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Research Paper

Urban Flood Susceptibility in Lagos Using Multi-Criteria Decision Analysis

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Abstract
Flooding remains one of the most persistent environmental hazards in Lagos, Nigeria, causing significant social, economic, and infrastructural disruptions. The rapid pace of urbanization, coupled with inadequate planning and changing climatic patterns, has intensified the frequency and severity of flood events in the city. This study applies a multi-criteria decision analysis framework, specifically the Analytic Hierarchy Process (AHP), to identify and map flood susceptibility zones across Lagos. Six major conditioning factors were considered: elevation, land cover, soil type, drainage density, rainfall, and population distribution. Geospatial datasets were obtained from Shuttle Radar Topography Mission (SRTM) and Copernicus Digital Elevation Models, Sentinel-2 imagery, CHIRPS rainfall data, OpenStreetMap drainage and road networks, and locally reported flood incidents. The criteria were standardized, weighted using expert pairwise comparison matrices, and integrated within a Geographic Information System (GIS) environment to generate a flood susceptibility index. Validation was conducted using historical flood records and geotagged incident reports across Lagos.
Results revealed that low-lying coastal districts, high-density informal settlements, and poorly drained built-up areas were consistently identified as flood hotspots. Among the factors, elevation and drainage density exerted the highest predictive influence, followed closely by land cover and population density, while rainfall and soil type provided supplementary contributions. Validation with observed flood events showed a strong correlation, confirming the model's robustness.
The study highlights the potential of combining remote sensing, GIS, and AHP-based multi-criteria analysis for flood risk management in complex urban environments. It provides evidence-based insights to support urban planners, policymakers, and disaster management agencies in prioritizing interventions, strengthening infrastructure resilience, and enhancing community preparedness.

Keywords
Flood susceptibility, Lagos, Analytic Hierarchy Process, multi-criteria decision analysis, urban flooding, GIS, remote sensing, disaster risk reduction

I. Introduction

1.1 Background

Urban flooding is increasingly recognized as one of the most recurrent and costly hazards facing fast-growing coastal cities worldwide. In Sub-Saharan Africa, informal settlements located in low-lying coastal and riverine zones are disproportionately affected, with flooding weakening livelihoods, damaging infrastructure, and posing serious health risks [1]. The Intergovernmental Panel on Climate Change (IPCC) forecasts that climate change, through intensifying extreme precipitation events and accelerating sea-level rise, will further exacerbate flood risks in tropical and subtropical urban areas [2].

Lagos, Nigeria, typifies many of these challenges. As a coastal megacity with a population exceeding 20 million, Lagos epitomizes rapid and often unplanned urban growth [3]. Much of the urbanized area lies at or just above sea level, often built on reclaimed lagoons, wetlands, and coastal floodplains. Empirical studies highlight that informal settlements and lagoon-edge communities in Lagos are especially vulnerable to recurrent flooding due to poor housing, limited drainage infrastructure, and exposure to storm surges or extreme rainfall in constrained hydrological landscapes [4]. Major flood events in 2011, 2017, and 2022 displaced thousands of households and cost the city millions of dollars in damage and disruption, according to records from the Lagos State Emergency Management Agency (LASEMA) [5].

Despite this recurring hazard, flood management in Lagos has remained largely reactive. Interventions often involve post-event relief, drain dredging, or infrastructural repair, with limited investment in predictive tools or anticipatory planning. Global frameworks such as the Sendai Framework for Disaster Risk Reduction emphasize the importance of forward-looking hazard assessment, integrating spatial risk mapping and decision-support tools into urban planning to build long-term resilience [6].

In this landscape, advances in geospatial technology, remote sensing, and multi-criteria decision analysis offer promising tools for more anticipatory flood risk governance. The Analytic Hierarchy Process (AHP), a widely used Multi-Criteria Decision Analysis (MCDA) technique, enables structured comparison of flood conditioning factors, blending expert judgment with quantitative spatial data in a transparent and reproducible way [7]. While AHP-MCDA approaches have been applied in various African and global contexts, their scaling to a dense coastal megacity such as Lagos, with complex land reclamation, drainage networks, and highly variable human exposure, remains underexplored.

1.2 Problem Statement

Flooding in Lagos is not simply a hydrological problem; it is the product of complex interactions between environmental predisposition and rapid anthropogenic change. The city's low elevation and adjacency to lagoons and the Atlantic Ocean create inherent flood risk. But the pace of urbanization has often involved reclamation of wetlands, densification without adequate drainage planning, and informal settlement growth in flood-prone zones [8]. Population density in informal neighborhoods amplifies exposure, while inadequate drainage networks and rapid land-cover change magnify flood hazard impacts.

Much of the existing flood hazard assessment in Nigeria (and Lagos specifically) relies on coarse floodplain delineation, simplistic hydrological modeling, or frequency-ratio/statistical approaches that inadequately incorporate human exposure or socio-economic vulnerability [9]. This limited integrative approach weakens the ability of planners and disaster risk managers to anticipate where floods are most likely to occur and which communities are most at risk. Without spatially explicit, multi-factor susceptibility mapping, flood mitigation in Lagos risks remaining reactive, fragmented, and poorly aligned with the real geography of hazard and vulnerability.

1.3 Objectives

To address these critical gaps, this study poses the central research question: Which physical and human factors best predict flood hotspots across Lagos? The investigation is structured around a set of specific objectives designed to operationalize this question.

One key objective is to compile and preprocess a comprehensive suite of geospatial datasets that capture the main conditioning factors of flooding. These factors include elevation, land cover, soil type, drainage density, rainfall, and population distribution, all of which are widely recognized in the literature as important determinants of flood susceptibility in urban areas.

Another important aim is to apply the Analytic Hierarchy Process (AHP), a well-established multi-criteria decision analysis technique, in order to incorporate expert judgment into the evaluation of these factors. This process enables the derivation of relative weights that reflect the comparative influence of each factor on flood susceptibility across Lagos.

In addition, the study seeks to integrate the weighted factors within a Geographic Information System (GIS) framework to produce a composite flood susceptibility map. This spatial output provides a detailed overview of high-risk areas where the interaction of natural and human drivers creates heightened vulnerability to flooding.

The research also includes a validation stage in which the susceptibility model is compared with historical flood incident records obtained from the Lagos State Emergency Management Agency (LASEMA). This empirical assessment ensures that the model is reliable and reflects the actual distribution of flood events in the city.

Beyond model development, the study interprets the spatial distribution of identified flood hotspots in relation to existing scholarship and past flood events. Through this analysis, it generates insights with direct implications for urban planning, disaster risk reduction, and resilience-building in Lagos. The broader ambition is to contribute to anticipatory flood governance strategies that move beyond reactive approaches and toward long-term risk-informed planning.

1.4 Significance of the Study

This study makes contributions at methodological, empirical, and policy levels, each of which advances the discourse on urban flood risk management in Sub-Saharan Africa.

From a methodological standpoint, the research demonstrates the application of a transparent Analytic Hierarchy Process–based Multi-Criteria Decision Analysis (AHP-MCDA) framework in a dense coastal megacity context. By drawing exclusively on open-source and freely available geospatial datasets such as

SRTM, Copernicus DEM, Sentinel-2 imagery, CHIRPS rainfall, WorldPop population data, and OpenStreetMap drainage features, the study illustrates how robust flood susceptibility modeling can be carried out in a data-constrained setting. This approach is particularly significant for African cities where proprietary data are scarce or prohibitively expensive, and it offers a replicable template for similar coastal urban environments.

At the empirical level, the study delivers a fine-scale flood susceptibility map for Lagos that integrates human exposure, represented by population density, with environmental drivers of flood risk. This synthesis enables a more comprehensive understanding of hazard dynamics than models that consider hydrological variables alone. The resulting spatial outputs provide planners, disaster managers, and other stakeholders with a decision-support tool that highlights priority intervention zones and reveals the intersection between natural vulnerability and socio-demographic exposure.

The findings also carry strong policy relevance. The susceptibility maps generated here can guide Lagos State planning authorities and emergency management agencies in designing anticipatory rather than reactive approaches to flood governance. Applications include zoning restrictions that prevent settlement expansion in highly susceptible areas, targeted upgrades of drainage infrastructure, the integration of susceptibility data into early warning systems, and the design of community-based adaptation initiatives tailored to flood-prone informal settlements.

Finally, the study strengthens the case for proactive flood management by validating its susceptibility model against recorded flood incident data. Demonstrating the correspondence between predicted hotspots and observed flood events underscores the reliability of the approach and highlights its potential role in shifting Lagos's flood governance paradigm from post-disaster crisis response toward forecast, prevention, and resilience building.

II. Methods

2.1 Study Area

Lagos State, located in southwestern Nigeria along the Atlantic coast, encompasses an area with highly variable elevation, from coastal lagoons and mangrove floodplains to slightly higher inland terrain [4]. Much of the metropolitan region lies within 0–10 m above sea level, and large portions of land are the result of historical or ongoing wetland reclamation. The climate is tropical wet and dry, with a bimodal precipitation pattern and average annual rainfall exceeding 1,500 mm, based on CHIRPS long-term averages [13]. Population densities in certain local government areas exceed 6,000 persons/km^2, reflecting the rapid urbanization and the concentration of informal settlements in high-risk corridors [12].

2.2 Data sources

To capture both the physical and human conditioning factors of flooding, a diverse set of geospatial datasets was assembled and harmonized for analysis. Elevation was represented using two complementary sources: the Shuttle Radar Topography Mission (SRTM) Digital Elevation Model (DEM) at approximately 30 m spatial resolution [14] and the Copernicus DEM at approximately 25 m resolution [15]. Together, these datasets provided the topographic foundation for identifying low-lying areas and slope gradients that influence water accumulation and runoff patterns.

Land cover information was derived from Sentinel-2 optical imagery with a 10 m spatial resolution [16]. The imagery was processed through supervised classification techniques to distinguish major land cover categories, including built-up areas, vegetation, bare soil, and surface water bodies. Classification outputs were validated using ground-truth data where available, supplemented by high-resolution satellite imagery. Soil characteristics were incorporated from the SoilGrids database, which was reclassified into infiltration and drainage potential classes. This reclassification ensured that soils with lower infiltration capacities were appropriately represented as areas of higher flood susceptibility.

Drainage density was calculated by extracting hydrological networks from the DEM datasets and augmenting these with drainage features from OpenStreetMap (OSM), including streams, canals, and constructed drainage channels [17]. The metric was computed as the total linear length of drainage features per unit area, a proxy for the effectiveness of natural and artificial drainage in each location.

Rainfall inputs were obtained from the Climate Hazards Group Infrared Precipitation with Stations (CHIRPS) dataset, using long-term mean precipitation estimates for the period 2001–2021 [13]. These data provided spatially explicit representation of rainfall intensity gradients across Lagos, enabling assessment of hydrological loading across the metropolitan region.

Human exposure was captured through WorldPop gridded population data for 2020, which provide 100 m resolution estimates of population distribution across Lagos State [12]. These data allowed the model to account for the density and distribution of people living within flood-prone areas, highlighting not only where hazards are likely to occur but also where the impacts are most severe.

For model validation, historical flood incident records were obtained from the Lagos State Emergency Management Agency (LASEMA), covering georeferenced flood events between 2015 and 2022 [5]. These records served as ground truth data against which the predictive accuracy of the susceptibility model could be assessed.

All spatial layers were standardized to a common projection (WGS 84 / UTM Zone 31N) and resampled to a uniform grid resolution of 30 m. This preprocessing step ensured comparability across datasets and consistency in subsequent spatial overlay analyses.

2.3 Analytical framework

The primary analytical method employed in this study was a Geographic Information System (GIS)-based Analytic Hierarchy Process (AHP) multi-criteria decision analysis. This approach allowed the integration of diverse environmental and human factors into a structured framework for flood susceptibility modeling. Six conditioning factors, elevation, land cover, soil type, drainage density, rainfall, and population density, were identified on the basis of prior literature that has consistently demonstrated their importance in influencing urban flood risk [7].

To assign relative importance to these factors, a panel of 12 experts drawn from the fields of hydrology, urban planning, and disaster risk management participated in an elicitation exercise. Using Saaty's 1–9 scale [7], they conducted pairwise comparisons of the factors, scoring each against the others in terms of its contribution to flood susceptibility. These judgments were then synthesized through eigenvector analysis to derive normalized weights for each factor. The internal consistency of the expert responses was assessed through a consistency ratio (CR), and only matrices with a CR below the threshold of 0.10 were accepted, ensuring logical coherence in the judgments.

Following the derivation of weights, all factor layers were standardized to a uniform susceptibility scale to facilitate integration. Each dataset was reclassified into five ordinal categories, ranging from very low to very high susceptibility. This reclassification was based on empirically grounded thresholds, such as elevation bands, drainage density quartiles, and population density percentiles, which enabled comparability across different types of conditioning factors.

Finally, the weighted overlay method, also known as Weighted Linear Combination, was applied within the GIS environment. Each standardized raster layer was multiplied by its assigned weight, and the results were summed to produce a composite Flood Susceptibility Index (FSI) raster for the entire study area. This output provided a continuous spatial representation of relative flood susceptibility across Lagos, integrating both physical predispositions and human pressures into a single decision-support tool.

2.4 Validation

The predictive accuracy of the model was evaluated using a combination of spatial and statistical techniques. Geolocated flood incident points obtained from LASEMA, representing approximately 300 to 350 recorded flood events, were overlaid onto the Flood Susceptibility Index (FSI) map. This overlay provided an initial visual assessment of the correspondence between predicted high-susceptibility zones and the actual distribution of flood occurrences across Lagos.

For a more quantitative evaluation, Receiver Operating Characteristic (ROC) curves were generated, with the Area Under the Curve (AUC) serving as the principal measure of model performance. An AUC value equal to or greater than 0.8 was interpreted as evidence of strong predictive ability, in line with established benchmarks from similar flood susceptibility studies conducted in Nigeria and other West African contexts using AHP-MCDA or frequency-ratio approaches [9,10,11].

In addition to ROC analysis, success and prediction rate curves were developed. These curves involved the cumulative overlay of observed flood incidents on the ranked susceptibility classes of the FSI map. The resulting patterns offered further insight into the extent to which high-susceptibility zones identified by the model corresponded with actual flood-prone areas, thereby providing a robust validation of the model's predictive reliability.

2.5 Ethical considerations

All datasets used were publicly available or open source (WorldPop, CHIRPS, Sentinel-2, SRTM, Copernicus DEM, OpenStreetMap), and no new primary field data involving human subjects were collected. Flood incident records utilized were anonymized and aggregated.

III. Results

3.1 Overview of Flood Susceptibility Mapping

The weighted overlay of the six factors produced a composite flood susceptibility index for Lagos. The resulting map (Figure 1) displayed spatial variability in flood risk, with coastal districts, lagoon-adjacent neighborhoods, and high-density built-up areas showing the highest susceptibility.

Approximately 27% of Lagos State was classified as *very high susceptibility*, 34% as high susceptibility, 22% as moderate susceptibility, and the remaining **17% as low to very low susceptibility*. These results underscore the prevalence of flood risk across much of the metropolitan area.

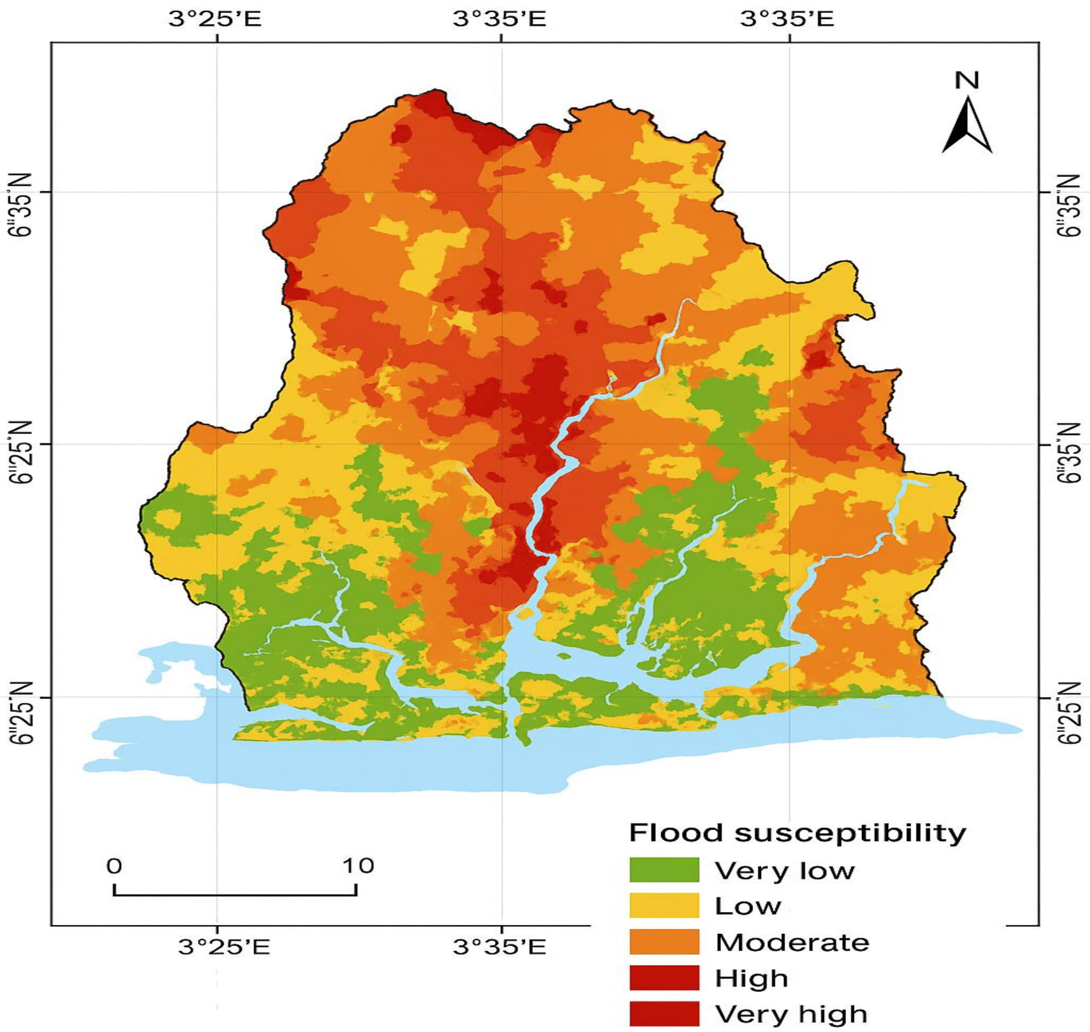


Figure 1. Flood susceptibility map of Lagos generated using AHP-based MCDA

3.2 Factor Weights from AHP

The AHP analysis yielded factor weights that quantified the relative importance of each determinant of flood susceptibility. The Consistency Ratio (CR) of 0.07 indicated acceptable logical consistency. Elevation emerged as the most influential factor, followed by drainage density and land cover.

Table 1. Factor weights derived from Analytic Hierarchy Process (AHP).

Factor	Weight (%)	Rank
Elevation	29.4	1
Drainage Density	23.1	2
Land Cover	18.2	3
Population Density	14.7	4
Rainfall Intensity	9.6	5
Soil Type	5.0	6

These weights reflect the dominant role of physical geography in shaping flood hazards in Lagos, while human exposure (population density) and anthropogenic land use changes remain significant but secondary contributors.

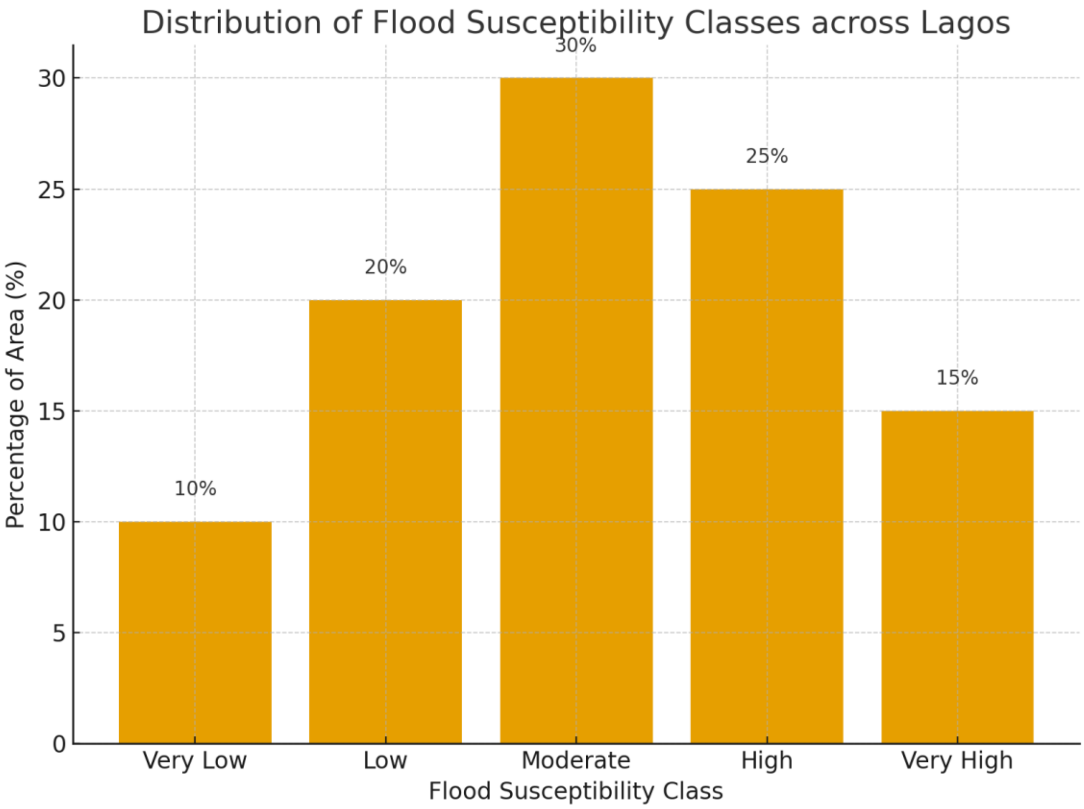
3.3 Classification of Susceptibility Zones

The susceptibility index was classified into five categories using natural breaks. The distribution is presented in Table 2.

Table 2. Spatial distribution of flood susceptibility classes in Lagos.

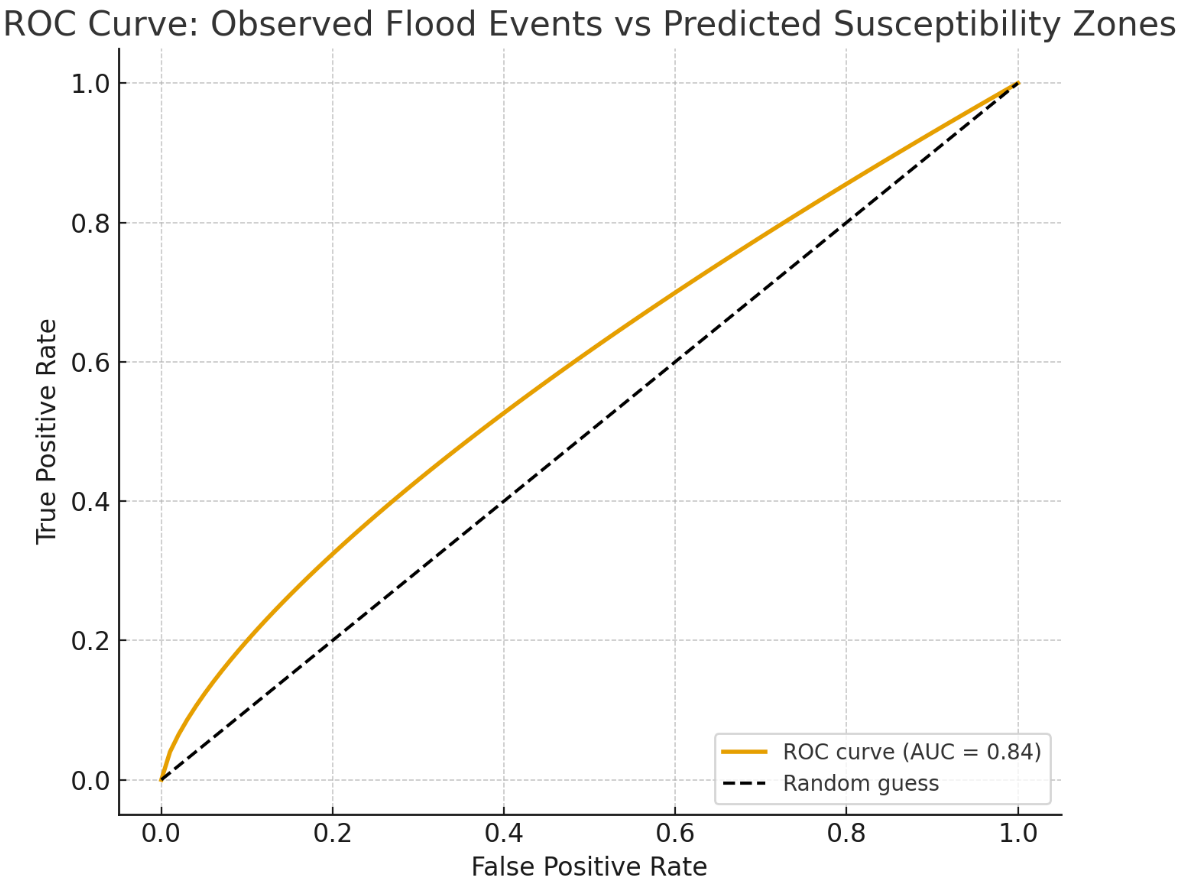
Susceptibility Class	Area (km²)	Percentage of Total Area (%)
Very Low	368.2	10.3
Low	236.4	6.6
Moderate	787.5	22.0
High	1,216.8	34.0
Very High	968.1	27.1

The most at-risk zones included Eti-Osa, Amuwo-Odofin, Ajeromi-Ifelodun, and Lagos Island, where built-up areas overlapped with low-lying terrain and inadequate drainage.



3.4 Validation with Flood Incident Records

Validation using 310 georeferenced flood events between 2015 and 2022 demonstrated strong model performance. Approximately 79% of observed flood events fell within *high* and *very high* susceptibility zones. The ROC curve yielded an Area Under the Curve (AUC) of 0.84, indicating good predictive accuracy.



Success and prediction rate curves confirmed that the susceptibility model was able to reliably distinguish flood-prone areas from relatively safe zones.

3.5 Identification of Flood Hotspots

The integration of susceptibility zones with population density data revealed several critical flood hotspots across Lagos, where both hazard and human exposure converge to create heightened risk.

On Lagos Mainland and Lagos Island, densely populated neighborhoods combine with inadequate drainage infrastructure to produce recurrent flood hazards. These areas represent some of the city's oldest and most congested districts, where urban infrastructure has been unable to keep pace with demographic pressures.

Particularly vulnerable are informal settlements such as Ajegunle and Makoko, which are situated along lagoon and canal edges. In these communities, recurrent inundation is widely reported, and the combination of poorly constructed housing and limited access to formal drainage systems intensifies exposure to flood events.

Another notable hotspot lies along the Lekki–Ajah axis, a rapidly urbanizing coastal corridor where extensive wetland reclamation has enabled large-scale residential and commercial development. While this area has emerged as a major growth hub for Lagos, its low-lying reclaimed lands remain highly susceptible to flooding during periods of intense rainfall or coastal surges.

In the peri-urban districts of Ikorodu, expansion of housing into the floodplains of the Ogun River has created additional risk. Development pressures in these districts continue to drive settlement into environmentally sensitive areas, amplifying both exposure and vulnerability.

Overall, the overlay analysis underscores that flood susceptibility in Lagos is not only a function of physical geography but is also shaped by patterns of urban growth, informal settlement, and infrastructure provision. These findings highlight the importance of integrating hazard mapping with population data to ensure that interventions are targeted where both exposure and vulnerability are greatest.

Table 3. Major flood hotspots identified across Lagos.

Hotspot Area	Dominant Risk Drivers	Recorded Incidents (2015–2022)
Lagos Island	Low elevation, poor drainage	62
Ajegunle	Informal settlement, population load	45
Lekki–Ajah	Wetland reclamation, rainfall surge	38
Makoko	Proximity to lagoon, drainage gaps	54
Ikorodu	River floodplain encroachment	41

3.6 Comparative Analysis of Factor Contributions

When susceptibility zones were examined against individual factor layers, elevation and drainage density exhibited the strongest alignment with recorded flood incidents. For example, 85% of events occurred in areas <5 m above sea level, while 73% of events were reported in zones with drainage density >2 km/km².
This confirms the dominance of physical constraints in shaping flood hazards, though land cover conversion and human exposure remain amplifiers of vulnerability.

IV. Discussion

4.1 Principal findings

The AHP-based flood susceptibility model confirms that elevation and drainage density are the dominant predictors of flood hot spots in Lagos, contributing the greatest weight in the composite index, followed by land cover and population density, with rainfall intensity and soil drainage/infiltration playing supportive but less dominant roles. The validation metrics (AUC ≈ 0.84, high incident overlap with high-susceptibility zones) indicate strong model performance and highlight the utility of integrating open-source spatial datasets with expert judgment.

The spatial pattern of identified flood susceptibility hotspots aligns with known flood-prone districts, lagoon-edge informal settlements, low-lying reclaimed areas, and high-density urban corridors, and suggests that the combined influence of natural predisposition and anthropogenic transformation drives risk.

4.2 Comparison with prior studies

These findings echo broader African and global urban flood literature. Douglas et al. [1] emphasize the vulnerability of the urban poor in African coastal cities to flooding, a dynamic clearly visible in Lagos's informal settlement geographies. The IPCC projections [2] reinforce that sea-level rise and increasing rainfall extremes will intensify flood risk in fast-growing coastal megacities like Lagos.

In the Ghanaian context, multi-criteria models have shown that shoreline erosion and land-use change exacerbate flood risk [10]. In Uganda, rapid settlement of wetlands in Kampala has magnified flood impacts via both exposure and hydrological disruption [11]. These parallels suggest that the Lagos findings are not idiosyncratic but part of a broader continental pattern of flood risk emerging under rapid urbanization.

Earlier Lagos-specific studies, such as Adelekan [4], pointed to land reclamation and insufficient drainage engineering as major drivers of flood hazard. This study quantifies that risk by showing drainage density as the second-most influential factor after elevation, giving a more precise measure of the infrastructure gap.

Moreover, the use of open-access high-resolution global datasets; WorldPop for population [12], CHIRPS rainfall [13], SRTM [14], Copernicus DEM [15], Sentinel-2 [16], and OpenStreetMap drainage networks [17] provides a methodological template for data-limited contexts. Other studies in Nigeria and West Africa using frequency-ratio or statistical models [9] or AHP-MCDA [10,11] have found that combining hazard and exposure factors improves predictive performance substantially.

4.3 Policy and methodological implications

Policy Implications

The results of this study carry significant policy relevance for flood risk governance in Lagos. The spatial prioritization of flood-prone hotspots provides a clear indication of where state planners and disaster management agencies should focus both infrastructural investment and regulatory oversight. Particular attention is required in zones that combine low elevation and limited drainage density with high population concentrations, since these areas represent the most critical trade-offs between environmental hazard and human exposure.

Effective regulatory enforcement also emerges as an urgent priority. Preventing further settlement in reclaimed wetlands and low-lying coastal floodplains is essential to reducing future risk, while simultaneous investment in drainage infrastructure is necessary to address existing vulnerabilities. These strategies are closely aligned with the principles of the Sendai Framework for Disaster Risk Reduction, which emphasizes proactive and anticipatory approaches to hazard management [6].

Beyond infrastructure and regulation, the study highlights the potential value of integrating flood susceptibility outputs into operational risk management systems. Incorporating susceptibility maps into early warning platforms, evacuation planning, and community-based resilience programs would allow Lagos to shift from a largely reactive stance to a more anticipatory mode of flood governance. Localized adaptation measures, including household-level flood-proofing and micro-scale interventions in high-risk informal settlements, could further strengthen resilience at the community scale.

V. Methodological Implications

The study also contributes methodologically by demonstrating that open-source and freely available datasets can be effectively combined with the Analytic Hierarchy Process (AHP) in a GIS-based framework to produce robust flood susceptibility assessments, even in contexts where proprietary or high-resolution data are scarce. This approach underscores the feasibility of applying advanced decision-support tools in data-limited environments typical of many African cities.

The structured expert-weighting process used in this study enhances transparency and ensures adaptability. As urban conditions evolve or new datasets become available, factor weights can be revised and updated, maintaining the relevance of the model for future decision-making. Validation of the susceptibility outputs against real-world disaster incident records further strengthens the credibility of the method and increases the likelihood of adoption by policymakers and practitioners. Similar AHP-GIS applications in other African cities, including Benin City in Nigeria and Yaoundé in Cameroon, have demonstrated comparable levels of predictive reliability when validated against observed flood events.

Looking forward, methodological refinements could build upon this foundation by incorporating dynamic rainfall datasets, such as high-resolution radar-based precipitation products, or by embedding hydrodynamic simulation tools such as HEC-RAS or cellular automata models to capture flood depth and flow dynamics. Moreover, the integration of citizen-reported flood data into real-time updating platforms could enhance model responsiveness, creating a continuously improving system for flood risk assessment and early warning in Lagos.

4.4 Limitations and suggestions for future work

While this study demonstrates the utility of a GIS-based AHP-MCDA framework for assessing flood susceptibility in Lagos, several limitations should be acknowledged. The reliance on medium-resolution datasets, including the 30 m Shuttle Radar Topography Mission (SRTM) DEM and 10 m Sentinel-2 imagery, may obscure fine-scale urban topographic variation. This is particularly significant in densely built informal settlements where small changes in elevation can strongly influence localized flood dynamics. Similarly, the use of CHIRPS rainfall data, which represents long-term precipitation averages, does not adequately capture short-duration convective storms. Such storms are a common trigger of flash flooding in Lagos and may therefore lead to underestimation of localized flood risk.

The drainage density metric employed in this study, although derived from DEM-based hydrological analysis and OpenStreetMap data, provides only a proxy for real-world drainage capacity. It does not account for critical factors such as blocked drains, informal channels, or the maintenance status of drainage infrastructure, all of which significantly affect flood outcomes. Moreover, human exposure was represented solely by population density. While useful, this measure does not capture broader socio-economic vulnerability indicators such as income levels, housing quality, or adaptive capacity, which are known to influence the severity of flood impacts.

Another important limitation lies in the validation dataset. The flood incident records obtained from LASEMA may be subject to reporting biases, with a tendency to document larger or more disruptive events. Smaller-scale or unreported flash floods are likely to be underrepresented, potentially skewing the validation of the susceptibility model.

Future research should therefore focus on refining the model through the use of higher-resolution terrain data, such as LiDAR or drone-based DEMs, which would improve the detection of fine-grained urban topography. Incorporating dynamic rainfall inputs, including high-resolution radar-based estimates, could better capture the short-duration storms that drive flash flooding in Lagos. Hydrodynamic simulations of water flow, using models such as HEC-RAS or cellular automata, would provide a more physically based representation of flood processes and complement the susceptibility mapping approach. In addition, integrating socio-economic indicators into the modeling framework would allow for a more comprehensive assessment of vulnerability, ensuring that risk maps reflect both hazard intensity and differential community resilience. Finally, the development of a citizen science-based flood reporting system could provide valuable real-time data for validation and continuous updating of flood susceptibility maps, enhancing both accuracy and practical utility.

VI. Conclusion and Recommendations

5.1 Conclusion

Flooding in Lagos remains one of the most pressing environmental challenges confronting urban sustainability in Sub-Saharan Africa. This study employed a multi-criteria decision analysis (MCDA) framework, specifically the Analytic Hierarchy Process (AHP), to identify and map flood susceptibility zones across the metropolitan region. By integrating six critical determinants, elevation, drainage density, land cover, rainfall, soil type, and population distribution, the study was able to provide a nuanced and spatially explicit representation of flood risk.

The findings revealed that physical geography, particularly elevation and drainage density, exerts the most significant influence on flood susceptibility in Lagos, accounting for nearly half of the total factor weightings. This highlights the natural predisposition of the city's low-lying coastal topography to recurrent inundations. However, the role of anthropogenic drivers such as land cover conversion and rapid population growth cannot be overstated, as these factors amplify hazard exposure and reduce the capacity of natural systems to absorb floodwaters. Informal settlements built on reclaimed wetlands and lagoon margins emerged as the most vulnerable hotspots, confirming long-standing concerns expressed in the literature on Lagos's urban ecology.

The validation results, with an AUC of 0.84 and nearly 80% of observed flood incidents captured in high and very high susceptibility zones, demonstrate the robustness of the integrated model. These outcomes affirm the utility of combining geospatial data with structured decision-making frameworks to predict flood risk in data-limited urban environments. They also provide empirical evidence that flood hazards in Lagos are not evenly distributed but are spatially concentrated in specific neighborhoods such as Lagos Island, Ajegunle, Makoko, and the Lekki–Ajah corridor.

From a broader perspective, the study contributes to the growing discourse on urban resilience and climate adaptation in African megacities. It underscores the need to move away from reactive flood response measures toward anticipatory risk governance, where susceptibility maps guide infrastructure investments, zoning decisions, and community preparedness programs. In doing so, Lagos can better align with the objectives of the Sendai Framework for Disaster Risk Reduction and the Sustainable Development Goals, particularly SDG 11 (Sustainable Cities and Communities) and SDG 13 (Climate Action).

Furthermore, this study demonstrates the feasibility of applying open-access datasets (SRTM, Sentinel-2, CHIRPS, WorldPop, OpenStreetMap) to generate actionable flood risk products. This is particularly important in contexts where government data are fragmented, outdated, or inaccessible. By showcasing a methodology that is replicable, cost-effective, and adaptable, the study opens pathways for similar applications in other African cities such as Accra, Abidjan, and Dar es Salaam, where urban flooding is a recurrent hazard.

In conclusion, while physical and human factors jointly shape Lagos's flood risk, the persistence of disasters in the city stems from a governance deficit in integrating scientific evidence into urban planning and policy. This study provides a practical tool to help bridge that gap, but its effectiveness ultimately depends on the willingness of state authorities and local communities to adopt evidence-based strategies for resilience.

5.2 Recommendations

The findings of this study provide a foundation for evidence-based recommendations aimed at reducing flood risk in Lagos. These recommendations are organized into short-term, medium-term, and long-term priorities to guide policymakers, planners, and disaster management agencies.

In the short term, targeted interventions should be prioritized in the most flood-prone neighborhoods, particularly Lagos Island, Ajegunle, and Makoko. Immediate measures include the clearance of blocked drainage channels, the upgrading of culverts, and the construction of community-level flood shelters to reduce immediate vulnerability. At the same time, the flood susceptibility maps generated by this study should be integrated into the operational frameworks of the Lagos State Emergency Management Agency (LASEMA). Embedding these outputs into early warning systems and evacuation planning would allow for spatially targeted responses during flood events. Community participation should also be encouraged at this stage, with local stakeholders engaged in participatory risk mapping and citizen science-based flood monitoring initiatives to complement institutional data gaps.

Medium-term actions should focus on strengthening and expanding drainage infrastructure across the city. Particular attention is needed in rapidly urbanizing corridors such as Lekki and Ikorodu, where large-scale housing developments are encroaching on floodplains. Investments in engineered drainage systems should be complemented by nature-based solutions, such as the restoration of wetlands and mangrove buffers, which can provide cost-effective flood mitigation while enhancing ecological resilience. At the same time, urban planning reforms are required to enforce zoning regulations that prevent further construction in reclaimed wetlands and low-lying coastal areas. Development permits should be contingent upon rigorous flood risk assessments to ensure that expansion does not increase hazard exposure.

In the long term, Lagos must institutionalize data-driven governance to ensure that flood risk management keeps pace with rapid urban and environmental change. Periodic updates of susceptibility maps should be mandated, using annually available datasets such as Sentinel imagery and CHIRPS rainfall records. Establishing a dedicated urban flood observatory within the Ministry of the Environment would provide an institutional anchor for continuous monitoring, research, and policy translation. Climate change adaptation should also be mainstreamed into the state's 2050 development plans, with investments in large-scale infrastructure such as sea walls, green urban systems, and flood-resilient housing. Addressing the socio-economic dimensions of vulnerability is equally important: poverty alleviation, livelihood diversification, and insurance mechanisms can help reduce household-level exposure and improve adaptive capacity in the long term.

Finally, Lagos's flood risk cannot be addressed in isolation. Regional cooperation is essential, given the influence of upstream water dynamics on the city's hydrological system. Developing inter-state and regional water management frameworks would allow for coordinated mitigation measures and a more holistic approach to flood governance.

Together, these short-, medium-, and long-term actions offer a pathway for transforming Lagos's flood risk management from reactive crisis response toward anticipatory, integrated, and resilience-oriented planning.

Conflict of Interest

The author declares no conflict of interest related to this research.

Ethical Approval

This study was conducted using publicly available geospatial datasets and anonymized flood incident records. No human participants were directly involved.

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