergency responders, and community leaders consistently highlighted that areas with informal settlements (such as Gamboru, Gwange, Bulabulin, Fori, and Galtimari) were the hardest hit. These communities, already facing limited access to essential services, such as drainage systems and adequate housing, were largely left without formal disaster response mechanisms. This aligns with broader findings in the literature, which emphasize that rapid urbanization, inadequate infrastructure, and unplanned urban growth in cities across the Global South amplify the risks for marginalized populations (Cobbinah, 2021; Aliyu & Zubairu, 2020). The displacement of over 157,274 people, as recorded by the International Organization for Migration (IOM, 2024), illustrates how climate risks intersect with existing vulnerabilities, placing an unequal burden on those least equipped to cope.

In the context of governance, the delayed maintenance of the Alau Dam further exemplifies the climate injustice that these communities experience. Despite significant financial allocations to rehabilitate critical infrastructure, mismanagement, and corruption within the local government stalled repairs, directly contributing to flood severity (NEMA, 2024). Interviews with officials revealed a clear breakdown in the communication between government agencies and local communities, with warnings of the dam's deteriorating condition going unheeded. As one community leader stated, "*We have been warning the government about the dam for over three years, but nothing was done until it was too late*" (R4). This failure in governance disproportionately affected vulnerable populations whose homes and livelihoods were destroyed, leaving them unable to recover quickly. In addition, the gendered dimension of vulnerability was acutely felt during the disaster. Among the 320,791 individuals affected, 45,138 were pregnant or breastfeeding women, many of whom required immediate care and support, which was largely unavailable in the immediate aftermath of the flood (IOM, 2024). Respondents noted that "*women in informal settlements were often left out of early warning systems, with many reporting that they did not receive any formal alerts before the flood hit*' (R5, R6). This mirrors global patterns where women, especially those in low-income regions, face higher climate risks due to their roles as caregivers and reduced access to resources. This exclusion of women from disaster planning reflects a broader climate injustice, as gender disparities often go unaddressed in climate resilience strategies despite evidence that women are disproportionately impacted by climate crises. Social capital, however, played an important role in mitigating some of the immediate impacts of the disaster. Local community networks mobilized quickly to provide relief, with neighbours pooling resources to assist displaced individuals, particularly in the most affected areas such as Gwange and Budum (R11). However, these grassroots initiatives were limited in their reach because of a lack of formal support from governmental agencies. Interviews with emergency responders revealed that coordination between community-led efforts and formal disaster response teams was minimal, leaving local volunteers to operate without the resources necessary to manage large-scale displacement.

The climate justice lens also reveals how external partnerships and international aid, while critical, often fail to address the long-term vulnerabilities of marginalized populations. In the case of Maiduguri, international organizations, such as the International Organization for Migration and the North-East Development Commission, provided key emergency aid, including water purification systems and temporary shelters. However, these efforts "*were unevenly distributed, with some communities, particularly in wealthier areas, receiving aid faster than others in more marginalized settlements*" (R9). This unequal distribution of resources further highlights the inequities in disaster recovery, which climate justice frameworks aim to address by calling for a more inclusive and equitable allocation of aid, ensuring that those most affected are prioritized.

5. Discussion

The 2024 Maiduguri flood exemplifies the intersection of weather events, urban vulnerabilities, and systemic governance challenges. This study investigates three critical aspects: the immediate and long-term impacts of the flood; the role of rainfall trends in its severity; and the contribution of governance, preparedness, and response mechanisms to disaster outcomes. The flood displaced over 157,000 people, severely damaging homes, farmland, and critical infrastructure (IOM 2024). The destruction of farmlands, a key source of livelihood, left many residents vulnerable to prolonged economic hardship. This aligns with global findings that disasters disproportionately affect low-income urban populations, exacerbating preexisting vulnerabilities and poverty cycles (Wisner et al., 2004; Cutter et al., 2003). Vulnerable groups, including women, children, and the elderly, were disproportionately impacted, which is consistent with disaster studies showing that these populations face the greatest challenges during crises (Blaikie et al. 1994; Sultana 2022). Beyond physical displacement, the collapse of water and sanitation facilities stresses how disasters can escalate into public health emergencies, a common consequence in the flood-prone regions of the Global South (Cobbinah, 2021; Ajibade & McBean, 2014). These findings highlight the critical need to integrate livelihood restoration, public health, and social protection into post-disaster recovery efforts to reduce long-term vulnerability.

The analysis of rainfall trends from 1992 to 2024 revealed a sustained upward trend in seasonal rainfall intensity, with an annual increase of 10.27 mm (Sen's slope). The Rainfall Anomaly Index for 2024 (3.07) marked it as one of the wettest years on record, highlighting the intensifying impact of climate variability. These shifts toward wetter conditions align with global observations of increasing rainfall variability and flood frequency driven by climate change (Tellman et al., 2011; Tellman et al., 2021). While the Coefficient of Variation for June–October rainfall was moderate (0.34), the extreme rainfall in 2024 overwhelmed the city's drainage and flood management systems, which were designed for historical lower rainfall levels (Aliyu & Zubairu, 2020). Similar patterns in cities such as Lagos and Dhaka demonstrate that urban infrastructure often fails to adapt to shifting climatic conditions (Adelekan 2016; Wang et al. 2023). These findings emphasize the importance of integrating climate projections into urban planning and infrastructure design to enhance resilience against future extreme weather events. The preparedness and response mechanisms during the 2024 Maiduguri flood were constrained by resource limitations and communication barriers. Despite the warnings issued by NiMet in forecasting heavy rainfall, the failure to translate these warnings into actionable public responses significantly exacerbated the disaster. Many at-risk communities are unaware of the impending flood due to communication gaps and the absence of localized warning systems (Boulton et al., 2022; Deng et al., 2023). This challenge mirrors the findings in other flood-prone regions, such as the Mekong Delta and coastal Bangladesh, where early warning systems often fail to effectively reach vulnerable populations (Glantz, 2019). Enhancing early warning dissemination through localized messaging, mobile alerts, and community networks is critical for improving preparedness in resource-constrained settings, such as Maiduguri. Overlapping responsibilities and unclear institutional roles mirrored the challenges observed in other disaster-prone regions, such as the 2010 Haiti earthquake, where fragmented disaster management systems compromised response efficiency (Comfort et al., 2010; Kapucu, 2006). Strengthening institutional frameworks and pre-positioning resources can help mitigate these delays in future disasters.

Additionally, the emergency response was hampered by the destruction of critical infrastructure, including roads and bridges, which limited access to the affected areas (IOM, 2024). Similar logistical challenges have been observed in urban centers worldwide, highlighting the importance of resilient infrastructure in supporting disaster response (Coppola, 2020). Community-led initiatives play a significant role in immediate relief efforts, demonstrating the potential of social capital in disaster recovery (Aldrich & Meyer, 2015). However, the limited integration of these initiatives into formal disaster management frameworks has reduced their scalability and impact (Leal Filho et al. 2020). Formalizing partnerships between community networks and institutional actors can enhance response efficiency and leverage local knowledge to improve outcomes. The interplay between impacts, rainfall trends, and response mechanisms highlights the multifaceted nature of the disaster risk in Maiduguri. Increasing rainfall intensity, combined with infrastructure, has created conditions that expose cities to extreme hydrological events. This requires sustained investment in resilient infrastructure, such as updated drainage systems and dam rehabilitation, to mitigate the risks posed by increasing rainfall variability. Strengthening early warning systems by integrating technology and community-based dissemination strategies is critical for improving disaster preparedness. Finally, integrating community-led initiatives into formal disaster management frameworks can leverage local knowledge and social capital and enhance resilience to future climate-induced disasters.

6. Conclusion and Recommendations

These findings contribute to the discourse on climate resilience by introducing the role of external support and social capital in disaster response in developing countries. This study uniquely advances understanding by linking governance, infrastructure resilience, and community engagement to disaster outcomes, which are often studied separately. To address the highlighted challenges, targeted recommendations are proposed to enhance flood resilience and disaster management in Maiduguri and similar urban contexts. First, investment in resilient infrastructure is critical for reducing exposure to flood risks. This includes upgrading drainage systems to handle increased rainfall intensity and rehabilitating essential structures, such as the Alau Dam, through regular maintenance. Second, strengthening early warning systems is essential for ensuring timely and actionable communication with at-risk communities. Localized and community-focused warning mechanisms such as mobile alerts and grassroots dissemination networks can bridge communication gaps. Advanced technologies, such as GIS and remote sensing, should be leveraged to improve flood forecasting and monitoring accuracy. Third, integrating community-based approaches into disaster management could increase resilience by leveraging local knowledge and fostering social capital. Community participation in risk assessment and preparedness planning ensures that disaster strategies reflect local priorities. Finally, urban planning and policy must incorporate climate projections to account for future risk. Climate models should inform infrastructure investment and policy decisions to ensure their robustness against changing precipitation patterns. Collaboration between academic and international partners can provide technical expertise and financial support for climate adaptation initiatives. Future research should focus on the intersection of climate adaptation, urban planning, and community engagement to identify scalable solutions to manage climate-induced disasters in vulnerable regions.

Consent:

Written informed consent was obtained from all participants after thorough briefing on the objectives and procedures of the study.

Disclaimer (Artificial intelligence)

Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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