
HYDROLOGICAL IMPLICATIONS OF WETLAND ENCROACHMENT ON LOCAL FLOOD REGULATION IN ABEOKUTA, OGUN STATE, NIGERIA

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<https://doi.org/10.3303/jees.2026.0301/025>

ABSTRACT

Wetlands function as natural hydrological buffers, storing excess floodwaters and gradually releasing them to maintain hydrological balance, thereby playing a critical role in flood management. Anthropogenic flood buffering of wetlands in Abeokuta, Ogun State, has driven rapid urban growth, thereby reducing the city's natural capacity to buffer floods. Despite the recurrent flooding, there remains a paucity of empirical studies that have quantitatively evaluated the hydrological effects of such encroachment. This study attempts to map the geographical scope of wetland loss and assess its impact on runoff and peak discharge using a combined geospatial and hydrological analysis. The geospatial design, based on a quantitative approach using remote sensing, GIS, and HEC-HMS modelling, was adopted. Landsat 7 TM (2015) and Landsat 8 ETM+ (2025) multispectral satellite images (spectral range of 0.45-2.35 μm and 30-meter resolution, respectively) were used in the study, and rainfall and discharge data were obtained from NiMet and the Ogun-Osun River Basin Authority. Land use analysis revealed that wetlands increased by 7% and water bodies decreased by 0.3%. The model had a high calibration, $NSE = 0.77$ and $R^2 = 0.81$. Findings indicated that runoff and peak discharge increased by 19.8% and 22.4%, respectively, and the lag time decreased by 24.4%. These results indicate that the loss of wetlands increases the velocity of surface water runoff and amplifies flood peaks. The study recommends delineating the boundaries of protected wetlands within the Abeokuta master plan and integrating wetland variables in urban hydrological models to enhance sustainable flood control.

Keywords: Flood regulation, Geographic Information System, Hydrological modelling, Wetland encroachment

INTRODUCTION

Wetlands perform important hydrological functions, such as regulating runoff, storing surplus water, and attenuating flood peaks (Impacts of climate change on environmental flows, 2021). When wetlands are destroyed or encroached upon, they lose their ability to buffer floodwaters, resulting in increased surface runoff, faster flood response, and more intense flood peaks. Simply put, wetlands act as natural sponges in landscapes. If they have a lower absorption capacity, downstream flooding will be more intense.

In Africa, wetlands and floodplains are being converted to urban areas at an uncontrolled rate, leaving no control over drainage. Existing studies (e.g., Garba et al., 2025; Mumuni et al., 2025) reveal that wetland fragmentation in Africa is closely linked to high population density, indicating a conflict between urbanisation and wetland quality. These trends indicate that urban pressure will most likely result in the depletion of hydrological buffering capacity, thereby increasing flood risk.



Nigeria, with a land area of 923,768 km², contains approximately 2.6% wetlands; however, these ecosystems are being lost at an alarming rate of 6.5% annually, primarily due to rapid urbanization (Oscar et al., 2022). The unchecked sprawl of urban settlements and industrial expansion has driven extensive land conversion, with wetlands increasingly reclaimed, thereby intensifying ecological degradation and exacerbating flood risks (Adeleke, 2022). Consequently, land-use transformation, climate variability, and alterations in drainage systems have become subjects of hydrological and flood-related research. Komolafe et al. (2020) employed GIS-based multi-criteria analysis in the Ogun River Basin to map potential flood hazard zones and vulnerability, revealing that land-use patterns play an important role in the distribution of floods. Eteh et al. (2025) also utilised machine learning and geospatial analysis to determine the extent to which floods in downstream Nigerian basins change due to land-use change and climate abnormalities. The literature reveals that Nigeria's hydrological systems are acutely sensitive to landscape modifications, with wetlands representing particularly vulnerable ecosystems; nevertheless, there is a dearth of published literature that specifically measures the impact of wetland encroachment on hydrology and flood peaks in the region, within Abeokuta and Ogun State. In the absence of this localised evidence, planners lack a robust foundation for developing flood-mitigation strategies, as there is limited empirical evidence on the actual hydrological changes resulting from wetland loss in this context. Hence, the extent to which such encroachment alters runoff dynamics and flood peaks remains insufficiently understood in this area. Therefore, this study examines wetland encroachment in Abeokuta, which not only compromises the landscape's natural flood-control function but also diminishes its broader hydrological performance. Through a synthesis of geospatial change detection and hydrological modelling, the proposed study will produce a sound, policy-grounded understanding of how wetland degradation affects urban flood behaviour in Abeokuta and analogous cases.

STUDY AREA

The research was carried out in Abeokuta, Ogun State. Abeokuta is located between longitudes 3°30' and 3°37' E and latitudes 7° and 7°5' N on the eastern bank of the Ogun River, adjacent to a cluster of rocky outcrops within a wooded savanna landscape (Tonade, 2023). The city's population is about 557,000 (PopulationStat, 2026). The city has a tropical climate, classified as Aw by the Köppen-Geiger system. The Köppen climate classification "Aw" denotes a tropical wet-and-dry climate, also known as a tropical savanna climate. The temperature here averages 27.1 °C. Precipitation here averages 1238mm. The state has two main types of vegetation, namely tropical rainforest and guinea savanna (Olabode et al., 2025). The entire study area is lowland, with elevations between 0 and 200 meters above sea level. The town is composed of two distinct topographical units: the uplands, flat to gently rolling plateaus on the low-elevation terrace and farther from the rivers, and the flat, low-lying areas, which are mostly adjacent to the rivers. The two major rivers of the town are the Ogun and Oyan rivers, which flow together in the North of the state capital, Abeokuta (Adeyefa, 2023; Popoola, 1990). Since the soil is very heavy and there is a natural drainage system that removes excess rainfall, the areas experience a high water table despite not being naturally flooded (Soaga et al., 2014). The vegetation covers are the southern Guinea savanna, which is a grass-with-tree complex, and the derived savanna (Popoola, 1990). A peri-urban forest (Arakanga Forest Reserve, 2.39 km²) is located in the Odeda Council Area of Abeokuta, near Akomoje, the headquarters of the Abeokuta North Council Area. The forest and wildlife populations were, however, affected by encroachment and destruction accompanying Abeokuta's growing population, leading to a decline in the reserve's animal populations.

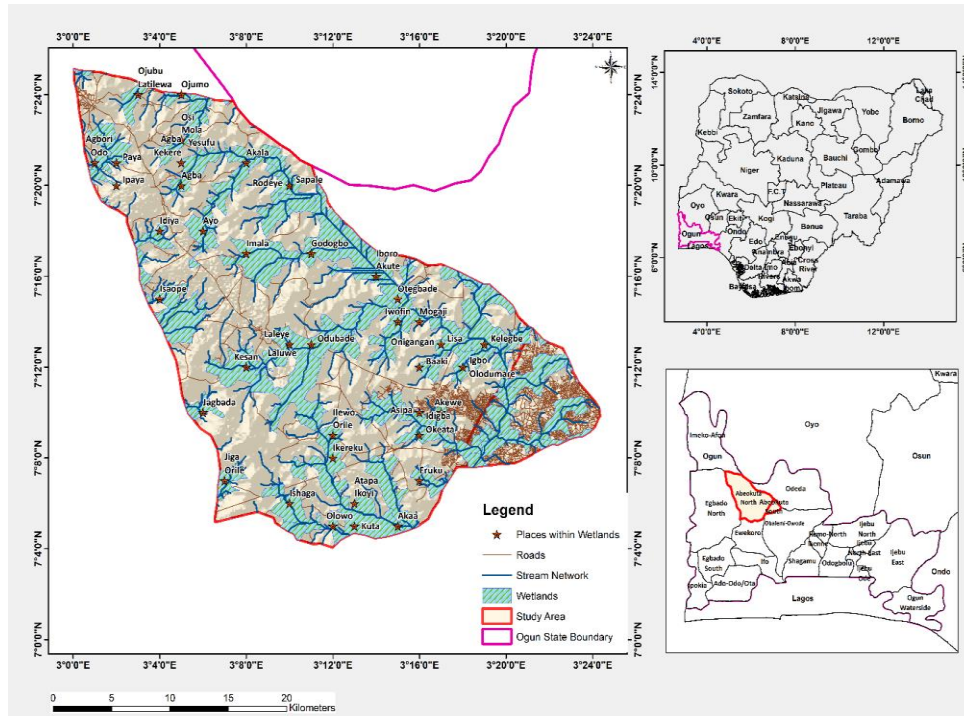


Figure 1: Map of the study area showing Hydrological features and wetland areas

MATERIALS AND METHODS

Wetlands are hydrologically dynamic systems, that is, saturated soils and regular floods, which allow wetlands to capture surface water, mitigate flood peaks, and recharge groundwater (Wu et al., 2023). The ability to store surplus rainfall and release it over time gives them a regulatory role by stabilising flow regimes and minimising flood magnitude (Zeng et al., 2024). Wetlands play a crucial hydrological role in maintaining watershed balance, but when modified through reclamation, drainage, or urban development, they alter infiltration patterns, reduce storage capacity, and increase surface runoff (Agonafir et al., 2023).

Wetland encroachment is the process by which human development occupies or converts wetland areas, such as housing, road development, and industrial facilities (Maryland Department of the Environment, 2023). This human-made intrusion disrupts the natural flow of water, increases impervious surface area, and impairs wetlands' capacity to provide essential hydrological services (Islam et al., 2023). Weak spatial planning, excessive urban development, and inadequate enforcement of environmental protection laws often lead to encroachment (Echendu et al., 2021).

One of the ecosystem services that floodplains and wetlands offer is flood regulation. It entails the uptake and retention of surface runoff, thereby reducing the intensity and frequency of floods (Yang, 2024). Hydrologically, flood control is mainly manifested in the volume of runoff and the peak discharge; the two indicators of how much and how fast water flows on the surface. The loss or fragmentation of wetlands alters the hydrological balance by increasing runoff coefficients, reducing lag times, and increasing the steepness of hydrograph peaks (Manandhar et al., 2023). As a result, with the degradation of wetlands, the risk of flooding increases directly, especially in rapidly developing urbanised catchments where areas that retain water are covered by impermeable surfaces (Moon et al., 2024).



The paper is based on two theoretical perspectives: the Urban Hydrological Response and Ecosystem Services Theory. According to the Ecosystem Services Theory (Daily, 1997, reaffirmed by Prasanya et al., 2024), ecosystems provide goods and services that support human well-being, including flood control, climate stability, and water purification. The theory presumes that as the integrity of the ecosystem decreases, the ability to supply regulating services also declines in proportion to that integrity. In hydrology, wetlands are considered natural infrastructure that provide flood-moderating services. This encroachment disrupts the structure and function of wetlands, thereby reducing the system's capacity to buffer flood peaks and maintain hydrological stability (Prasaya et al., 2024).

The Urban Hydrological Response Theory (Dunne & Leopold, 1978) describes how land-use change influences the partitioning of rainfall among infiltration, evapotranspiration, and runoff. Due to increased impervious surfaces and the loss of vegetated or permeable lands, infiltration rates are low, and runoff volumes are high, triggering a faster hydrograph response and a greater increase in flood peaks. Wetlands, in this context, are the essential modifiers of the rainfall-runoff association. They are degraded or converted, reducing detention capacity and leading to faster surface flow and a higher risk of flooding (Wu et al., 2023).

These theories lend this research a logical dualistic identity. According to the Ecosystem Services Theory, the normative value of wetlands is defined as a source of hydrological stability, whereas the Urban Hydrological Response Theory is considered a physical model of how wetland encroachment restructures flow regimes. By combining the two points of view, one obtains a solid basis for judging the hydrological implications of wetland encroachment in Abeokuta.

Recent research always supports the idea that wetlands play an important role in hydrological regulation and flood management. Wu et al. (2023) have shown that wetlands are effective nature-based solutions for flood control because they can buffer peak flows by holding and releasing runoff slowly. According to Zeng et al., the reduction in wetlands in the Yangtze Basin increased surface runoff and reduced groundwater recharge, indicating that hydrological systems are highly sensitive to landscape changes (Zeng et al., 2024).

In a global review of urban flood studies, Agonafir et al. (2023) found that rapid urbanization and the loss of natural storage areas, such as wetlands, are key factors driving the increase in flood frequency and severity. On the same note, the authors of Prasanya et al. (2024) asserted that degraded wetlands can be restored to regain their flood-controlling role, supporting wetland conservation as an element of integrated watershed management.

Manandhar et al. (2023) conducted a review of worldwide experiences in urban flood hazard evaluation. They showed that models such as HEC-HMS, SWMM, and MIKE 21 are effective at capturing land-use changes in runoff. In the study by Zhang et al. (2023), the authors analyzed changes in the hydrology of Chinese wetland systems. They demonstrated that changes in water-level regimes resulting from human activities are the primary contributors to accelerated wetland degradation and increased flood exposure. Similarly, Hockaday et al. (2024) showed that hydrologically connected wetlands are more effective at flood control than isolated wetlands, underscoring the importance of landscape connectivity.

The systematic review highlights how wetland conservation, connectivity, and land-use dynamics influence runoff, flood peaks, and vulnerability, thereby providing the empirical foundation for this study's analysis of Abeokuta. However, these studies emphasize regional datasets, with limited attention to fine-scale, city-level hydrological modeling. Critically, no research has yet integrated



remote sensing of wetland encroachment with quantitative hydrological modeling in Nigeria, leaving a significant methodological gap that this study addresses.

Despite the extensive global literature supporting the importance of wetlands in hydrology, empirical data on the hydrological effects of wetland encroachment in the urban context of Nigerian cities remain scarce. The majority of existing studies in Nigeria focus on general land-use change and urban flooding (Komolafe et al., 2020; Echendu et al., 2023), and there is no attempt to treat wetlands as a critical variable affecting runoff and flood dynamics. On the same note, the current literature commonly uses large-scale regional models that do not capture the local impacts of wetland encroachment on flood control at the city level. Moreover, few studies in West Africa combine remote-sensing-based wetland change detection with hydrological modelling to provide direct, data-driven information on the impact of wetland change on runoff and peak discharge. This disparity is notable in Abeokuta, where floods are exacerbated by urban growth and wetland degradation, and where they remain understudied scientifically.

The research employed a descriptive geospatial design, using remote sensing and GIS tools to examine temporal land-cover changes and the impact of wetland encroachment on flood control in Abeokuta, Ogun State. This methodology facilitated the spatial analysis of wetland alterations and the modelling of hydrological effects on runoff and peak discharge. To determine land-use and land-cover change in the study area, geospatial analysis of Landsat imagery from 2015 and 2025 was conducted. Publicly available Landsat data (Path 191, Row 55) were used. The study used bands 2, 3, and 4 of Landsat 7 and bands 3, 4, and 5 of Landsat 8. These datasets were processed in ArcGIS 10.4, and false-colour composite images were generated for each year. After cutting the study area from the composite images, the land cover was monitored and categorised into four classes: vegetation, built-up, wetland, and water body.

Table 1: Summary of data source

| Satellite | Sensor | Band | Spectral Range | Pixel Resolution | Year | Path and Row |
|-----------|---------------------|-------|-------------------------|------------------|------|--------------|
| L7 | TM multi-spectral | 2,3,4 | 0.45-2.35 μm | 30meters | 2015 | P191 r55 |
| L8 | ETM+ multi-spectral | 3,4,5 | 0.45-2.35 μm | 30 meters | 2025 | P191 r55 |

Source: NASA Program, Landsat ETM+ scene, USGS

The 2015-2025 hydrometeorological data on rainfall and discharge were received by the national agencies for use in model calibration and validation. Hydrological data were gathered by meteorological and basin entities. Triangulation was done to ensure data validity, and Nash-Sutcliffe Efficiency and Coefficient of Determination were used to test the model Reliability. To assess the extent of wetland loss and its hydrology, the spatial and statistical analyses were performed. The HEC-HMS model was used to simulate pre- and post-encroachment conditions, and descriptive and inferential statistics were used to establish the interdependence between changes in wetland area and flood response. The results were summarized using maps, tables, and graphs to facilitate interpretation.

RESULTS AND DISCUSSION

Results

In the analysis, remote sensing and spatial evaluation of wetland encroachment on flood control in Abeokuta during the study period of 2015 and 2025 were conducted. Table 2 shows the land-use proportions in the study area for both 2015 and 2025.

Table 2: Landuse Classification and Area Coverage of Abeokuta for 2015 and 2025

| Landuse | 2015 | | 2025 | |
|--------------|-----------------|----------------|------------------|----------------|
| | Area(ha) | Percentage (%) | Area(ha) | Percentage (%) |
| Water Body | 2,317.77 | 2.7 | 2,093.31 | 2.4 |
| Built up | 11,686.86 | 13.5 | 12,211.83 | 14.1 |
| Vegetation | 31,535.1 | 36.4 | 25,180.2 | 29.0 |
| Wetlands | 41,174.55 | 47.5 | 47,228.94 | 54.5 |
| Total | 86,714.3 | 100.0 | 86,714.28 | 100.0 |

Source: Author’s Fieldwork 2025

The findings indicate that wetlands covered about 47.5% of the land. The next category was vegetation, with 36.4% indicating the percentage of land covered by natural vegetation. The constructed land covered 13.5%, representing moderate urbanization in the region. This implies that at 2015, wetlands and vegetation were predominant in Abeokuta with moderate urbanization and surface water cover. Alternatively, the wetlands accounted for only 54.5% of the total land area, compared with 29% vegetation and 14.1% built-up. This implies that the landscape is dominated by wetlands, which are vital to the region's hydrology.

The spatial patterns of land use in 2015 and 2025 in Abeokuta and the surrounding areas are presented in Figure 2. The map shows that there is a lot of wetland as represented by the light blue area that is hatched at the river valleys and the low-lying lands in Abeokuta. They are mainly located in the central and southern floodplains, particularly around Ilogun, Olowonyo, Ketu, Jagbada, Yogon, Itesi, Ishaga, Agbagi, Kaiyero, among others. These wetlands are important for flood control but are being endangered by encroaching development. These wetlands are situated in regions near lowlands and stream networks, which serve as natural flood-control mechanisms. The expansion of built-up areas is identified as a contributing factor to increased encroachment in these wetland areas, diminishing their inherent water-retention capacity and increasing the risk of flooding during heavy rainfall. According to this spatial interaction, urban development is influencing the hydrological role of wetlands in controlling local floods.

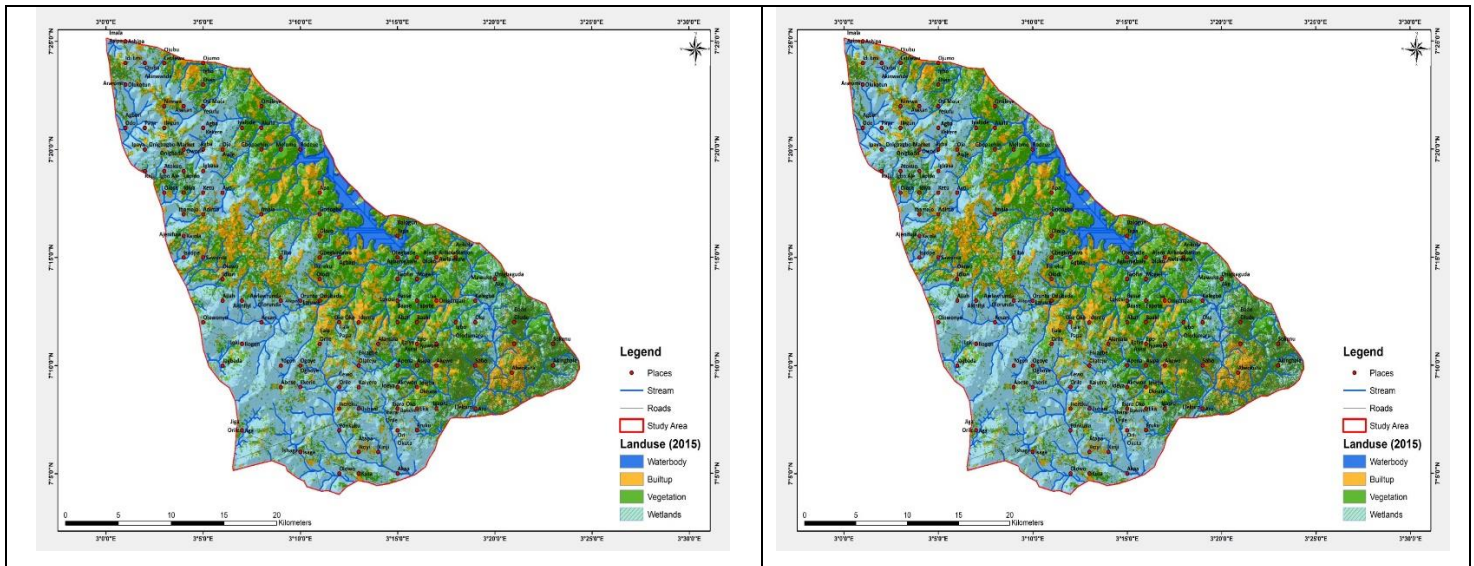


Figure 2: Spatial pattern of land use showing wetland areas in Abeokuta for 2015 and 2025
Source: Author’s Design, 2025

Table 3: Changes in Land Use and Land Cover between 2015 and 2025

| Landuse | Change Area (ha) | Change Percent (%) |
|------------|------------------|--------------------|
| Water Body | -224.46 | -0.3 |
| Built-up | 524.97 | 0.6 |
| Vegetation | -6,354.9 | -7.4 |
| Wetlands | 6,054.39 | 7.0 |

Source: Author’s Fieldwork 2025

Table 3 in the study showed that there were considerable differences in the landuse of Abeokuta in 2015 and 2025. The wetlands have increased by 6,054 hectares (7), with a marginal 0.6 increase in built-up areas. The water bodies have, however, declined by 0.3 percent, and vegetation declined by 7.4 percent. Such alterations indicate that Abeokuta is more affected by human factors and prone to floods. Besides, the research found that the wetland loss and the volume of the runoff of the study area with significant changes that have been realized in the landuse of Abeokuta between 2015 and 2025. The wetlands have grown by 6,054 hectares (7 percentage) and the built-up areas have recorded a margin of growth of 0.6. The water bodies have, however, declined by 0.3 and the vegetation by 7.4. These variations indicate the added human factor and the vulnerability to flooding in Abeokuta.

The outcome of the analysis on the Hydrological simulation Implication runoff behaviour that is to be compared in the state of pre- and post-encroachment using the hydrologic modelling system Hydrologic Environment (HEC-HMS). The Nash-Sutcliffe Efficiency (NSE) and coefficient of determination (R²) of the model calibration are 0.77 and 0.81, respectively, which indicates a good performance of the model. In pre-encroachment conditions (2015), the average volume of runoff was 3.95 x 10⁶ m³, with a peak of 161m³/s. Post-encroachment scenario (2024), on the other hand, generated 4.73 x 10⁶ m³ of runoff and a peak discharge of 197 m³/s, representing increases of 19.8% and 22.4%, respectively (Table 3). Lag time between the onset of rainfall and peak flow reduced to

68 minutes compared to 90 minutes and this indicates a rapid hydrological response because of the reduced detention storage and reduced infiltration capacity.

Table 4: Simulated Hydrological Parameters under Pre- and Post-Encroachment Scenarios

| Parameter | 2015 (Pre-Encroachment) | 2024 (Post-Encroachment) | % Change |
|------------------------------------|-------------------------|--------------------------|----------|
| Runoff Volume (m ³) | 3.95 × 10 ⁶ | 4.73 × 10 ⁶ | +19.8 |
| Peak Discharge (m ³ /s) | 161 | 197 | +22.4 |
| Lag Time (minutes) | 90 | 68 | -24.4 |
| Infiltration Rate (mm/hr) | 21.1 | 15.6 | -26.1 |

Source: HEC-HMS Simulation Results (2025)

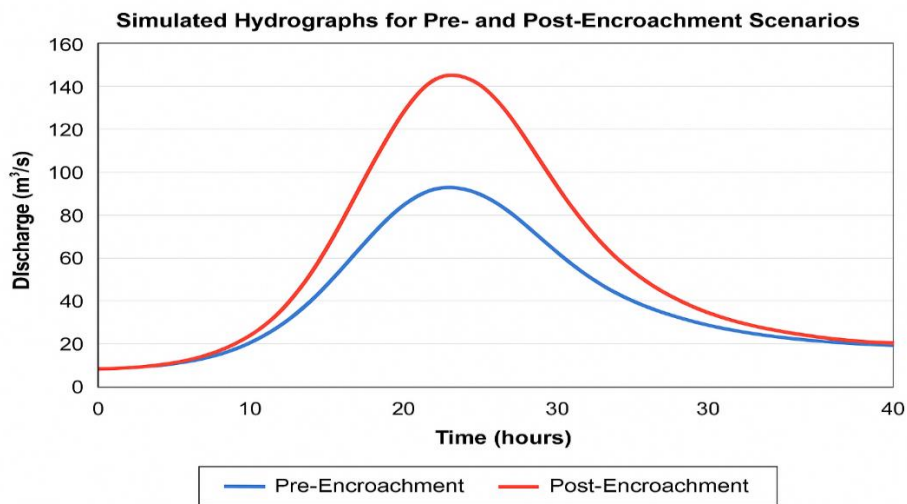


Figure 3: Simulated Hydrographs for Pre- and Post-Encroachment Scenarios (The graph depicts the post-encroachment curve peaking higher and earlier, confirming an accelerated runoff response and increased flood intensity.)

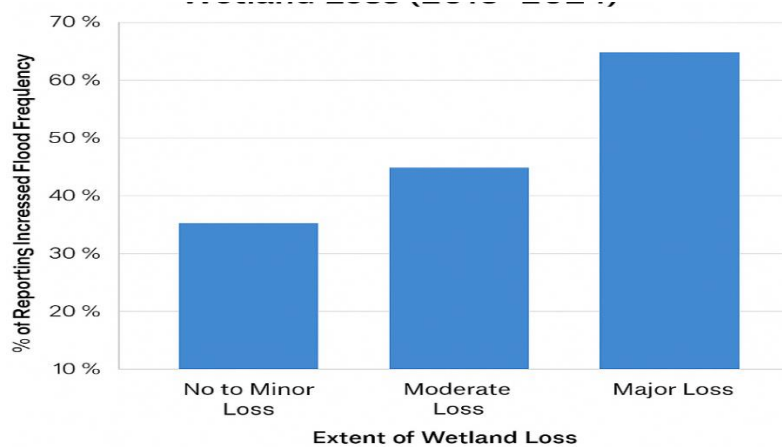


Figure 4. Perception of Flood Frequency Relative to Wetland Loss (2015–2024)
 (Bar chart shows increasing flood reports in areas experiencing major wetland conversion.)



Discussion

The findings indicate that the wetlands in the peri-urban Abeokuta have grown in size tremendously during the period between 2015 and 2025, illustrating their significance to the hydrology and the physical appearance of the region. Such growth is due to an increase in anthropogenic pressure, which threatens natural flood regulation mechanisms, vegetation loss and urbanisation (Idiege et al., 2017). These results of the research show a pattern which is consistent: the gradual wetlands encroachment has resulted in quantifiable changes in the hydrological regime of Abeokuta. These 20-22 percentages of increase in runoff and peak flow prove that urban flood susceptibility has been compounded by the loss of natural retention areas.

These results support the Urban Hydrological Response Theory that implies that an increase in impervious surfaces hastens the runoff, reduces lag times, and increases peak discharge (Manandhar et al., 2023). At the same time, the findings support the Ecosystem Services Theory because wetlands have been degraded, which reduced their potential to deliver important regulating functions, including flood control and groundwater replenishment (Nepal et al., 2024).

The results are also consistent with empirical data of other cities in the sub-Saharan region, such as Lagos (Komolafe et al., 2020) and Nairobi (Echendu et al., 2023), where a fast process of urbanization has caused the breakdown of drainage systems and increased the risk of floods. Nonetheless, the case of Abeokuta also adds fresh localized knowledge by quantifying the hydrological response and scenario-based modelling and associating it with spatial evidence and community experiences.

The growth of wetlands in Abeokuta indicates that more low-lying zones are being retained to trap water, which can help control peak flood levels and enhance groundwater recharge. It can also, however, be a signal of poor drainage or an increasing frequency of floods due to heavy rainfall, which makes flood control in the Ogun River Basin necessary. Unless land-use planning and wetland protection is effectively in place, the likelihood of additional encroachment into wetlands will probably compound the occurrence and severity of floods. Wetland conservation in urban planning, increased regulation of buffer zones, and the use of nature-based drainage management are thus essential for regenerating hydrology and improving urban resilience to floods in Abeokuta.

CONCLUSION AND RECOMMENDATIONS

The paper evaluated the hydrological consequences of wetland encroachment on flood control in Abeokuta, Ogun State, using a descriptive geospatial-hydrological design that employed remote sensing, GIS, and HEC-HMS models. The results showed that wetlands have been expanding by 7% and water bodies have been shrinking by 0.3%, principally along the Ogun and Oyan floodplains. This led to a 19.8% increase in runoff volume, a 22.4% increase in peak discharge, and a 24.4% decrease in lag time, which proved that the increase in wetland area is caused by poor drainage and inundation in the zone. The research finds that encroachment on wetlands in Abeokuta has significantly altered the region's hydrological balance, leading to increased surface runoff and peak discharges, and reduced infiltration capacity. These modifications have reduced the lag time between the precipitation and peak flow, hence increasing risks of floods. Hydrological modelling and residents' perceptions are valid, as further degradation of wetlands compromises the environment's natural flood control.

The study suggests the following, among others:



- i. The physical planning ministry of Ogun State is expected to lay out and implement the wetlands in the master plan of the city. In areas at least 100 meters surrounding wetlands, development should be limited as a GIS-based map would be used to guide zoning and eliminate further encroachments.
- ii. Wetland parameters need to be incorporated in the hydrological and flood prediction models by the Ogun-Osin River Basin Development Authority and NiMet. The nature-based flood management strategy to mitigate or manage flood runoff should include restoring degraded wetlands through vegetation recovery, reconnecting floodplains, and using retention ponds as part of the green infrastructure.
- iii. The development of urban areas should be in a way that includes the use of sustainable drainage systems and green infrastructure to minimize surface run-offs and allow natural infiltration in flood-prone zones.
- iv. Educational campaigns should be introduced to the citizens to educate them on the ecological and hydrological value of wetlands and promote conservation efforts by the community.

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