

STAKEHOLDERS' PERCEPTION OF GIS AND AI-DRIVEN NATURE-BASED SOLUTIONS FOR RESILIENCE AND MITIGATION IN THE FLOOD-VULNERABLE COMMUNITIES OF SOUTH WEST NIGERIA

¹Adebayo Samson Adeoye*, ²Oluwole Olalekan Oke,

³Adekunle Sarafadeen Adetunji

^{1,2,3}Department of Agricultural Extension and Management, Federal College of Forestry, Ibadan, PMB 5087, Jericho Hills, Ibadan, 200272, Nigeria. Forestry Research Institute of Nigeria

ABSTRACT

Flooding remains a major environmental challenge in southwest Nigeria due to extreme rainfall, rapid urbanization, deforestation, and inadequate drainage systems. In response to the limitations of conventional flood control measures, innovative approaches such as Geographic Information System (GIS) and Artificial Intelligence (AI)-driven Nature-based Solutions (NbS) are increasingly being considered. These technologies support the identification of flood-prone areas and the strategic deployment of natural infrastructure to enhance resilience and mitigate flood risks in vulnerable communities. This study employs a mixed-methods approach combining GIS spatial analysis, AI-based flood prediction models, and 50 stakeholders were interviewed to evaluate the effectiveness and barriers to utilization of these technologies in Lagos, Ibadan, and Abeokuta. A survey method was used to collect data from the stakeholders. Results show that GIS-based flood models significantly enhance real-time flood monitoring, while AI-driven NbS reduce runoff, improve urban resilience, and minimizes flood damage. Most stakeholders (24%) from agencies such as NiMET,

NEMA, Urban Authorities, IUFMP, and NGOs, along with 16% of community leaders, reported awareness of GIS and AI-driven Nature-based Solutions (NbS) for flood management in Southwest Nigeria. However, an equal proportion (24%) noted poor GIS effectiveness in detecting flood risks and the limited usefulness of AI-NbS. Additionally, 30% of respondents identified inadequate flood management data as a major barrier. A large majority highlighted systemic constraints, including weak policy enforcement (82%), insufficient funding (84%), and limited community engagement (76%), all of which hinder the effective deployment of GIS/AI-NbS in the region. However, challenges like limited access to real-time hydrological data, weak policy enforcement, and financial constraints hinder full implementation. The study concludes by recommending integration of AI and GIS into Nigeria's flood risk management systems through improved policy frameworks, strengthened data infrastructures, and increased stakeholder engagement.

Keywords: *GIS, Artificial intelligence, Nature-based solutions, Flood management, Stakeholders' perception.*

Corresponding author: Adebayo Samson Adeoye can be contacted at samalaba77@gmail.com

1. INTRODUCTION

Flooding is one of the most destructive natural hazards affecting communities in Southwest Nigeria (Umar and Gray, 2023). Major cities such as Lagos, Ibadan, Abeokuta, and Ondo routinely experience urban and flash floods triggered by intense rainfall, poorly maintained drainage systems, and rapid, unregulated urban expansion (Koko *et al.*, 2021). Climate change has intensified rainfall patterns, leading to increased flood frequency and severity (Eteh *et al.*, 2025). Increased

flooding in the Niger Delta stems not only from natural processes like heavy seasonal rainfall and upstream runoff but also from intensified human interventions. Climate change further disrupts hydrological balance by altering rainfall intensity and seasonal patterns, thereby prolonging wet seasons and reducing dry spells (Ogunkoya & Olayiwola, 2022). More so, dam operations like those at Kainji, Jebba, and Lagdo have significantly modified natural river flow, building up volume that compounds downstream flood risks (Echendu, 2023). Traditional flood mitigation strategies, including drainage expansion, dredging, and concrete embankments, have proven insufficient due to poor maintenance, high cost, and limited long-term sustainability (Sohn *et al.*, 2020). However, past studies have revealed that compact densely populated areas of development encountered fewer flood losses than medium and low-density populated areas of development because of well-structured drainage infrastructure, as propounded by Lee and Brody (2018).

Modern approaches to flood management emphasize the integration of Geographic Information System (GIS) technologies and Artificial Intelligence (AI)-enabled Nature-Based Solutions (NBS) (Liu *et al.*, 2025). Artificial intelligence (AI), particularly machine learning (ML) and deep learning (DL), offers transformative potential to overcome these constraints and better anticipate the evolving nature of flood risk. One of the significant advantages of AI, ML, and DL is their ability to handle vast and complex datasets (Farahmand *et al.*, 2024). AI-based models can process a wide array of data sources, including real-time hydrological measurements, satellite imagery, weather forecasts, and historical flood records,

without the intensive computational burden typical of conventional physical models (Zhou, 2023). GIS provides spatially explicit flood hazard information through hydrological modelling, satellite imagery, and terrain analysis (Liu *et al.*, 2025). AI-driven NBS use machine learning and ecological modelling to optimize natural infrastructure interventions such as wetlands, bioswales, permeable pavements, green roofs, and floodplain restoration (Prodanovic *et al.*, 2024). NbS has been gaining recognition at the moment as a result of its multifaceted approach to tackle a number of local issues, from climate, water, and air pollution to green space promotion for biodiversity and inclusion. Whereas biodiversity is often not considered in traditional urban planning, but NbS gives us an opportunity for reconciliation between humans and nature to co-exist together in urban spaces, which is also increasingly explored in architectural design parlance (Braidotti, 2020). Some solutions, such as tree pits, rain gardens, wetlands, and other nature-based solutions (NBS, provide a wealth of habitats and resources for biodiversity conservation in cities and rural areas, while at the same time increasing human health, decreasing urban heat, and managing urban water and pollution (European Commission *et al.*, 2020). However, this exact multifaceted nature of NbS is challenging to urban planners, due to a large number of, sometimes conflicting, priorities (Kuller *et al.*, 2019).

This study investigates the perception of stakeholders on the combined application of GIS-based flood detection and AI-driven NbS in flood-vulnerable communities in Southwest Nigeria. The objectives are to evaluate the effectiveness of GIS-based flood detectors in identifying high-risk areas; assess how AI-optimized NbS contribute to flood resilience and mitigation;

and to identify barriers hindering the adoption of AI and GIS in Nigeria's flood management strategies.

2. REVIEW OF LITERATURE

2.1 Flooding in Southwest Nigeria

Southwest Nigeria is characterized by massive and unorganized urbanization, informal settlements, and inadequate drainage infrastructure, making it highly prone to incessant and recurrent flooding (Olufadewa *et al.*, 2025). In the study, it was expounded that the rapid expansion of informal settlements and slums in southwestern Nigeria, particularly along the Lagos-Ogun-Oyo corridor, underscores the critical challenges posed by rapid urbanisation and population growth in this major economic hub of West Africa. This corridor, home to key infrastructure, industries, and economic activities, has seen a significant rise in unplanned communities due to its economic opportunities. In particular, Ogun and Oyo states, both sharing borders with Lagos, have become hotspots of these communities, characterised by inadequate housing, poor sanitation, unsafe drinking water, and heightened vulnerability to climate-related hazards. Lagos, a coastal megacity, experiences frequent coastal and urban flooding due to its low elevation and high impervious surface cover. Ibadan and Abeokuta are prone to flash floods caused by steep slopes and clogged waterways (Ekoh *et al.*, 2023).

2.2 GIS-Based Flood Detection and Hazard Mapping

Geographic Information Systems (GIS) support flood detection through remote sensing, hydrological modelling, and spatial analyses of elevation, rain patterns, soil types, and land use

(Onatayo & Adelesi, 2021). According to the study, understanding spatial patterns of flood vulnerability is important for effective disaster risk management, sustainable urban planning, and community resilience building. Thus, remote sensing and GIS have emerged as powerful tools in this regard, providing high-resolution, multi-temporal data that can be integrated into vulnerability assessments. Through the use of satellite imagery and digital elevation models, remote sensing enables the identification of hydrological features, drainage networks, land cover changes, and flood-prone areas. Flood hazard maps generated by GIS have demonstrated high prediction accuracy (often 80–90%). They enable proactive flood preparedness, resource allocation, and risk communication (Adeyemi & Komolafe, 2025).

2.3 Artificial Intelligence in Flood Modelling and Nature-Based Solutions

AI-driven NbS combines machine learning with ecological design to optimize natural solutions for flood mitigation (Dammack *et al.*, 2025), and the efficacy of NbS is influenced by many factors, comprising the specific location, layout, and scale of implementation. Machine learning models such as Support Vector Machines, Artificial Neural Networks, and Random Forests are increasingly used to predict flood events, assess runoff distribution, and recommend optimal NBS interventions. NbS such as wetlands, green roofs, floodplain restoration, and permeable pavements enhance infiltration and reduce peak discharge, contributing to urban resilience (Aghaloo *et al.*, 2024). Urban nature-based solutions (NbS) have the potential for adaptation and mitigation; however, it is not entirely clear

how NbS can drive transformative changes in cities worldwide (Goodwin *et al.*, 2023). Although NbS has gained recognition as a sustainable approach, it remains a topic of debate in many cities owing to the uncertainties surrounding its implementation.

2.4 Barriers to Digital Flood Management in Nigeria

Studies highlight several constraints such as inadequate hydrological data, limited technical capacity, weak urban planning policies, insufficient funding, and lack of community awareness (Abu-Hanifa *et al.*, 2025; Abdelmajeed & Juszczak, 2024). Flood scenario is a frequent and destructive natural disaster that is global, with intensifying socioeconomic and environmental consequences linked to rapid urbanisation and climate change, and this persistent challenge undermines effective flood risk management, including incompatible datasets, limited stakeholder participation, and inadequate integration with formal planning systems (Nwogu *et al.*, 2025). These challenges undermine efforts to mainstream GIS and AI tools in national flood risk management strategies.

3. RESEARCH METHODOLOGY

The study was conducted in Southwest Nigeria with a focus on residents in flood-prone areas. The Southwest is a geopolitical region in Nigeria and is the hometown of the Yoruba people having land size of 114.271km². This region was estimated in 2020 to have a population of about 32.5 million, with an approximate figure of 20.44 percent of Nigeria's population, according to the National Bureau of Statistics, NBS (2022). This study adopts a mixed-methods framework that combines GIS-

based spatial analysis, AI-driven modelling, and qualitative stakeholder inquiry to assess flood vulnerability in Southwest Nigeria. Within the GIS environment, platforms such as ArcGIS and QGIS were used to construct key spatial layers: digital elevation, slope, flow direction, soil infiltration, land-use/land-cover, and drainage networks, which were subsequently integrated using a weighted overlay hydrological model to produce flood hazard maps for each study area. The AI component of the study builds on machine learning applications in flood risk prediction, employing Random Forest, Support Vector Machine, and Artificial Neural Network algorithms trained on a decade-long dataset encompassing rainfall intensity, soil permeability, land cover, and documented flood occurrences. These models were used both to delineate high-risk flood zones and to determine optimal locations for nature-based interventions. In line with emerging literature on AI-supported environmental planning, the system evaluated and ranked potential sites for wetland restoration, permeable pavements, bioswales, rain gardens, green roofs, and floodplain rehabilitation. Complementing the quantitative analyses, the study incorporates insights from 50 stakeholders, including officials from NiMet, NEMA, urban planning authorities, non-governmental organizations, and community leaders. Data from these stakeholders were collected through a survey method. Thematic analysis of interview responses highlights recurring barriers to effective GIS and AI adoption, such as inadequate data availability, weak policy enforcement, insufficient funding, and limited community engagement. Together, these components provide a comprehensive review of the technical

and institutional factors shaping flood risk management in the region.

4. RESULTS AND DISCUSSION

4.1 GIS-Based Flood Risk Assessment

Most stakeholders (24.0%) from NiMET, NEMA, Urban Authority, IUFMP, and NGO across southwest Nigeria were aware of GIS/AI-NbS utilization for flood management, with 16.0% of community leaders inclusive (Table 1). This indicates a significant number of personnel from environmental agencies and community leaders are knowledgeable about the importance of GIS/AI-NbS for flood mitigation. This corroborates Bello *et al.* (2024) that professionals use satellite and geographical information system (GIS)-based hydrological model detect areas vulnerable to flooding and synthesize needed management measures. GIS mapping identified high-risk flood zones in Lagos (Eti-Osa, Ikorodu), Ibadan (Orogun, Apete), and Abeokuta (Isale-Igbein) according to Mafimisebi (2024). The study affirms that GIS mapping shows areas such as Epe, Badagary, Eti-Osa, and Ibeju-Lekki are at a high risk of flooding, whereas Ifako-Ijaiye, Agege, Alimosho, Ikeja, Mushin, Shomolu, Lagos Mainland, and Ajeromi/Ifelodun have a lower vulnerability to floods. Flood hotspots correlated with areas exhibiting poor drainage, rapid urbanization, and high impervious surfaces (Orimoogunje & Aniramu, 2025). This corroborates Osayomi *et al.* (2022) and Lagos State Government (2022) that over 70% of flooding in southwest Nigeria, Lagos, especially, is attributed to poor waste management blocking drainage systems. Further studies establish that the GIS hydrological model achieved 85%

predictive accuracy according to Adeyemi & Komolafe (2025), which also aligns with NIHSA (2023) on flood projections.

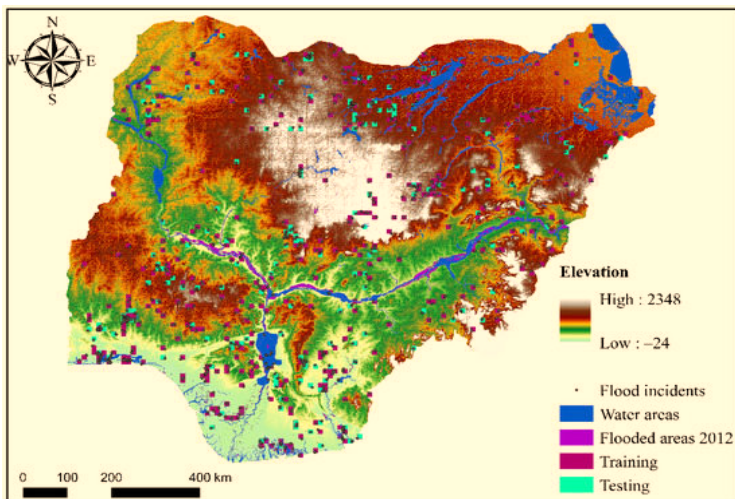


Figure 1. GIS Map of the Study Area

4.2 AI-optimized NbS interventions showed significant improvements

It was observed that 24.0% of stakeholders across southwest Nigeria, including NiMET, NEMA, Urban Authority, IUFMP, and NGO attest to poor GIS effectiveness in detecting flood risk and the usefulness of AI-NbS (Table 1). This implies a fair number of personnel in environmental agencies are without doubt about the efficacy of GIS/AI-NbS for flood detection and flood mitigation in southwest Nigeria. This concurs with Abioye (2025) that the potential efficiency of technology for flood drainage measures is still very low in southwest Nigeria.

Wetland restoration has been widely documented as one of the most effective nature-based solutions for flood mitigation, with studies showing that restored wetlands can reduce peak flood depths by 30-50% by enhancing natural water retention, delaying flood wave propagation, and increasing groundwater recharge (Singh, 2021; Acreman & Holden, 2013). Similarly, permeable pavements substantially lower surface runoff by 25-40%, as their porous structure allows rainwater to infiltrate rather than accumulate on impermeable surfaces, thereby reducing pressure on drainage systems during heavy rainfall events (Li *et al.*, 2013). Green roofs also contribute meaningfully to urban stormwater control, with evidence showing a 15-22% reduction in stormwater discharge due to vegetation layers that intercept rainfall and promote evapotranspiration (Vijayaraghavan, 2016). Additionally, bioswales, engineered vegetated channels designed to slow and filter runoff, have been found to improve infiltration rates by approximately 28%, enhancing soil absorption and reducing overland flow during peak storm events (Eckart *et al.*, 2017). Overall, these outcomes highlight the significant potential of Artificial Intelligence to optimize the cost-effectiveness and spatial placement of nature-based solutions by identifying areas where each intervention can deliver maximum hydrological and ecological benefits, thus strengthening climate resilience in flood-prone environments.



Figure 2. AI Nature-based Solutions Diagram in the Study Area

4.3 Barriers to Implementing GIS and AI in Flood Management

About 30.0% of stakeholders agreed to inadequate data availability on flood management in southwest Nigeria (Table 1). This suggests insufficient data might really affect the adoption of GIS/AI-NbS for flood management. This corroborates Haou *et al.* (2025) that better data will improve flood prediction and technology infrastructure management. Limited access to real-time environmental and hydrological data remains a major barrier to effective GIS and AI applications in flood management, as inadequate monitoring networks restrict the accuracy of predictive models and hinder timely updates needed for early warning and adaptive planning (Niang *et al.*, 2014). Furthermore, most stakeholders (82.0%) pointed to the fact that weak policy enforcement affect use of GIS/AI-NbS for flood management (Table 1). This indicates absolute poor

government policy drive and implementation could hamper the utilization of GIS/AI-NbS for flood mitigation. This aligns with the submission of Abubakar *et al.* (2025) and Ilesanmi *et al.* (2025) that poor data, weak institutional enforcement, and infrastructure hinder full adoption of GIS despite its benefits. Weak policy and institutional frameworks further exacerbate these limitations; in many Nigerian cities, urban planning regulations are poorly enforced, allowing unregulated construction in floodplains and wetlands, which increases exposure to flood hazards and reduces the effectiveness of both structural and nature-based interventions (Mbajjorgu, 2019). Also, most stakeholders (84.0%) agreed that insufficient funds posing challenge to the utility of GIS/AI-NbS for flood management (Table 1). This corroborates Ilesanmi *et al.* (2025) that inadequate funding hinders the implementation of GIS for effective flood management. Financial constraints also impede progress, as the acquisition of GIS hardware, licensing of AI software, and continuous technical training require substantial investment that many local governments and agencies struggle to provide due to limited budgetary allocations for environmental monitoring and disaster risk reduction (UNDRR & UNU-EHS, 2023). Moreover, the majority of stakeholders (76.0%) agreed that poor management engagement with vulnerable communities to flood obstructs the use of GIS/AI-NbS for flood management in southwest Nigeria (Table 1). This concurs with UNESCO (2013) that the lack of inclusiveness of local actors' voices and communities may cause loss of immense opportunity to maximize technological infrastructure for flood mitigation around the world. Additionally, technical capacity limitations pose a significant challenge, with a persistent

shortage of skilled GIS analysts, hydrologists, and AI specialists across relevant institutions, resulting in difficulties in system maintenance, data interpretation, and the long-term sustainability of advanced flood management systems (Oyedele & Oyesode, 2019). Collectively, these constraints underscore the need for stronger institutional support, capacity building, and investment to enable the effective deployment of GIS- and AI-driven flood resilience solutions.

Table 1. Stakeholders' Perception of Effectiveness and Barrier to Utilization of GIS and AI-NbS (N = 50)

Statements	Stakeholders											
	NiMET		NEMA		Urban Authority		IUFMP		NGO		Community	
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Aware of GIS/AI-NbS importance to flood risk management	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	8(16.0)	0(0)	8(16.0)	30(60)
GIS is effective in mitigating flood	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	8(16.0)	0(0)	3(6.0)	35(70)
AI-NbS is very useful for flood control	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	8(16.0)	0(0)	2(4.0)	36(72)
Inadequate data availability	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	3(6.0)	5(10)	8(16.0)	30(60)
Weak policy enforcement	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	7(14.0)	1(2)	30(60)	8(16.0)
Insufficient funding	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	0(0)	8(16.0)	38(76)	0(0)
Poor engagement with flood-prone villages	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	1(2.0)	0(0)	2(4.0)	6(12)	32(64)	6(12.0)

Note: NiMET = Nigerian Meteorological Services, NEMA= National Emergency Management Agency, IUFMP= Ibadan Urban Flood Management Project, NGO= Non-Governmental Organization
 Source: Field survey, 2024.

5. CONCLUSION

The findings of this research demonstrate that GIS-based flood detection systems substantially improve the accuracy of flood prediction and the effectiveness of early-warning mechanisms, while AI-driven nature-based solutions (NbS) significantly reduce flood vulnerability by optimizing the spatial placement and hydrological performance of natural infrastructure. Despite these benefits, the integration of GIS and AI technologies remains constrained by persistent data gaps, limited financial resources, weak institutional frameworks, and shortages in technical expertise. Overall, the results show that GIS- and AI-supported NbS provide a sustainable, proactive, and cost-efficient strategy for flood mitigation in Southwest Nigeria by enhancing early-warning capabilities, reducing surface runoff, improving natural water absorption, and informing adaptive urban planning practices. To fully realize these advantages, Nigeria needs to strengthen data governance systems, enforce robust policy frameworks, increase funding for geospatial and AI innovations, and promote active community participation in flood risk management initiatives. Strengthening flood resilience in Southwest Nigeria requires an integrated suite of policy interventions spanning data governance, financing, community participation, regulatory reforms, and capacity development. The following policy recommendations are proposed:

- i. A robust national flood information architecture is essential for accurate forecasting and timely interventions. Government agencies should establish a centralized, real-time flood risk database that harmonizes outputs from GIS-based

models, AI-driven analytics, remote sensing platforms, and local field observations. This system must be supported by the expansion and modernization of hydrological and meteorological monitoring stations across all states, ensuring a continuous flow of high-quality data required for early warning and adaptive risk management.

ii. Sustained financing is crucial for the effective implementation of GIS and AI technologies as well as nature-based solutions (NBS). National and state governments should allocate dedicated funding for NBS implementation, procurement of GIS equipment, AI infrastructure, and maintenance of monitoring networks. Additionally, investment incentives—such as tax breaks, grants, and innovation funds—should be introduced to encourage private-sector participation in developing eco-digital flood management systems and climate-resilient infrastructure.

iii. Community involvement is critical for achieving long-term flood resilience. Policy frameworks should incorporate structured community training on the benefits and maintenance of NBS, as well as flood-preparedness strategies tailored to local contexts. The establishment of community-led early warning systems, supported by mobile communication technologies and local disaster volunteers, will strengthen grassroots responsiveness and improve the timely dissemination of alerts.

iv. Urban planning regulations must be revised and rigorously enforced to reduce exposure to flood hazards. Authorities should enforce compliance with building codes, restrict development in designated floodplains, and integrate

green infrastructure—such as permeable pavements, bioswales, retention ponds, and urban forestry—into all new developments. Comprehensive land-use planning that reflects updated hazard maps and climate projections will further guide safer, more sustainable urban expansion.

v. Bridging existing technical gaps requires targeted investment in human-resource development. Policy initiatives should support continuous professional training for urban planners, hydrologists, GIS analysts, disaster risk managers, and environmental officers in advanced geospatial technologies, hydrological modelling, and AI applications. Strengthening institutional collaborations among universities, research institutes, and government agencies will ensure sustained knowledge transfer and innovation.

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