

Review

Integrating GIS into Flood Risk Management: A Global South Perspective on Resilience, Planning, and Policy

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Abstract

Flooding is one of the most frequent and destructive natural disasters worldwide, with intensifying socioeconomic and environmental consequences linked to rapid urbanisation and climate change. This review examines flood risk delineation and assessment in Nigeria within a broader Global South perspective, synthesising evidence from peer-reviewed studies that employ remote sensing, GIS-based techniques, and multi-criteria decision analysis. The analysis reveals persistent challenges that undermine effective flood risk management, including incompatible datasets, limited stakeholder participation, and inadequate integration with formal planning systems. To address these gaps, the study introduces the GIS-Integrated Flood Risk Management (GIFRM) Framework, a conceptual model that integrates high-resolution risk mapping, adaptive infrastructure design, sustainable urban planning, and participatory governance. GIFRM advances resilience discourse beyond hazard mapping, offering a practical bridge between science, policy, and implementation by aligning technical geospatial analysis with actionable planning solutions. Comparative case insights from flood-prone countries such as Bangladesh, India, and Kenya highlight transferable strategies, including community-led data integration, modular infrastructure approaches, and localised zoning reforms. The review concludes by critically examining the operational disconnect between advanced geospatial risk assessment and its application in resource-limited, rapidly urbanising settings. It reframes flood risk assessment as an interdisciplinary planning tool with global relevance, delivering lessons for disaster preparedness, urban sustainability, and climate resilience. In the face of escalating hydrometeorological extremes, this research offers applied strategies for embedding GIS technologies into adaptive policy frameworks, positioning flood risk management as a core driver of sustainable development.

Keywords: disaster preparedness; flood risk assessment; Global South; GIS integration; urban resilience; sustainable urban planning



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1. Introduction

Flooding represents one of the most persistent and destructive hydrometeorological hazards globally, inflicting significant losses on human life, economic productivity, and ecosystems [1]. Intensified by climate variability, rapid urbanisation, and unsustainable land conversion, flood frequency and severity are projected to rise in both developed and developing contexts [2]. In the Global South, these risks are amplified by weak

institutional frameworks, inadequate infrastructure, and informal urban development that often encroaches upon natural floodplains [3]. The resulting surface runoff, combined with the loss of natural drainage capacity, regularly transforms rainfall events into large-scale disasters.

Flood risk is conventionally conceptualised as a function of hazard, exposure, and vulnerability, encompassing the probability of loss of life, property damage, and infrastructure disruption [4,5]. Accurate flood risk assessment depends on reliable spatial and temporal data capable of representing both current and projected hydrological conditions. Over the past two decades, Geographic Information Systems (GIS), remote sensing, and hydrological modelling have revolutionised flood risk delineation and vulnerability analysis [6,7]. However, the operationalisation of these technologies in policy and planning remains limited in many Global South countries, including Nigeria, where disjointed governance and data fragmentation hinder effective risk management.

In Nigeria, flooding has evolved into a multidimensional challenge that disrupts housing, transportation, agriculture, and public health systems, thereby constraining sustainable urban growth [8]. The 2030 Agenda for Sustainable Development identifies disaster risk management as central to achieving Sustainable Development Goal (SDG) 11, which targets inclusive, safe, and resilient cities [9]. Yet, while several Nigerian studies apply GIS and statistical models to delineate flood-prone areas [10–12], their outputs often remain disconnected from urban planning instruments such as zoning regulations, drainage master plans, and building codes. This disconnect highlights the absence of an integrated framework linking spatial risk assessment to actionable planning decisions.

Comparative evidence from other flood-prone nations underscores the benefits of integrated flood risk governance. In Bangladesh, hazard mapping is combined with socio-economic vulnerability indices to inform adaptive urban planning [6]; India integrates flood modelling into municipal planning supported by real-time monitoring systems [13]; and Kenya demonstrates how participatory-based GIS initiatives enhance preparedness and resilience [14]. These cases illustrate that the primary challenge in the Global South lies not only in generating high-quality data but in institutionalising its use within planning and policy mechanisms.

A complementary dimension of flood risk management is the Flood Vulnerability Index (FVI), developed by Balica, Wright, and van der Meulen [15], which provides a composite approach for assessing exposure, sensitivity, and adaptive capacity. This index bridges hydrological modelling with socio-economic parameters, enabling a more holistic understanding of community-level vulnerability. Applying such an approach within the Nigerian context allows for a comparative perspective with global practices and informs the development of integrative models like the GIFRM Framework proposed in this study.

Nigeria currently lacks a standardised, implementation-oriented framework that effectively connects geospatial flood analysis with practical urban governance. This review therefore addresses two interrelated gaps: (a) the absence of frameworks linking technical spatial analysis with policy implementation, and (b) the limited comparative insight into how Nigeria's practices align with international standards. Accordingly, the study pursues four objectives:

- (a) Identify the principal physical, socio-economic, and institutional drivers of flooding in Nigeria;
- (b) Review and evaluate current flood risk assessment methods;
- (c) Analyse the strengths and limitations of GIS-based delineation approaches; and
- (d) Propose an integrative strategy for enhanced management and resilience-building.

With Nigeria's urban population expected to grow rapidly and climate-induced extremes intensifying, developing a scalable, GIS-driven, and governance-embedded frame-

work is urgent. This paper contributes to advancing that agenda by synthesising current evidence, introducing a conceptual integration model, and drawing transferable insights from the wider Global South to inform sustainable, adaptive flood risk governance.

2. Literature Review

Flooding is widely recognised as a complex, multidimensional phenomenon shaped by the interaction of climatic, hydrological, geomorphological, and anthropogenic factors operating across multiple spatial and temporal scales [5,16]. Climatic variability, particularly the increasing intensity and irregularity of rainfall events, is one of the most critical drivers influencing the magnitude and frequency of flood hazards worldwide [17,18]. In addition to climatic influences, hydrological characteristics such as river discharge, soil infiltration capacity, and catchment topography determine the extent of inundation and the persistence of floodwaters [19]. However, the growing dominance of human-induced factors, especially rapid urbanisation, deforestation, and poor land management, has significantly altered natural drainage systems and exacerbated flood risk, particularly across the rapidly urbanising regions of Sub-Saharan Africa [18].

In Nigeria, the complexity of flooding is amplified by socio-economic, infrastructural, and governance deficiencies. Recurrent floods have become a major constraint on national development, causing widespread displacement, destruction of property, and losses in agriculture and public infrastructure [5,20]. Urban centres such as Lagos, Aba, and Port Harcourt are particularly vulnerable due to uncontrolled urban expansion, weak enforcement of planning regulations, and inadequate stormwater infrastructure [5,18]. Moreover, the concentration of informal settlements in low-lying areas further compounds exposure to recurrent flood events. The consequences extend beyond physical damage; floods disrupt agricultural cycles, exacerbate food insecurity, and increase the prevalence of water-borne diseases, especially in densely populated, poorly serviced neighbourhoods [21,22].

The adoption of GIS and remote sensing has enhanced the ability of researchers to model, delineate, and predict flood-prone zones. GIS-based modelling integrates hydrological and topographical data to simulate flood scenarios, identify hotspots, and classify risk levels. Despite this progress, most studies remain data-limited and methodologically fragmented, with minimal incorporation of socio-economic indicators or community-based validation [23]. The result is a persistent gap between technical hazard assessments and actionable risk management strategies.

In contrast, several Global South case studies demonstrate how GIS integration, when combined with institutional commitment and participatory governance, can lead to more effective flood risk management. In India, the National Disaster Management Authority (NDMA) embeds GIS-based hydrological modelling within city planning and zoning frameworks, ensuring that spatial risk information informs infrastructure investments and land-use decisions [24]. Similarly, Bangladesh has developed integrated hazard mapping systems that combine hydrological data with socio-economic vulnerability indices, validated through community participation, thereby enhancing both accuracy and legitimacy [25]. In Kenya, the deployment of participatory GIS and localised early warning systems has strengthened community resilience and fostered trust between residents and municipal authorities [26]. These examples demonstrate that the key challenge is not the absence of technology, but rather the lack of institutional and participatory mechanisms that enable its consistent use in planning and governance.

Across Africa, diverse approaches to GIS-based flood risk assessment reflect varying degrees of technical sophistication and governance integration. In Ghana, rainfall-runoff modelling has been employed to identify flood-prone areas, yet its impact remains limited by fragmented municipal coordination [22]. Tanzania's efforts to mainstream flood data

into urban plans face political and institutional barriers that hinder long-term implementation [27]. Rwanda, however, offers a promising example where community mapping of wetland zones has been incorporated into district land-use plans, illustrating how local knowledge can complement scientific data in resilience planning [28].

Recent advances in machine learning and artificial intelligence (AI) have further expanded the capabilities of GIS-based flood modelling, especially in data-scarce environments. Techniques such as dual-view image fusion and convolutional neural networks now allow for rapid, automated flood identification and damage classification. For instance, Zhao et al. [29] demonstrated the use of an attention-based image fusion model for post-flood building damage detection, while Zhang et al. [30] applied an enhanced ResNet50 architecture with a Convolutional Block Attention Module (CBAM) to estimate flood depths in urban environments. These studies illustrate the transformative potential of combining AI and remote sensing for high-resolution, near-real-time flood monitoring capabilities that remain underutilised in Nigeria and many other parts of the Global South.

Despite these advancements, the Nigerian flood risk research landscape remains characterised by several systemic limitations. First, datasets are often outdated, incomplete, or inconsistent across regions, hindering model accuracy and reproducibility [31]. Second, there is limited integration of local knowledge and stakeholder input, which constrains the contextual validity of geospatial outputs [32]. Third, institutional fragmentation across federal, state, and municipal levels leads to duplication of efforts and weak policy translation [33]. Consequently, while hazard mapping is increasingly sophisticated, it remains largely technocratic and disconnected from urban policy instruments such as zoning regulations, drainage planning, and environmental impact assessments.

In a bid to address these shortcomings, contemporary research advocates for hybrid modelling approaches that merge physical hazard data with socio-economic and governance indicators. Studies reveal that integrating spatial and social variables produces more accurate vulnerability profiles and supports inclusive adaptation planning [34,35]. In Nigeria, emerging applications such as the Multi-Criteria Analysis (MCA) and Height Above Nearest Drainage (HAND) model [36] illustrate progress toward this integration, yet their application remains limited to specific basins or pilot projects rather than national-scale frameworks.

Drawing from comparative Global South experiences, it becomes evident that GIS-based flood risk management must evolve from a purely technical exercise into a governance-embedded, participatory process. Countries that have successfully bridged this divide such as Bangladesh and Brazil, demonstrate that when geospatial tools are institutionalised within urban policy and supported by community engagement, they become effective instruments for resilience building. Within this context, Nigeria's situation presents an urgent need for an integrated, adaptive, and participatory model.

This review thus positions the proposed GIFRM Framework as a necessary advancement, one that synthesises global best practices with local realities by linking geospatial intelligence, socio-economic profiling, and participatory governance. The framework aims to bridge the persistent gap between science and policy, transforming GIS from a mapping tool into a driver of resilient urban planning and sustainable flood governance across the Global South (Figure 1).

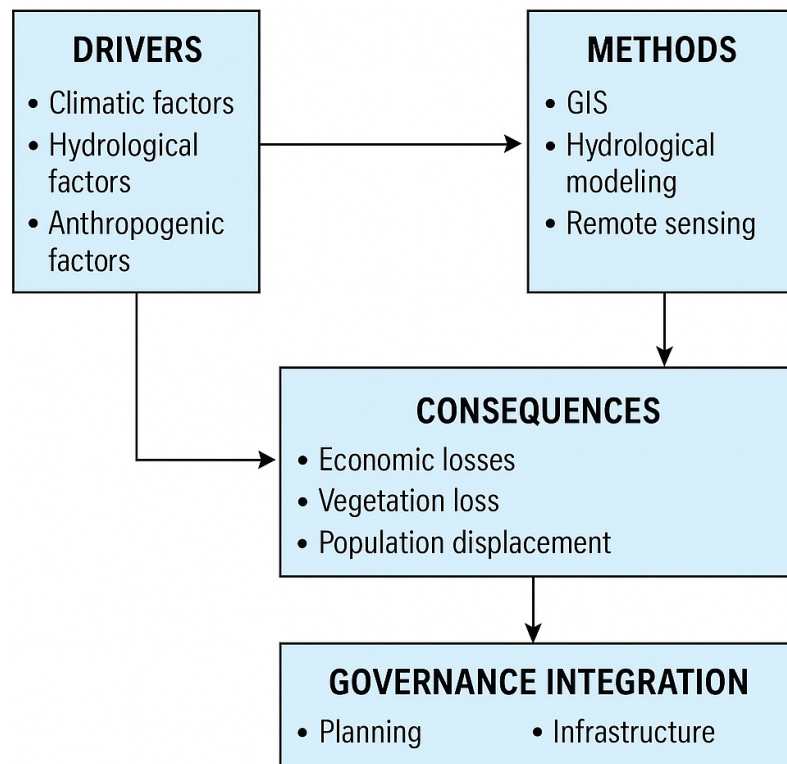


Figure 1. Conceptual Framework.

Expanding Global South Insights

Besides the Nigerian situation, recent Global South case studies further reveal the diverse nature of GIS applications in flood risk management. Referring to the situation in Bangladesh, Haque and Uddin [32] utilised Google Earth Engine to examine land-use and land-cover (LULC) changes in Sylhet, linking the rapid urban transformation to increased flood vulnerability. Serame, Afuye, and Kalumba [33] in their study on South Africa elaborated on how flood risk index mapping could be made in data-scarce areas, indicating the impediments and possibilities of GIS integration in disaster risk reduction. The same type of progress is also visible in India, where Dahiya et al. [34] pointed out the contribution of GIS-based flood zonation and time-series hazard mapping for guiding resilient planning of megacities. These or rather similar methods were implemented in Iran as well, where Kiani, Ahmadabadi, and Azariun [35] combined GIS and elevation modelling to evaluate flood impacts on the infrastructure projects in Tabriz, thus showing how the lack of vegetation cover aggravates the flood risks. Not only that, but cities in Latin America are the new leaders in the field, offering valuable insights alongside Brazil and Colombia examples of GIS flood mapping, being mainstreamed into urban resilience and planning policies [37]. Altogether, these instances reaffirm the fact that, though there are still data constraints and governance gaps throughout the Global South, innovative geospatial approaches are not only bridging the gap between hazard analysis and urban policy but also providing cities in Nigeria and far beyond with the tools and the strategies that they can use for their own context.

3. Research Methodology

This study adopts a Systematic Literature Review (SLR) methodology to synthesise peer-reviewed evidence on the integration of Geographic Information Systems (GIS) into flood risk assessment and management within Nigeria and comparable Global South contexts. The SLR design was selected for its ability to provide a transparent, replicable, and

structured synthesis of existing empirical knowledge. By systematically collecting, evaluating, and integrating findings from multiple studies, the approach enables the identification of research patterns, methodological limitations, and conceptual gaps relevant to the development of the GIFRM Framework. The review followed internationally recognised guidelines for systematic reviews, including the Centre for Reviews and Dissemination (CRD, 2009) and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) standards. These protocols ensured consistency in search strategy, inclusion and exclusion criteria, and the appraisal of methodological quality.

The inclusion and exclusion criteria were adapted from the University of York’s Centre for Reviews and Dissemination (CRD) guidelines to ensure methodological clarity and avoid unnecessary ambiguity [38]. The criteria were designed to generalize the findings without being overly restrictive, thereby ensuring that relevant studies were captured while excluding those of poor quality (Table 1).

Table 1. Criteria for data extraction.

Inclusion Criteria	Exclusion Criteria
Studies conducted in Nigeria	Studies that adopted systematic reviews
Studies reporting methods of delineating flood risk areas	Studies not focused on the delineation of flood risk areas
Published in English up to 30 August 2023	Studies not in English
Conducted on the delineation of risk areas	Studies conducted outside Nigeria
Focus on flooding and flood-prone areas	Studies published before 2001
Published from 2001 onward	Studies not addressing delineation methods
Published in peer-reviewed journals	Articles without full-text availability
Contain an abstract or executive summary	Studies with no sampling technique
Methodological focus on delineation approaches	Studies with poor methodological quality

Source: Author’s compilation.

A systematic search was conducted in June 2024 across major databases, including Google Scholar, dimensions and Web of Science (Figure 2). Boolean operators and keyword combinations were applied to capture a comprehensive set of studies. Only peer-reviewed journal articles and full-text conference papers were included. Non-academic sources such as letters, case reports, news articles, and meeting abstracts were excluded. Reference lists of included papers were screened for additional relevant studies. The search terms included:

- “flooding” AND “flood risk” OR “flood hazard” OR “flood vulnerability” OR “flood-prone areas”
- “delineation” AND “flood risk assessment” OR “hazard mapping” OR “flood susceptibility mapping”
- “Geographic Information Systems (GIS)” AND “remote sensing” OR “spatial analysis” OR “geospatial modelling”
- “Nigeria” AND “disaster risk reduction” OR “urban resilience” OR “climate adaptation”
- “sustainable urban planning” AND “adaptive infrastructure” OR “community engagement”

JB1 Scoring

Detailed JB1 scoring criteria are presented in Appendix A. Studies scoring ≥ 6 were retained.

In a bid of ensuring methodological clarity and consistency, the review established explicit inclusion and exclusion parameters that guided the screening process. Only studies that directly addressed flood risk assessment or delineation using GIS, remote sensing, or related spatial techniques were considered eligible for inclusion. Emphasis was placed on works conducted within Nigeria or comparable regions in the Global South, as these provide the most relevant socio-environmental contexts for the proposed framework. Eli-

gible papers were restricted to peer-reviewed journal publications written in English and released between 2001 and August 2023, a timeframe chosen to capture developments coinciding with the growing application of geospatial technologies in disaster risk management. Furthermore, included studies were required to demonstrate methodological transparency clearly articulating data sources, analytical tools, and procedures and to provide empirical findings that could inform policy, planning, or resilience outcomes.

In contrast, several categories of literature were deliberately excluded to maintain analytical rigour. Studies conducted outside the Global South were omitted, as were publications that discussed flooding in general terms without employing GIS or remote-sensing methods. Descriptive or purely conceptual papers lacking empirical data were also excluded, together with grey literature such as policy briefs, reports, editorials, or conference abstracts that had not undergone peer review. Likewise, any article that failed to provide sufficient methodological detail, presented ambiguous sampling procedures, or did not report replicable analytical steps was deemed unsuitable for inclusion. Finally, non-English publications and studies unavailable in full text were excluded to preserve consistency in linguistic interpretation and data accessibility. These criteria collectively ensured that the final corpus of literature represented a coherent and high-quality evidence base. By filtering studies according to methodological transparency, empirical depth, and contextual relevance, the review was able to generate a focused synthesis that reflects both the strengths and the limitations of GIS-based flood risk management research across Nigeria and the broader Global South.

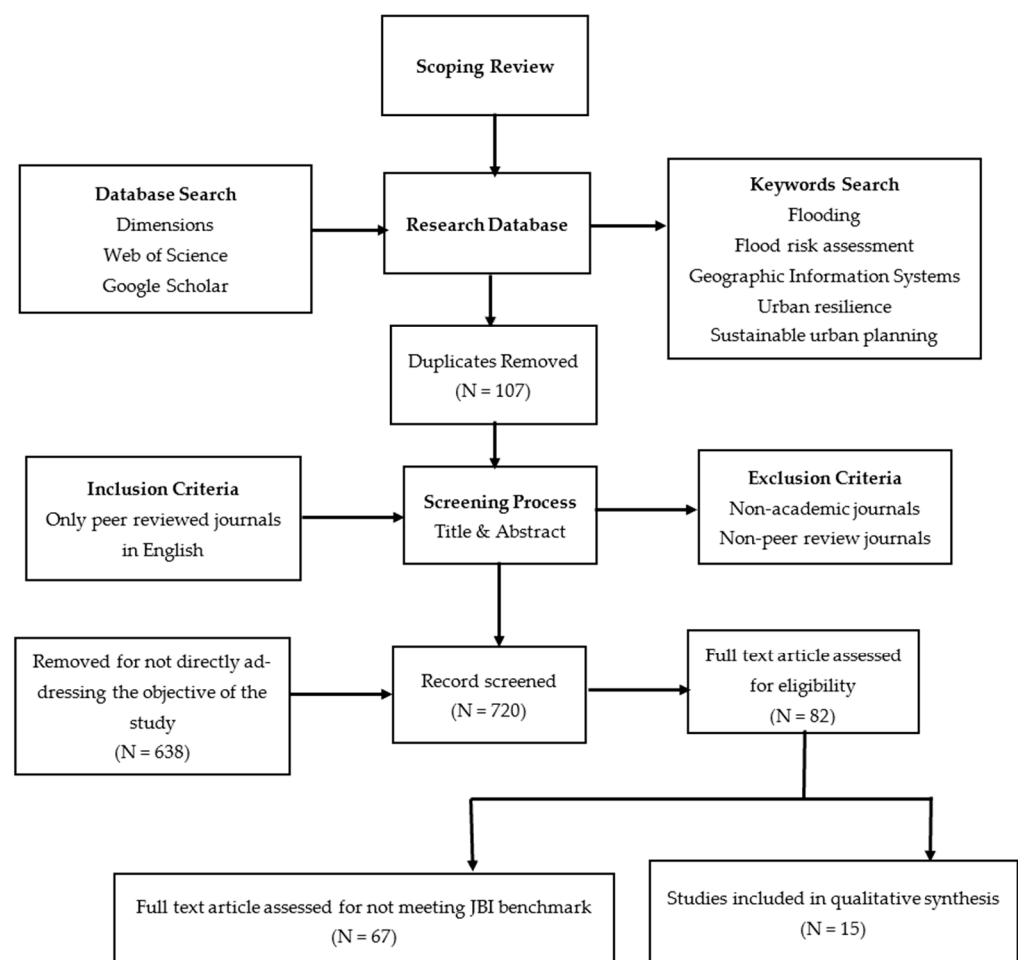


Figure 2. PRISMA Flowchart.

3.1. Screening and Selection Process

Following the establishment of inclusion parameters, the study selection process was carried out in three sequential stages to ensure methodological transparency and rigour. The first stage involved a preliminary review of all retrieved publications based on their titles and abstracts. From an initial pool of 827 records, 107 duplicates were removed, leaving 720 unique studies for screening. Each remaining article was evaluated for relevance to GIS-based flood risk management, with particular attention to the Nigerian and wider Global South contexts. At this stage, studies that did not align with the research objectives or failed to incorporate geospatial techniques were excluded, resulting in a refined set of 82 papers.

The second stage consisted of full-text evaluation, during which the 82 retained studies were examined in greater detail. The full-text review assessed methodological robustness, data quality, analytical rigour, and contextual relevance. Articles that lacked empirical grounding, relied solely on descriptive commentary, or provided insufficient detail about their analytical procedures were excluded from further consideration. This process led to the elimination of 40 papers, narrowing the selection to 42 methodologically sound studies.

The final stage entailed a critical quality appraisal using the Joanna Briggs Institute (JBI) Critical Appraisal Checklist. This instrument was employed to evaluate each study's design appropriateness, data validity, analytical precision, and reproducibility. A minimum quality threshold of six points out of a possible ten was adopted to ensure that only robust and reliable studies were included. After this appraisal, 15 studies met the established criteria and were retained for synthesis. Of these, ten focused explicitly in Nigeria, while five provided complementary insights from other Global South countries, including Bangladesh, South Africa, India, Iran, and Brazil. This distribution allowed for both national and comparative perspectives, thereby enriching the analytical depth of the review. The entire process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 guidelines to maintain transparency and replicability.

3.2. Data Extraction and Synthesis

The data extraction process was undertaken systematically to ensure comprehensive coverage of the selected studies. For each of the included papers, key information was identified and recorded, including the authorship, publication year, study location, type of flood hazard investigated, analytical methods, spatial scale, and the GIS or remote sensing techniques applied. Particular attention was given to the analytical frameworks employed such as Digital Elevation Models (DEMs), Multi-Criteria Analysis (MCA), Normalised Difference Vegetation Index (NDVI), and Height Above Nearest Drainage (HAND), as these represented the dominant tools used in the literature. Additional information was extracted regarding the main findings, reported limitations, and the extent to which each study contributed to resilience planning or policy development.

Given the heterogeneity of research approaches and datasets, a narrative synthesis rather than a meta-analysis was employed. This qualitative integration enabled the identification of recurring patterns, thematic consistencies, and methodological gaps across studies. The synthesis sought to answer three guiding questions: first, what are the dominant physical, socio-economic, and governance factors influencing flood vulnerability in Nigeria? Second, how effectively have GIS and remote-sensing technologies been employed to delineate and manage flood risk? And third, what transferable practices can be drawn from other Global South contexts to inform Nigeria's flood resilience strategy? The outcomes of this synthesis provided the empirical foundation for the development of the GIFRM Framework, which is presented later in this paper.

3.3. Validity and Reliability

To safeguard the validity and reliability of the review, several strategies were employed throughout the research process. Multiple databases were used to achieve triangulation of data sources and to minimise potential selection bias. The inclusion decisions were cross verified by two independent reviewers who examined the retrieved studies against the established eligibility criteria. Any discrepancies in judgment were resolved through discussion and consensus to ensure consistency. Furthermore, all search strings, exclusion decisions, and coding procedures were documented systematically to enhance transparency and enable replication by other researchers.

The application of internationally recognised quality appraisal tools, such as the JBI checklist and the PRISMA framework, further reinforced the credibility of the process. These instruments provided standardised benchmarks for assessing methodological soundness, analytical rigour, and reporting completeness. The combined use of these measures ensured that the findings derived from the review were both reliable and representative of current trends in GIS-based flood risk assessment across the Global South. By adhering to these established protocols, the review achieved a high level of internal validity and demonstrated replicability consistent with the methodological standards of the *Water* journal.

3.4. Ethical Considerations

Although this research did not involve human subjects or the collection of primary data, it adhered strictly to academic and ethical standards governing the use of secondary sources. All literature included in the review was properly cited, and intellectual contributions were acknowledged in accordance with the Committee on Publication Ethics (COPE) guidelines. The study was conducted under the ethical oversight of Robert Gordon University, United Kingdom, and was supported by the Tertiary Education Trust Fund (TETFUND), Nigeria. These institutions provided the academic and financial framework that ensured the integrity and ethical compliance of the research process.

4. Results

4.1. Overview of Included Studies

The systematic review identified fifteen studies that met the established inclusion criteria and quality standards (Table A2). Of these, ten were conducted in Nigeria, while the remaining five provided comparative insights from Bangladesh, India, South Africa, Iran, and Latin America. Collectively, these studies illuminate both the methodological progression and the persistent challenges associated with integrating GIS into flood risk management across diverse socio-environmental contexts. The Nigerian studies reveal a consistent pattern of exposure in low-lying settlements situated along river basins and coastal zones, while the comparative cases from Asia and Latin America illustrate how institutionalised data integration and community participation can significantly enhance flood resilience outcomes.

The findings indicate that flood risks in Nigeria range from consistently high to spatially variable depending on local topography, land use, and infrastructure quality. The Niger–Benue Basin repeatedly emerges as a critical hotspot, with over 50 percent of settlements in identified flood danger zones. Urban areas such as Aba, Port Harcourt, Surulere (Lagos), and Yenagoa similarly exhibit heightened exposure due to a combination of low elevation, rapid urbanisation, and inadequate drainage systems. These findings echo the experiences of other Global South cities such as Sylhet in Bangladesh and Hyderabad in India, where unregulated land conversion and population pressures have intensified hydrological hazards. The comparative distribution of studies highlights a shared vulnerability

pattern, in which environmental degradation, infrastructural deficit, and weak governance converge to amplify risk.

4.2. Spatial and Demographic Patterns of Vulnerability

A recurring theme across the reviewed literature is the spatial concentration of vulnerability within densely populated, poorly serviced urban areas. In Nigeria, this pattern is particularly evident in Yenagoa, Aba, and Port Harcourt, where flood exposure is intensified by proximity to rivers, unplanned housing expansion, and insufficient stormwater infrastructure. The research by Nkeki et al. [11] and Ogbonna et al. [20] demonstrate that over 70 percent of land areas in parts of Aba and the Niger–Benue Basin are classified as highly flood-prone, while studies such as Akukwe and Ogbodo [39] identify socio-economic deprivation and housing density as major aggravating factors. Similar results were observed in Bangladesh, where Haque and Uddin [32] linked land-use transformation and vegetation loss to the expansion of flood-prone areas, and in India, where Dahiya et al. [34] showed that megacities such as Delhi and Kolkata face increasing exposure due to uncontrolled urban sprawl.

The demographic dimensions of vulnerability are equally significant. Informal settlements and low-income communities are often located in floodplains where land is more affordable, yet most susceptible to inundation. The Nigerian examples mirror the situation in South Africa and Kenya, where studies have shown that socio-economic marginalisation, poor infrastructure, and limited access to drainage systems exacerbate flood impacts in informal neighbourhoods. These findings collectively affirm that flood risk in the Global South cannot be understood solely through physical geography; it must also be viewed through the lenses of poverty, governance, and environmental justice.

4.3. Severity and Extent of Flood Impacts

The reviewed studies reveal substantial variation in flood severity and spatial extent across different geographical and socio-economic contexts. In Yenagoa, for instance, approximately 64 square kilometres—equivalent to seven percent of the urban area—were inundated during the 2012 flood event, while in Aba, nearly three-quarters of the municipal landmass was classified as flood-prone. The Niger–Benue Basin studies further demonstrate that over half of the settlements in the catchment area were directly affected by flood events in the same year. Such figures underscore the magnitude of the disaster's impact and the urgent need for a coordinated response. Comparable trends are documented internationally; in Tabriz, Iran, Kiani et al. [35] found that major transport infrastructure projects were located in zones of high flood susceptibility, while in Brazil and Colombia, Dahiya et al. [34] reported the integration of GIS mapping into urban resilience policies as a strategic response to recurrent flooding.

These observations demonstrate that while the physical causes of flooding vary, the consequences particularly in terms of displacement, infrastructure damage, and economic disruption are consistent across the Global South. The evidence also confirms that data-driven planning, if systematically institutionalised, can substantially reduce flood losses and guide investments toward adaptive infrastructure.

4.4. Techniques and Methodological Trends

The selected studies reveal a clear evolution in methodological sophistication over time. Early Nigerian research primarily employed Digital Elevation Models (DEMs) and remote sensing tools such as MODIS imagery to identify low-lying flood-prone zones and simulate inundation patterns [11,40]. While these methods provided valuable baseline data, their precision was constrained by low spatial resolution and limited integration of socio-economic indicators. More recent works have adopted hybrid techniques that combine

Multi-Criteria Analysis (MCA), Height Above Nearest Drainage (HAND) models, and indicator-based vulnerability assessments to capture both physical and human dimensions of flood risk [35,36]. These approaches enable the simultaneous analysis of topographic, hydrological, and social data layers, offering a more comprehensive understanding of vulnerability distribution.

Beyond Nigeria, methodological innovation is advancing rapidly. In Bangladesh, Haque and Uddin [32] employed Google Earth Engine for real-time land-use monitoring, while in India, Dahiya et al. [34] utilised time-series GIS mapping for flood zoning in megacities. Similarly, South African and Latin American studies have experimented with flood risk index mapping and urban resilience modelling in data-scarce contexts [30,34]. The emergence of artificial intelligence in flood analysis such as Zhao et al. [29] and Zhang et al. [30] who applied attention-based deep learning models further demonstrates the expanding capacity of GIS and remote sensing for predictive and impact assessments. Collectively, these methodological developments mark a paradigm shift from static hazard mapping to dynamic, resilience-oriented spatial modelling that aligns with modern risk governance frameworks (Table A3).

4.5. Determinants of Vulnerability

Across all reviewed contexts, several determinants consistently explain differential vulnerability to floods. Topography remains the most fundamental factor, with low-lying basins and floodplains such as those in the Niger–Benue region demonstrating the highest exposure. Drainage infrastructure quality is another critical determinant, as inadequate or poorly maintained systems exacerbate waterlogging in cities such as Aba and Port Harcourt. Urbanisation and land-cover change further amplify flood risk by increasing surface runoff and reducing infiltration capacity, as evidenced by Adewumi et al. [41], who reported a 44.76 percent decline in vegetation cover in Igbokoda between 1986 and 2013. The findings from Bangladesh and India mirror this trend, revealing that rapid urban development and vegetation loss have severely disrupted local hydrological cycles, while Iranian studies attribute rising flood impacts to poor land management in areas of low elevation [32]. Socio-economic conditions including income levels, housing quality, and access to infrastructure also play a defining role, shaping communities' adaptive capacity and recovery potential.

4.6. Implications for Flood Risk Management

The collective findings from the fifteen studies underscore the urgent need for a paradigm shift in flood risk governance across Nigeria and the Global South. While GIS and remote sensing have become indispensable tools for mapping and monitoring flood hazards, their potential remains underexploited due to persistent data gaps, weak institutional linkages, and the limited integration of social and governance variables into spatial models. The evidence from countries such as Bangladesh, India, and Brazil demonstrates that sustainable flood risk management requires more than technical precision, it demands institutionalised processes that embed geospatial intelligence into urban planning, infrastructure design, and policy implementation.

For Nigeria, this implies the necessity of transitioning from reactive hazard management to proactive, resilience-oriented planning. Integrating socio-economic indicators, local knowledge, and participatory mechanisms into GIS frameworks can ensure that flood mapping translates into meaningful policy action. The reviewed studies suggest that when communities are engaged in data collection, validation, and decision-making, the resulting outputs are not only more accurate but also more legitimate and implementable. Thus,

bridging the divide between science and governance becomes a central prerequisite for effective flood risk management.

These insights directly inform the conceptual development of the GIFRM Framework proposed in the next section. Through the synthesising of the spatial, socio-economic, and governance dimensions identified in the literature, the GIFRM framework aims to operationalise the integration of geospatial data into planning and policy systems, providing a scalable model for flood resilience in Nigeria and other Global South contexts.

Table A4 offers an extensive understanding of flood risk mapping, vulnerability assessment, and hazard detention in Nigeria and the rest of the Global South. Being different in focus as well as in method, these studies still have something in common: they aim at locating the areas that are prone to flooding the most and to providing the decision-support tools to the authorities, emergency planners, and local communities. The results are recapped here in terms of their contributions, commonality, spatial relationships, and insights from international perspectives. Flood risk in Nigeria is a consequence of the interaction of physical geography, land-use change, and socio-economic vulnerability. Besides elevation and slopes that are the main physical factors, unplanned urbanisation and the removal of vegetation have also contributed to the severity of floods as the amount of surface runoff has increased. Haque and Uddin [32] mention almost the same situation in Sylhet, Bangladesh where the rapid transformation of land use reduced the capacity of the land to absorb water and increased the area's vulnerability to flooding/mudslide during the monsoon season.

The existence of such similarities indicates that decrease of vegetation and urbanisation are not only drivers of flood risk at regional level but also at global level. Technical hazard mapping, by itself, is still a very important tool for defining baseline risk, but it cannot go very far in vulnerability. Nigerian examples from Port Harcourt and Aba illustrate how social and economic vulnerabilities, such as housing quality, poverty, drainage access, are at the centre of flood causes [20,36]. The same results were obtained in the research carried out in South Africa, where Serame et al. [33] pointed out the shortcoming of hazard-only mapping scenarios when socio-economic variables were missing, particularly in regions that suffer from a lack of data. The findings together confirm the necessity of using mixed physical–social models for portraying the extent of actual flood vulnerability.

Methodological diversity indicates the development of flood risk assessment. The usage of remote sensing and DEM-based techniques still dominates in Nigeria [11,12,40]; however, it is evident that there is a shift towards the multi-criteria and hybrid approaches which are basically the combination of physical and social indicators [35]. The same trends are observed in different parts of the world. The research conducted by Dahiya et al. [37] in India is an excellent example as it shows the time-series GIS mapping used for the delineation of urban flood risk zones in megacities and how the hazard mapping can be used for resilience planning. In Iran, Kiani et al. [35] experiments on DEM modelling to the infrastructure projects in Tabriz demonstrate how topography and weak vegetation cover led to hazard exposure increase.

Fast disaster mapping is developed as another advantage. Nkeki et al. [11] employed MODIS satellite data to outline the water spreading during Nigeria's 2012 Niger–Benue flood, thus, they were able to depict the 58 LGA from the 14 states that were impacted as a result. Methods like that are used at present in various places. For instance, flood mapping based on GIS has been integrated in Latin America into the resilience policy of Brazil and Colombia, thus, by the easy access to the hazard data planning can be carried out more efficiently [34]. It is these instances that point out the increasing reliance on near-real-time geospatial analysis not only for emergency scenarios but also for long-term adaptation.

Urbanization and vegetation loss are still the issues most often mentioned. By the time Adewumi et al. [41] made a comparison between the vegetation in Igbokoda from 1986 to 2013, the researchers realized that the greenery had undergone a decline of 44.76% and this owed to the higher runoff and subsequent flooding. Aja et al. [40] gave a demonstration that even though rainfall was uniform, the flood extent was affected by elevation with those areas that were below 40 m being the most prone to exposure. Nearly the same results have been found in the Global South: in India, urban expansion disturbed the natural hydrological cycles [13], and in Bangladesh, the change of land use was the biggest cause that led to the flood vulnerability intensification [25]. In general, these studies confirm that the major cause of floods in the Global South is unplanned development.

5. Discussion of Results

The findings from the systematic review reveal that flood risk management within Nigeria and the broader Global South remains dominated by a reactive, technically fragmented approach, despite significant progress in geospatial and remote-sensing technologies. Although the reviewed studies demonstrate an increasing use of GIS and spatial modelling techniques, these applications are often confined to hazard delineation rather than being embedded within a broader decision-making or policy framework. In Nigeria, for instance, GIS-based flood risk studies have achieved remarkable technical precision in mapping flood-prone areas across states such as Lagos, Anambra, Rivers, and Bayelsa; however, their practical influence on planning decisions, zoning reforms, or infrastructural design remains minimal. This disconnect between research output and implementation limits the transformative potential of GIS in shaping resilient urban futures.

The evidence also indicates that most Nigerian studies prioritise physical and topographical indicators such as elevation, slope gradient, land cover, and proximity to drainage channels while giving less emphasis to socio-economic or institutional determinants of vulnerability. As a result, many risk maps depict where floods occur but fail to explain why certain communities remain persistently vulnerable. In contrast, comparative studies from Bangladesh, India, and Brazil integrate hydrological, social, and governance dimensions, producing multi-layered vulnerability profiles that inform both emergency response and long-term adaptation. These integrated approaches demonstrate that flood resilience cannot be achieved through technical precision alone; rather, it requires coordinated governance structures, participatory processes, and a continuous feedback system linking science and policy.

This divergence between technological advancement and institutional practice underscores the need for a new integrative model that situates GIS within a broader governance and resilience framework. The GIFRM Framework proposed in this study arises from this necessity. It seeks to operationalise geospatial intelligence within an inclusive, adaptive, and policy-responsive structure that reflects the socio-ecological realities of the Global South. The framework not only consolidates lessons from Nigeria's fragmented flood management practices but also synthesises comparative insights from international contexts to produce a transferable, evidence-based model for sustainable flood risk governance.

5.1. Theoretical Context: Risk, Resilience, and Governance

The conceptual foundation of GIFRM lies at the intersection of risk governance theory, resilience thinking, and the socio-ecological system (SES) perspective. These complementary frameworks collectively provide a comprehensive understanding of how societies anticipate, absorb, and adapt to flood risks in complex and dynamic environments.

Risk governance, as conceptualised by Renn [42], extends beyond the technical assessment of hazards to encompass the societal processes by which risks are evaluated,

managed, and communicated among stakeholders. It highlights that effective risk management requires transparent communication, participatory decision-making, and institutional coordination across scales. Within the Nigerian context, the reviewed studies consistently reveal weak institutional alignment, overlapping mandates among agencies, and the absence of interoperable data-sharing systems. These governance deficiencies not only undermine the efficacy of GIS-based analyses but also hinder their translation into practical interventions [43]. GIFRM addresses these institutional bottlenecks by embedding spatial intelligence into the governance process, thereby promoting evidence-based decision-making and cross-sectoral collaboration.

Resilience theory further enriches this conceptual foundation by focusing on a system's capacity to withstand, recover from, and adapt to shocks. Folke et al. [44] and Njoku [45] emphasise that resilience is not a static state, but a dynamic process characterised by learning, transformation, and adaptability. Within flood-prone urban systems, resilience depends on both structural measures, such as flood defences, drainage infrastructure, and land-use regulation and non-structural factors, including community preparedness, institutional flexibility, and knowledge exchange. The literature demonstrates that in Nigeria and other parts of the Global South, resilience is often constrained by socio-economic inequalities, limited technical capacity, and a lack of coordinated planning. GIFRM conceptualises resilience as an evolving interaction between human and environmental systems, guided by real-time geospatial data that inform adaptive responses and continuous learning.

The socio-ecological system (SES) framework, which views cities as integrated networks of human and ecological processes, provides the final pillar supporting GIFRM. It acknowledges that flood risks emerge from the interplay between natural hydrological cycles and anthropogenic alterations such as deforestation, urbanisation, and infrastructural expansion. Managing such risks requires governance systems that recognise feedback loops between ecological health, social wellbeing, and spatial planning. By integrating GIS within the SES framework, GIFRM facilitates the visualisation of these interactions, allowing decision-makers to anticipate how environmental degradation, land-use changes, or infrastructural investments might alter flood dynamics. In essence, the framework situates flood risk management within a broader sustainability discourse one that aligns with the Sendai Framework for Disaster Risk Reduction (2015–2030) and the Sustainable Development Goals (SDGs), particularly Goals 11 and 13, which advocate for resilient cities and climate action.

5.2. The GIS-Integrated Flood Risk Management (GIFRM) Framework

The GIFRM Framework is conceptualised as a multi-dimensional, adaptive system that integrates spatial intelligence, socio-economic analysis, and participatory governance into a unified model for managing flood risks. The framework is designed to address three critical shortcomings identified in the literature: the fragmentation of spatial data, the weak linkage between geospatial analysis and policy action, and the limited inclusion of local stakeholders in decision-making processes.

At its foundation, GIFRM begins with data integration and spatial intelligence, which involves consolidating hydrological, meteorological, topographical, and socio-economic datasets within a single GIS platform (Figure 3). This integration enhances the precision of risk mapping and facilitates the identification of high-exposure zones, infrastructure vulnerabilities, and population clusters at risk. The next layer, vulnerability assessment and modelling, combines multi-criteria evaluation techniques with spatial weighting methods to generate composite vulnerability indices. These indices account for both physical exposure and social sensitivity, thereby providing a more holistic depiction of flood risk patterns.

A defining feature of the framework is the policy and planning interface, which translates analytical outputs into actionable governance tools. This interface supports urban planners and policymakers in embedding flood risk data into land-use zoning, infrastructure design standards, and early warning systems. The final dimension, stakeholder participation and capacity building, ensures that local communities, civil society organisations, and private actors are active contributors in data generation, validation, and interpretation. Through iterative feedback loops, GIFRM fosters adaptive learning and continuous improvement, enabling flood risk management to evolve in response to emerging data and changing environmental conditions.

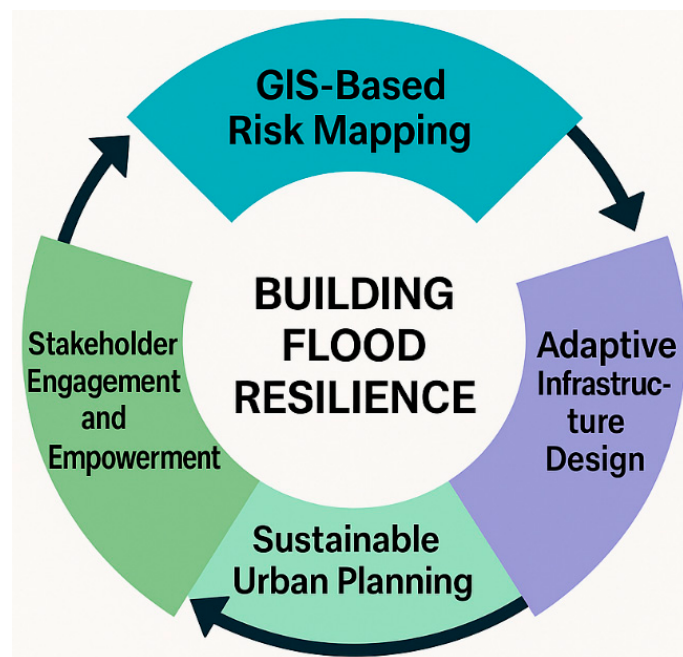


Figure 3. GIS-Integrated Flood Risk Management (GIFRM) Framework.

Conceptually, GIFRM redefines the role of GIS from a passive analytical tool to an active decision-support mechanism that integrates scientific knowledge, institutional processes, and community engagement. By linking spatial analytics with participatory governance, the framework operationalises the transition from reactive disaster response to proactive, resilience-oriented planning.

5.3. Comparative Advantages of GIFRM

The novelty of GIFRM lies in its ability to bridge the persistent divide between technological innovation and institutional practice. While GIS and remote sensing have long been used to map flood hazards, their integration into the governance process has remained limited. GIFRM transforms this paradigm by positioning GIS as a central element of the policy cycle beginning with data collection, continuing through spatial analysis, and culminating in implementation and monitoring. This cyclical integration ensures that policy interventions are grounded in evidence and continuously updated in line with new data inputs and community experiences.

Another distinguishing feature of GIFRM is its capacity for adaptive resilience. Traditional flood risk management models are often static, designed to address current risks without accommodating future uncertainties. GIFRM, however, incorporates dynamic updating mechanisms that allow decision-makers to recalibrate priorities as new information emerges. This aligns with the principles of adaptive management, where policies are treated as experiments subject to refinement based on real-world feedback.

Equally important is the framework's emphasis on inclusivity. By embedding participatory processes into each phase of the model, GIFRM ensures that vulnerable communities are not merely recipients of risk information but active agents in its production and application. This participatory dimension enhances the legitimacy, local ownership, and sustainability of flood management strategies. Moreover, by integrating socio-economic indicators into geospatial analysis, the framework promotes equity by recognising that exposure to flood hazards is shaped not only by geography but also by income, housing quality, and access to infrastructure. In doing so, GIFRM advances a multidimensional understanding of vulnerability that is both technically robust and socially grounded.

5.4. Policy and Practical Implications

The policy implications of GIFRM are profound, particularly for developing countries grappling with rapid urbanisation and increasing climate-related disasters. For national and subnational governments, the framework provides a blueprint for institutionalising GIS-based intelligence within formal planning and disaster management systems. Integrating GIFRM into the operations of agencies such as the Nigerian Meteorological Agency (NiMet), the National Emergency Management Agency (NEMA), and state-level planning ministries could foster greater coordination, reduce duplication of efforts, and ensure that flood risk considerations are mainstreamed into all stages of urban development.

From a planning perspective, the framework offers urban planners a systematic approach to incorporating flood risk data into zoning decisions, infrastructure design, and environmental impact assessments. It also supports the design of nature-based solutions—such as wetland restoration, green buffers, and permeable surfaces—that complement structural interventions. For policymakers, GIFRM provides a data-driven tool for aligning national flood management strategies with global frameworks, particularly the Sendai Framework and the SDGs. In practice, the adoption of this model would facilitate the transition from crisis-driven responses to anticipatory governance grounded in spatial evidence.

Furthermore, the participatory component of GIFRM has significant implications for community empowerment. By involving residents in data collection and validation, the framework not only enhances the accuracy of flood risk maps but also builds local capacity and awareness. Communities that understand spatial risk patterns are better positioned to take preventive action, engage constructively with authorities, and advocate for equitable resource allocation. As urban flooding continues to intensify due to climate change and unplanned growth, such empowerment becomes essential for fostering resilient societies.

5.5. Limitations and Future Research Directions

While GIFRM offers a robust conceptual structure, several limitations must be acknowledged. The framework is currently theoretical and derived from secondary data synthesis. Its empirical validation requires pilot implementation across selected flood-prone regions in Nigeria to evaluate its operational feasibility, cost-effectiveness, and institutional adaptability. Future research should therefore focus on testing the framework's applicability in real-world settings, examining how different governance structures, data ecosystems, and socio-cultural contexts influence its performance.

Another area for future exploration lies in the integration of artificial intelligence (AI) and machine learning (ML) into the GIS-embedded decision process. AI-driven predictive models, when coupled with high-resolution satellite imagery and Internet of Things (IoT) sensors, could significantly enhance GIFRM capacity for early warning and adaptive planning. Likewise, future research should examine how climate scenarios and

socio-economic projections can be integrated into the framework to support long-term adaptation planning.

Finally, successful implementation of GIFRM will require interdisciplinary collaboration among hydrologists, urban planners, data scientists, policy experts, and community organisations. Such collaboration would ensure that spatial intelligence is translated into equitable and practical interventions capable of reducing vulnerability while promoting sustainable development. The framework's strength lies in its potential to evolve continuously, guided by the interplay of technology, governance, and societal learning, a hallmark of resilience-oriented flood risk management in the twenty-first century.

6. Conclusions

This study has examined the integration of GIS into flood risk management within the Nigerian context and across the broader Global South, revealing both the technological potential and institutional constraints shaping current practices. Through a systematic review of fifteen peer-reviewed studies, it becomes evident that GIS and remote sensing technologies have significantly advanced the precision and predictive capacity of flood risk assessment. However, their application remains largely confined to hazard delineation and spatial mapping, with limited translation into policy action, infrastructure design, or urban governance. This persistent gap between spatial analysis and practical implementation underscores the necessity for a more holistic framework that bridges scientific knowledge and decision-making processes.

The findings highlight that flood risk in Nigeria is driven not only by climatic and hydrological dynamics but also by socio-economic disparities, institutional fragmentation, and weak governance structures. Urban areas such as Lagos, Port Harcourt, and Aba illustrate how unplanned expansion, inadequate drainage infrastructure, and the proliferation of informal settlements combine to exacerbate exposure and vulnerability. These realities are echoed in comparable Global South settings such as Bangladesh, India, and Brazil, where similar interactions between rapid urbanisation and insufficient planning have intensified disaster risks. Nonetheless, these international cases also demonstrate that integrating GIS into governance systems, supported by participatory data collection and local empowerment, can substantially improve resilience outcomes.

Building on these insights, this paper proposed the GIFRM Framework as a conceptual and practical innovation that embeds geospatial intelligence within the processes of policy formulation, spatial planning, and community engagement. The framework provides a structured approach that links technical analysis with governance and social participation, offering a multi-layered platform through which risk information can inform real-time decision-making. GIFRM advances the understanding of resilience as an adaptive and learning-oriented process by conceptualising flood risk management as a dynamic interaction between environmental processes, infrastructural systems, and human behaviour.

At the theoretical level, GIFRM contributes to the evolving discourse on risk governance and resilience thinking, aligning with the socio-ecological systems approach that views cities as interdependent networks of human and environmental components. It extends existing frameworks by operationalising the integration of spatial data into governance mechanisms, thereby transforming GIS from a diagnostic instrument into a decision-support system. The framework also aligns with the global policy landscape articulated in the Sendai Framework for Disaster Risk Reduction (2015–2030) and the Sustainable Development Goals (SDGs 11 and 13), reinforcing the call for data-driven, inclusive, and forward-looking strategies for urban resilience and climate adaptation.

From a practical perspective, the adoption of GIFRM offers a pathway for reconfiguring flood management in Nigeria from a reactive posture to a proactive, anticipatory, and adap-

tive system. Federal and state agencies can strengthen coordination and reduce redundancy in data collection and analysis by institutionalising GIS-based intelligence. Incorporating spatial vulnerability maps into land-use zoning and infrastructural design processes can ensure that urban growth occurs within safe thresholds. Moreover, embedding participatory components into the framework encourages local knowledge integration, thereby fostering community trust, ownership, and preparedness. When communities are actively involved in data validation and decision-making, they become partners rather than passive recipients of risk information—an essential condition for building long-term resilience.

Policymakers should therefore prioritise the development of interoperable spatial data systems that link ministries, research institutions, and local authorities. Such systems would facilitate the seamless exchange of real-time flood information, enabling early warning, rapid response, and coordinated recovery efforts. Furthermore, the establishment of National Spatial Flood Risk Observatories could serve as repositories for GIS-based hazard data, supporting both academic research and practical decision-making. Strengthening the technical capacity of planning and environmental agencies through targeted training, funding, and technology transfer is equally critical for sustaining the functionality of such systems.

At the urban planning level, flood risk information should be mainstreamed into statutory instruments, including master plans, development control guidelines, and building regulations. Integrating GIFRM into these instruments would ensure that new developments adhere to hydrological realities, thereby reducing future exposure and potential economic losses. Additionally, planners should embrace nature-based solutions such as green infrastructure, wetland restoration, and permeable pavements to complement conventional engineering measures. These approaches not only mitigate flood risks but also enhance biodiversity, improve urban air quality, and contribute to the broader objectives of environmental sustainability.

The research also highlights the importance of community education and awareness as critical enablers of resilience. Flood preparedness programmes should extend beyond early warning dissemination to include public training on evacuation procedures, water safety, and property protection strategies. Encouraging citizen participation through mobile GIS applications, crowd-sourced data reporting, and local mapping initiatives can democratise information and increase response efficiency during emergencies. The intersection of technology, governance, and citizen science represents an emerging frontier in climate adaptation that GIFRM is designed to accommodate.

In terms of future research directions, empirical validation of GIFRM is essential to assess its applicability and scalability in different geographic and institutional contexts. Pilot implementations across flood-prone states in Nigeria such as Lagos, Anambra, or Bayelsa would provide valuable insights into its operational feasibility, data interoperability challenges, and cost–benefit dynamics. Furthermore, the integration of emerging technologies, including artificial intelligence (AI), machine learning (ML), and the Internet of Things (IoT), offers significant potential for enhancing the predictive accuracy and real-time adaptability of the framework. Incorporating high-resolution satellite imagery and sensor-based monitoring systems could further enable dynamic modelling and early warning capabilities, especially in regions with limited ground-based data.

Future research should also examine the socio-political conditions that enable or constrain the adoption of such frameworks. Understanding the power dynamics, institutional cultures, and governance incentives that influence the use of spatial information will be crucial to achieving long-term integration of GIS within national flood management systems. Collaboration between universities, government agencies, and international organisations

can accelerate capacity building, promote data standardisation, and enhance the diffusion of innovative practices across developing economies.

In conclusion, this study contributes to the growing body of knowledge that positions GIS not merely as a mapping tool but as a transformative instrument for risk-informed development and climate resilience. By proposing the GIFRM Framework, the research advances both theory and practice, offering an integrative model that connects scientific analysis with participatory governance. The framework's emphasis on adaptability, inclusivity, and evidence-based planning provides a foundation for reimagining flood risk management in Nigeria and other regions of the Global South. As climate change continues to intensify hydrological hazards, the implementation of such integrative, data-driven frameworks becomes not only a policy necessity but a moral imperative for safeguarding human lives, livelihoods, and sustainable urban futures.

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Appendix A

Table A1. JBI Scoring Table.

Criterion	Description	Scoring (0/1)
Clear research question	Study states explicit aim	1 = Yes, 0 = No
Study design appropriateness	Alignment with research objectives	1/0
Data collection method	Reliability and validity of data	1/0
Sample representativeness	Generalizability of study	1/0
Methodological transparency	Description of tools/techniques	1/0
Analytical rigor	Use of statistical/analytical methods	1/0
Consideration of bias	Identification of limitations	1/0
Ethical approval/standards	Explicit statement on ethics	1/0
Relevance to review objectives	Direct contribution to flood risk/GIS research	1/0
Replicability	Methods can be reproduced	1/0

Threshold: Studies scoring ≥ 6 were retained.

Table A2. Overview of flood risk in the inclusion papers.

Author(s)	City/Region	Flood Risk Category	Key Findings	Techniques
Akinbobola, Okogbue, & Olajire (2015) [10]	Niger-Benue Basin, Nigeria	High	45% of settlements in flood danger zones	GIS mapping
Nkeki, Henah, & Ojeh (2013) [11]	Niger-Benue Basin, Nigeria	High	58 LGAs across 14 states highly exposed	MODIS, GIS analysis
Wizor & Week (2014) [12]	Yenagoa, Bayelsa, Nigeria	High	64.42 km ² inundated (7% of city)	GIS, land-use maps

Table A2. *Cont.*

Author(s)	City/Region	Flood Risk Category	Key Findings	Techniques
Ogbonna, Ike, & Okwu-Delunzu (2015) [20]	Aba, Nigeria	High	71.65% of area flood-prone	GIS, Mann–Kendall analysis
Haque & Uddin (2025) [32]	Sylhet, Bangladesh	High	LULC change intensified monsoon floods	Google Earth Engine
Serame, Afuye, and Kalumba (2023) [33]	South Africa	Variable	GIS feasible in data-scarce contexts	Flood risk index mapping
Dahiya et al. (2025) [34]	Indian megacities	High	Time-series mapping identified urban flood zones	GIS, urban resilience planning
Kiani et al. (2024) [35]	Tabriz, Iran	High	Infrastructure projects exposed in low-lying areas	DEM + GIS
Komolafe et al. (2020) [36]	Ogun River Basin, Nigeria	Variable	Risk varied by settlement patterns	GIS, MCA, HAND model
Dahiya et al. (2025) [37]	Brazil & Colombia	Variable	GIS flood mapping integrated into policy	GIS for resilience planning
Akukwe & Ogbodo (2015) [39]	Port Harcourt, Nigeria	Variable (High in NW, SW, S, NE)	Vulnerability uneven across city	Indicator-based GIS
Aja, Elias, & Obiahu (2019) [40]	Abakaliki, Nigeria	High/Low	22.8% very high risk; elevation key	GIS, flow modelling
Adewumi et al. (2016) [41]	Igbokoda, Nigeria	Variable	Vegetation loss increased risk	Remote sensing, NDVI
Okoye & Ojeh (2015) [43]	Surulere, Lagos, Nigeria	High	Most areas in Surulere is prone to flooding	GIS, DEM
Njoku, Amangabara, & Duru (2013) [45]	Aba, Abia State, Nigeria	High	Elevation range critical in management	GIS, DEM

Source: Author's compilation.

Table A3. Methodological Framework Comparison.

Method/Study	Strengths	Limitations	Best Use Case
Remote Sensing with MODIS (Nkeki et al., 2013) [11]	Rapid detection, large coverage	Coarse resolution, cloud cover issues	National-scale disaster mapping
Land Use/Flood Extent Intersection (Wizor and Week, 2014) [12]	Links hazard to land-use impacts	Needs accurate land-use data	Post-flood damage assessment
MCA with HAND Model (Komolafe et al., 2020) [36]	Combines physical & social data	Data-intensive	Basin-wide prioritisation
Indicator-Based Assessment (Akukwe and Ogbodo, 2015) [39]	Captures socio-economic risk	Subjective weighting	Urban vulnerability profiling
NDVI Change Detection (Adewumi et al., 2016) [41]	Tracks vegetation change	Indirect hazard measure	Long-term land cover monitoring
Relational Rule-Based Modelling (Aja et al., 2019) [40]	Integrates multiple risk factors	Requires robust datasets	Local hazard mapping
DEM-Based Mapping (John, Gordon & Pat, 2013) [45]	Direct elevation–risk link	Omits socio-economic factors	Drainage design planning

Table A4. Issues investigated in the inclusion papers.

Author(s), Year	Region	Aim	GIS Approach	Key Findings	Limitations
Akinbobola, Okogbue & Olajiire (2015) [10]	Niger-Benue Basin, Nigeria	Map vulnerable cities & villages	GIS-based risk mapping	45% of cities/villages in flood danger zone	Limited to rainfall & SPI data

Table A4. Cont.

Author(s), Year	Region	Aim	GIS Approach	Key Findings	Limitations
Nkeki, Henah & Ojeh (2013) [11]	Niger-Benue Basin, Nigeria	Assess 2012 flood impact	MODIS remote sensing + GIS	58 LGAs affected; identified most exposed states	MODIS resolution limits detail
Wizor & Week (2014) [12]	Yenagoa, Nigeria	Map 2012 flood extent	Land-use maps + Radarsat	Flood covered 64.42 km ² (7% area); built-up zones worst hit	Limited correlation with land use
Ogbonna, Ike & Okwu-Delunzu (2015) [20]	Aba, Nigeria	Map at-risk areas	DEM + GIS tools	71.65% of area flood-prone; Ogbor Hill less vulnerable	Short time-series rainfall
Haque & Uddin (2025) [32]	Sylhet, Bangladesh	Detect LULC change for flood risk	Google Earth Engine	Identified transformation hotspots linked to flooding	Dependent on satellite resolution
Serame, Afuye & Kalumba (2023) [33]	South Africa	Explore GIS for DRR	Flood risk index mapping	Showed GIS potential in data-scarce contexts	Limited participatory integration
Dahiya et al. (2025) [34]	Indian Megacities	Urban flood zoning	Time-series GIS mapping	Provided hazard zoning for urban planning	Rapid urbanization dynamics underrepresented
Kiani, Ahmadabadi & Azariun (2024) [35]	Tabriz, Iran	Assess flood impact on infrastructure	DEM + GIS	Revealed freeway projects highly flood-prone	Vegetation factor excluded
Komolafe et al. (2020) [36]	Ogun River Basin, Nigeria	Hazard zoning	GIS + MCA + HAND	Clear spatial variation in vulnerability	Model sensitivity to DEM accuracy
Dahiya et al. (2025) [37]	Brazil & Colombia	Urban resilience	GIS flood mapping in planning	GIS integrated into resilience policy	Institutional gaps in application
Akukwe & Ogbodo (2015) [39]	Port Harcourt, Nigeria	Assess spatial flood risk variation	Indicator-based vulnerability assessment	Identified high-risk NW, SW, S, NE zones	Relies on survey data, subject to bias
Aja, Elias & Obiahu (2019) [40]	Abakaliki, Nigeria	Develop hazard map	GIS + rational model + overlay	22.8% very high-risk zone; low areas < 40 m most exposed	Rainfall data uniformity assumption
Adewumi et al. (2016) [41]	Igbokoda, Nigeria	Assess LULC change	NDVI + DEM	Vegetation declined 75% → 47% (1986–2013); urbanization main driver	No direct flood impact measurement
Okoye & Ojeh (2015) [43]	Surulere, Lagos	Identify flood factors	DEM + LULC + ArcGIS	Most of Surulere prone to flooding	Ignores socio-economic vulnerability
Njoku, Amangabara & Duru (2013) [45]	Aba, Nigeria	Map flood zones	DEM + GIS + GPS	Elevation (36–72 m) key for flood channelization	Narrow geographic focus

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