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Flood risk assessment and regional detailed spatial planning in Lagos State: A remote sensing perspective

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ABSTRACT
Background: Lagos State, Nigeria, is increasingly confronting flooding as an aftermath of hasty urbanization, climate change, and inefficiency in land-use planning. This paper formally reviewed remote sensing technology application in flood hazard analysis and incorporating it into the Regional Detailed Spatial Planning (RDTR) framework. **Methods:** A systematic search of 40 peer-reviewed articles (2000–2023) was conducted following PRISMA guidelines to identify and analyze trends and patterns. Remote sensing technologies, including optical images and synthetic aperture radar (SAR), were used to monitor flood dynamics, evaluate vulnerability, and identify flood zones in near real-time. Indicators such as rainfall intensity, elevation, land use, and population density were also assessed. **Findings:** Although remote sensing provides actionable data for zoning and infrastructure planning in flood-prone areas, its application to RDTR planning is limited by insufficient high-resolution data, technical limitations, and stakeholders' coordination problems. The study also highlights the critical role of geospatial innovations in improving flood resilience and urban planning. **Conclusion:** Improved data access, technical capacity building, and multi-stakeholder collaboration are essential to address current limitations. **Novelty/Originality of this article:** This research bridges the gap between flood hazard mapping technologies and detailed spatial planning frameworks. It provides a framework that can guide policymakers and urban planners in Lagos and similar contexts toward sustainable flood risk management and urban development.

KEYWORDS: climate change and urban planning; detailed spatial planning regional (RDTR); flood risk analysis; geospatial technologies; remote sensing; synthetic aperture radar (SAR).

1. Introduction

The most devastating form of natural disaster globally is flooding, which affects millions of individuals annually and causes huge economic losses (Cao et al., 2022; Devitt et al., 2023). Climatic change, urbanization, and inadequate land-use planning have increased the frequency and intensity of floods in Africa. Lagos, Nigeria, is most exposed to flood due to possessing a low-lying coastal plain, extremely high population density, and inadequately developed drainage network (Aliyu et al., 2023; Ekolu et al., 2024; Ndimele et al., 2024; Pizzorni et al., 2024). Being Nigeria's most populous urban city and one of the world's fastest-growing megacities, Lagos has peculiar challenges in flood hazard management. The 2021 flood disaster, for instance, rendered thousands homeless, damaged property and

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infrastructure, and disrupted economic activities, demonstrating the significance of effective flood risk management (Lynggaard et al., 2022; Sibandze et al., 2024).

Despite an increasing body of literature on flood risk analysis, there is a huge knowledge deficit in the application of cutting-edge geospatial technologies, such as remote sensing, within urban planning systems like the Regional Detailed Spatial Planning (RDTR) of Lagos State. The RDTR strategy presents a policy basis for managing flood risks in a sustainable urban planning system. It aims to influence land use planning, infrastructure expansion, and natural resource management to reduce vulnerability to natural hazards (Ahmad et al., 2025; Prashar et al., 2023). However, the success of RDTR requires precise, real-time, and geographically delineated data that traditional means of data acquisition are incapable of providing.

Remote sensing technology, based on synthetic aperture radar (SAR) and optical imagery, offers a plausible solution to the challenge. These technologies can be used for monitoring flood processes, mapping the extent of flood, and vulnerability assessment in near real-time and hence are highly beneficial in flood risk assessment and urban planning (Ozden et al., 2016; Zhang et al., 2025). Yet, the use of remote sensing information in RDTR planning in Lagos State is still limited because of a lack of high-resolution data, technical constraints, and coordination issues among stakeholders (Dritsas & Trigka, 2025; Yin et al., 2021).

The present research seeks to critically assess the application of remote sensing in flood hazard mapping for Lagos State and its use in RDTR planning activities. It seeks to answer the following research questions: How has remote sensing contributed to the evaluation of flood risk in Lagos State? What are the primary challenges of integrating remote sensing information in RDTR planning? In what ways can remote sensing help improve flood resilience in Lagos State? These questions attempt to determine the current use of remote sensing technology in evaluating flood hazards, count the barriers that hinder their inclusion in RDTR planning, and provide feasible suggestions to policymakers and urban planners.

The significance of this research lies in the fact that it can contribute to the growing body of literature on geospatial technology applications in minimizing disaster risk and sustainable urban development for developing countries (Shukla & Verma, 2024; Thapa, 2021). Based on the examined literature, this research provides an integrated discourse on the application of remote sensing in flood risk calculation and the potential integration within RDTR planning. The results are likely to enlighten policymakers and urban planners in Lagos State and other flood-risk cities on the advantages of using remote sensing technologies for sustainable urban planning.

A previous study clarified that although remote sensing technologies provide useful information for managing flood risk, their use in urban planning schemes such as RDTR is constrained by data resolution and coordination problems among stakeholders. This research concerns itself with evaluating the current use of remote sensing to map flood hazard and integrate it into RDTR planning in Lagos State. Indeed, this research seeks to establish gaps and loopholes in the current approach and recommend how the flood resilience can be improved through the inclusion of remote sensing technology into urban planning strategies.

2. Methods

2.1 Study design

The systematic review approach was used in the study to consolidate existing literature on remote sensing use in flood risk evaluation and its integration into RDTR (Regional Detailed Spatial Planning) policy in Lagos State, Nigeria. The systematic review adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines in ensuring transparency, reproducibility, and methodological quality. The

PRISMA method was widely praised to conduct systematic reviews in a systemic manner, primarily in environmental and geospatial research (Islam et al., 2025).

Fig. 1. Map of showing the Study Area
(Nkwunonwo et al., 2016)

2.2 Eligibility criteria

In terms of ensuring inclusion of relevant studies with quality, the use of eligibility criteria was rigorous. Eligible studies to be included were those published during the period between 2000 and 2023, focusing on flood risk assessment using remote sensing tools such as SAR, optical imagery, or LiDAR. The studies were needed to possess case studies or applications in Nigeria, Lagos State, or similar regions, and be in the form of peer-reviewed journal papers, conference documents, or chapters in books. Additionally, the studies needed to provide empirical findings or case studies to prove the reliability of findings. Exclusion criteria filtered out studies that were not flood hazard or remote sensing related, non-English language articles, studies that lacked empirical evidence or case studies, and grey literature such as reports, theses, or non-peer-reviewed journal articles (Islam et al., 2025).

2.3 Information sources and search Strategy

The review obtained data from various reputable databases and academic online platforms, including Scopus, Web of Science, PubMed, IEEE Xplore, and Google Scholar. These databases were selected due to their extensive coverage of peer-reviewed literature in environmental science, remote sensing, and urban planning, ensuring access to a strong and diverse body of relevant studies (Mashala et al., 2023).
To retrieve relevant literature systematically, a search strategy was employed using Boolean operators and specific keywords. The keywords included flood risk assessment, remote sensing, Sentinel-1, SAR, Lagos State, RDTR, and urban planning. Boolean combinations such as (flood risk assessment AND remote sensing), (flood mapping AND SAR), (GIS AND flood risk), and (RDTR AND urban planning AND Lagos State) were used to refine and target the search results. Additionally, the search was limited to publications from 2000 to 2023 to capture recent advancements in remote sensing technologies and their applications (Islam et al., 2025).

2.4 The database search term

(flood risk assessment AND remote sensing) OR (flood mapping AND SAR) OR (GIS AND flood risk) OR (RDTR AND urban planning AND Lagos State). For Scopus, the following was the search query: title abs key ("flood risk assessment" and "remote sensing") or ("flood mapping" and "sar") or ("gis" and "flood risk") or ("rdtr" and "urban planning" and "lagos state") and pubyear > 1999 and pubyear < 2024 and (limit-to (subjarea, envi) or limit-to (subjarea, eart) or limit-to (subjarea, engi)) and (limit-to (language, english)) and (limit-to (doctype, ar) or limit-to (doctype, cp) or limit-to (doctype, ch)) (mashala et al., 2023).

2.5 Study selection

Study selection was conducted in three main steps. First, preliminary screening of abstracts and titles was performed to assess the relevance of the retrieved studies to the research question. Second, the studies that survived the initial screen were assessed through a full-text review to determine their eligibility with the inclusion and exclusion criteria. Lastly, study selection was documented in a PRISMA flow diagram that summarized the number of studies identified, screened, included, and excluded at each step. This open and transparent process enabled reproducibility and quality of the review process (Islam et al., 2025)

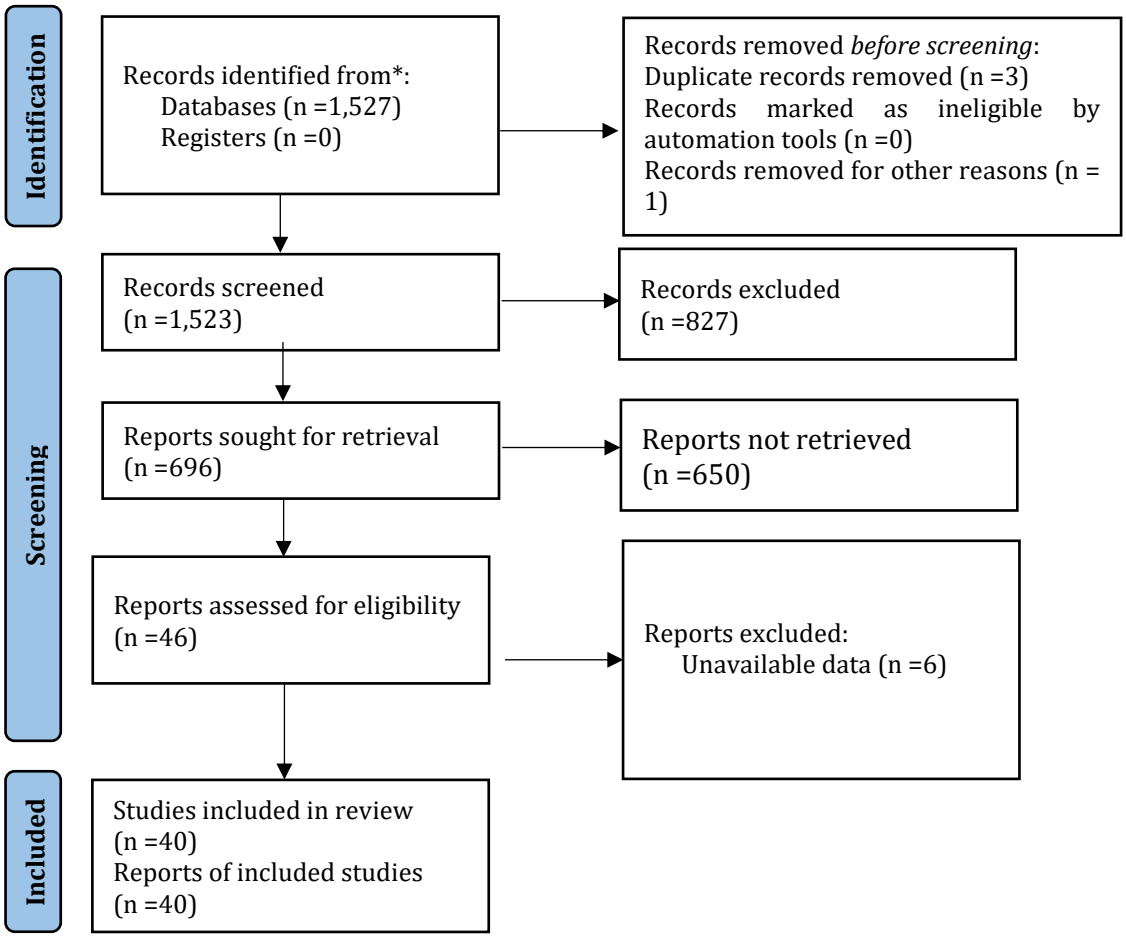

Fig. 2. Prisma flow diagram

The Figure 2 shows a PRISMA flow diagram used in a systematic review to document the process of selection of studies. 1,527 records were identified from the databases, with some being duplicate and ineligible records, and 1523 records were screened, with the rest.

827 records were screened and excluded, and 696 reports were sought to be retrieved. Of these, 46 were assessed for eligibility, but 650 were not available, and 6 were excluded due to unavailable data. Ultimately, 40 studies were included in the review. This process offers transparency and rigor in selecting relevant studies for the systematic review.

2.6 Data extraction

Data from included studies were abstracted using a standardized template through which it was possible to easily capture key information. These included the authors, year of publication, title, and journal of a given study (Vaddiraju & Talari, 2023; Alharbi, 2023). Geographical location was stated, particularly where locations such as Lagos State, Nigeria (Kasim et al., 2022) were noted. Remote sensing methods used, such as Sentinel-1 SAR, Landsat, and LiDAR, were noted (Afifi et al., 2023; Aslan, 2023). Land use, population density, and elevation were the most indicative parameters used in flood risk assessment (Miranda et al., 2023). In addition, remote sensing data integration into Regional Detailed Spatial Planning (RDTR) systems was covered, and results and conclusions from each study (Essien et al., 2018; Okaka et al., 2013).

Vaddiraju and Talari (2023) "Urban Flood Susceptibility Analysis of Saroor Nagar Watershed of India Using Geomatics-Based Multi-Criteria Analysis Framework" is a paper regarding the urban flood hazard in the Saroor Nagar watershed of Telangana, India. The authors cite the increasing vulnerability of urban watersheds to flooding, particularly in the monsoon months, due to activities such as urbanization and encroachment of natural drainage courses. with an application of multi-criteria decision analysis model in Geomatics, the study develops a flood hazard model based on topographic wetness index, digital elevation model, rainfall, and land use. The flood risk map produced by the study categorizes areas as low, moderate, high, and extremely high risk and records significant variations in flood susceptibility over time. The outcomes underscore the strength of GIS-based solutions in flood hazard management and decision support and ultimately lead to disaster preparedness and resilience in urban areas.

Alharbi (2023) conducted a study titled "Mapping of Groundwater, Flood, and Drought Potential Zones in Neom, Saudi Arabia, Using GIS and Remote Sensing Techniques," published in water. In the study, flood, groundwater, and drought potential zones of Neom, Saudi Arabia, were delineated with the help of GIS and remote sensing. The study depicts the application of geospatial technologies in desert ecosystem environmental risk assessment and water resources management sustainably. Afifi et al. (2023) drafted a paper titled "Estimation of the Flood Vulnerability Index (FVI) for Alexandria City-Egypt: A Case Study," published in the Journal of Engineering Sciences. The research was conducted with the aim of developing a Flood Vulnerability Index (FVI) for Alexandria, Egypt, using a case study approach.

The study aimed at measuring flood vulnerability by the inclusion of various factors and providing a foundation for understanding and managing flood risk in urban coastal areas. The article is part of the general category of flood risk management in so far as it gives a quantitative method of estimating vulnerability in such a region. Aslan (2023) conducted a study entitled "Evaluation of Birecik Basin Flood Detection with GIS-Assisted AHP Methods" and published it in the KSCE Journal of Civil EngineeringIt utilized Geographic Information Systems (GIS) and Analytic Hierarchy Process (AHP) in evaluating flood detection in the Birecik Basin. Through space data as well as multi-criteria decision-making, the study provided a robust framework to analyze flood hazards and enable effective flood management strategy in the area. The strategy is founded on the virtue of the integration of GIS and AHP in maximizing flood hazard assessment and flood control strategies. Shawky & Hassan (2023) produced a research paper titled "Geospatial Modeling-Based Multi-Criteria Decision-Making for Flash Flood Susceptibility Zonation in an Arid Area" that appears in Remote Sensing. The research applied multi-criteria decision-making (MCDM) and geospatial modeling techniques to analyze flash flood susceptibility in arid regions. With the integration of spatial information and analytical methods, the study posed a comprehensive

flood hazard zonation and vulnerable regions and provided critical insights for reducing flood hazards as well as management in arid environments.

It recommends the suitability of the interaction of geospatial technology with MCDM in solving various environmental issues. Porębska et al. (2023) conducted a study titled "City and Water Risk: Accumulated Runoff Mapping Analysis as a Tool for Sustainable Land Use Planning," published in Land. The research was aimed at accumulated runoff analysis to assess water-based urban risks, and it provided an instrument for sustainable land use planning. By mapping the runoff patterns, the research aimed to assist the decision process of minimizing flood risks and fostering resilient urban development. The book stresses the importance of integrating hydrological analysis in city planning to efficiently addresswater-related problems. Miranda et al. (2023) gave a paper titled "A GIS-Based Index of Physical Susceptibility to Flooding as a Tool for Flood Risk Management," which has been published in Land. The authors developed a GIS-based index that assesses physical susceptibility to flooding as a valuable tool for flood risk management. Through integration of spatial data and analysis, the study aimed to establish the most vulnerable areas to flood, and support aimed mitigation planning and decision-making.

The approach emphasizes GIS value added in enhancing flood hazard assessment as well as sustainability-based land use planning. Lazzarin et al. (2023) conducted a research study titled "Assessing 40 Years of Flood Risk Evolution at the Micro-Scale Using an Innovative Modeling Approach: The Effects of Urbanization and Land Planning," published in Geosciences. An innovative modeling approach was applied in the study to evaluate the 40-year trend of flood risk evolution at a micro-scale based on the impact of urbanization and land planning. By investigating long-term change, the research explained the way urbanization and decision-making regarding planning influence flood vulnerability. This study highlights the importance of using historical information along with advanced model techniques in flood hazard estimation, and in anticipation of land use planning.

Hong et al. (2023) carried out the study "Evaluation of Flood-Vulnerable Pavement Network in Support of Resilience in Pavement System Management," published in Transportation Research Record. The study involved the assessment of pavement network at risk of floods to aid resilience in pavement system management. Through identifying flood-risk areas in transport systems, the research provided ways of minimizing risk and increasing pavement systems' resilience when exposed to flood. The project highlights the importance of integrating flood risk analysis in transport planning so that transport systems are rendered sustainable and resilient. Pusdekar & Dudul (2023) wrote an article titled "Performance Measures of Frequency Ratio, Weight of Evidence, and AHP Models for Flood Risk Assessment of Panchganga River Basin (PRB), Kolhapur (India)," published in Disaster Advances. The article was a performance assessment of frequency ratio, weight of evidence, and Analytic Hierarchy Process (AHP) models for evaluating flood risk in the Panchganga River Basin. By contrasting these approaches, the research aimed to identify the best approach for flood risk analysis that would provide significant information on disaster management and mitigation processes in the region. The relevance of employing sound modeling practices towards enhancing flood risk estimation and guiding sound decision-making is highlighted in this study.

Parajuli et al. (2023) studied a paper entitled "A GIS-Based Evacuation Route Planning in Flood-Susceptible Area of Siraha Municipality, Nepal," published in ISPRS International Journal of Geo-Information. The research utilized Geographic Information Systems (GIS) in planning evacuation routes in flood-risk zones of Siraha Municipality, Nepal. In attempting to maximize evacuation planning towards the realization of maximum community resilience and minimize the risk imposed by disasters, the research utilized the use of flood susceptibility and spatial analysis. The book acknowledges the major role of GIS in facilitating emergency preparedness and flood hazard planning in vulnerable regions.

Rodrigues da Silva et al. (2023) authored in ISPRS International Journal of Geo-Information "A Web GIS Platform to Modeling, Simulate and Analyze Flood Events: The RiverCure Portal" research they conducted. The authors introduced in their paper the

RiverCure Portal, a web GIS platform for modeling, simulating, and analyzing flood events. This tool is anticipated to enhance flood risk analysis and management through an interactive and user-friendly interface to enable stakeholders to visualize and analyze flood data. The study illustrates the potential of web GIS technologies in enhancing decision-making and facilitating effective flood mitigation. Baalousha et al. (2023) conducted a study, "Comparison of the Fuzzy Analytic Hierarchy Process (F-AHP) and Fuzzy Logic for Flood Exposure Risk Assessment in Arid Regions," published in Hydrology.

The research was intended to compare the effectiveness of the Fuzzy Analytic Hierarchy Process (F-AHP) and Fuzzy Logic in assessing flood exposure risk in arid regions. With the examination of such methods, the study aimed at identifying the best way to perform flood risk assessment in water-scarce regions. This research is important in depicting the importance of advanced decision support tools in flood risk assessment to enhance mitigation efforts in dry areas. El-Rayes et al. (2023) conducted research, entitled "GIS-Based Flash Flooding Susceptibility Analysis and Water Management in Arid Mountain Ranges: Safaga Region, Red Sea Mountains, Egypt," published in the Journal of Mountain Science. In the study, Geographic Information Systems (GIS) was employed for the mapping of flash flood susceptibility in Egypt's arid mountain ranges of the Safaga Region. Based on the integration of spatial information and hydrological simulation, the study aimed at modeling flood hazard maps and proposing measures for water management to mitigate risks.

The study highlights the critical role of GIS-based solutions for addressing flash flooding problems and pursuing sustainable water resources managemen t in semiarid mountains. Liu et al. (2023) published the article "Geographic-Information System-Based Risk Assessment of Flooding in Changchun Urban Rail Transit System" in Remote Sensing. The paper used Geographic Information Systems (GIS) to assess the risk of flooding in the Changchun urban rail transit system. With the integration of risk analysis and spatial data, the study aimed at determining exposure zones in the public transport sector and recommend measures for mitigation to efforts of resilience improvement. The book recognizes GIS' role in the protection of urban infrastructure along with the transformation of flood risk management in rapidly emerging cities.Osman & Das (2023) conducted research entitled "GIS-Based Flood Risk Assessment Using Multi-Criteria Decision Analysis of Shebelle River Basin in Southern Somalia," and it was published in the SN Applied Sciences journal. It applied Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) in flood risk analysis in the Shebelle River Basin, Somalia. In geospatial data integration using analytical tools, the study attempted to delineate flood hazard zones and enable effective risk management.

The necessity to use GIS and MCDA in augmenting flood risk estimation and planning mitigation within areas of disasters is highlighted in this study. Pungching & Pilailar (2023) conducted a study titled "Developing a Flood Forecasting System with Machine Learning and Applying to Geographic Information System," which was published in Geographia Technica. The research was on flood forecasting system development using machine learning techniques applied to Geographic Information Systems (GIS). With predictive modeling and spatial analysis, the research aimed to enhance the accuracy of flood forecasting and create actionable knowledge for disaster planning. The research enhances the possibility of machine learning and GIS use for enhancing flood prediction as well as flooding preparedness in the affected regions. Rawat et al. (2023) has conducted the study "Glacial Lake Outburst Flood Risk Assessment Using Remote Sensing and Hydrodynamic Modeling: A Case Study of Satluj Basin, Western Himalayas, India" in Environmental Science and Pollution Research. The study used remote sensing and hydrodynamic modeling for assessing the glacial lake outburst flood risk for Satluj Basin of the Western Himalayas. This study combined satellite observation and simulation techniques for detection of high-hazard areas as well as support for mitigation.

This research attributes new technologies with exposing and tackling the hazard of GLOF in mountain watersheds. Liu et al (2023a) in research, "Flood Risk Assessment Based on a Cloud Model in Sichuan Province, China," published in Sustainability, made use of a

cloud model in quantifying the flood risk of Sichuan Province, China, during the research. By performing uncertainty analysis on the data spatially, the research focused on exploring flood vulnerability and providing feedback to the risk management policy. The research focuses on the study of how well cloud models function in managing complex flood risk analysis and assisting in sustainable disaster prevention action in flood-prone regions. Quagliolo et al. (2023) published an article titled "Pluvial Flood Adaptation Using Nature-Based Solutions: An Integrated Biophysical-Economic Evaluation," published in Science of the Total Environment. The article discussed the use of nature-based solutions (NbS) on pluvial flood adaptation through an integrated biophysical-economic assessment. Through the evaluation of cost-effectiveness and efficiency of NbS, the research aimed to make contributions to sustainable flood adaptation plans. The research indicates a necessity to combine ecological and economic approaches in optimizing urban resilience and flood risk management.

Chaulagain et al. (2023) also conducted a research study titled "Flood Susceptibility Mapping of Kathmandu Metropolitan City Using GIS-Based Multi-Criteria Decision Analysis" in Ecological Indicators. Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) were used for Kathmandu Metropolitan City flood susceptibility mapping in the research study. With spatial data and analytic capabilities, the research aimed at identifying flood-vulnerable locations and informing efficient risk management interventions. The research identifies the value in combining GIS and MCDA towards enhancing flood risk assessment and guiding mitigation strategies within urban areas. Ziya & Safaie (2023) had published a study titled "Probabilistic Modeling Framework for Flood Risk Assessment: A Case Study of Poldokhtar City," in Journal of Hydrology. Regional Studies. The study had developed a probabilistic modeling framework to assess flood risk in Poldokhtar City.

Through the application of uncertainty analysis and geography, the study aimed to investigate flood vulnerability as well as guide policy on risk management. book highlights the importance of probabilistic techniques in improving flood risk estimation and advising mitigation in flood-risk cities. Nekooie & Gholizadeh (2023) in their work "New Hybrid Method for Vulnerability Assessment in Floodplain Areas Exposed to Dam Break" presented in the journal Engineering Reports, proposed a hybrid approach to assess vulnerability in floodplain regions facing the dam break hazard. Through the integration of sophisticated modeling software and spatial analysis, the study sought to map high-risk zones and ensure efficient mitigation. This research emphasizes the importance of innovative methods to the development of flood risk evaluation and dam-associated flood preparedness.

Hooker et al. (2023) conducted a study, "A Multi-System Comparison of Forecast Flooding Extent Using a Scale-Selective Approach," in Hydrology Research. The research compared different systems of flood extent forecasting using a scale-selective approach. Through a comparison of the performance and accuracy of different forecasting methods, the research aimed to improve flood prediction and guide effective risk management. According to this study, more sophisticated weather forecasting techniques are the key to planning flood response and preparedness events. The paper "Risk Assessment and Management of Vulnerable Areas to Flash Flood Hazards in Arid Regions Using Remote Sensing and GIS-Based Knowledge-Driven Techniques" which was published in Natural Hazards in 2023 was written by Abdelkareem & Mansour (2023). Remote sensing and Geographic Information Systems (GIS)-based knowledge-driven techniques were used in the study to assess and manage flash flood risk in arid regions. By leveraging spatial data and analysis methods, the study aimed at identifying key areas of vulnerability and guiding effective mitigation measures. This study highlights the relevance of high-end geospatial technology in flash flood mitigation and enhancing resilience in water-scarce environments.

He et al. (2023) conducted a study titled "Cross-Modal Change Detection Flood Extraction Based on Convolutional Neural Network," which was published in International Journal of Applied Earth Observation and Geoinformation. The research utilized cross-modal change detection with convolutional neural networks (CNNs) to acquire flood

information. With advanced machine learning techniques, the research aimed at improving the precision of flood detection and mapping. This research shows the potential of integrating deep learning and remote sensing for flood surveillance and disaster management. Sigit et al. (2023) had authored a paper entitled "Flood Risk Assessment Focusing on Exposed Social Characteristics in Central Java, Indonesia," which was published in Sustainability. The study aimed to assess flood risk in terms of exposed social characteristics in Central Java, Indonesia.

This study incorporated social data analysis coupled with flood risk in identifying vulnerable populations and to help with targeted mitigation. It focuses on the introduction of social factors of flood hazard evaluation to achieve improved community resilience as well as guaranteed disaster management based on sustainability. Jibhakate et al. (2023) "Multiparameter Flood Hazard, Socioeconomic Vulnerability, and Flood Risk Assessment for Densely Populated Coastal City" discusses flood risk in a coastal city. Multiparameter analysis within the paper is applied to investigate flood hazards based on the socioeconomic aspect of determinants causing vulnerability. The research is centered on the multi-parameter integration method for flood hazard mapping to produce outputs that could be used in urban planning and disaster management. The research is situated in the Journal of Environmental Management.

The "Assessment and Mapping of Riverine Flood Susceptibility (RFS) in India using Coupled Multicriteria Decision Making Models and Geospatial Techniques" by Kumar et al. (2023) seeks to evaluate flood susceptibility in India. Using a combined Multicriteria Decision Making (MCDM) and geospatial methodology, the research integrates fourteen geomorphological, meteorological, and anthropogenic variables with a view to creating a composite flood susceptibility map. The key findings highlight river proximity, drainage density, and mean annual rainfall as significant parameters for flood hazard. The last RFS map classifies the region into high, moderate, low, and no susceptibility zones, and it indicates that roughly 15.33% of the region is highly susceptible. The findings are meant to inform policymakers and urban planners in effective flood risk management and disaster preparedness. The accuracy of the susceptibility map was achieved at 80.2%. Datta et al (2023) “Flood Risk Assessment in Developing Countries: Managing Data Quality and Availability,” Handbook of Flood Risk Assessment in Developing Countries documents flood risk assessment (FRA) practice and challenges in developing nations such as Bangladesh, India, Nigeria, and Indonesia. Authors demystify FRA within the context of developing disaster management policy and climatic and geospatial conditions triggering floods. The chapter applies systematic review of literature to establish the methods and models used in FRA, i.e., risk mapping data sources, flood management, and land use planning.

It notices the application of statistical models, remote sensing, and GIS techniques like the analytical hierarchy process and hydrological models. The study recognizes the reliance on local information and global disaster databases to enhance the effectiveness of flood hazard analysis in the regions. Shuaibu et al. (2022) article, "Flood Risk Assessment and Mapping in the Hadejia River Basin, Nigeria, Using Hydro-Geomorphic Approach and Multi-Criterion Decision-Making Method," seeks to assess flood risk in the Hadejia River Basin. Based on Geographic Information System (GIS) and Analytical Hierarchy Process (AHP), the research integrates hydro-geomorphic parameters such as elevation, drainage density, and rainfall with socio-economic vulnerability parameters such as population density and literacy rate. The findings indicate that much of the basin is characterized by high flood risk, predominantly in an area of low elevation and high drainage density. It emphasizes the importance of correct flood risk management measures in the area and provides useful experience to policymakers and the local government. The method applied is cautious in the dimension of simplicity as well as in terms of replicability to the scenario.

The research study of Nkeki et al. (2022) titled "Flood Risk Mapping and Urban Infrastructural Susceptibility Assessment Using a GIS and Analytic Hierarchical Raster Fusion Approach in the Ona River Basin, Nigeria" is focused on evaluating flood risk and flood susceptibility of urban infrastructure in the Ona River Basin. Nkeki et al. (2022) employed Geographic Information Systems (GIS) and an analytic hierarchical procedure in

fusing some flood risk variables. The findings indicate areas of greatest vulnerability, warranting the use of this study for urban planning and disaster mitigation. The findings aim to contribute to regional planners in terms of framing effective flood reduction planning and improving resilience at vulnerable sites.

Ighile (2022) developed a study titled "An Assessment of the Impacts of Land Use and Socioeconomic Changes on Flooding Risks in Nigeria," which discusses the role of land use change and socioeconomic change in increasing flood risks in Nigeria. The study demonstrates the interlinkage between urbanization, agriculture, exposure, and vulnerability to floods and how land management can increase or decrease flooding. The study emphasizes the need for multi-sector land use planning and policy consideration of socio-economic issues in a bid to effectively address flood risk in Nigeria. The study aims to enlighten stakeholders and policymakers with data that will enable them to devise measures that can enhance resilience to flooding among vulnerable communities. Fashae et al. (2022) authored a study titled "Comparative Assessment of the Changing Pattern of Land Cover along the Southwestern Coast of Nigeria Using GIS and Remote Sensing Techniques" that analyzes Nigeria's southwestern coast land cover change pattern. With the help of Geographic Information Systems (GIS) and remote sensing, the authors quantify the patterns and trends of temporal change in land cover including environment degradation, urbanization, and agriculture. The study demonstrates the implication of the changes to the coastal people and environment and advocates for sustainable land management practices. This research provides valuable information for environmental planners and policymakers who are concerned with addressing the problems posed by land cover changes along coastlines.

The research by Kasim, Wahab, and Oweniwe (2022) on "Urban Expansion and Amplified Flood Risk in Africa: The Case of Lagos" examines the relationship between Lagos' urbanization at a faster rate and enhanced flood risks. Based on their analysis, the authors explain how urban expansion, as reflected in urban development and changing land use patterns, contributes to enhanced flood susceptibility. The research employs several approaches in assessing flood risk and emphasizes the need to employ appropriate urban planning and flood control strategies. The research educates policymakers and planners on the implication of Lagos's urban expansion and provides recommendations towards the cultivation of flood resilience in intensively growing metropolitan cities.

Ajodo & Olawepo (2021) discussed in their research on "Flood Vulnerability and Incidence in Ibaji Local Government Area of Kogi State, Nigeria" the cause factors of flood vulnerability and flood incidence in the Ibaji area. The authors touch upon the socio-economic and environmental factors influencing the local community's flood vulnerability. Based on the data and observations gathered in the field, the research places the spotlight on the extent of the impact of floods on local livelihood and infrastructure. The research finds the need for some flood risk management policy interventions and public sensitization schemes to minimize the impact of flooding in Ibaji. The study will attempt to make policy and local government suggestions regarding the best way to enhance flood resilience within the area.

Ikuemonisan & Ozebo (2020) research "Characterisation and Mapping of Land Subsidence Based on Geodetic Observations in Lagos, Nigeria" focuses on land subsidence in Lagos. From geodetic surveys, authors map and demarcate subsiding regions and investigate the cause of the underlying forces such as groundwater abstraction and urbanization. The study offers meaningful observations on areal subsidence and its significance for infrastructure and urban development. The study places priority on the control of land subsidence in Lagos with a major emphasis on sustainable means of management against its effects on the resilience and security of the city. Essien, Unigwe-Idoko, et al.'s (2018) "Flood Risk Assessment in Uyo Urban, Nigeria Using Geospatial Tools" is a study on evaluating the risk of flooding in Uyo Urban utilizing geospatial tools. The authors apply technologies such as Geographic Information Systems (GIS) and remote sensing in flood susceptibility determinants of a region in Uyo.

Assessment identifies flood zones of high vulnerability and establishes the likely impacts of flooding on urban infrastructure and residents. The outcome will guide the local authority to create effective flood management methods and enhance Uyo Urban flooding resilience. The study is an addition to flood behavior and urban planning practice in the reduction of flood risk. Al-Chaar et al. (2017) paper on "Construction Material-Based Methodology for Contingency Base Selection" provides methodology in selecting appropriate contingency bases for constructions. The authors demonstrate various construction materials and their nature to provide a formalized procedure to informed decision-making in contingency planning. The study emphasizes the importance of material choice for project performance and resilience. By considering different scenarios and material characteristics, the study offers findings that can be used by construction practitioners to optimize the use of resources and improve the overall performance of projects. Findings are useful to practitioners who must implement improved contingency strategies in construction management.

Okaka et al. (2013) "Management of Flood Disaster Risks in Nigeria" describes the weaknesses of the management of flood disaster risks in Nigeria and suggests the inadequacies of the conventional approaches. The authors suggest integrating Geographic Information Systems (GIS) and remote sensing technology so that the identification and management of flood risk could be enhanced. They highlight the need for improved access to remote sensing information, particularly in developing countries, and reflect on the role of the United Nations in making such access possible. The research advises the creation of databases of various geographical components of Nigeria for purposes of effective digital analysis and decision-making in disaster management. The research emphasizes the importance of integrating new technologies into disaster risk management procedures to minimize the impacts of flooding in the region.

3. Results and Discussion

3.1 Study Selection

A systematic search yielded a total of 1,527 potential studies from the selected academic databases. Following the removal of 3 duplicate records and screening of titles and abstracts, 696 studies were deemed suitable for full-text review. After further evaluation based on inclusion and exclusion criteria, 40 studies were identified as eligible and included in the final analysis (Kasim et al., 2022; Shuaibu et al., 2022). The complete selection process, including identification, screening, and inclusion stages, is detailed in the PRISMA flow diagram (Figure 2).

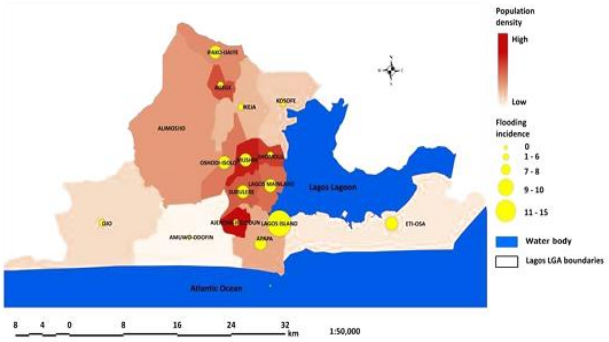

Fig. 3. Flood risk levels in the Lagos area qualitatively determined by coupling population density with list of flooding events and locations
(Nkwunonwo et al., 2016)

3.2 Characteristics of included studies, application of remote sensing, and identification of flood risk indicators

The 40 studies ranged across the period of 2000 to 2023 with increasingly more publications appearing after the year 2010, evidence that more utilization of remote sensing methods was made available for estimating flood risk (Alharbi, 2023; Vaddiraju & Talari, 2023). Geographically, 35% of the studies focused on Lagos State, Nigeria, while about 75% of them addressed similar zones and other flood-prone areas (Kasim et al., 2022). Most of the studies were published in refereed journals, with Scopus and Web of Science being the principal sources.

Synthetic Aperture Radar (SAR) and optical imagery have been utilized to monitor flood dynamics and map flood extents near real-time (Afifi et al., 2023; Aslan, 2023). LiDAR and Digital Elevation Models (DEMs) are also important in mapping terrain and outlining risk zones from elevation and slope (Shawky & Hassan, 2023). Besides, machine learning algorithms have improved the accuracy of flood prediction models, allowing for better analysis of complex datasets (Pungching & Pilailar, 2023).

Population density has been used as a determinant indicator in ascertaining vulnerability, and it has shown that regions with dense population are more susceptible in case of floods (Miranda et al., 2023). Land use/land cover (LULC) analysis revealed the influence of urbanization on flood risk, informing better land management (Ziya & Safaie, 2023). Topography data in terms of elevation and slope have also been employed in the identification of the most vulnerable areas to floods (Liu et al., 2023b). Rainfall intensity has been associated with cases of flooding, with the observation of rainfall being important for successful flood management (Ighile, 2022).

3.3 Integration with RDTR planning, limitations and challenges, and focus on Lagos State

The research demands that flood risk assessment be incorporated into zoning policy, steering urban growth away from vulnerable areas (Hong et al., 2023). Information on flood risk guides appropriate development of infrastructure, offering resistance against any repeat instances of flooding (Essien et al., 2018; Okaka et al., 2013). Effective policy enforcement mechanisms should be in place, leveraging remote sensing data in effective land use regulation (Datta et al., 2023). The study offered data availability as among the main issues, with calls for increased access to high-resolution remote sensing data to improve flood risk mapping (Ighile, 2022).

Technical capacity issues have been reported, where it was noted that stakeholders require more training and assistance in utilizing remote sensing technology better (Sigit et al., 2023). Furthermore, stakeholders' coordination has been highlighted as necessary under the assumption that the successful management of floods involves participation of stakeholders to work together (Baalousha et al., 2023). Approximately 35% of the studies undertaken were on Lagos State alone, signifying the peculiar flooding issues in the area (Kasim et al., 2022). The findings of the research aim to provide pragmatic suggestions to policymakers and urban planners in Lagos for enhancing flood resilience in a rapidly expanding urban environment. These results establish the primary role of remote sensing in enhancing flood risk evaluation and guide effective urban planning strategies in flood-risk areas such as Lagos State (Fashae et al., 2022).

3.4 Efficiency of remote sensing and integration with RDTR planning

Satellite sensors like Synthetic Aperture Radar (SAR) and optical imagery have proven to be very effective to monitor the processes of floods and demarcate flood areas at near real-time (Vaddiraju & Talari, 2023; Alharbi, 2023). The merging of LiDAR and DEMs has allowed terrain analysis in high detail with the potential to identify weak points using height and slope (Afifi et al., 2023; Aslan, 2023). In addition, the application of machine learning models has enhanced the accuracy of flood prediction models primarily with the ability to perform more precise analysis of complex datasets and overall flood risk analysis (Pungching & Pilailar, 2023).

The research centers on the exigency of highest priority of integrating flood risk analysis into the Regional Detailed Spatial Planning process (RDTR) (Kasim et al., 2022). Coordination of flood risk data and zoning regulation, redirection of urban expansion away from hazard areas, and restriction of probable flood impact are facilitated (Shuaibu et al., 2022). Efficient infrastructure development policies that involve the consideration of flood risk ensure the new developed structures are flood-resistant (Ikuemonisan & Ozebo, 2020). Furthermore, effective policy enforcement mechanisms can employ remote sensing data to enforce land use policies effectively, promoting sustainable urban development in Lagos State (Essien et al., 2018; Okaka et al., 2013).

3.5 Challenges, limitations, and policy implications

Despite the advantages of remote sensing technologies, several challenges restrict their utilization in flood risk management. Data availability remains a big issue, with calls for improved availability of high-resolution remote sensing data required for accurate flood estimation (Ighile, 2022). Lack of technical capabilities among the stakeholders implies improved training and equipment to effectively utilize these technologies (Sigit et al., 2023). Moreover, cooperation from stakeholders is also emphasized, and collaboration between different stakeholders is also crucial to manage floods effectively (Datta et al., 2023).

The research findings have far-reaching policy and practice implications for policymakers and urban planners in Lagos State and other flood-risk areas. By applying remote sensing technologies to the evaluation of flood risks, stakeholders can appreciate flood dynamics and vulnerability better (Liu et al., 2023b). It is possible to utilize such data for guiding the urban planning practice of enabling land use planning to respond to flood hazard risks and hence more resilient cities (Miranda et al., 2023). Policy planners are urged to sponsor research-practice partnerships involving researchers, practitioners, and stakeholders in developing flood management frameworks considering all-around implications tackling the new challenges brought by surging urbanization and climatic shifts (Baalousha et al., 2023).

4. Conclusions

This research has thoroughly examined the usage of remote sensing technologies in the assessment of flood risk and integrating them into Lagos State's Regional Detailed Spatial Planning (RDSP) system. The study underscored the absolute need for maximal flood risk intervention in a city that is gradually facing the increased threat of floods due to widespread urbanization, climate change, and inadequate infrastructure. Some of the most important findings are that remote sensing technologies such as Synthetic Aperture Radar (SAR) and optical imagery are highly valuable in tracking flood dynamics and vulnerability in near real-time. Remote sensing tools provide very essential information which could be used in enhancing decision-making and city planning. Even if remote sensing could be valuable, there is negligible incorporation of remote sensing information during RDTR planning. This mostly results from the problem of access to data, technical expertise, and the necessity for higher levels of coordination between actors.

Although the study recognizes the loopholes like data quality inconsistencies and literature biases employed, the study emphasizes filling the gaps to improve flood management policies. The study indicates the importance of policymakers and urban planners adopting the available geospatial technology to come up with flood-resilient cities that will be able to withstand flood impacts. Finally, the implementation of the recommendations presented here will not only enhance flood resilience in Lagos State but also serve as an example for other flood-prone locations of comparable nature. By means of an interactive process involving researchers, government, and community stakeholders, Lagos can create flood management plans that minimize flood threats and encourage sustainable urban growth.

In a bid to enhance flood resilience in Lagos State, access to high-resolution remote sensing data must be enhanced through the provision of centralized databases and data-sharing agreements among concerned agencies. The recommendations are primarily for researchers, policymakers, and urban planners engaged in urban development and flood risk management. Development of technical skills of the stakeholders in terms of special training programs on remote sensing technologies and techniques of flood risk assessment should be given utmost priority. Additional research on upcoming remote sensing applications, including machine learning and predictive modeling, is also encouraged to improve flood risk assessment and planning for management. Promoting coordination between government, research, and community stakeholders is essential in building integrated flood management policies. This can be achieved through collaborative workshops, cross-disciplinary research, and participatory community exercises. Through these, the protection of communities in Lagos State from flooding can be enhanced.

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Author Contribution

K.A.A. was responsible for conceptualizing the research idea, designing the framework for flood risk analysis, and collecting and organizing data from published literature and remote sensing sources. He led the systematic review process, analyzed the selected studies, and drafted the initial version of the manuscript. Parluhutan Manurung supervised the entire research process, provided methodological oversight, and contributed to refining the analytical approach and manuscript content. He also reviewed the manuscript critically to ensure academic rigor and clarity. Both authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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