Copyright ©2026
National Centre for Energy and Environment, Energy Commission of Nigeria, University of Benin:
ISSN 2504-9593
DOI: 10.5281/zenodo.20832556
https://ijree.com/index.php/publications/article/view/73

Int. J. Renew. Energ & Environ Vol.4 (2), pp 261-270(2026)

CLIMATE-RESILIENT HOUSING STRATEGIES IN FLOOD-PRONE URBAN AREAS: A GIS-BASED ASSESSMENT OF SOUTH-SOUTH NIGERIA

[1*]Okafor, I. U and [2]Nwodo, G. O.

Department of Architecture Faculty of Environmental Sciences University of Benin, Benin City, Edo State.
Department of Geomatics, University of Benin, Benin City, Edo State.
***Corresponding author's address:** arcokaforiwu@gmail.com or iwuchukwu.okafor@uniben.edu

ABSTRACT
Flooding has become one of the most severe environmental and socio-economic challenges confronting urban settlements in Nigeria, especially in rapidly urbanizing coastal and low-lying cities. This study assesses climate-resilient housing strategies in flood-prone urban areas using a Geographic Information System (GIS)-based analysis of Benin City, Warri, and Port Harcourt. The objectives of the study were to identify flood-prone zones, examine the spatial distribution of housing within vulnerable areas, evaluate existing climate-resilient housing strategies, and recommend sustainable planning measures for reducing flood risks. The study adopted a mixed-method approach involving GIS spatial analysis, field observations, and secondary data collection. Data sources included satellite imagery, Digital Elevation Models (DEM), rainfall and hydrological records, land-use maps, and urban planning documents. GIS techniques such as overlay analysis, flood susceptibility mapping, buffer analysis, and vulnerability indexing were employed to classify areas into high, moderate, and low flood-risk zones. Findings reveal that significant portions of residential developments in Port Harcourt and Warri are located within high-risk flood zones due to coastal exposure, wetland encroachment, poor drainage systems, and uncontrolled urbanization. Benin City shows moderate but increasing flood vulnerability associated with blocked drainage channels and rapid urban expansion. Existing climate-resilient housing measures identified include elevated foundations, reinforced concrete structures, improved drainage systems, and raised floor platforms, although these measures remain largely inadequate and poorly regulated. The study concludes that integrating GIS-based planning, strict land-use regulation, climate-adaptive housing policies, and sustainable drainage infrastructure is essential for enhancing urban resilience and reducing flood risks in Nigerian cities.

***Keywords**: Climate-resilience; flooding; GIS-analysis; housing-vulnerability; urban-planning; Nigeria*

1.0 INTRODUCTION

1.1 Background to the Study

Flooding is increasingly recognized as one of the most destructive environmental hazards affecting urban settlements across the world. In many developing countries, the impacts of flooding have intensified due to rapid urbanization, population growth, inadequate infrastructure, and climate change. Urban flooding disrupts transportation systems, damages housing and infrastructure, contaminates water supplies, and threatens public health and livelihoods. According to the Intergovernmental Panel on Climate Change (IPCC, 2021), climate variability has increased the intensity and frequency of rainfall events globally, thereby increasing flood occurrences in urban regions. In Nigeria, flooding has become a recurrent environmental problem affecting both coastal and inland cities. The 2012 nationwide flood disaster, regarded as one of the worst flood events in Nigeria's history, affected millions of people and caused severe destruction of infrastructure and housing. Since then, cities such as Lagos, Port Harcourt, Warri, Benin City, and Yenagoa have continued to experience annual flood events.

The increasing severity of flooding in Nigerian cities is linked to climate change, inadequate drainage infrastructure, poor waste management practices, weak planning regulations, and uncontrolled urban expansion.

Benin City, Warri, and Port Harcourt are among the fastest-growing urban centers in southern Nigeria. These cities are highly vulnerable to flooding because of their environmental and socio-economic characteristics. Port Harcourt and Warri are located within the Niger Delta region and are characterized by low elevation, extensive wetlands, and high rainfall intensity. Benin City, although inland, experiences significant flooding due to poor drainage systems, land-use change, and increasing impervious surfaces resulting from urbanization.Urban growth in these cities has often occurred without adequate planning control. Residential buildings are frequently constructed on wetlands, floodplains, and drainage channels, thereby increasing vulnerability to flood hazards. Informal settlements are particularly exposed because of inadequate infrastructure and poor construction quality. Flooding in these communities often results in displacement, property damage, environmental degradation, and economic losses.

Climate-resilient housing has emerged as an important strategy for reducing urban vulnerability to flooding and other climate-induced hazards. Climate-resilient housing involves the design and construction of buildings capable of withstanding and adapting to environmental risks such as flooding, erosion, and extreme rainfall events. Such strategies include elevated foundations, resilient construction materials, sustainable drainage systems, rainwater harvesting, permeable surfaces, and proper site planning.

The integration of Geographic Information Systems (GIS) into urban planning has significantly improved the ability to assess environmental risks and support sustainable decision-making. GIS provides tools for mapping flood-prone areas, analyzing spatial relationships, monitoring land-use change, and identifying vulnerable communities. Through GIS-based flood risk assessment, planners can develop evidence-based strategies for climate adaptation and resilient urban development.

This study therefore focuses on climate-resilient housing strategies in flood-prone urban areas using GIS-based assessment of Benin City, Warri, and Port Harcourt. The study examines the spatial dimensions of flood vulnerability, evaluates existing housing adaptation strategies, and proposes sustainable planning measures for improving urban resilience.

1.2 Statement of the Problem

Flooding remains one of the most persistent environmental challenges affecting urban development in Nigeria. Despite increasing awareness of climate change and environmental risks, urban planning systems in many Nigerian cities remain weak and ineffective. Residential developments continue to expand into environmentally sensitive areas such as wetlands, riverbanks, and floodplains without adequate regulation. Benin City, Warri, and Port Harcourt have experienced recurrent flooding over the years, resulting in destruction of housing, loss of livelihoods, disruption of transportation systems, and environmental degradation. In many cases, drainage systems are poorly designed, blocked by waste, or entirely absent. Furthermore, climate change has intensified rainfall variability, thereby increasing the frequency and severity of flood events.

Many residents in flood-prone communities adopt temporary coping mechanisms such as sandbagging and drainage diversion rather than sustainable adaptation measures. Existing climate-resilient housing strategies are often informal, unregulated, and insufficient to address the growing risks associated with urban flooding.

Although GIS technologies have proven effective in flood risk assessment and urban planning globally, their application in many Nigerian cities remains limited. There is inadequate integration of GIS-based flood mapping into urban planning policies and housing development frameworks. Consequently, decision-makers often lack accurate spatial information needed for sustainable planning and disaster risk reduction. This study seeks to address this gap by conducting a GIS-based assessment of climate-resilient housing strategies in Benin City, Warri, and Port Harcourt.

1.3 Aim and Objectives of the Study

The aim of this study is to assess climate-resilient housing strategies in flood-prone urban areas using GIS-based analysis of Benin City, Warri, and Port Harcourt.

The specific objectives are to:

1. Identify flood-prone zones in the selected cities using GIS techniques.
2. Examine the spatial distribution of housing within vulnerable areas.
3. Assess the causes and drivers of urban flooding in the study areas.
4. Evaluate existing climate-resilient housing strategies.
5. Assess the effectiveness of urban planning and flood management systems.
6. Recommend sustainable strategies for reducing urban flood vulnerability.

1.4 Research Questions

i. What are the spatial patterns of flood vulnerability in Benin City, Warri, and Port Harcourt?
ii. What factors contribute to flooding in the selected cities?
iii. How are residential buildings distributed within flood-prone zones?
iv. What climate-resilient housing strategies are currently adopted in the study areas?
v. How effective are existing urban planning systems in mitigating flood risks?
vi. What sustainable measures can improve climate resilience in Nigerian cities?

1.5 Significance of the Study

This study contributes significantly to knowledge on climate resilience, GIS-based urban planning, and sustainable housing development in Nigeria. The findings will provide useful information for policymakers, architects, urban planners, environmental managers, and disaster management agencies.

The study also demonstrates the usefulness of GIS as a decision-support tool for identifying flood-prone areas and guiding sustainable urban development. The recommendations from this study can assist governments and planning authorities in integrating climate adaptation strategies into housing and infrastructure development. Furthermore, the study contributes to the broader discourse on climate change adaptation and disaster risk reduction in developing countries. By focusing on flood-prone cities in southern Nigeria, the research highlights the urgent need for resilient urban planning approaches capable of reducing environmental vulnerability and improving quality of life.

1.6 Scope of the Study

The study focuses on climate-resilient housing strategies in flood-prone urban areas of Benin City, Warri, and Port Harcourt. The research examines flood vulnerability, housing exposure, GIS-based flood mapping, and adaptation strategies within the selected cities. The study covers environmental, infrastructural, and planning dimensions of flood resilience. However, the research is limited to spatial and housing-related aspects of urban flooding and does not extensively examine economic loss estimation or detailed hydrological modeling.

1.7 Conceptual Clarifications

Climate Resilience

Climate resilience refers to the capacity of communities, infrastructure, and environmental systems to anticipate, adapt to, and recover from climate-related hazards such as flooding, storms, and sea-level rise.

Flood-Prone Areas

Flood-prone areas are locations susceptible to flooding due to environmental and physical characteristics such as low elevation, proximity to rivers, poor drainage systems, and high rainfall intensity.

GIS-Based Assessment

GIS-based assessment involves the use of Geographic Information Systems to collect, analyze, and visualize spatial data for environmental planning and decision-making.

Climate-Resilient Housing

Climate-resilient housing refers to buildings designed and constructed to withstand environmental hazards while ensuring sustainability, safety, and adaptability.

1.8 Literature Review

1.8a Concept of Urban Flooding

Urban flooding occurs when rainfall exceeds the carrying capacity of drainage systems, rivers, or natural waterways within urban environments. Flooding may result from heavy rainfall, storm surges, tidal influences, blocked drainage systems, and land-use changes. In many developing countries, urban flooding is intensified by rapid urbanization and inadequate infrastructure. Studies have shown that urban flooding is increasingly linked to climate change and anthropogenic activities. According to the IPCC (2021), global warming has intensified extreme rainfall events, thereby increasing the occurrence of flash floods in urban regions.

1.8b Climate Change and Urban Vulnerability

Climate change has become one of the major drivers of environmental hazards globally. Rising temperatures, changing rainfall patterns, and sea-level rise contribute significantly to urban flood risks. Coastal cities such as Port Harcourt and Warri are particularly vulnerable because of their exposure to tidal flooding and coastal erosion. Urban vulnerability is influenced by socio-economic and environmental factors including poverty, weak infrastructure, poor governance, and land-use change. Informal settlements often face the highest risks because they are usually located in environmentally sensitive areas.

1.8c GIS in Flood Risk Assessment

Geographic Information Systems (GIS) have become important tools in flood risk assessment and urban planning. GIS allows planners to analyze spatial data related to elevation, rainfall, drainage networks, land use, and population distribution.

Several studies have applied GIS techniques in flood mapping and vulnerability assessment in Nigeria. Nkeki et al. (2023) demonstrated the effectiveness of GIS-based overlay analysis for identifying flood-prone zones in urban environments.

1.8dClimate-Resilient Housing Strategies

Climate-resilient housing strategies involve architectural and planning measures aimed at reducing vulnerability to climate-induced hazards. These strategies include elevated foundations, flood-resistant materials, proper site planning, and sustainable drainage systems. Resilient housing also emphasizes environmental sustainability through energy efficiency, water conservation, and ecosystem protection. According to Jha et al. (2012), resilient housing should be integrated into broader urban planning and disaster management systems.

1.8e Theoretical Framework

The study is anchored on the Resilience Theory and Environmental Systems Theory.

Resilience Theory

Resilience Theory explains the capacity of systems and communities to absorb disturbances and recover from environmental shocks. In the context of urban flooding, resilience refers to the ability of housing systems and urban infrastructure to withstand flood hazards. Environmental Systems Theory

Environmental Systems Theory emphasizes the interaction between human activeties and environmental processes. Urban flooding is viewed as a product of interactions among land use, infrastructure, hydrology, and climate systems.

2.0 METHODOLOGY

2.1 Study Area

Benin City (Edo State)

Benin City is the capital of Edo State and one of

the fastest-growing urban centers in southern Nigeria. The city lies approximately between latitude 6°20′N and longitude 5°37′E. Benin City experiences a tropical climate characterized by high rainfall and humid conditions. Flooding in the city is influenced by rapid urbanization, poor drainage systems, and land-use change.

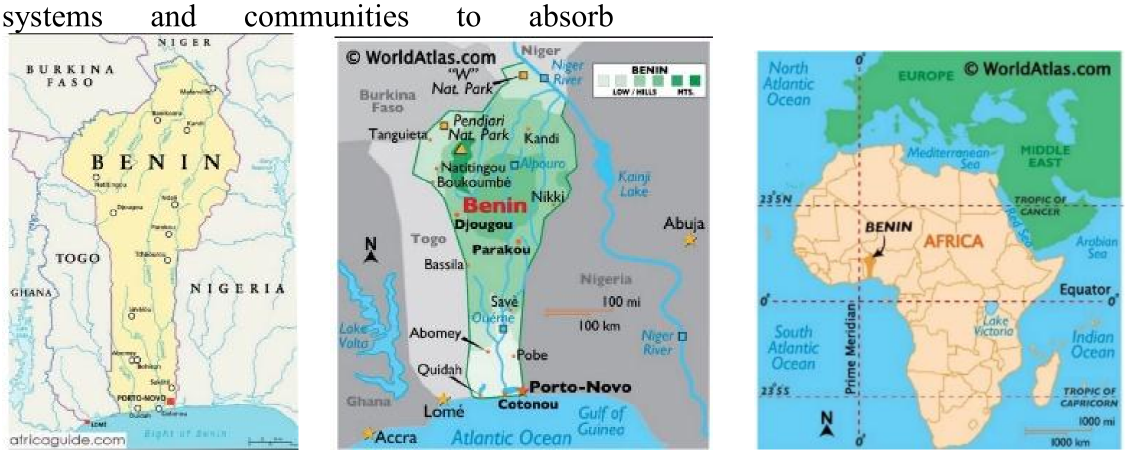

Fig 1: Showing Regional Location Map

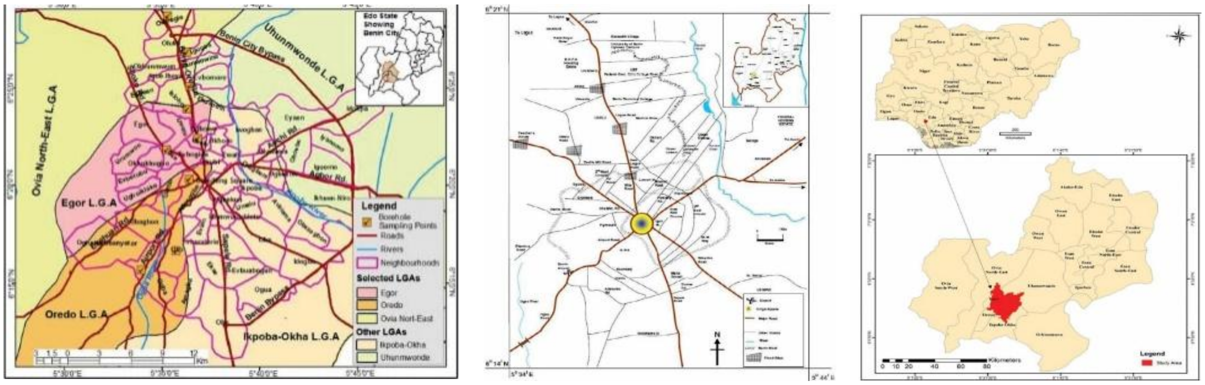

Fig 2: Showing Edo State and Local Government Maps.

Warri (Delta State)

Warri is a major oil-producing city in Delta State located within the Niger Delta region. The city is characterized by low elevation, swampy terrain, and proximity to rivers and creeks. Flooding in Warri is associated with tidal influences, coastal inundation, and wetland encroachment.

Below is a map of Delta State showing the Local Government Areas (LGAs):

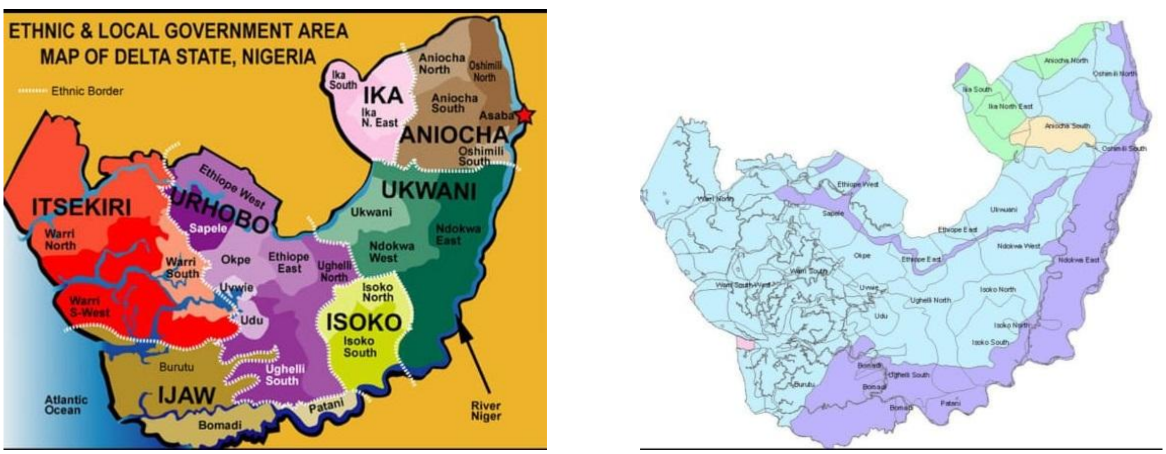

Fig 3: map of Delta State showing the Local Government Areas (LGAs):

Port Harcourt (Rivers State)

Port Harcourt is the capital of Rivers State and one of Nigeria's major industrial and commercial cities. The city lies within the Niger Delta coastal environment and experiences heavy rainfall throughout the year. Flooding in Port Harcourt is intensified by poor drainage infrastructure, wetland reclamation, and uncontrolled urban expansion.

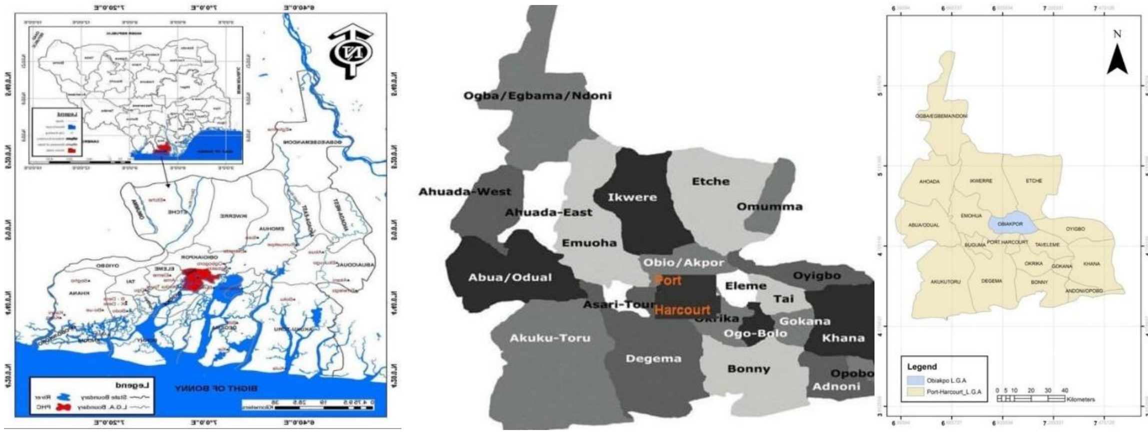

Fig4: Port Harcourt and Surrounding LGAs Map

2.2 Research Design

The study adopted a mixed-method research design involving quantitative GIS spatial analysis and qualitative field assessment. The quantitative component focused on flood vulnerability mapping and spatial analysis, while the qualitative aspect involved field observations and assessment of housing adaptation strategies.

2.3 Sources of Data

Primary Data

Primary data were collected through:

Field observations;

Photographic documentation;

Assessment of housing conditions;

Observation of drainage infrastructure.

Secondary Data

Secondary data sources included:

Satellite imagery (Landsat and Sentinel datasets);

Digital Elevation Models (DEM);

Rainfall records;

Hydrological maps;

Land-use and land-cover maps;

Urban planning documents;

Existing literature and flood studies.

2.4 GIS Data Processing and Analysis

The GIS analysis involved several stages:

2.4.1 Data Preparation

Spatial datasets were imported into GIS software and geo-referenced. Satellite imagery and DEM datasets were processed to generate elevation maps and land-use classifications.

2.4.2 Flood Susceptibility Mapping

Flood susceptibility maps were developed using environmental variables including:

Elevation;

Slope;

Drainage density;

Land use;

Rainfall intensity;

Proximity to rivers.

2.4.3 Overlay Analysis

Spatial overlay analysis was conducted to identify relationships between residential housing and flood-prone zones.

2.4.4 Vulnerability Index Calculation

The Flood Vulnerability Index (FVI) was calculated using:

FVI = (Exposure × Sensitivity) / Adaptive Capacity

Where:

Exposure refers to proximity to flood sources and rainfall intensity. Sensitivity includes population density and housing concentration.

Adaptive capacity includes drainage infrastructure and resilience measures.

2.5 Data Presentation

Data were presented using tables, GIS maps, charts, and descriptive statistics.

3.0 RESULTS

3.1 Spatial Distribution of Flood-Prone Areas

GIS analysis revealed significant spatial variation in flood vulnerability across the study areas.

Benin City

Flood-prone zones in Benin City are concentrated around low-lying districts and river corridors. Areas such as Ugbowo, Aduwawa, and Ikpoba Hill show high vulnerability due to poor drainage systems and urban expansion.

Warri

Warri exhibits extensive flood-prone zones due to its low elevation and proximity to rivers and creeks. Coastal flooding and tidal inundation affect residential areas such as Okumagba Layout and waterfront communities.

Port Harcourt

Port Harcourt recorded the highest flood vulnerability among the study areas. Waterfront settlements including Borikiri, Eagle Island, and Trans-Amadi experience recurrent flooding due to wetland encroachment and drainage failure.

3.2 Housing Exposure Patterns

The overlay of housing distribution and flood-risk zones indicates that:

Over 60% of residential buildings in Port Harcourt are located within high-risk flood zones.

Approximately 55% of residential areas in Warri are flood-prone.

About 38% of residential areas in Benin City are vulnerable to flooding.

Informal settlements were found to be the most exposed due to poor construction quality and inadequate infrastructure.

3.3 Existing Climate-Resilient Housing Strategies

Several adaptation measures were identified in the study areas:

Elevated building foundations;

Reinforced concrete structures;

Drainage channels;

Raised floor platforms;

Sandbag barriers.

However, most of these strategies remain informal and lack technical planning support.

3.4 Flood Vulnerability Index Results

The Flood Vulnerability Index shows:

City	FVI Score
Benin City	0.52
Warri	0.68
Port Harcourt	0.74

Port Harcourt recorded the highest vulnerability due to coastal exposure and infrastructure limitations.

3.5 GIS Maps and Spatial Interpretation

Figure 1

GIS-Based Flood Risk Map of Benin City, Edo State.

Figure 2

GIS Flood Vulnerability Map of Warri, Delta State.

Figure 3

GIS Flood Exposure Map of Port Harcourt, Rivers State.

The maps reveal that high-risk flood zones are concentrated in low-elevation coastal and riverine areas.

4.0 DISCUSSION

The findings of this study reveal a strong relationship between rapid urbanization and flood vulnerability in Nigerian cities. In Benin

City, Warri, and Port Harcourt, urban expansion has led to the occupation of wetlands, drainage channels, and floodplains. This has significantly increased the exposure of residential buildings to flooding.

Port Harcourt exhibits the highest vulnerability because of its coastal location and extensive wetland reclamation. Akukwe and Ogbodo (2015) observed that the conversion of wetlands into residential and industrial land uses has increased flood risk in the city.

Warri experiences severe flooding due to tidal influences and low elevation. Odemerho (2014) emphasized that climate change and sea-level rise continue to increase flood risk in Niger Delta cities.

Although Benin City is located inland, flooding has become increasingly severe due to drainage blockage and poor waste management practices. Nkeki et al. (2023) noted that poor urban planning and inadequate drainage systems contribute significantly to urban flooding in Nigerian cities.

The study also reveals that existing climate-resilient housing strategies are inadequate. Most residents adopt temporary coping mechanisms such as sandbag barriers and drainage diversion rather than sustainable adaptation measures.

GIS analysis proved effective in identifying flood-prone zones and assessing housing vulnerability. Through spatial analysis, vulnerable communities can be identified and targeted for intervention.

The study highlights the importance of integrating GIS-based planning into urban governance systems. Sustainable urban development requires proactive approaches to flood risk management, including land-use regulation, resilient housing policies, and infrastructure investment.

5. CONCLUSION

This study assessed climate-resilient housing strategies in flood-prone urban areas using GIS-based analysis of Benin City, Warri, and Port Harcourt. The findings indicate that flooding remains a major environmental challenge driven by rapid urbanization, climate change, wetland encroachment, and poor infrastructure.

Port Harcourt and Warri exhibit high flood vulnerability due to coastal exposure and inadequate drainage systems, while Benin City shows increasing vulnerability associated with urban expansion and blocked drainage channels.

Although several climate-resilient housing measures were identified, including elevated foundations and reinforced structures, these strategies remain largely informal and insufficient.

The study concludes that GIS is an effective tool for flood risk assessment and climate-resilient urban planning. Integrating GIS into planning systems will enhance decision-making and reduce urban flood vulnerability.

Recommendations

1. Governments should integrate GIS-based flood mapping into urban planning systems.
2. Strict enforcement of land-use and zoning regulations is necessary.
3. Climate-resilient building codes should be developed and implemented.
4. Investment in sustainable drainage infrastructure should be prioritized.
5. Wetlands and natural drainage channels should be protected from encroachment.

6. Public awareness programs on climate resilience should be strengthened.

6.0 REFERENCES

Akukwe, T. I., & Ogbodo, C. (2015). Spatial analysis of vulnerability to flooding in Port Harcourt metropolis, Nigeria. Urban Climate, 14, 1–12. https://doi.org/10.1177/2158244015575558

IPCC. (2021). Climate change 2021: The physical science basis. Cambridge University Press.

Jha, A. K., Bloch, R., & Lamond, J. (2012). Cities and flooding: A guide to integrated urban flood risk management for the 21st century. World Bank.

Nkeki, F. N., Bello, E. I., & Agbaje, I. G. (2023). GIS-based flood risk mapping in Nigerian cities. MethodsX, 11, 102348. https://doi.org/10.1016/j.mex.2023.102348

Odemerho, F. O. (2014). Building climate change resilience through adaptation in Warri, Nigeria. Environment and Urbanization, 27(1), 89–102. https://doi.org/10.1177/0956247814558194

Okafor, G. U., & Oriakhi, O. (2024). Flood susceptibility modelling using GIS-AHP in Benin City, Nigeria. *NIPES Journal of Science and Technology Research*, 6(3), 229–242. https://doi.org/10.5281/zenodo.13937655

UN-Habitat. (2020). World cities report 2020: The value ofsustainable urbanization. United Nations Human Settlements Programme.

United Nations. (2019). World urbanization prospects 208. United Nations Department of Economic and Social Affairs