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Systematic review of flood resilience strategies in Lagos Metropolis: pathways toward the 2030 sustainable development agenda

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Flooding presents a significant challenge in the Lagos metropolis, driven by rapid urbanization, poor drainage infrastructure, and climate change. This study evaluates flood resilience strategies in Lagos, analyzing their effectiveness in mitigating flood risks and their alignment with the 2030 Agenda. The research utilizes the PICO (Population, Intervention, Control, and Outcomes) framework to refine research questions and follows PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines for study selection, search strategies, and data extraction. A thorough search across databases such as Google Scholar, SCOPUS, and government data repositories was conducted to ensure the inclusion of relevant studies while minimizing selection bias. The study emphasizes the severe impacts of flooding, referencing the 2022–2023 flood event which resulted in USD 262,500 damages and displaced 8000 residents in Lagos State. Current flood resilience strategies are inadequate to meet the Sustainable Development Goals (SDGs) due to insufficient urban flood infrastructure, poor waste disposal practices, and worsening climatic conditions. The livelihoods, income, health, and overall survival of vulnerable communities are at significant risk. Key gaps identified include the weak enforcement of urban planning regulations, limited community engagement, ineffective early warning systems, and poor intervention initiatives. This study suggests a multi-stakeholder approach that enhances both structural and non-structural flood resilience. Improving drainage systems, promoting sustainable waste management, improving climate adaptation policies, and fostering community-based flood mitigation strategies are crucial for achieving long-term urban resilience. These findings offer valuable insights for policymakers, urban planners, and climate resilience advocates working toward the Sustainable Development Agenda in Lagos metropolis.

KEYWORDS

urban flood, resilience capacity, Lagos Metropolis, sustainable development, disaster risk reduction, community engagement

1 Introduction

1.1 Background to the study

According to the United Nations Office for Disaster Reduction (2023), floods are characterized by factors such as depth, volume of inundation, flow velocity, and associated magnitude. Similarly, the National Emergency Management Agency (NEMA) (2022) describes floods as occurring when water levels rise beyond the capacity of drainage systems, resulting in inundation. Urban flooding specifically affects densely populated built-up areas (Abeka et al., 2020; Onajomo, 2022). In Lagos State, Nigeria, urban flooding has become a recurring environmental challenge, exacerbated by climate uncertainty, rapid urbanization, inadequate drainage systems, and waste disposal problems (Adeola and Adetola, 2018; Adejobi, 2022; Ibeabuchi, 2023). As a result, the city's continuous expansion has heightened flood-related risks, posing threats to economic activities, human settlements, and public health (Gelleh et al., 2016; Gumbo, 2021; Lawanson et al., 2023). Most communities face flood impacts and uncertainties during the rainy seasons (Ahmad and Ma, 2020; Chinedu et al., 2024). The trend of urbanization has relied on unsustainable human activities that deplete the environment (Olukunga et al., 2024), leading to increased vulnerability to environmental problems (Wahab and Ojolowo, 2018; Ali, 2020; Aniramu et al., 2021; Biswas, 2023; Odunsi et al., 2024).

Population growth influences the rate and pattern of urbanization and impervious surfaces, resulting in the conversion of natural land cover into urban residences (Ogbonna and Umeh, 2023). During rainfall seasons, the surface runoff mechanism becomes compromised as extensive impervious surfaces inhibit water absorption into the underground water (Olatunde and Adejoh, 2017), leading to surface inundations (Ologunorisa and Eludoyin, 2022). This put pressure on the surface generation mechanism, overwhelming existing drainage systems, and altering natural water flow patterns (Ologunorisa et al., 2022). This challenge enhances urban flood vulnerability, particularly in urban areas where the topography is low and urban drains are inadequate (Orimoogunje et al., 2016; Abdel-Karim et al., 2020; Asumadu-Sarkodie et al., 2021). Poorly planned infrastructure can redirect water flows, causing previously dry areas to flood (Awe et al., 2020). As urban areas continue to grow, it is crucial to integrate flood resilience assessments into the urban planning and development process to avoid regular episodes of flood inundation by the urban populace (Osayomi et al., 2022). This proactive approach helps in understanding the potential for flooding and designing infrastructure that can withstand these risks.

Flood resilience strategies encompass physical infrastructure, scientific modeling, and community engagement to prevent, manage, and recover from flood events (Ijaware, 2020; Environment Agency, 2023). Flood intervention initiatives and compensation schemes provide post-disaster relief, promoting socio-economic recovery (Idowu and Zhou, 2019; Elum and Lawal, 2022). Integrating flood management into urban planning aligns with sustainable development goals, ensuring resilient, and sustainable cities (Adewumi et al., 2019; Masik and Grabkowska, 2020; Laidlaw and Percival, 2024). Ogbonna and Umeh (2023) addressed the shortcomings of urban flood resilience in arresting challenges of flood eventualities, while Magami et al. (2020) advocate for the repositioning of cities for modern adaptive capacity. The crucial interplay of resilience is linked to harmonizing efforts in addressing flood impacts and challenges of flood control measures (Nkwunonwo, 2016; Adegboyega et al., 2019; Almoradie et al., 2020; Septiningtiyas and Ananda, 2023), as the city progresses toward the 2030 Sustainable Development Agenda. The focus is to offer a critical assessment of the existing flood reduction framework, generating more insights into transformative pathways that incorporate climate adaptation and urban growth rate across the general landscape of the Lagos Metropolis. Previous efforts to mitigate flood risks involving flood hazard mapping (Njoku et al., 2020), the effectiveness of structural resilience (Salami and Otokiti, 2022), and non-structural strategies (Yoade et al., 2023) can be evaluated for urban resilience building.

Although abundant studies have examined the occurrence, causes, socio-economic impacts, and fatalities of flooding in Lagos Metropolis (Gelleh et al., 2016; Wahab and Ojolowo, 2018; Adejobi, 2022; Olukunga et al., 2024), a noteworthy gap exists in the systematic evaluation of resilience strategies and their relevance to the Sustainable Development Goals (SDGs). A significant part of the literature focuses on infrastructural deficits, informal settlements, and emergency response plans to salvage flood losses, often providing descriptive inventory rather than critically assessing the effectiveness of ongoing interventions, their importance and alignment with global sustainability goals (Okoye, 2019). Moreover, few studies have explored localizing flood resilience initiatives to specific SDG indicators, particularly, SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action) which are integers of urban livelihood. There is a limited analytical framework in the literature that links resilience-building efforts, for instance early warning systems, drainage system efficiency, and urban planning reforms, to quantifiable results of the SDG framework.

Additionally, the role of federal and state governance, specific institutional mandates, and policy implementation on flood reductions remain underexplored in many resilience evaluations. Many developing states have policies that exist on paper and in public hearing, while the literature has failed to capture their inadequacies, inefficiencies and how robust the resilience strategies have been effectively executed, monitored, and scaled across diverse socio-economic dimensions in the flood zones within Lagos Metropolis. In furtherance, there is a dearth of comparative analyses that benchmark the trajectory of flood resilience in Lagos against other megacities facing similar climate vulnerabilities regionally and globally (Iyeshim, 2023). Most of the studies often neglect the agitations of vulnerable communities and how nature-based solutions can be profound. It is also important to examine the role of grassroots adaptation and public-private partnerships in enhancing resilience, in view to provide holistic understanding necessary for developing inclusive and transformative pathways toward the 2030 Agenda.

The present study aims to analyze literature and other published materials on flood issues, focusing on the historical flood impacts in Lagos state over the past decade. The goal is to examine spatial flood incidents reported in media and literature

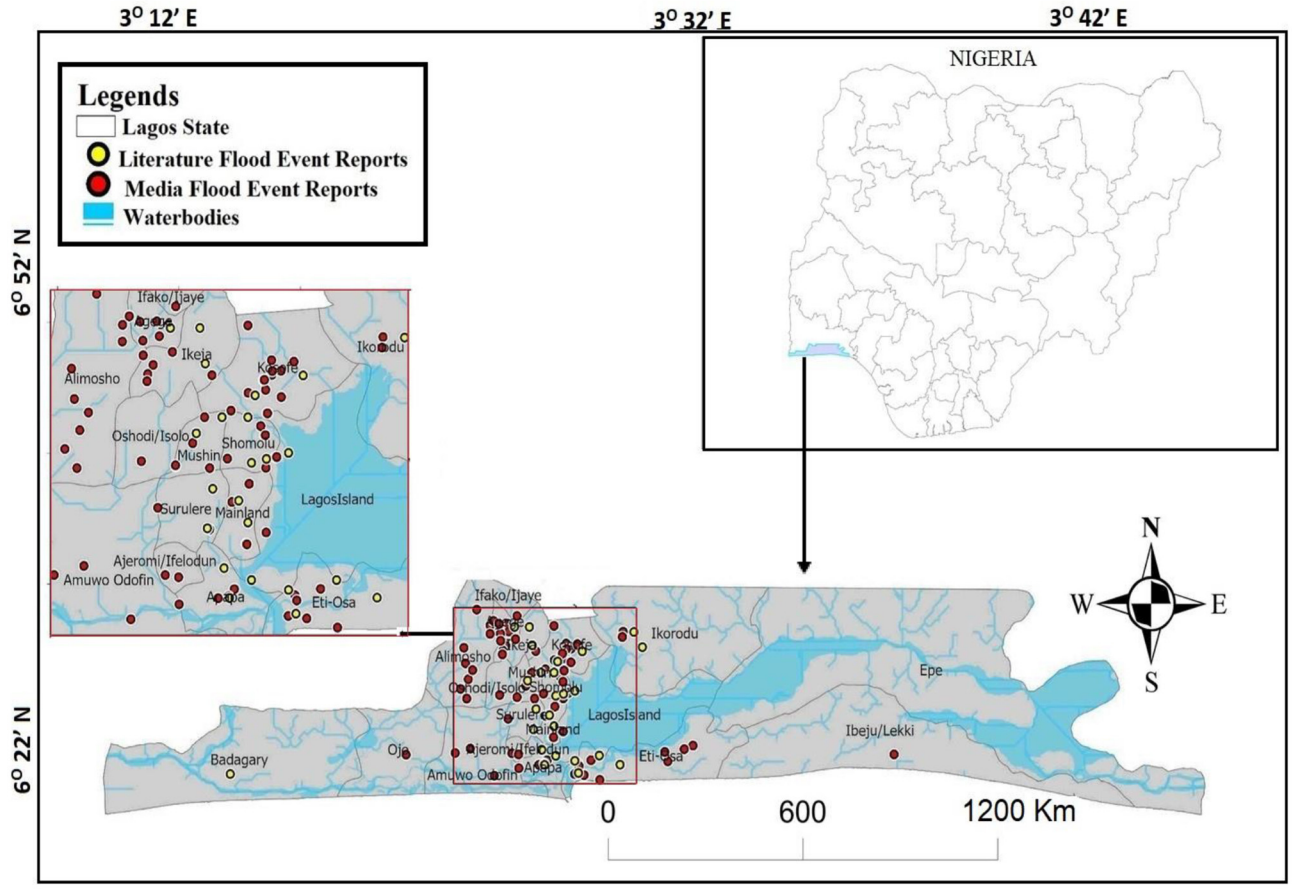


FIGURE 1
Map of the study area showing highly vulnerable locations within the Centralized Urban Districts (CUD).

(see Figure 1), identify successes, and pitfalls of resilience structures in addressing recurrent urban flood disasters, and highlight the need for more interventions in highly vulnerable floodplains of Lagos Metropolis. The review will integrate the Sustainable Development Goals (SDGs) policy framework, identifying steps to improve flood resilience strategies in alignment with the SDGs of the 2030 agenda for sustainable cities and development. The review aims to achieve the following objectives: (a) assess urban flood dynamics and its impacts on vulnerable communities in Lagos State; (b) evaluate the effectiveness of existing flood resilience strategies in Lagos Metropolis, including both structural and non-structural measures; and (c) explore the challenges of resilience strategies and propose pathways for improving flood resilience strategies in Lagos in accordance with global best practices and the 2030 Agenda for Sustainable Development.

Despite numerous flood management frameworks, the severity of flood events has continued to rise, resulting in significant loss of lives and properties, disruption to economic activities, and negative effects urban infrastructures. The call for a critical assessment of existing flood resilience strategies is timely, especially as we approach the 2030 mandate for the long-term sustainable development objectives. The SDGs emphasize the importance of resilient urban infrastructures, enhancing adaptive capacity, and disaster reduction efforts. The increasing focus on climate vulnerabilities has prompted scholarly attention to systematically evaluate of current flood resilience efforts in Lagos Metropolis, in line with these global targets.

1.2 Theoretical foundations

1.2.1 The Sendai Framework for disaster risk reduction (2015–2030)

The Sendai Framework for Disaster Risk Reduction (SFDRR), adopted on March 18, 2015, at the Third UN World Conference on Disaster Risk Reduction in Sendai, Japan, sets out 17 global targets and four key priorities to minimize disaster risks. These priorities include: (a) Understanding disaster risk, (b) Strengthening disaster risk governance, (c) Investing in risk reduction for resilience, and (d) Enhancing preparedness for effective response and promoting "Build Back Better" in recovery and reconstruction. The framework seeks to significantly reduce disaster-related losses in lives, livelihoods, health, and economic, social, cultural, and environmental assets over 15 years (2015–2030). The SFDRR is a global strategy that encourages multi-stakeholder collaboration, involving governments, civil society, and vulnerable communities to develop locally relevant disaster risk reduction (DRR) strategies.

The multi-stakeholder collaboration involves regional organizations, such as those in West Africa, where the Economic Community of West African States (ECOWAS) has played a crucial role in coordinating DRR efforts, securing foreign intervention support, and fostering community resilience in the region. Additionally, engaging marginalized groups will ensure that DRR strategies are inclusive and effective, encouraging social equity among large urban landscapes (United Nations International Strategy for Disaster Reduction, 2022). Furthermore, the application of technological advancement and education seems promising. The DRR framework supports technology integration, including satellite systems, climate modeling, and Artificial Intelligence (AI) knowledge, to improve disaster recovery and maintain critical services. Schools worldwide are incorporating DRR into education, focusing on building practical skills and awareness from a formative age of the students, rather than just theoretical knowledge of flood risk reduction (United Nations Environment Program, 2022).

The Humanitarian and Peacebuilding Connections of the SFDRR are linked to humanitarian action, in which its integration remains a challenge in most developing countries (Johnson et al., 2022). However, an emerging approach to address the limitation is anticipatory humanitarian action, aimed at strengthening and offering solutions to SDGs alignment (Mansour et al., 2022). The framework in socially unrest areas could create a strong tie to conflict resolution and peacebuilding, suggesting a need for a more integrated approach to addressing disaster risks in unstable regions across the globe (Chinedu et al., 2024). Despite its strengths, the SFDRR faces gaps in governance, funding, and stakeholder engagement. Expanding its focus to include peacebuilding and technological resilience could improve its effectiveness (Obiefuna et al., 2021). Success depends on innovative strategies, strong partnerships, and context-specific solutions tailored to vulnerable communities.

1.2.2 Urban resilience theory

The modern resilience theory was derived from urban resilience theory systems postulated by the Canadian ecologist (Holling, 1973), which was first applied to the concept of ecology in 1973. Urban resilience theory focuses on a city's ability to withstand, adapt to, and recover from shocks and stresses, while maintaining its essential functions and overall wellbeing, particularly in the face of climate change, urbanization, and globalization (Raufu et al., 2023). The carrying capacity of a city system involves the social, economic, natural, human, technical, and physical resources to absorb strong perturbations, reduce the impacts from disturbances, adapt to change, and transform systems that limit resilience.

The theory addresses the ability of cities to cope with various natural disasters and socio-economic risks, including climate change, globalization, and urbanization (Salami and Otokiti, 2022). It is crucial to understand that urban resilience enables cities to be prepared for disasters and unexpected events, including those caused by climate change-induced extreme weather conditions (Zhao et al., 2020) Cities face growing threats from climate change, rapid urbanization, and globalization, making resilience critical for disaster preparedness and sustainable development. Urban resilience encompasses various dimensions, including: (a) leadership and Strategy for effective planning and decision-making processes, (b) health and wellbeing accessibility to the urban population as part of social support systems, (c) Infrastructure and environment that is enriched with robust and sustainable infrastructure, including transportation, energy, and water systems; and (d) an economy and society where stability, social cohesion, and equitable access to resources are for the common man.

Urban resilience dynamics are not about returning to a static "normal" state but rather about adapting and transforming to face changing conditions. Figure 2 showed the dimensionality of urban resilience systems in building future recovery against flood challenges, and the relevance of resilience theory in understanding these complexities. There are multiple pathways to resilience, including persistence, transition, and transformation.

a) **Persistence:** This refers to the ability of a system (e.g., a community, ecosystem, or economy) to withstand shocks and stresses while maintaining its core structure and functions. It involves resistance to change and the capacity to absorb disturbances without significant alteration.
b) **Transition (Adaptation):** This pathway involves incremental adjustments and modifications that help a system cope with new conditions. It focuses on flexible and adaptive responses to change without completely altering the fundamental structure or identity of the system.
c) **Transformation:** When persistence or adaptation is no longer sufficient, transformation occurs. This involves a fundamental shift in the system's structure, processes, or goals to create a new and more sustainable or effective way of functioning. Transformation is necessary when existing conditions make survival or success impossible without significant change.

These pathways are particularly relevant in contexts like climate change adaptation, disaster risk reduction, urban planning, and socio-economic resilience. In most studies involving environmental sustainability, urban resilience, and climate change adaptation in Nigeria, this theory explores how cities can anticipate, absorb, recover from, and adapt to various shocks and stresses while maintaining their essential functions, structures, and identity. It integrates concepts from ecology, engineering, social sciences, and urban planning to create frameworks that help cities respond to challenges such as climate change, economic downturns, rapid urbanization, and social disruptions.

2 Materials and methods

2.1 Description of Lagos State

Lagos State, is located in the southwestern part of Nigeria on the narrow coastal floodplain of the Bight of Benin, occupying approximately between longitudes 2° 42′ to 3° 42′ E and latitudes 6° 22′ to 6° 52′ N. The population of Lagos State has grown significantly over the years, from around 305,000 in 1950 to 5.3 million in 1991, and 9.1 million in 2006 (Federal Republic of Nigeria Population Census Commission, 2006). The projected

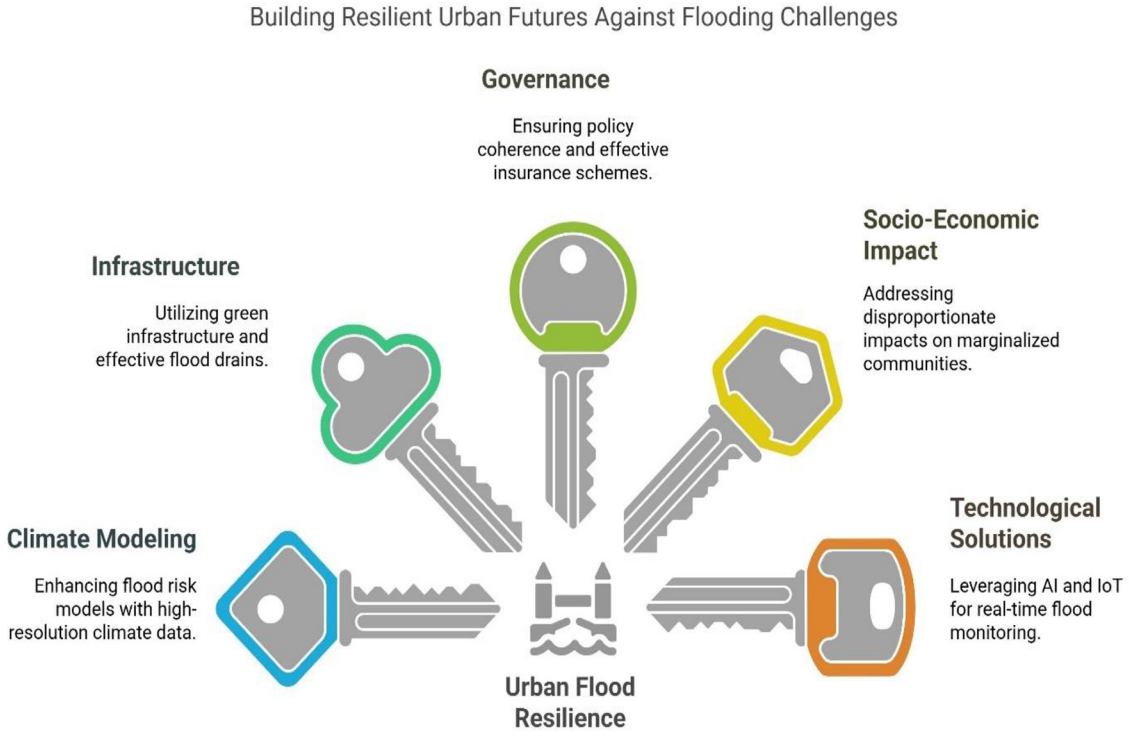


FIGURE 2
Conceptual framework on urban disaster resilience.

population of Lagos is expected to reach 25 million people by 2025 (Lagos Bureau Government, 2022).

Lagos Metropolis boasts a complex drainage system comprising rivers, lagoons, creeks, and the ocean, covering approximately 22% (787 km^2) of the state's total landmass. Population densities in Lagos Metropolis vary, ranging from about 4,907 persons/km^2 in sparsely populated areas to 20,000 persons/km^2 in densely populated areas (Adeaga et al., 2020). The central corridor of the state, where a significant portion of the population resides, faces challenges from flooding due to poor drainage systems, rapid urbanization, and an increasing rate of slum developments (Raufu et al., 2023).

The Nigeria Hydrological Services Agency (NIHSA) has classified major part of Lagos State, including Agege, Alimosho, Ikorodu, Lagos Island, Ikeja, and Eti-Osa, as High-Risk Areas for flooding in 2025. Other Local Government Areas (LGAs) were classified as moderate flood risk. The agency reported an increase in rainfall frequency and intensity, particularly in the southern region of the country, indicating a heightened risk of flooding.

2.2 Research method

This review examines existing literature to assess the impact of recurrent flood events on vulnerable communities in Lagos State and the resilience structures in place. The focus of the reviews is particularly suited for examining diverse topics with their study designs, policy documents, and gray literature, systematically drawing evidence, identifying gaps, and informing future research. Additionally, identifying the current gaps in resilience strategies and exploring solutions to tackle future challenges leading up to the 2030 agenda is key to the study. The systematic review justified the broad complexity of heterogeneous studies ranging from peer-reviewed studies, government reports, and policy briefs, capturing the exploratory nature of urban flood resilience and synthesizing evidence. The study also conceptualized flood impacts and resilience in Lagos Metropolis, and where these efforts translate to achieving SDGs. The study adhered to recommended scientific principles outlined by Masik and Grabkowska (2020), Laidlaw and Percival (2024), Ndimele et al. (2024), and was guided by the PICO framework (Population, Intervention, Control, Outcomes) to formulate the research questions stated in the introduction section. The use of the PICO method in flood resilience study justified the negative menace associated with flooding, its effect on the vulnerable population, while outcomes of intervention are critical to synthesizing solutions. Therefore, the study adopted the PICO framework for structuring and scoping research questions into highlighted PICO elements, addressing each section of the questions appropriately and the specific area of interest.

2.3 Literature search

The study utilized and followed the Systematic Review Process (Liberati et al., 2009) as stated by PRISMA guidelines for reviews and meta-analysis reporting. A structured approach

was employed for study selection, literature search strategy, and data extraction to ensure transparent reports. Multiple online databases, including Google Scholar, SCOPUS, and Agency Data Repositories were searched using specific terms related to urban flooding in Lagos State, Nigeria. Key search terminologies include: "Flooding in Nigeria," "Urban Flood Causes in Lagos State," "Impacts of Flooding," "Flooding and Sustainable Livelihoods in Nigeria," "Social and Economic Implications of Flood," "Flood Resilience Strategies in Southwestern Nigeria," "Flood Disaster Reduction Framework," "Social Vulnerability and Adaptations to Flooding," "Resilience of Lagos Flooding," "Structural and Non-structural resilience," and "Challenges of Flood Adaptations in Lagos, Nigeria." The search spanned a 10-year time-frame, from January 1, 2013 to December 31, 2023, resulting in a dataset of 87 studies.

The PICO criteria guided the study's objectives and the selection of studies for review. Two independent authors screened search results, extracted data from the selected studies, and assessed the quality of the studies based on various criteria. The study utilized a set of PRISMA guidelines for reporting systematic reviews, providing synthetic meaning to findings from examined broad studies. Evidence has proven the usability, accuracy, and appropriateness of the PRISMA method (McClymont et al., 2019). Hence, the study followed specific steps including screening and selection, full-text articles, and a critical appraisal was conducted to evaluate the strengths, limitations, and potential biases of the studies (see PRISMA 2020 Checklist in the Supplementary materials). The systematic review was conducted to find syntheses in the studies, focusing on the individual study aim, methods, their findings, implications of the study, and recommendations. Essentially, findings were presented to report urban flooding impacts, current resilience strategies, and challenges of flood resilience in achieving SDGs as stated in the research objectives. The selection process is illustrated in Figure 3.

3 Results and discussion

3.1 Spatial flood locations in Lagos metropolis: history and perspective

Lagos State's geographical features, characterized by lowland terrain and high river basin collection, make it prone to surface inundation (Chinedu et al., 2024). Floods in Lagos have had severe consequences, affecting millions of people and causing substantial economic losses (Adeaga et al., 2020; Odunsi et al., 2024). Recent flood events in 2019 resulted in significant human and economic tolls, with hundreds of thousands affected and numerous fatalities recorded (Ologunorisa and Eludoyin, 2022; Oladipo, 2023). The indirect impacts on public infrastructure further exacerbated the economic burden, with losses extending to property, farmland, buildings and ecological systems (National Emergency Management Agency (NEMA), 2022; Lagos State Ministry of Economic Planning Budget, 2023).

The combination of Lagos' geographical attributes, population density, and coastal influences contributes to the frequency of flooding (Adegboyega et al., 2019; Lagos State Government, 2022). Despite challenges in accurate data collection, it is evident that flood management capacities in Lagos are inadequate (Lawanson et al., 2023). The inadequacy in accurate data hampers efforts

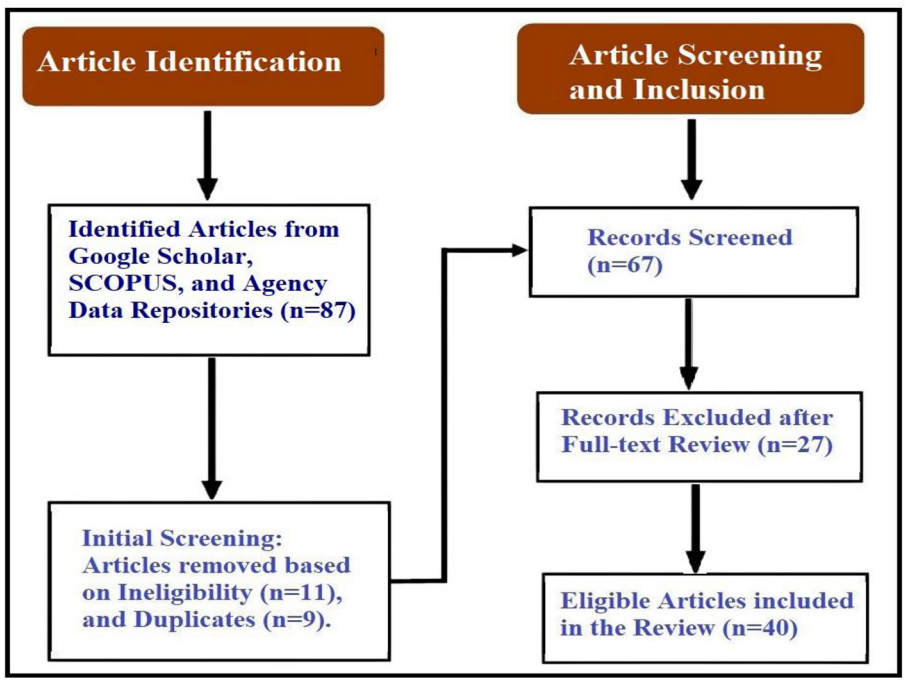


FIGURE 3
PRISMA methodological flow chart for article identification and review reporting.

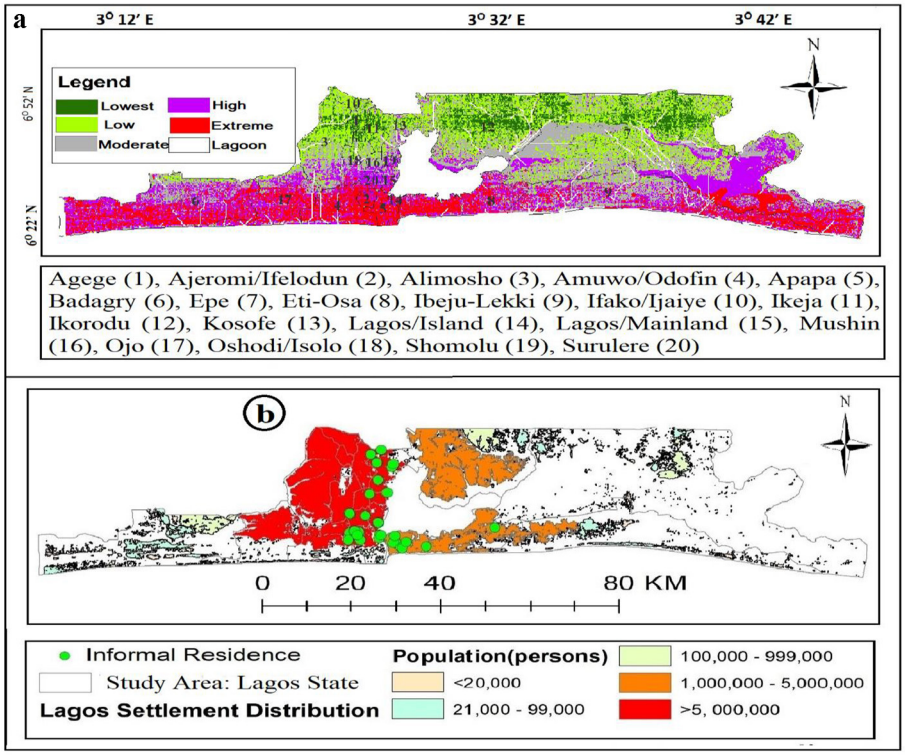


FIGURE 4
Showing: **(a)** flood hazard mapping of the 20 LGAs of Lagos State and **(b)** population density with their vulnerability to flood.

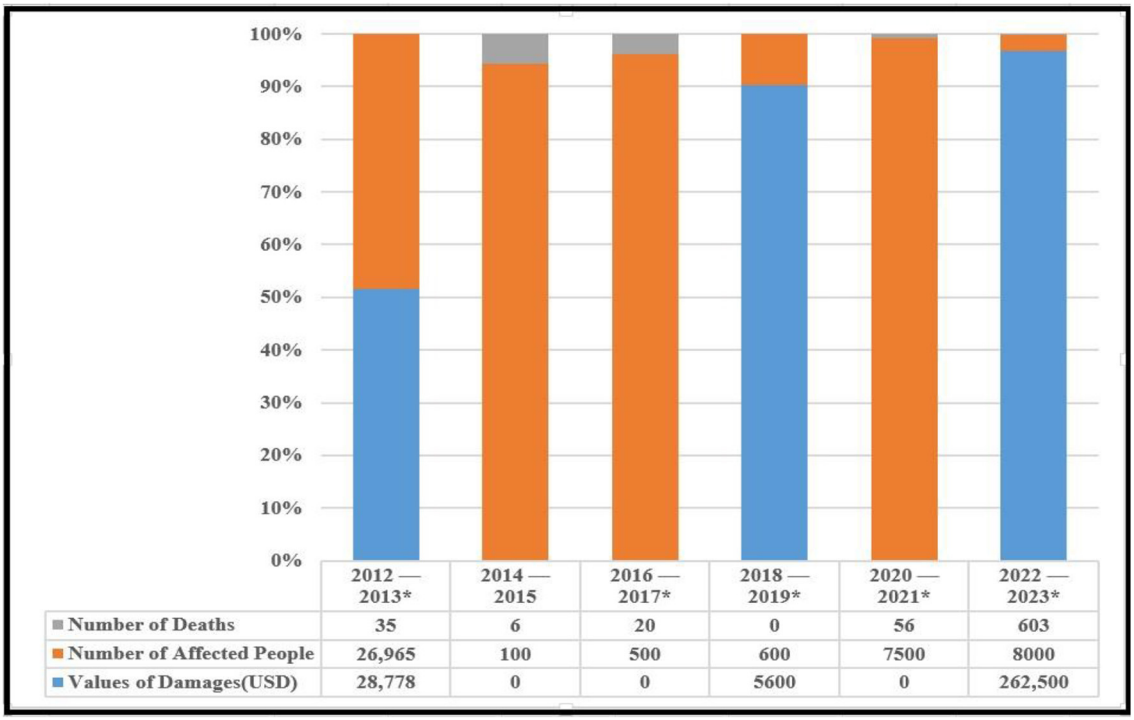
to model flood impacts effectively, leading to sub-optimal early warning systems and quick response (Isiaka et al., 2023). Certain areas within Lagos, such as Ajeromi-Ifelodun, Surulere, and Mushin, face heightened flood risks due to population density and poor urban infrastructure (Obiefuna et al., 2021; Osayomi et al., 2022; Isiaka et al., 2023). Efforts to mitigate flood hazards have been initiated, but they fall short of addressing the scale of the problems, necessitating a comprehensive approach to sustainable urban flood control.

Figures 4a, b show the flood hazard and settlement density mapping, revealing the Lagos State Flood Data inventory from 2013 to 2023. These highlight the historical flood occurrences, areas affected, and informal vulnerable settlements that are grossly affected. Recent flood events have led to the classification of Lagos Metropolis into three floodable zones:

a) Coastal Areas (40%): include vulnerable area like Lagos Island, Lekki, Victoria Island, Ajeromi/Ifelodun, Amuwo-Odofin, and Apapa, due to their proximity to the major waterbodies, high rainfall variability, and elevation pattern.
b) Mainland Urban Areas (35%): areas such as Surulere, Yaba, Ojo, Festac, and Ikoyi are characterized by poor drainage infrastructure, defaulted setback regulations and urban layout inadequacies.
c) Residential Districts (25%): Rapidly urbanizing areas like Kosofe, Ketu, Ikeja, Isolo/Oshodi, Agege, Alimosho, Ajah, Shomolu, and Ikorodu where ongoing construction, urban sprawl, and the presence of River Ogun contribute to flood risks.

Lagos faces frequent and severe flood hazards, primarily due to a combination of natural factors and human-induced contributors including unregulated rapid urbanization, inadequate waste disposal systems, clogged drains, poor infrastructural development, and preparedness. These issues characterize flooding in Nigeria and other developing countries (Adetunji and Oyeleye, 2020; Iyeshim, 2023). Meanwhile, developed countries like the Netherlands and Germany also face flood hazards, but the nature of their response differs significantly (Okoye, 2019). The utilization of advanced forecasting and early warning systems, engineered flood protection, and flood intervention schemes are part of the resilience available for affected communities. Unlike before, even in Western nations, climate change has increased flash flood events, overwhelming existing systems, yet fatalities are well managed (Adelekan and Asiyanbi, 2016). This advancement mirrors the struggles of developing nations and their systemic vulnerabilities, such as infrastructure gaps, governance issues, and socio-economic constraints. However climate change is challenging existing resilience strategies globally, creating new modalities to ameliorate recent flooding intensity.

Unfortunately, Nigeria like other developing countries can upgrade its approach toward flood resilience. The institutional framework for disaster management in Nigeria emphasizes coordinated efforts at the federal, state, and grassroots levels,



	2012 — 2013*	2014 — 2015	2016 — 2017*	2018 — 2019*	2020 — 2021*	2022 — 2023*
Number of Deaths	35	6	20	0	56	603
Number of Affected People	26,965	100	500	600	7500	8000
Values of Damages(USD)	28,778	0	0	5600	0	262,500

FIGURE 5
Flood impact in Lagos State and other Nigerian States for the years 2013–2023. Source: Dartmouth Flood Observatory (2023), Centre for Research on the Epidemiology of Disasters (2023). Zero (0) indicate record "Not Available." Date* Indicate grouped record of flood impact.

even though wide gaps exist in their functionality. Implementing flood resilience initiatives, public awareness, improved mitigation measures, and research-based flood solutions are crucial for building a more resilient urban environment. Comprehensive resilience strategies are essential to address the current flood challenges and prepare for a more resilient future.

3.2 Socio-economic impacts of floods

The recurring floods in numerous cities and towns across Nigeria have become a pressing concern for citizens, government officials, and scientists' alike (Abimbola et al., 2020). Reports by Orimoogunje et al. (2016), Obiefuna et al. (2021), and Isiaka et al. (2023) highlight devastating flood events in cities such as Lagos, Osogbo, Yobe, and Akure, occurring in multiple years and inflicting significant damage. Coastal communities along the Atlantic Ocean, including Lagos, Ondo, Port-Harcourt, Calabar, Uyo, and Warri, have consistently faced annual floods over the past two decades (Elum and Lawal, 2022; Odunsi et al., 2024). Catastrophic floods in cities along the Niger basin have resulted in the displacement of residents and damage to properties (Ologunorisa et al., 2022). In addition to urban areas, rural communities and agricultural lands have also been adversely affected by flooding (Ijaware, 2020; Aniramu et al., 2021). Rainwater inundation has led to the destruction of agricultural crops, disrupting food production and livelihoods (Kastridis et al., 2020; Echendu and Georgeou, 2021; Lawanson et al., 2023).

Furthermore, excess water release from dams like the Ogun-Oshun River Basin Development Agency has inundated communities in Ketu, Isheri, Kara, and Agiliti areas, exacerbating the flood situation in 2023 (Ogbonna and Umeh, 2023). The consequences of floods extend beyond physical damage, encompassing economic losses, environmental pollution, and public health risks (Dike et al., 2020; Shi et al., 2020). Flood-related fatalities and economic hardships have been widespread, particularly in areas where floodwaters contaminate underground water reservoirs and wells, rendering them unfit for domestic use (Ologunorisa and Eludoyin, 2022). Catastrophic events such as dam failures have resulted in significant loss of life and property, as seen in the Kano flood of 2008 (Gumbo, 2021).

In Lagos State, diverse locations have also experienced their share of devastating floods, with places like Eti-Osa, Agege, Ajeromi/Ifelodun, Ikoyi, Shomolu, and Lekki facing repeated inundation events over the years (Ndimele et al., 2024). These floods have led to extensive displacement of residents, loss of homes, and destruction of infrastructure, amounting to substantial economic losses (Elum and Lawal, 2022). The impact on agriculture is particularly severe, with informal settlements in areas like Surulere, Amuwo-Odofin, and Amukoko losing multiple commercial properties to flooding, posing a threat to the economic stability and income of the victims (Olorunfemi et al., 2020).

As shown in Figure 5, the most catastrophic flood event occurred in 2022–2023 with $262,500 in damages and 8,000 affected residents recorded in Lagos State (Centre for Research on the Epidemiology of Disasters, 2023). The primary driver of urban floods is the rainfall trend between June to October, emerging as

the high-risk period for flood fatalities (Buba et al., 2021). This available data persists in presenting economic impact assessments and geographical extent documentation of flood events in Lagos State (Echendu, 2021), highlighting the multiple causal patterns evident in the seasonal rainfall variation, river overflows, coastal storms, and dam management issues (Eilander et al., 2020; Faccini et al., 2021; Kasim et al., 2022). The monetary value loss is so enormous, not to be calculated with the present situation of inflation rates across the 23-year period (Ibeabuchi, 2023). In light of these complexities and socio-economic losses, there is a pressing need to explore flood resilience strategies for the strategic development of urban centers across Nigeria. Effective flood management strategies are tailored to the specific needs of urban delta environments (Arshad et al., 2021; Eilander et al., 2020), by addressing the multifaceted challenges posed by floods. This requires comprehensive planning, infrastructure development, and community engagement to build resilience and mitigate future risks (Asiedu, 2020; Fang et al., 2021).

3.3 Flood impacts on sustainable development goals

Floods have significant impacts on the Sustainable Development Goals (SDGs) in various ways. The SDGs are a set of goals aimed at addressing social, economic, and environmental challenges facing the world today with the goal of improving the lives of people, society, and the environment by 2030. However, floods pose a significant challenge to achieving some of these goals as the impacts of flooding are devastating to infrastructure, economies, and the wellbeing of individuals, ultimately hindering progress toward the SDGs.

The direct impact of floods on No Poverty and Zero Hunger (Goals 1 and 2 of the SDGs) is massive. Floods trigger all forms of poverty and hunger, destroying homes, businesses, and lowering livelihood standards, pushing people further into poverty (Olanrewaju et al., 2019; Echendu and Georgeou, 2021). The cost of preventing and rebuilding human capital infrastructure after a flood event is exorbitant, leaving many communities struggling to recover from financial losses. For example, Nigeria's 2012 floods affected 16 million people, many of whom lost homes and suffered significant income loss (Ndimele et al., 2024). This undermines efforts to reduce poverty and improve the livelihoods of those living in affected areas. Furthermore, flooding can also affect progress toward zero hunger by destroying crops and livestock, leading to food shortages and price spikes that make it difficult for vulnerable populations to access food, resulting in malnutrition and food insecurity (Lawal and Iwajomo, 2020).

In addition, flooding can have a significant impact on the health of people and the environment (SDG 3), which aims to ensure healthy lives and promote wellbeing for all ages (United Nations Environment Program, 2022). Floods can affect vulnerable populations in urban environments by contributing to disease outbreaks through the erosion of contaminants and pollutants into community water resources (Tramblay et al., 2020). This can overwhelm healthcare systems and pose other health risks, hindering efforts to improve public health systems and impeding progress toward this goal.

The Lagos environment faces challenges in achieving Clean Water and Sanitation (SDG 6) due to urban population practices and water scarcity (Echendu, 2022). Rivers and streams are often polluted with improper waste disposal, and floods further contaminate water resources (Elum and Lawal, 2022). Floodwaters can contaminate drinking water sources, disrupt sanitation systems, and damage water infrastructure, making it challenging to provide safe and reliable water and sanitation services to communities in need, perpetuating poverty and disease cycles.

Achieving sustainable cities (SDG 11) is under threat from flooding, as floods can cause significant damage to urban infrastructure, homes, and public services, making cities more vulnerable to future disasters. Additionally, Wizor and Mpigi (2020) opined that flooding disrupts economic activities, leading to job losses and hindering efforts to create sustainable and inclusive economies, impacting the livelihoods and wellbeing of individuals living in affected areas.

Flooding is also a result of climate variability, impacting the Climate Change Framework of SDG 13, which focuses on combating climate change and its impacts (United Nations Convention to Combat Climate Change, 2022). Climate scenarios in Lagos state, such as heatwaves, flooding, and soil erosion, are exacerbated by climate extremes and rising global temperatures, leading to coastal and wetland degradation and more frequent severe weather events (Idowu and Zhou, 2019; Idowu et al., 2022). This has contributed to increased flooding and natural disasters in the area, destabilizing communities and ecosystems and impeding progress toward this important SDG.

Flood impacts on the environment are consequential to SDG 15, which focuses on conserving marine resources and biodiversity (Umar and Gray, 2022). When floods occur, they can carry pollutants and debris into waterways, harming marine ecosystems and threatening aquatic species' health, ultimately impeding efforts to achieve this goal. Flooding can also impact Goal 15, which focuses on protecting terrestrial ecosystems, forests, and biodiversity (Olorunfemi et al., 2020). Flooding can destroy habitats, displace wildlife, and degrade ecosystems, leading to loss of biodiversity and ecological balance, hindering progress toward this goal (Okafor, 2020).

In conclusion, the impacts of flooding on achieving the SDGs are significant and multifaceted (see Figure 6). Unfortunately, current practices has failed to fully achieve the set-out goals, but there is room for improvement. Unsustainable flood resilience strategies can hinder the progress toward multiple SDGs, by undermining efforts to reduce poverty, end hunger, promote health and wellbeing, ensure water and sanitation access, foster economic growth, build resilient cities, combat climate change, and protect biodiversity. Addressing the challenges posed by flooding is essential to achieving the SDGs by 2030.

3.4 Current resilience strategies to mitigate flooding

Flood resilience in Lagos State, Nigeria, is a critical issue due to the city's vulnerability caused by various environmental factors and rapid urbanization. Studies by Rezende et al. (2019), Zhao

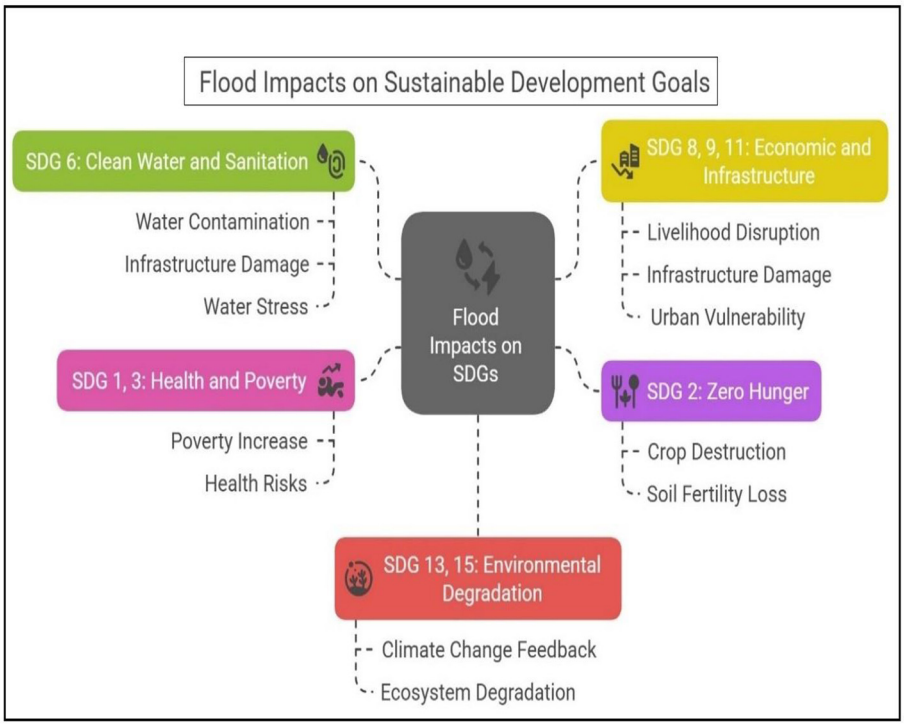


FIGURE 6
Urban flood impacts in Lagos State, Nigeria, and their non-alignment with SDGs.

et al. (2020), Nwagbara and Okwuonu (2021), and Yoade et al. (2023) have emphasized several efforts being made by agencies to improve flood resilience through a combination of structural and non-structural measures. This study explores the current flood resilience practices in Lagos State, focusing on the key strategies being implemented to address this persistent issue.

3.4.1 Structural strategies

One important aspect of flood resilience practices in Lagos State is the construction of drainage infrastructure to manage stormwater runoff. The city has suffered from inadequate storm drain systems, leading to frequent inundation of urban residences and public buildings during the rainy season. In response to this challenge, the Lagos State government has embarked on various drainage projects, dredging, and channelization efforts to improve the city's ability to cope with heavy rainfall events and surface runoff (Adeaga et al., 2020). An important aspect of flood resilience practices is the promotion of sustainable urban drainage solutions. Green infrastructure such as rain gardens, permeable pavements, and rooftop gardens can help absorb and infiltrate stormwater, reducing the pressure on drainage systems and preventing flooding in urban areas (Lawal and Iwajomo, 2020). These nature-based solutions not only improve flood resilience but also enhance the quality of the urban environment (Abass, 2022).

The construction of various engineered structures to control the flow of water and reduce inundation in flood-prone areas (Oladipo, 2023). Levees are embankments built along rivers or coastlines to prevent flooding, while dams are barriers built across rivers to regulate water flow and reduce flooding downstream (Olokeogun et al., 2020). Flood walls are vertical barriers constructed around buildings or communities to protect them from rising water levels. These structures can be highly effective in reducing flood risk, but they can also be costly to construct and maintain.

Furthermore, the government has been implementing land use planning regulations to reduce flood risk in vulnerable areas. Adeleke et al. (2019), Bandauko et al. (2021), and Odunsi and Onanuga (2022) reported that the current efforts of shanty building removal along waterways, enforcing setback regulations, and implementing urban development framework recommendations are breakthroughs for urban planning development. This includes zoning regulations, building codes, and enforcement measures to prevent the construction of buildings in flood-prone areas. By controlling development in high-risk areas, the government aims to minimize the exposure of residents to flood hazards and reduce the potential for property damage.

In recent years, there has been a growing recognition of the need to integrate climate change considerations into flood resilience strategies. As the city faces the increasing threat of climate-related disasters, such as sea-level rise and more intense rainfall events, it is crucial to adopt adaptive measures that can withstand the impacts of a changing climate (Chinedu et al., 2024). This requires long-term planning and investment in resilient infrastructure that can withstand future climate challenges (McClymont et al., 2019). Additionally,

the government has been working to improve coordination and collaboration among different stakeholders involved in flood resilience efforts. This includes partnerships with NGOs, academia, private sector organizations, and international agencies to leverage their expertise, resources, and innovation to address the complex challenges of flooding (Buba et al., 2021). By fostering multi-sectoral partnerships, the government can enhance the effectiveness of flood resilience initiatives and achieve sustainable outcomes.

3.4.2 Non-structural strategies

Non-structural flood resilience strategies involve policies and planning measures to reduce vulnerability to flooding (Umar and Gray, 2022). These strategies include concerted efforts from all stakeholders, particularly, community awareness programs that are required to increase public understanding of flood risks and encourage people to take proactive measures to protect their properties. One critical component of flood resilience practices in Lagos State is community awareness and resident education on the handling and disposal of solid waste (Ibeabuchi, 2023). Government officials, in conjunction with local community leaders, are responsible for raising awareness about flood risks, educating residents about preparedness measures, and involving them in the planning and implementation of resilience projects (Odunsi et al., 2024). This bottom-up approach helps to build community resilience and empower residents to take proactive measures to protect themselves from flooding (National Emergency Management Agency (NEMA), 2022).

Non-structural strategies address underlying vulnerabilities that contribute to flood risk, such as poor land use decisions, unsustainable urban practices, and inadequate infrastructure. The government is urged to invest in flood early warning systems to improve preparedness and response to flooding events (Olukunga et al., 2024). These systems help monitor rainfall patterns, river levels, and weather forecasts to provide timely warnings to residents in flood-prone areas. This is essential for reducing the impact of flooding and saving lives during emergencies. Additionally, non-structural strategies are often more cost-effective than structural measures, making them accessible to a wider range of communities (Lagos State Ministry of Economic Planning Budget, 2023). Many of these measures rely on voluntary compliance from property owners and developers, which can be difficult to enforce. Moreover, changing to standard urban development framework can be challenging but has a long-term benefit on community resilience to flooding (Echendu, 2021).

In practice, a combination of both structural and non-structural flood resilience strategies is often the most effective approach to reducing flood risk (Wahab and Ojolowo, 2018; Adejobi, 2022; Isiaka et al., 2023). By integrating engineered structures with policy interventions and community engagement initiatives, communities can create a comprehensive flood management strategy that addresses multiple aspects of vulnerability (Hamidi et al., 2020). This hybrid approach can help build resilience at multiple scales, from individual properties to entire regions, and can enhance the overall effectiveness of flood risk reduction efforts.

3.5 Impact of current resilience strategies on SDGs: progress, pitfalls, and future expectations

Lagos's flood resilience strategies and the SDGs indicators require a multifaceted approach, including investing in modern infrastructure, enhancing community engagement, enforcing environmental regulations, improving data collection and monitoring, securing diversified funding sources, fostering institutional collaboration, and addressing socioeconomic inequalities. However, the recurrence of floods in Lagos has shown some meaningful progress since the beginning of the millennium, aligning with the key goal of developing a sustainable and resilient urban city in line with the 2030 Sustainable Development Agenda.

In 1999, the Federal Government and the National Emergency Relief Agency (now NEMA), established Emergency Management Agencies at the national, state and local levels (NEMA, SEMA, and LEMA). NEMA then developed the National Disaster Management Framework (NDMF) in 2010, with the primary function of addressing flood and other disaster challenges. These efforts have led to the construction and rebuilding of disaster management infrastructures, providing accessible facilities for urban convenience. As a result, there has been a reasonable reduction in the number of death or people affected by disasters, including water-related drowning in major coastal areas of the Lagos State, Nigeria. The construction of groins and other embankments around the Lagos Lagoon has provided protection for coastal residents and tourism visitors.

The Lagos State Government undertook several structural initiatives in recent time, including building 69 km of concrete secondary stormwater drainage to manage coastal flooding, constructing the "Great Wall of Lagos," multiple shoreline protection projects in Eti-Osa area, draining 100,000 hectares of land, dredging and maintaining 32 stream/rivers, delivering five channelization projects, citywide de-flooding and de-silting of drainage systems, and maintaining the existing drainage network. As part of the sustainability plan, the Ministry of the Environment increased the number of engineers and staff in the office of drainage services from five to 57, with structural engineers deployed to oversee the condition of drainage channels at the local level.

Similarly, the Lagos Government improved flood risk information and GIS-based analysis with the support of Space Monitoring and Meteorological Institutions for flood management, resulting in a drastic reduction in coastal flood severity, knowledge mapping, and enhanced emergency team efficiency toward disaster reduction.

Between 2019 and 2023, the Lagos State Government (LASG) halted physical development in major wetland and areas prone to flooding. The Lagos State Resilience Office (LASRO) was launched as a partnership between the State Government and the Rockefeller Foundation through the 100 Resilient Cities (100RC) program. Additionally, the Federal Government and LASG initiated dredging projects along the Ogun River downstream, from Ikorodu to Isheri, which began in September 2024, and is expected to last 6–8 months. The trajectory of flood management is aimed at minimizing flood impacts, Figure 7 presents some of the resilience effort in Lagos State, Nigeria.

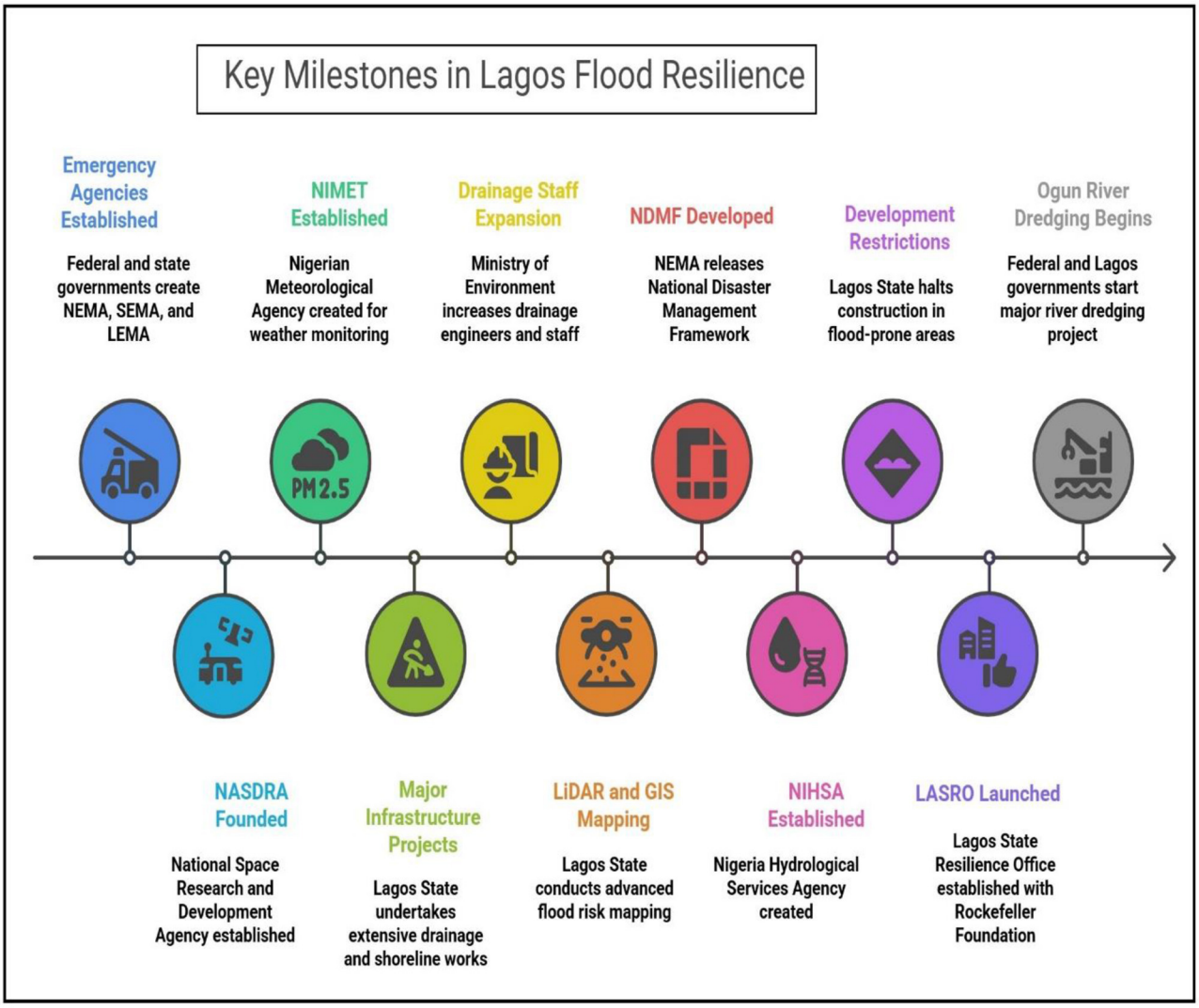


FIGURE 7
Progress of flood resilience in Lagos State, Nigeria.

However, the study identified social disparities in flood resilience efforts, particularly the impact severity on low-income communities where urban disaster management is insufficient, exposing more informal settlements to high-risk flooding. These communities have limited access to resources and support systems, making them more vulnerable to flood-related disasters. Addressing these socioeconomic disparities is crucial for achieving inclusive and equitable urban resilience. Environmental regulations in major residential area are often weakly enforced in Lagos, leading to illegal constructions and the blockage of drainage channels by waste, increasing flood risks. Many communities lack awareness of flood warnings, proper waste disposal compliance, and preparedness measures, resulting in inadequate responses during flood events (Akinloye, 2018). This weak enforcement undermines efforts to create a sustainable and resilient urban environment. The inadequacy of climate adaptation and social knowledge integration remain a significant pitfall for urban policy-makers. Numerous studies worldwide have examined the efficiency of functional and sustainable resilience, emphasizing the use of technological water level sensors for flood monitoring, predictions, and timely information dissemination (Shi et al., 2020; Van-Berchum et al., 2020; Johnson et al., 2022). While many of these studies focus on recommendations for better flood measures in developed countries (Gregory and Gerald, 2020), major part of West Africa states are lagging behind.

In addition, there is a gap between policy formulation and execution, with many initiatives suffering poor funding, technical know-how, and appropriate institutional supports (Mansour et al., 2022). The unsupportive role of certain agencies and their conflicting line of duties pose another challenge, limiting the synergy expected from disaster resilience institutions in Nigeria (Echendu, 2020). This disconnect hampers the city's ability to build resilience against climate-induced flooding, a challenge that needs to be addressed in the future.

3.6 Challenges of urban flood resilience on SDGs achievement

The flooding crisis in Lagos is a result of interconnected natural and anthropogenic factors. Urban expansion has encroached into drainage systems and canals, hindering the smooth flow of floodwater away from vulnerable areas (Lawanson et al., 2023). Wetlands, waterlogging, and low-lying areas face diverse challenges. The current situation is unable to minimize the impact of heavy rainfall on residents and protect vital infrastructure such as roads and buildings. Climate change impacts are on the rise (Ansah et al., 2020), with sea levels rising by 3.7 mm annually (Nigeria Meteorological Agency, 2021), further heightening the vulnerability of coastal environments to flood risks (Kasim et al., 2022). The recent intensity in rainfall events due to climate change overwhelms drainage systems, rendering the flood warning system ineffective.

The urban planning framework has failed the city, with issues such as the lack of implementation of the Urban Planning Act, personnel negligence, and weak municipal authority. Despite 40% of Lagos' land area consisting of water bodies and wetlands, uncontrolled development persists in these vulnerable zones. Poor waste management clogs drainage channels (Osayomi et al., 2022), with 70% of flooding attributed to blocked drainage system (Lagos State Government, 2022). Social stratification in Lagos is evident, with most developmental projects focusing on elite areas like Eko Atlantic City (Ogbonna and Umeh, 2023), displacing average or poor residents to flood-prone communities (Lawal and Iwajomo, 2020). This social marginalization has led to a significant portion of Lagos being underdeveloped, reserved exclusively for low-income and mid-income residents (Rahman et al., 2021).

There are several challenges in the flood resilience efforts in Lagos State that need to be addressed. Rapid urbanization and informal settlements have encroached on floodplains and natural waterways, increasing the vulnerability of these areas to flooding (Ullah et al., 2021). The government must develop and enforce land use policies to regulate development in flood-prone areas and prevent further encroachment on natural drainage systems (Ndimele et al., 2024). Policy makers and urban development regulators must be professional and non-partisan in their activities to avoid fragmented institutional responsibilities in flood management, emphasizing proactive approaches to disaster risk reduction (Onajomo, 2022). Resilience in Lagos State remains a continuous effort, advancing partnership and resilient programs, and delivering the Sustainable Development Goals (SDGs):

i Financial Innovation for Resilience (SDGs 8, 9, 11): The Lagos Flood Resilience Project (2022–2024) is developing financial instruments such as insurance and investments in resilient infrastructure to mobilize commercial capital for flood protection and benefit 500,000 residents.

ii Community-Based Adaptation (SDGs 11, 13): Community Development Associations (CDAs) play a crucial role in local flood response by organizing drainage clearing, early warning systems, and community shelters.

iii Policy and Planning Reforms (SDGs 11, 16): Lagos Sustainability Summit (2024) aims to align urban development with SDG targets, focusing on ethical business practices, sustainable finance, and resilient infrastructure.

iv Floating Community Solutions (SDGs 1, 2, 11): Innovative approaches for water-based communities like Makoko include prioritizing livelihoods, resilient housing, and adaptive architectural designs like floating schools and homes.

v Waste Management Improvements (SDGs 6, 11, 12): Improved waste management methods, including integrated solid waste management and the use of information technology for smarter waste collection will significantly reduce drainage blockages.

4 Study implications

4.1 Pathways to 2030: recommendations for transformative resilience

As we approach the year 2030, it is imperative that we begin to strategize and plan for future challenges to ensure climate impact resilience. The current challenges of climate change, rapid urbanization, and social inequality call for a more transformative pathway toward a resilient future, accelerating the progress on the SDGs while reducing flood risks. Lagos municipal authority and other stakeholders should prioritize:

a) Mainstreaming flood risk in SDG implementation through the explicit inclusion of flood resilience in local SDG monitoring frameworks, and adopting context-specific indicators for floating communities in the state.

b) Strengthening governance coordination by improving cross-agency collaboration on flood management and enforcing urban planning regulations such as setbacks, zone regulation, and urban layout approval.

c) Upscaling Nature-Based Solutions (NbS) by regulating and restoring wetlands and mangroves as natural flood buffers, and developing improved urban green alongside gray infrastructural projects.

d) Empowering vulnerable area and groups by targeting more support for women, children, and people with disabilities, flood-prone households, and slum communities in a co-designing resilience framework that merges their respective solutions.

e) Utilizing technology and space information is a key aspect in advancing flood information dissemination, early warning systems, and climate modeling for real-time flood detection.

f) Securing sustainable finances that can expand the flood resilience finance framework to attract private investment, delivering intervention insurance products for low-income residents.

5 Conclusion

This study has attempted to examine urban flood impacts and resilience strategies in Lagos with respect to achieving the sustainable development agenda of 2030. Several discourses have analyzed flood impacts resulting from state inaction

on the provision of necessary urban infrastructure, waste management challenges, and policies that can ameliorate flooding. Urban flooding remains a pressing challenge in Lagos, necessitating multi-sectoral and proactive approaches to resilience building through policy reforms, infrastructure improvements, and community-driven initiatives. Apart from anthropogenic factors, environmental factors including topography and rainfall significantly add pressure to urban flood occurrence in Lagos State, Nigeria. The recent climate inconsistency equally affects sea level rise, which is challenging in coastal areas of Lagos Metropolis. In addition, the effects of flooding include settlement displacement, property loss, disease outbreaks, and fatalities are on the high side annually. Nevertheless, Lagos can navigate the complexities of flood issues while progressing toward sustainable urban city. A holistic and integrated flood mitigation strategy will be crucial for ensuring the city's long-term sustainability and resilience in the face of climate change and urbanization.

Lagos stands at a critical juncture of resilience deficits to achieving its 2030 Sustainable Development Agenda. While challenges are formidable, resilience capacity can be demonstrated through innovative approaches, financial mechanisms, community-led adaptation, and sustainable urban infrastructure. By treating flood resilience not as a standalone issue but as integral to all SDGs, Lagos can transform its vulnerabilities into opportunities for more equitable and sustainable urban development. The lessons emerging from Lagos' experience offer valuable insights on advancing resilience measures toward coastal city protection against future climate adaptation challenges. In conclusion, building resilience by 2030 requires a multi-faceted approach that encompasses environmental stewardship, infrastructure resilience, social resilience, and technological innovation. The significance of the sustainable development goals by 2030 promises enormous benefits for residents, repositioning Lagos Metropolis for disaster-safe and resilient urban center.

Author contributions

OO: Project administration, Formal analysis, Visualization, Resources, Validation, Conceptualization, Methodology, Supervision, Writing – review & editing, Investigation, Writing – original draft. OA: Resources, Validation, Project administration, Writing – review & editing, Software, Formal analysis, Methodology, Writing – original draft, Conceptualization, Visualization.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fclim.2025.1603798/full#supplementary-material

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