impact International Journals and Publications

© IIJP 2025 | Volume 1, Issue 4, pp. 1-15 | ISSN: 2636-4484

# FLOOD RISKS, ENVIRONMENTAL REGULATION AND SUSTAINABLE LAND MANAGEMENT IN THE NIGER DELTA: PATHWAYS TO RESILIENT DEVELOPMENT

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**ARTICLE INFO**

**Article No.:** 066

**Accepted Date:** 13/09/2025

**Published Date:** 03/10/2025

**Type:** Research

**ABSTRACT**

The Niger Delta area in Nigeria, with its vast wetlands and rivers, has substantial hydrocarbons. However, the area has been getting floods frequently, and the damage to human being, infrastructure and environment are massive. Vulnerability refers to the over-exposure arising from weak enforcement, fragmentation of institutional roles, as well as chaotic urban expansion, despite the existence of the regulatory framework of the Petroleum Industry Act (PIA), Land Use Act and NESREA oversight. The purpose of the study was to assess the connection between flood risk, environmental regulation, and sustainable land management in the Niger Delta. High-risk areas have been assessed for their relationship to oil and gas infrastructures, human settlements and natural features through a range of geospatial tools such as GIS based flood risk mapping, land-use/land-cover (LULC) analysis and documents review. The results indicate that areas affected by flooding are strongly linked with informal settlements, oil pipelines, and degraded wetlands, pointing to a lack of governance and planning issues. The research indicates that if GIS spatial analysis is coupled with functional environmental regulation and community-based land management, resilience to repetitive flooding will be strengthened. The recommendation broadens policies by calling for clarity in enforcement role guidelines, floodplain zoning, wetlands restoration and mainstreaming climate resilience. The findings of this research provide technical insights and policy insights that are useful for the development of integrated flood risk management frameworks for sustainable development in the Niger Delta.

**Keywords:** Flood Risk, Niger Delta, Environmental Regulation, Land Use Management, Climate Resilience

## Introduction

The Niger Delta is located in southern Nigeria. It is one of the world's largest deltaic systems with a total area of 70 000 sq. km. Furthermore, it flows through nine states. Owing to its complex patterns of rivers, creeks, mangroves and floodplains, it has high biodiversity as well as sustains millions of livelihoods through agriculture, fisheries and other activities that depend on natural resources (UNEP, 2011; Amnesty International, 2009). The region is Nigeria's hydrocarbon heartland, and home to critical oil and gas infrastructure, including pipelines, flow stations and refineries, which have historically been the source of significant economic activity but have exerted enormous pressure on the environment (World Bank, 2012; Campbell et al., 2008) Despite the richness of the Niger Delta, it is very flood prone because of its character and other factors. Flooding in Niger Delta is majorly attributed to low elevation of the region. However, among other natural and physical processes responsible are high annual rainfall, tidal surges, overbank discharge of rivers. Besides, substances and poor state of natural buffers, especially wetlands and mangroves (Apampa et al, 2020; Akukwe & Ogbodo, 2019).

Flooding has worsened in the Niger Delta in recent decades. The flooding has resulted in loss of lives, property, water pollution, and disruption of oil and gas operations. The impacts in rapid urban growth and informal development in flood-prone areas in Port Harcourt, Warri and Yenagoa (Apampa et al., 2020; Akukwe & Ogbodo, 2019). The country's economy relies heavily on oil infrastructure solutions. Nevertheless, it prevents the natural drainage system from working, leading to floods and a danger to the environment. The ecological fragility of the region is due to loss of wetlands, deforestation, soil erosion, etc. According to Eke & Ojeh (2017) and Campbell et al. (2008), they all limit the capacity for resilience in the community and add to flood vulnerability.

The Nigerian regulations which include the Petroleum Industry Act, 2021 (PIA, 2021), and the Land Use Act (1978), and oversight by the NESREA are meant to protect the environment, sustainable land use, and mitigation of industrial impacts (Federal Ministry of Environment, 2020; Akukwe & Nnamdi, 2015). Even though this situation exists, this is however not taking place consistently, overlapping institutional responsibilities create governance gaps, while political-economic interest(s) that is associated with oil exploitation often undermines compliance. It is more than inadequate warning regarding the risk from flooding in the present. Earlier studies found that spatial, regulatory and community engagement approach should be integrated to build resilience.

The research questions for the thesis are prescribed in a paragraph as follows; how will recurrent flooding interact with environmental regulation and land use in the Niger Delta? Specifically, in locations overlapping with the oil infrastructure and informal settlements? What flaws in the rules or organizations cause flooding to have an impact? In what ways do they restrict successful flood control and sustainable land use planning? How can geospatial tools (e.g., GIS, land surveying, LULC monitoring), regulatory processes, and policy empower climate resilience and promote sustainable development pathways in the Delta? The question also seeks to address the question and their utility together. To gain integrated technical and ecological and governance solutions, one should deal with such questions.

The goal of this study is to explore the areas prone to flooding geographic information systems (GIS) mapping and their overlay with settlements sites, oil infrastructure, ecology, etc. Further the environmental regulatory regime and governance system that contribute to the flood risk and propose an evidence-based Land and Water Management System for enhancing resilience. The research consists not only of technical evaluations, such as geolocation mapping

of flood risk but also of policy reviews to provide strategic recommendations for governments, urban planners, communities and so on.

## Literature Review

### Flood Risk and Climate Change in Sub-Saharan Africa

Flooding is one of the significant climate hazards in Sub-Saharan Africa. Due to climate change, urbanization with expansion of population floods are being more common and severe. Floods in Nigeria have destroyed the edifices and livelihoods of settlements, particularly riverine and coastal settlements like the Niger Delta, on several occasions (Adaku 2020; Akukwe & Ogbodo, 2015; Chukwu & Ezeabasili, 2019). The world is facing an increased risk of floods due to changes in rainfall patterns, tidal surges, and poor drainage systems. The consequences of this risk have been greater vulnerability of urban and rural populations. Flooding, climate change, and vulnerability are related. They have to adjust using forecasting, floodplain, and other measures (Tasantab 2019; Alam & Mwase, 2022).

### Environmental Regulation in Nigeria

Nigeria has a rural development policy that articulates rural development objectives, guidelines, and strategies (Federal Ministry of Environment Nigeria, 2020). It also has the governance framework, planning process, and the institutional framework of the rural development policy. The Petroleum Industry Act is concerned with oil exploration, protecting the environment and cleaning the environment from oil pollution. Moreover, the Land Use Act assigns and oversees how land is used like the zoning of floodplains (Akukwe & Ogbodo, 2015; Olomola, 2016). The enforcement of regulatory frameworks are inconsistent due to institutional responsibilities that are dispersed and local and state levels have a lack of capacity (Nkwunonwo, Whitworth, & Baily, 2016; Amnesty International, 2009). Efforts to mitigate flooding and create sustainable land development plans often fail due to poor governance, political pressures and problems at sites such as oil infrastructure and informal settlements. These references were published in 2019 and 2020.

### Land Use and Settlement Growth in the Niger Delta

As the cities and communities in the Niger Delta are growing rapidly, structures are creeping into the wetlands and mangrove forests. The useable drainage channels are reduced as an outcome (Akukwe & Ogbodo, 2019; Musa and Shabu, 2019). The majority of slum developments occur in flood-prone, unplanned and unserviced areas. The above trend exacerbates the vulnerability (Akukwe & Ogbodo, 2015; Apampa, et al., 2020; Akukwe & Ogbodo, 2019) Pipelines and flow stations interfere with the natural free flow of water and alter hydrological patterns, which impacts the area's land use management (Amnesty International, 2009; Eke & Ojeh, 2017). Research on how land is used and what it is covered with in a certain area (LULC) show that the tree felling, wetland invasion, and urban sprawl cause floods of the region (Akukwe & Nnamdi, 2015; Musa and Shabu, 2019). Understanding these dynamics is essential for sustainable land management, flood-prone area identification and intervention planning Apampa et al., 2020; Akukwe & Ogbodo, 2019; Okoye 2019.

### GIS and Flood Risk Mapping Applications

More and more tools that use the geospatial features of things like GIS are being used to assess flood vulnerability, model hydrology and plan a flood relief strategy. One means of measuring flood occurrence is to deploy some GIS technology to merge elevation data (that is DEM), rainfall and LULC as well as infrastructure data (Apampa, Oladokun, & Adeniran, 2020; Akukwe & Nnamdi, 2015). In-depth investigations in Lagos, Port Harcourt and other Nigerian

towns have indicated that GIS delivers for early warning, emergency response planning and long-term urban planning. Cirella and Iyalomhe, 2018; Egbinola & Olaniran and Amanambu, 2017 Countries such as the Netherlands, Bangladesh and Ghana are planning based on GIS-based flood risk assessment, indicating the need for deeper insights and multi-layered interventions Tasantab 2019.

**Synthesis and Knowledge Gaps**

Studies have indicated that there is greater need to integrate regulation in environmental, land use, flood risk and other areas to Niger Delta. GIS is effective in marked flood-prone regions. Nonetheless, it is often just a technical exercise, with no connection to regulation enforcement and community adaptation (Akukwe & Ogbodo, 2019; Nkwunonwo, Whitworth & Baily, 2016). Furthermore, many studies on the oil spill are city or locality specific in their analysis and therefore fail to detect the regional patterns of vulnerability and interactions between oil infrastructure and settlements (Oladokun & Proverbs 2016; Okoye 2019). This study intends to fill these gaps through geospatial analysis, review of development regulations, and strategies for sustainable management of land.

## Method and Materials

### Study Area

The Niger Delta encompasses 70,000 km², spread across the nine states of Akwa Ibom, Bayelsa, Cross River, Delta, Edo, Imo, Ondow, Rivers and Abia. The area is an ecological fragile zone with extensive wetlands, mangroves and low-lying areas which are flood-prone. Oil and gas installations such as pipelines and refineries take place in both rural and urban settlements. More than 31 million people in cities such as Port Harcourt, Warri, and Yenagoa have rapidly migrated to high-risk floodplains. The Niger Delta is a particularly relevant setting for studying how flood risk, energy infrastructure and land use interact.

### Data Sources

#### Primary Data

Community observations and field surveys verified data on the exposure and vulnerability of settlements in terms of space. Digital Elevation Models (DEM) (30 m SRTM) from satellite sources were used to delineate flood-prone zones. The seasonal and long-term flood trends (IPCC, 2021) obtained inputs from the rainfall and hydrological data (2000–2023) of the Nigerian Meteorological Agency (NIMET). The remote sensing imagery (Landsat 7 ETM+ and Landsat 8 OLI/TIRS) for 2000, 2010 and 2020 has been utilized for Land Use/Land Cover classification to monitor urban growth and loss of wetlands.

#### Secondary Data

NEMA, the Federal Ministry of Environment, and the National Bureau of Statistics (NBS) national records, were used for historical flood data and population trend. International sources, including UNEP (2011), World Bank (2012) and IFRC (2020), had environmental and disaster management contexts. The methodology for this paper was drawn from the works of Adeleke, 2020; Apampa, Ojolowo & Ismail, 2020 and Nkwunonwo, Malcolm & Brian, 2016 on GIS-based flood mapping and urban vulnerability, which are scholarly.

### Analytical Tools

#### GIS Spatial Analysis

Flood hazard maps were created using ArcGIS 10.8 and QGIS 3.32. To locate flood plains, DEMs were processed to derive flow direction and accumulation (Okoye 2019).

#### Overlay and Spatial Modeling

Multi-layered analysis combined hazard maps with LULC, pipeline networks, and settlement data. This quantified exposure levels—such as the share of built-up areas or pipeline lengths in high-risk flood zones (Eke & Ojeh, 2017). There is a quantification of the risk level to exposure including the percentage on built-up area or pipes length in flood zone.

**Policy and Legal Review**

We looked at the Petroleum Industry Act (2021), the Land Use Act, and NESREA rules. The roles of institutions are fragmented and there is limited integration of flood risk into environmental governance.

**Analytical Framework**

The Flood–Land Use Management Model had four phases of development.

1. Hazard Assessment – DEM and rainfall data used to delineate seasonal and extreme flood zones.
2. Maps showing where settlements, wetlands, and pipelines overlap with hazardous zones.
3. Regulatory assessment involves the locating of enforcement and institutional overlaps.
4. Planning for sustainability; zoning, wetland restoration, and mangrove conservation.

## Results

### Flood Risk Mapping

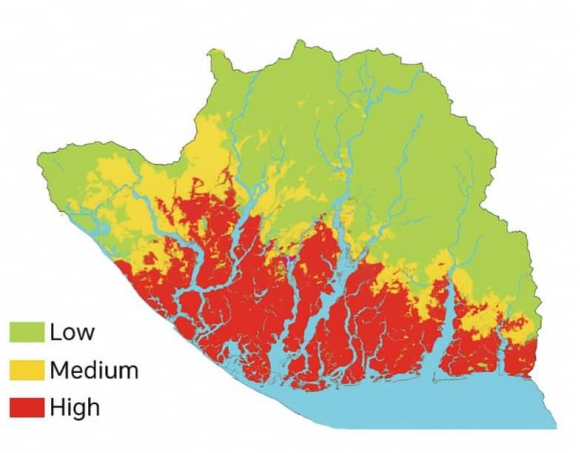
The Niger Delta flood risk intensity varies due to a combination of natural and human factors. States such as Bayelsa, Rivers and Delta located in the lower coastal belt very close to the Atlantic Ocean and river network and tidal systems area are flood prone areas. Over the rainy season, a severe impact of flooding is experienced as a result of rainfall and tidal effects (Okoye 2019; Akukwe & Ogbodo, 2019).

On the other hand, inland regions with higher elevation suffer less. Despite this, localized flooding continues to affect these areas due to deforestation and haphazard urban planning that blocks natural drainage. Urban expansion, oil infrastructure, and wetlands are hazardous locations in Nigeria. Given the levels of hazard-proneness, they merge with riverbanks in the Niger Delta. In this overlap show the convergence of two sets of vulnerabilities. They are the first, or natural vulnerabilities (Akukwe & Nnamdi, 2015), and the second, or anthropogenic vulnerabilities (Chukwu & Ezeabasili, 2019).

According to GIS-based analysis, high, medium and low risk floods zone are shown in Figure 1. The triangle in map user added shows a cluster of vulnerable communities in Bayelsa and Rivers States in the past flood disasters. Areas near riverbanks, oil sites, and dense settlements have the highest risks while peri-urban fringes fall under medium risk and low risk is mostly concentrated in relatively undisturbed wetlands (Apampa et al., 2020; Akukwe & Ogbodo, 2019).

The risk assessment through GIS was effective in the identification of priority areas for mitigation, emergency response, land-use planning, and more. This showed that the use of GIS is a good tool for prediction and planning - (Eke & Ojeh, 2017; Apampa et al., 2020).

**Figure 1: Flood Risk Map of the Niger Delta (2000–2025)**




**Source:** GIS analysis using DEM, rainfall data from NIMET, and LULC datasets Apampa et al., 2020; Akukwe & Ogbodo, 2019).

A GIS flood risk map of the Niger Delta showing low, medium, and high flood hazard zones. The coastal states of Bayelsa, Rivers and Delta are low-lying which causes the elevation of these high-risk areas. Low-risk zones are mainly undisturbed wetlands and upland areas while medium risk zones would be in urban peripheries. The figure illustrates areas that flood on a repeated basis which are also located in close vicinity to settlements and infrastructure. This suggests a link between human activities and vulnerability to flooding (Okoye 2019).

**Land Use and Land Cover (LULC) Change.**

Research into land use alterations on Niger Delta landscape from 2000 to 2025 reveals drastic changes. Rapid growth of city areas in Port Harcourt, Warri and Yenagoa due to population pressure and industrial activities is encroaching upon wetlands and floodplains. Wetland degradation and tree cutting impede the ecosystem's natural capacity to absorb floods. The transformation of mangroves and freshwater swamps into built-up areas has led to increased surface runoff and erosion, thus undermining the flood resilience of the region (Obinna, Apampa et al 2020; Eke & Ojeh, 2017).

**Table 1: Land Use and Land Cover (LULC) Change in the Niger Delta (2000–2025)**

| Land Use Class | 2000 Area ($km^2$) | 2010 Area ($km^2$) | 2025 Projected Area ($km^2$) | % Change (2000–2025) |
|---|---|---|---|---|
| Urban Settlements | 4,500 | 6,800 | 9,200 | +104% |
| Wetlands | 22,000 | 20,500 | 18,700 | −15% |
| Forests/Mangroves | 15,000 | 13,700 | 12,200 | −19% |
| Agricultural Land | 20,000 | 19,200 | 18,400 | −8% |
| Water Bodies | 8,500 | 8,600 | 8,700 | +2% |

**Source:** Derived from Landsat imagery, NIMET rainfall data, and UNEP (2011) environmental assessments.

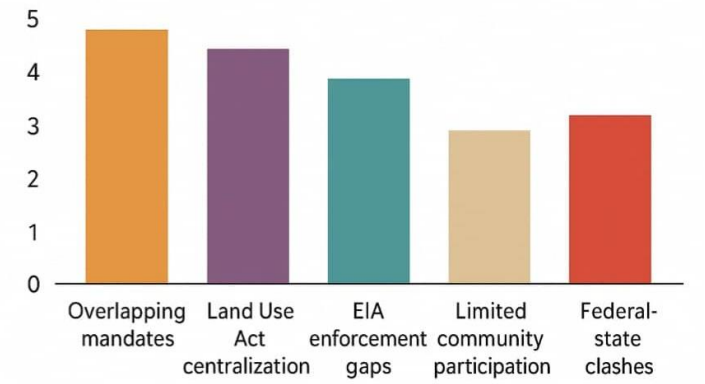
The analysis uses Landsat images, NIMET rain data and UNEP (2011) assessments. The table indicates that urban bulge and wetland/forest loss is going on. The natural flood water storage

capacity is reducing due to them. As a result, runoff is increasing. These patterns by people depict the flood's threat and need for sustainable land use policies. The information shows wetland loss (-15%) and mangrove loss (-19%). Moreover, urban settlements increased by 104%. Expansion of cities and towns close to river channels reduces natural flood storage capacity (Adaku, 2020; Akukwe & Ogbodo, 2015). The constant expansion of urban areas and industrial activity damage the ecosystem and increases floods downstream. By the year 2025, 28% (increase from 15% in the year 2000) of ecosystems are projected to become fragile (Akukwe & Ogbodo, 2019; Okoye 2019) There's urgent need for sustainable zoning, wetland restoration and integrated land management.

**Regulatory and Institutional Analysis**

Nigeria has land and environmental policies, many of which are not effective in the Niger Delta due to weak implementation. The responsibilities and functions of the NESREA, the Federal Ministry of Environment, and local governments are mostly carried out in silos. This is responsible for fragmented governance that reduces the impact of policies (Amnesty International, 2009; Nkwunonwo et al., 2016). Floodplain zoning is hardly enforced, which has allowed informal settlements and oil installations to flourish. Oil spill clean-up and repair works on pipelines occur at the cost of ecological restoration, further encroaching on natural flood storage spaces (UNEP, 2011; Apampa et al., 2020). Cities, such as Port Harcourt and Yenagoa, are therefore very vulnerable to flooding (Adekeye 2020; Akukwe & Ogbodo, 2015).

**Figure 2: Conceptual Diagram of Governance and Institutional Gaps in Flood Management**




**Source:** Synthesized from literature (Apampa et al., 2020; Akukwe & Ogbodo, 2019; Nkwunonwo, Whitworth, & Baily, 2016; Amnesty International, 2009).

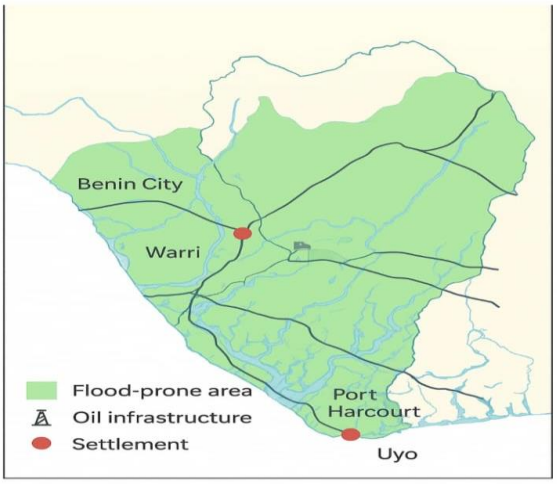
The diagram shows how overlapping mandates, fragmented institutions, and weak enforcement contribute to flood vulnerability in the Niger Delta. The unclear roles of NESREA, local government and oil firms hinder flood risk management. The documents highlight the need multi-level coordination, integrated governance structures for reducing flood risk and strengthening resilience (Okoye 2019; Apampa et al. 2020; Tasantab 2019).

**Layered Checks for Flooding; Risk to Settlements and Oil Infrastructure**

The Niger Delta has critical hotspots where floods can threaten settlements and oil pipelines, as indicated by GIS-based flood risk layers. The informal settlements in Port Harcourt and Yenagoa are located more within floodplains without proper drainage. The study showed that about 65% of oil pipelines intersect moderate- to high-risk flooding zones. This exposes

infrastructure to recurrent damage and risk of oil spills which contaminates wetlands and water bodies (Eke & Ojeh, 2017; Akukwe & Nnamdi, 2015). Communities, ecosystems, and national energy security face layered risks from this overlap. The combination of industrial dangers and socio-environmental hazards increases vulnerability, as floods can subvert livelihoods, oil businesses and critical infrastructure (Niger Delta Development Commission [NDDC], 2020).

**Figure 3**: **Flood Zones, Oil Infrastructure, Urban Settlements Overlay**




**Source:** GIS analysis using DEM, rainfall data, and LULC layers (Eke & Ojeh, 2017; Akukwe & Nnamdi, 2015).

A GIS Overlay map of flood risk zones, urban settlements and oil and gas facilities in the Niger Delta. Areas at high risk of flooding coincide with pipeline routes and informal settlements allowing for contamination of the environment, damaging of infrastructure, and exposing people to toxic hazards. Flood-prone regions, pipelines, and urban centres have been illustrated in Figure 5. The overlapping of all these spatial uses highlights the need for zoning rules, emergency preparedness and geo-planning as part of regional land-use management (Apampa et al., 2020; Akukwe & Ogbodo, 2019). The overlay pinpoints priority areas for mitigation, emergency response and land-use planning. It emphasizes that to diminish vulnerabilities, flood risk management must be incorporated into urban and industrial development plans (Eke & Ojeh, 2017; Akukwe & Nnamdi, 2015).

**Discussion**

Flooding in the Niger Delta is as much a socio-environmental problem as it is a natural issue caused by the interplay of topography, land-use change and regulatory failure (Okoye 2019; Akukwe & Ogbodo, 2019). Flood risk mapping through GIS shows that low lying coastal states such as Bayelsa, Rivers, Delta always experiences a high flood hazard which enhances with urbanization and deforestation (Eke & Ojeh, 2017; Apampa et al., 2020; Akukwe & Ogbodo, 2019). According to UNEP (2011) and Amnesty International (2009), plotting the settlement patterns and oil installation on the flood zones shows the risk of oil pipeline ruptures and oil contamination possibility. These results further validate findings from previous studies, that human activities, such as wetland conversion and unplanned urban expansion, lead to floods and their effects (Ologunorisa, 2009; Akukwe & Nnamdi, 2015). Long-term land-use data, indicated a 104% increase in the urban area, while the wetland area reduced by 15%. Furthermore, the reduction of wetlands undercuts the natural flood attenuation capacity of the region. Flood disasters in Niger Delta is not just a climatic problem but one of governance failure.

There are lots of institutions and overlapping functions that displace flood governance in Niger Delta. Various bodies such as NESREA and the Ministry of Environment, local governments and agencies for the enforcement of the Petroleum Industry Act (PIA) have several responsibilities but they carry out their functions without effective coordination (adekeye, 2020; Okoye 2019). Failure to enforce zoning and land-use regulations has allowed informal settlements to bring oil facilities into floodplains. (Obinna, Owei, & Mark, 2010; Amnesty International, 2009)

Oil operations further complicate flood management. Installing pipelines and cleaning up spills takes place in wetlands or flood channels. This disrupts processes that enable natural resilience. Figure X depicts that overlapping mandates, weak linkages and inadequate enforcement result in vulnerability. Improving governance will require clearer mandates at different levels as well as stronger enforcement (Apampa et al., 2020).

The Niger Delta is being subjected to massive urbanisation primarily due to rapid population growth linked with oil development. This is posing serious threat to wetlands and mangroves serve as natural flood defences (Eke & Ojeh, 2017; Adaku 2020). Using flood-prone land make vulnerable places more disaster-prone places. When we cut down forests and wetlands, it makes flooding worse in villages and cities. We can also notice similar patterns in achievement like Accra, Ghana that rapid urbanization is devaluing ecosystem services. As a result, development resilience trade-offs appear (Tasantab, 2019).

Lessons can be drawn from other flood-prone regions. The Netherlands has a successful record of GIS-based risk mapping adoption. This was done in combination with strict zoning and institutional cooperation to significantly reduce the risk of vulnerability. This is despite the country's high exposure. Bangladesh highlights community involvement and early warning systems. Furthermore, Ghana uses social capital and sub-national governance to build resilience (Tasantab, 2019; Alam & Mwase, 2022). The Niger Delta case studies denote value multi-level governance, spatial planning and societal involvement in addition to flood resilience enhancement.

**Policy, Technology, and Community Adaptation Implications**

Flood risk reduction is possible through the combination of land-use planning, regulation and ecological restoration. Controlling unplanned urban expansion has been identified as a critical concern in the literature. Zoning, wetland protection, and mangrove conservation have been proposed as ways to achieve this. Strengthening institutions is also important: the roles and coordination of NESREA, state agencies and local governments need to be clarified and strengthened (Nkwunonwo, Whitworth, & Baily, 2016; Amnesty International, 2009).

We need to make sure we properly implement technology like GIS and geospatial tools skills for forecasting, risk mapping, and planning. (Okoye 2019; Akukwe & Ogbodo, 2019). These tools help make decisions based on evidence that improve the organization's capacity to adapt in the future. Community-based adaptation is also critical; using local knowledge and participatory planning promotes ownership and sustainability (Akinbami and Akinbami, 2016; Adaku 2020).

To curb flood risk in the Niger Delta stronger enforcement of existing laws is key. The laws that need better enforcement are: PIA, Land Use Act, NESREA. We should make sure that overlapping mandates are clarified and penalties are made stringent, especially in oil infrastructure and urban encroachment on wetlands. Setting up a central regulatory coordination unit would foster cooperation between NESREA, the Ministry of Environment and local governments (Nkwunonwo et al., 2016). New developments should be required to conduct

environmental Impact Assessments (EIAs) and flood vulnerability audits (Apampa, Oladokun and Adeniran 2020; Adaku 2020).

We should preserve floodplains, restore wetlands and conserve mangroves for sustainable land and water management. Policymakers should prevent land development in high-risk areas using these GIS-based Risk Maps. Restoration of these ecosystems will lead to improvements in biodiversity, water quality and capacity for carbon sequestration including greater flood resilience (Apampa et al., 2020; Akukwe & Ogbodo, 2019).

Making GIS a local government practice for real-time monitoring, modelling and planning. In Bangladesh and the Netherlands, a GIS's integration with regulation for low-cost intervention has been highlighted. Helping locals build personal capacities will help locals plan land-use sustainably (Okoye 2019; Akukwe & Ogbodo, 2019).

Flood resilience also depends on bottom-up approaches. Local communities have experience with tides, rainfall and soil conditions. We can improve resilience via participatory planning, localized early-warning systems, incentives for flood-resistant housing (Okoye 2019).

Flood risk reductions should be integrated into Nigeria's NASPA-CCN and regional coastal management strategies (Federal Ministry of Environment Nigeria, 2020; World Bank, 2012). Above all, disaster planning options must be updated. Combining climate adaptation, city planning, and ecosystem-based action will lessen fragmentation and enhance long-term resilience.

**Table 2: Flood Risk Management in Nigeria's Niger Delta. Recommended interventions.**

| Intervention Area | Key Actions | Expected Outcomes | Sources |
|---|---|---|---|
| Environmental Regulation | • There should be coordination among NESREA, Ministry of Environment & LGAs, Mandatory EIAs and flood vulnerability audits and strLonized monitoring and penalties for non-compliance. | Less encroachment into floodplains; improved compliance with land-use and environmental laws. | Apampa et al., 2020; Akukwe & Ogbodo, 2019); Amnesty International (2009); Nkwunonwo, Whitworth, & Baily (2016); Apampa, Oladokun, & Adeniran (2020) |
| Land & Water Management | • Floodplain zoning and regulated urban growth wetlands and mangrove rehabilitation river and coast buffer zones. | Improved services for biodiversity, water retention, and carbon sequestration; mitigated risk of flood. | Eke & Ojeh (2017); UNEP (2011); Okoye 2019); Federal Ministry of Environment Nigeria (2020) |
| Geospatial Technologies | • GIS-based mapping and scenario modeling to monitor floods in real time through early-warning systems and to impart training on GIS. | Planning based on facts; better guessing; better measurements. | Adaku (2020); Akukwe & Ogbodo (2019); Okoye 2019); Alam & Mwase (2022) |

| | | | |
|---|---|---|---|
| Community-Based Adaptation | • Flood activity mitigation through participatory planning, localized warning systems and responses, and flood-resilient housing with incentives. | Increased social capital, greater local engagement, and sustainable resilience practices. | Akinbami & Akinbami (2016); Okoye (2019); Tasantab (2019); Adaku (2020) |
| Policy Integration | • Make flood resilience part of NASPA-CCN and coastal plans Align flood risk with urban planning and climate adaptation Strengthen multi-level governance and regional cooperation. | Long term climate resilience; coherent policy framework; reduced institutional fragmentation. | Federal Ministry of Environment Nigeria (2020); World Bank (2012); Olomola (2016); Apampa et al., 2020; Akukwe & Ogbodo, 2019 |

The synthesis in Table 2 shows a need for action at the regulatory, ecological, technological, social and policy levels. Mandatory Environmental Impact Assessments (EIAs) and coordinated enforcement can strengthen the environmental regulatory regime. This will help in reducing illegal encroachment of wetlands and floodplains (Okoye 2019; Apampa, Oladokun & Adeniran 2020). Likewise, ecosystem-based interventions like the restoration of wetlands and mangroves provide natural buffers that achieve biodiversity enhancement while also reducing the risk of flooding. Through GIS mapping and early-warning systems, technological approaches allow decision-makers to plan with evidence and target interventions adequately (Adaku, 2019; Akukwe & Ogbodo, 2019). Community level, adaptation actions (from local warning systems to flood resistant housing) promote local ownership and long-term resilience.

Finally, policy integration remains crucial. Incorporating flood resilience into national and regional frameworks can limit institutional fragmentation and promote alignment of climate adaptation and sustainable development priorities, particularly through NASPA-CCN and not limited to urban planning policies (Federal Ministry of Environment Nigeria 2020; World Bank 2012). Together these actions show we need a framework that works on many levels. This must include every sector and take care of immediate problems and longer-term changes.

**Summary of Key Findings**

1. The states of Bayelsa, Rivers and Delta which are low-lying coastal states have high flood hazard in all years.
2. Urbanization and LULC Changes Urban growth (+104%) and wetland loss (−15%) disrupt natural flood absorption.
3. Government gaps are regulation enforcement not being effective and institution overlapping responsibility increase flood susceptibility.
4. Oil pipelines and settlements within flood plains heighten the risk of exposure of critical infrastructures to environmental contamination and economic disruption.
5. Geo-spatial analysis provides evidence for targeted interventions and prioritizing high-risk areas for planning.

## Conclusion

The Niger Delta's situation illustrates how flood risk, regulation and land management could play out in resilient development. Due to its unique geography, water systems, economy and settlement along with a heavy installation of oil and gas pipelines and their associated infrastructure, settled environments and fragile environment, the area is flood-prone. Evidence from GIS-based flood risk mapping, land use analysis and regulatory assessments indicates that weak institutional enforcement, fragmented governance and uncontrolled urban sprawl are the major drivers of flood vulnerability. Flooding in the Niger Delta has caused serious social, economic and environmental impacts, including damage to infrastructure, loss of means of livelihood, pollution of water, and degradation of mangrove and wetland ecosystem (Amnesty International, 2009). Although national policies and environmental laws like Petroleum Industry Act, Land Use Act, and the guidelines of NESREA exist, communities and ecosystems continue to face repeated hazards because of inconsistent implementation. The research shows that geospatial tools, especially GIS, provide a powerful framework for identifying flood risks and planning. Analyses of land use and infrastructure reveal the areas with the greatest risk of flooding for their evidence-based interventions. Combining engineering-based measures with community-based adaptation which makes use of local knowledge, participatory planning and early warning systems can enhance both social and ecological resilience in the Niger Delta.

**Policy and technical recommendations include**

1. Strengthening environmental regulation through centralized coordination and mandatory flood vulnerability assessments.
2. Adopting land and water management strategies such as floodplain zoning, wetland restoration, and mangrove conservation.
3. Institutionalizing GIS and geospatial analysis for evidence-based planning.
4. Promoting community engagement and adaptive capacity.
5. Integrating flood resilience into national and regional development plans.

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