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Research paper

GIS-Based Analysis of Wetland Conversion and Its Socio Economic and Environmental Implications in Bonny Local Government Area, Rivers State, Nigeria

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Abstract

This study examines spatial and temporal changes in wetland extent in Bonny Local Government Area, Rivers State, Nigeria, over 20 years, utilising Landsat satellite imagery from 2005, 2015, and 2025, analysed through remote sensing and GIS techniques. Key findings show an increase in built-up areas from 8,125.7 ha (22.70%) in 2005 to 24,485.2 ha (68.34%) by 2025, while mangroves and vegetation decreased from 12,011.3 ha (33.52%) to 3,625.4 ha (10.10%). Wetlands initially grew but significantly declined to 3,725.6 ha (10.40%) by 2025. Major drivers of these changes include urbanisation, industrial growth, and land reclamation, resulting in ecosystem deterioration, resource depletion, and increased flooding risks. Socioeconomic impacts include job losses and community displacement. The study concludes that poor development strategies threaten wetland ecosystems and recommends integrated land-use planning, enhanced environmental regulations, and wetland conservation for sustainable development.

Keywords: *Wetland Degradation; Land Use/Land Cover Change; Remote Sensing; Urban Expansion; Bonny LGA; Environmental Impacts, Niger Delta; and GIS Analysis.*

1. Introduction

Among the most productive ecosystems, wetlands serve humans ecologically and socioeconomically, especially in the areas of flood regulation, water purification, shoreline protection, and biodiversity conservation [1], [2]. Globally, wetlands make up around 6% of the world's land area and are essential to biodiversity and environmental stability [3], [4]. Africa is home to roughly 947,750 square kilometres of wetlands, which account for approximately 10% of all wetlands worldwide. Consequently, the continent plays a significant role in the global network of wetland ecosystems.

Wetlands in Nigeria are mostly found in the coastal and riverine habitats of the Niger Delta region, with an estimated total area of 29,000 km² [5]. These ecosystems support many activities that provide livelihoods, including fishing, farming, transportation, and the collection of forest resources [5], [6]. Isaac et al. [3]stated that wetlands perform important ecological activities like the mitigation of flooding, stabilisation of coastlines, replenishment of groundwater, and purification of water. Additionally, they, as stated by Onu [7], promote the protection of biodiversity by providing habitats for many kinds of aquatic and terrestrial organisms. According to Adewumi et al. [8], wetlands serve significant ecological, economic, and aesthetic services that contribute to environmental sustainability and human well-being. They support leisure activities that encompass wildlife observation, hunting, and fishing, while also increasing food production and economic growth.

Wetlands are characterised in several distinct ways based on their hydrological, ecological, and geomorphological features [9], [10]. They may also be categorised into marshes, swamps, bogs, and fens depending on their formation and plant composition [10], [11].

Anthropogenic activities remain the primary catalysts of wetland degradation around the world. In many parts of the world, wetlands have shrunk a lot because they have been turned into farmland, housing, and industrial areas [12], [13]. Specifically, pollution from both point and non-point sources [14], excessive use of fertilisers and pesticides [13], and land-use conversion and abandoned urban development also led to wetland degradation [15].

In the Niger Delta region of Nigeria, wetlands are increasingly threatened by rapid population growth, urban expansion, and infrastructural development [16]. In particular, significant wetland reclamation has occurred in Port Harcourt and surrounding areas as a result of increasing demand for land for residential, commercial, and industrial purposes [17]. According to Wali et al. [18], the conversion of saltwater-freshwater wetland ecosystems in the Port Harcourt metropolis has intensified due to urban land use change, resulting in environmental challenges such as flooding, loss of biodiversity, and degradation of ecosystem services.

The application of geographic Information Systems (GIS) and remote sensing technologies has become increasingly important for monitoring environmental change and wetland dynamics [19,20]. These technologies provide efficient tools for land-use mapping, change detection, and spatial analysis across different temporal scales [21]. The aforementioned standardised technologies present efficient methods for mapping, inventorying, and assessing wetlands on wide geographical and temporal scales [22]. Remote sensing data from satellites such as the Landsat Program have been frequently used for identifying land-cover changes and evaluating wetland conditions in many regions of the world [23-25].

Several studies, like those of Cheng and Dang [26], Kaplan and Avdan [27], and Sivakumar and Ghosh [28], have adopted remote sensing and GIS techniques to assess wetland dynamics in different parts of the world. As an instance, remote sensing techniques have been utilised by Rusnák et al. [29] and Gxokwe et al. [30] to evaluate aquatic habitats and wetland ecosystems in river basins and coastal environments, offering useful insights into wetland degradation and restoration processes.

In Nigeria, few studies have merged GIS-based wetland mapping with socio-economic assessments of wetland conversion, particularly in Rivers State. Given the rising pressure on wetlands due to urbanisation and land-use transformation, there is a need for thorough spatial analysis to understand the extent and implications of wetland conversion. Therefore, this study seeks to:

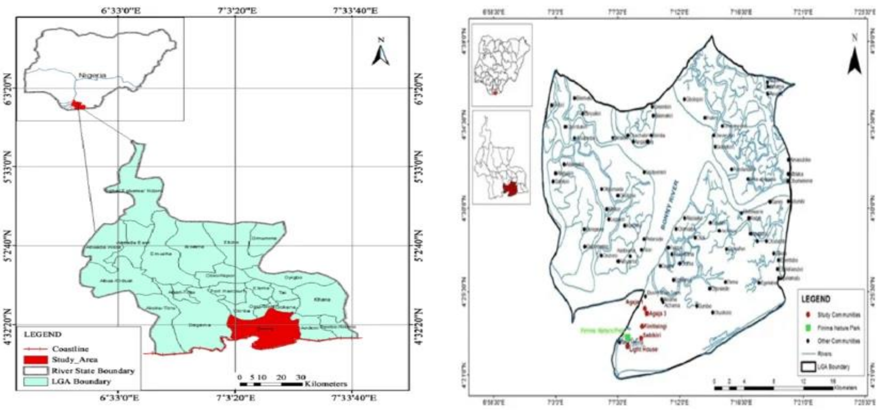
1) Determine the spatial and temporal changes in wetland areal extent within selected parts of Rivers State using GIS and remote sensing techniques;
2) Identify the major drivers responsible for wetland conversion in the study area;
3) Assess the environmental implications associated with wetland degradation; and
4) Examine the socio-economic impacts of wetland conversion on local communities.

2. Methodology

2.1. Study area

The study was conducted in selected wetland areas within Bonny Local Government Area, Rivers State. The study area lies approximately between latitude 4°45′N and 4°55′N and longitude 6°55′E and 7°10′E (Figure 1a and b). The area forms part of the Niger Delta coastal plain, characterised by extensive wetlands, mangrove swamps, tidal flats, and creeks. The climate is humid tropical with an average annual rainfall ranging from 2,000 mm to 2,500 mm, while the mean annual temperature ranges between 25°C and 28°C. The vegetation of the area is dominated by mangrove forests, raffia palm, swamp forests, and freshwater wetlands.

Hydrologically, the area is influenced by tidal flows from the Atlantic Ocean through numerous creeks and estuaries. These environmental characteristics make the region one of the most important wetland ecosystems in southern Nigeria. However, increasing urbanisation, industrial development, and population growth have led to significant wetland conversion within the study areas.



(a) Map of Rivers State **(b) Map of Bonny LGA**

Fig. 1: Map of Rivers State Showing Bonny Local Government Area (Uhunmwangho et al., 2021).

2.2. GIS and remote sensing analysis

Multi-temporal satellite images of the study area for the years 2005, 2015, and 2025 were obtained from the United States Geological Survey Earth Explorer database. Landsat imagery with a spatial resolution of 30 m was adopted for the study because of its suitability for monitoring land-use and land-cover (LULC) changes over time.

The satellite datasets utilised consisted of Landsat 5 TM imagery for 2005, Landsat 8 OLI/TIRS imagery for 2015, and Landsat 9 OLI-2/TIRS-2 imagery for 2025. Images with minimal cloud cover and similar seasonal conditions were selected to ensure consistency throughout the analysis. All satellite scenes were acquired between January and March in each study year to minimise seasonal variations in vegetation and hydrological conditions.

Image preprocessing and analysis were carried out using ENVI and ArcGIS software packages. The preprocessing procedures included geometric correction, radiometric correction, atmospheric correction, image enhancement, layer stacking, and subsetting of the study area. Atmospheric correction was performed using the Dark Object Subtraction (DOS) method to reduce atmospheric interference and improve image quality.

All spatial datasets were projected to the Universal Transverse Mercator (UTM) coordinate system, Zone 32 North, based on the World Geodetic System 1984 (WGS 84) datum to ensure spatial uniformity and compatibility among the datasets.

A supervised classification technique based on the Maximum Likelihood Classification (MLC) algorithm was employed to classify the satellite images into different land-use/land-cover categories. Training samples for each land-cover class were selected using field observations, expert knowledge, spectral characteristics of the imagery, and reference information obtained from Google Earth imagery. The identified land-use/land-cover classes included wetlands, built-up areas, vegetation, water bodies, agricultural land, and dunes.

To assess the reliability of the classification results, an accuracy assessment was conducted using randomly selected validation points obtained from field verification and high-resolution reference imagery. A confusion matrix was generated to compare the classified images with the reference data. Classification accuracy indicators, including producer's accuracy, user's accuracy, overall accuracy, and Kappa coefficient, were subsequently calculated.

The overall classification accuracies obtained for 2005, 2015, and 2025 were 86.4%, 89.1%, and 91.3%, respectively, while the corresponding Kappa coefficients were 0.82, 0.86, and 0.89. These values indicate a strong level of agreement between the classified outputs and the reference data, thereby confirming the reliability of the classification procedure adopted for the study.

The classified images were subsequently used to determine the spatial distribution and extent of wetlands and other land-use categories for each epoch year.

2.3. Change detection analysis

Change detection analysis was carried out in order to determine the spatial and temporal changes in wetland extent within the study area. This was achieved by comparing the classified satellite images for 2005 and 2015, and 2005 and 2025, using the change detection statistics tool in ENVI. The results obtained from the analysis were used to compute the total land area occupied by each land-use class in hectares and percentages. The analysis enabled the identification of areas where wetlands have been converted into built-up areas, dunes, or other land uses.

2.4. Identification of drivers of wetland conversion

To identify the major drivers responsible for wetland conversion within the study area, both spatial analysis and questionnaire-based field surveys were employed. Primary data were collected through the administration of structured questionnaires to residents and relevant stakeholders within selected communities in Bonny Local Government Area.

A multistage sampling technique was adopted for the study. In the first stage, communities located within or adjacent to wetland environments were purposively selected based on the extent of observed wetland conversion and accessibility. In the second stage, respondents were randomly selected from households and institutions within the selected communities. A total of 250 questionnaires were administered to community residents, fishermen, farmers, traders, community leaders, and environmental officers who possessed adequate knowledge of environmental changes occurring within the area.

The selection criteria for respondents were based on residency duration, occupational involvement in wetland-related activities, age, and familiarity with environmental conditions in the study area. Only respondents who had lived in the area for a minimum of five years and were willing to participate voluntarily were included in the survey.

The distribution of questionnaires across the selected communities was carried out proportionately based on population size and proximity to wetland areas. This ensured adequate representation of different socio-economic groups and communities affected by wetland conversion.

The questionnaire instrument contained both closed-ended and open-ended questions designed to obtain information on perceived causes of wetland conversion, land-use changes, environmental impacts, and socio-economic effects. Variables examined included urban expansion, industrial development, agricultural activities, land reclamation, infrastructural development, and population growth.

To ensure the validity of the research instrument, the questionnaire was reviewed by experts in environmental management, geography, and remote sensing before field administration. A pilot study involving 20 respondents outside the selected sample population was conducted to assess the clarity, consistency, and suitability of the questions. Reliability testing of the questionnaire was subsequently performed using Cronbach's Alpha method, which yielded a reliability coefficient of 0.81, indicating acceptable internal consistency of the instrument.

Ethical considerations were strictly observed throughout the study. Respondents were informed about the purpose of the research, and participation was entirely voluntary. Verbal informed consent was obtained from all participants before questionnaire administration, while confidentiality and anonymity of responses were assured.

2.5. Assessment of environmental impacts

The environmental impacts associated with wetland degradation within the study area were assessed primarily through field observations and secondary environmental data. Field investigations were conducted in selected wetland locations to identify and document visible signs of environmental degradation resulting from wetland conversion and land-use changes.

During the field survey, observations were made on environmental conditions such as vegetation loss, habitat destruction, flooding, soil erosion, blocked drainage channels, shoreline alteration, indiscriminate waste disposal, and water pollution. Photographs and field notes were taken to provide visual and descriptive evidence of the environmental conditions observed within the study area. Particular attention was given to areas experiencing rapid urban expansion, land reclamation, dredging, and infrastructural development due to their influence on wetland ecosystems.

Secondary environmental data were obtained from published journals, environmental reports, government publications, conference proceedings, and relevant literature relating to wetland degradation and environmental management within the Niger Delta region. These secondary sources provided supporting information on biodiversity decline, flood incidence, water quality deterioration, ecosystem instability, and other environmental impacts associated with wetland conversion.

The information obtained from field observations and secondary data sources was carefully reviewed, compared, and interpreted alongside the spatial analysis of land-use and land-cover changes derived from the classified satellite imagery.

2.6. Assessment of socio-economic impacts

The socio-economic impacts of wetland conversion on residents within the study area were assessed through household surveys conducted in selected communities within the Bonny Local Government Area. A total of 250 structured questionnaires were administered to household heads, fishermen, farmers, traders, community leaders, and environmental officers whose livelihoods depend directly or indirectly on wetland resources.

The questionnaire section on socio-economic impacts consisted of 10 structured items designed to obtain information on the effects of wetland conversion on the livelihoods and well-being of residents within the study area. The items covered livelihood activities, fishing and agricultural productivity, household income levels, employment opportunities, food security, access to natural resources, occupational changes, living conditions, and economic challenges associated with wetland degradation. Respondents were also asked to describe changes they had experienced over time as a result of wetland degradation and land-use conversion within their communities.

Household surveys were conducted across selected communities using purposive and random sampling techniques to ensure adequate representation of different socio-economic groups. The information obtained from respondents was supplemented with oral interviews and field observations to provide a broader understanding of the socio-economic conditions within the study area.

2.7. Statistical analysis

Data obtained from questionnaires, field observations, and spatial analysis were coded and analysed using IBM SPSS Statistics (version 21), ArcGIS, and ENVI. Descriptive statistical tools such as frequencies, percentages, tables, charts, and mean values were used to analyse the socio-economic and environmental data.
Spatial analysis and change detection techniques were used to determine changes in land-use and land-cover classes between 2005, 2015, and 2025. The area occupied by each land-use category was computed in hectares and percentages to evaluate the extent of wetland conversion over time.
Classification accuracy assessment was carried out using confusion matrix analysis, while accuracy indicators such as producer's accuracy, user's accuracy, overall accuracy, and Kappa coefficient were calculated to determine the reliability of the classified satellite imagery. The results obtained were presented using tables, charts, maps, and descriptive interpretations.

3. Results and Discussion

3.1. Results

- Classification and Mapping of Urban Wetlands in the Study Area

The study was divided into three epochs (2005, 2015, and 2025) for easy classification (see Figures 2, 3, and 4). After processing the imagery, five land use/land cover (LULC) classes, such as wetlands, built-up areas, mangrove vegetation, water bodies, and dunes, were developed.

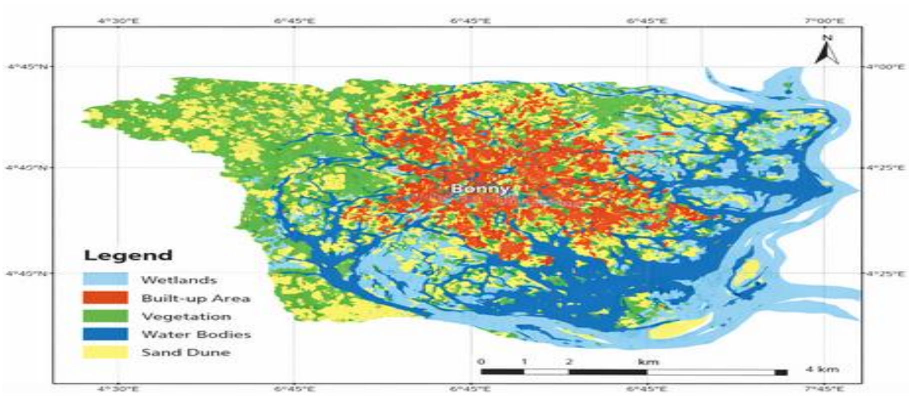


Fig. 2: 2005 Landsat TM Image.

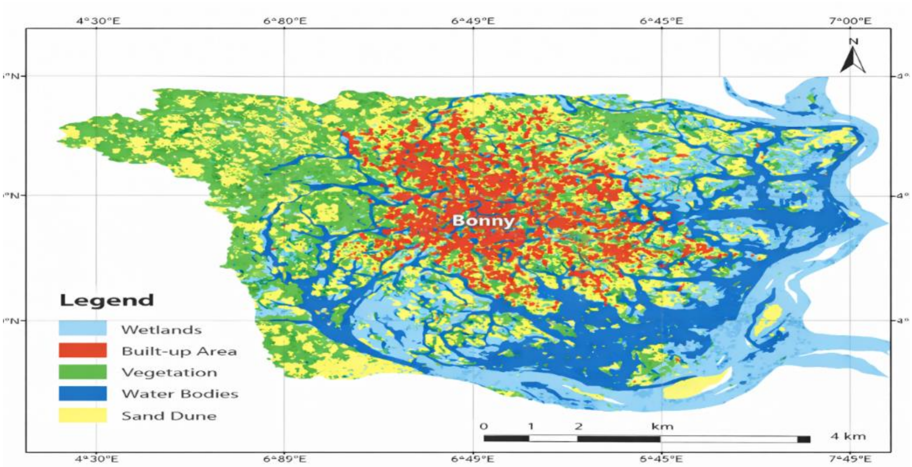


Fig. 3: 2015 Landsat TM Image.

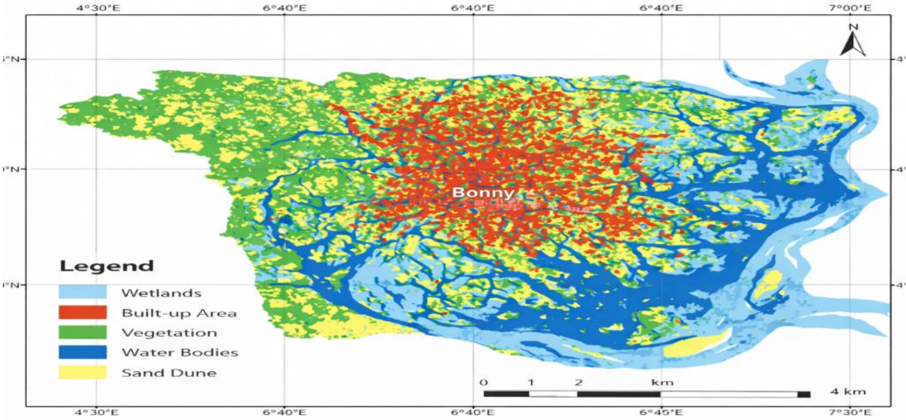


Fig. 4: 2025 Landsat TM Image.

- Spatial and Temporal Changes in Wetland Areal Extent

Table 1 and Figures 2-4 demonstrate the spatial distribution of land use/land cover levels in Bonny Local Government Area across 20 years. The results demonstrate enormous changes in the terrain, with major modifications from natural ecosystems to built-up habitats.

The built-up area displays the most dramatic expansion across the research period.

Spatially, the 2005 picture displays a relatively compact urban core, which increases fast by 2015 by means of visible development into neighbouring land covers. By 2025, the urban area will grow vast and continuous, including much of the core and outside zones. As a result, this leads to an increase from 8,125.7 ha (22.70%) in 2005 to 24,485.2 ha (68.34%) in 2025. This pattern demonstrates significant urbanisation induced by population increase, infrastructural growth, and land reclamation activities, establishing a built-up land as the dominating land cover class.

In contrast, mangrove/vegetation cover sees a steady and considerable reduction. The 2005 map displays vast vegetation, which becomes progressively fragmented by 2015 due to urban expansion. By 2025, vegetation will be reduced to sparse and isolated areas. This is confirmed by a reduction from 12,011.3 ha (33.52%) to 3,625.4 ha (10.10%). The loss of vegetation shows substantial deforestation and habitat degradation, likely related to urban growth and industrial activity, with implications for biodiversity loss and diminished ecosystem services.

Wetlands reveal a changing pattern over time. Spatial information indicates that wetlands were extensive in 2005 and had slight expansion or rearrangement by 2015. However, by 2025, wetlands will have considerably decreased and become fragmented. This tendency is shown in the increase from 9,405.6 ha (26.25%) in 2005 to 10,385.2 ha (28.98%) in 2015, followed by a steep fall to 3,725.6 ha (10.40%) in 2025. The initial increase may be linked to natural hydrological variability or classification improvements, whereas the subsequent decline points to intense land conversion, particularly for urban development. This reduction raises concerns regarding flood regulation, water quality, and ecological stability.

Water bodies remain relatively stable throughout the study period, both spatially and quantitatively. The maps show consistent distribution along river channels and coastal margins, with only minor edge modifications. The minor reduction from 1,864.4 ha (5.20%) to 1,615.8 ha (4.51%) indicates restricted encroachment or sedimentation processes, revealing that hydrological features have been less impacted compared to other land cover types. Similarly, dune areas show a gradual decline and increasing fragmentation. From a more continuous distribution in 2005, these features became reduced by 2015 and further diminished by 2025. The decrease from 4,423.0 ha (12.34%) to 2,378.0 ha (6.64%) suggests coastal modification, potentially driven by both natural geomorphological processes and human interference such as reclamation and construction.

Table 1: Total Area Per Class in Land Use/Land Cover Calculated in Hectares (Study Area: Rivers State)

LULC Type	2005		2015		2025	
	Area (Ha.)	% (Ha.)	Area (Ha.)	% (Ha.)	Area (Ha.)	% (Ha.)
Water bodies	1864.4	5.20	1742.6	4.86	1615.8	4.51
Built-up Area	8125.7	22.70	13940.5	38.89	24485.2	68.34
Mangrove/Vegetation	12011.3	33.52	7108.6	19.82	3625.4	10.10
Wetlands	9405.6	26.25	10385.2	28.98	3725.6	10.40
Sand Dune	4423.0	12.34	2653.1	6.30	2378.0	6.64
Total	35830.0	100	35830.0	100	35830.0	100

- Change detection analysis

Table 2 presents the net changes in land use/land cover between 2005 and 2025 in Bonny Local Government Area, Rivers State. The results provide further insight into the magnitude and direction of land cover transitions. Built-up areas recorded the greatest positive change, increasing by 16,359.5 hectares (45.66%), confirming urban expansion as the dominant land transformation process within the study area. Conversely, mangrove/vegetation experienced the greatest decline, with a loss of 8,385.9 hectares (23.41%). This highlights the extent of ecological degradation and underscores the vulnerability of natural habitats to anthropogenic pressures. Wetlands also recorded a substantial decrease of 5,680.0 hectares (15.85%), reinforcing the observation of significant wetland conversion, particularly in the latter decade.

Water bodies showed only a marginal reduction of 248.6 hectares (0.69%), indicating relative stability despite localised alterations. Dunes declined by 2,045.0 hectares (5.70%), reflecting gradual but consistent coastal landscape changes.

Table 2: Net Change in Land Use/Land Cover (2005–2025)

LULC Type	Change in Area (Ha)	Change (%)
Water Bodies	-248.6	-0.69
Built-up Area	+16359.5	+45.66
Mangrove/Vegetation	-8385.9	-23.41
Wetlands	-5680.0	-15.85
Sand Dune	-2045.0	-5.70

- Major Drivers of Wetland Conversion

Table 3 presents the key drivers influencing wetland conversion in the Bonny Local Government Area. The results indicate that wetland loss is largely driven by anthropogenic activities, with varying degrees of influence across different sectors.

Urban expansion emerges as the most significant driver, accounting for 36.0% of the total responses. This aligns with earlier findings from Table 1 and Figure 2, which show a substantial increase in built-up areas over time. The rapid growth of residential and commercial infrastructure has led to extensive encroachment into wetland areas, making urbanisation the primary force behind landscape transformation.

Industrial development, particularly oil and gas activities, represents the second major driver, contributing 22.0%. Given the strategic importance of Bonny within Nigeria's petroleum industry, industrial infrastructure such as refineries, pipelines, and export terminals has significantly altered the natural landscape. These activities often require large-scale land clearing and reclamation, thereby accelerating wetland degradation.

Land reclamation accounts for 19.2% of wetland conversion. This process is closely linked to both urban and industrial expansion, as wetlands are frequently filled to create stable land for construction and infrastructure development. The high contribution of this factor underscores its critical role in reshaping the coastal environment.

Agricultural expansion contributes 12.8% to wetland loss. Although less dominant than urban and industrial drivers, the conversion of wetlands into farmland reflects increasing demand for food production and livelihood sustenance. This activity further exacerbates ecosystem disruption, particularly in areas where subsistence farming is prevalent.

Population growth, accounting for 10.0%, serves as an underlying driver that indirectly influences all other factors. Increasing population pressure intensifies demand for housing, infrastructure, food, and economic opportunities, thereby amplifying land conversion processes.

Overall, the results highlight that wetland conversion in the study area is predominantly human-driven, with urban expansion, industrial activities, and land reclamation forming the core drivers. These findings reinforce the observed spatial trends and emphasise the need for integrated land use planning and sustainable environmental management to mitigate further wetland loss.

Table 3: Major Drivers of Wetland Conversion in the Study Area (Rivers State)

Driver	Frequency	Percentage (%)
Urban Expansion	90	36.0
Industrial Development (Oil & Gas)	55	22.0
Land Reclamation	48	19.2
Agricultural Expansion	32	12.8
Population Growth	25	10.0

- Environmental Implications of Wetland Degradation

Table 4 shows the major environmental implications associated with wetland degradation in Bonny Local Government Area, based on field observations, community responses, expert input, and spatial analysis. The results indicate that increased flooding, loss of biodiversity, decline in water quality, and habitat destruction are the most prominent impacts.

The findings highlight that the reduction in wetland extent has significantly impaired the natural flood regulation capacity of the area, leading to more frequent and intense flooding events in low-lying communities. It also reveals substantial biodiversity loss, particularly among fish species, birds, and mangrove vegetation, due to the destruction and fragmentation of natural habitats.

Furthermore, the findings show a deterioration in water quality linked to increased pollution from urban and industrial activities, exacerbated by the loss of wetlands that naturally filter contaminants. Habitat destruction is also identified as a critical consequence, resulting in ecosystem instability and reduced resilience.

Table 4: Environmental Implications of Wetland Degradation in Bonny Local Government Area

Environmental Impact	Basis of Assessment	Description	Key Consequences
Increased Flooding	Field observations, community responses, spatial analysis	Reduction in wetland areas has decreased the natural water retention capacity in low-lying zones	Increased flood frequency and intensity, damage to infrastructure, and displacement of residents
Loss of Biodiversity	Field observations, expert opinion	Conversion of wetlands has led to habitat destruction for fish, birds, and mangrove species.	Decline in species diversity, disruption of ecological balance, loss of breeding grounds
Decline in Water Quality	Secondary data, community responses, and spatial analysis	Urban and industrial activities have increased pollutant discharge into water systems following wetland loss	Water contamination, health risks, and reduced aquatic productivity
Habitat Destruction	Spatial analysis, field observations	Continuous wetland ecosystems have been fragmented or completely removed due to land conversion.	Loss of ecosystem services, reduced ecological resilience, and species displacement.

- Socio-Economic Impacts of Wetland Conversion on Local Communities

Table 5 presents the major socio-economic impacts associated with wetland conversion in Bonny Local Government Area. The results indicate that wetland degradation has had both adverse and limited beneficial effects on local communities, with negative impacts being more pronounced.

A major outcome is the loss of traditional livelihoods, particularly among households engaged in fishing, small-scale agriculture, and mangrove resource exploitation. The decline in wetland extent has reduced resource availability, leading to decreased income levels and increased economic vulnerability.

The results also highlight increased flooding and its associated economic costs. The loss of wetlands has weakened natural flood control mechanisms, resulting in more frequent flooding events that damage homes, farmlands, and infrastructure, thereby imposing financial burdens on affected communities.

Public health challenges have also intensified, as declining water quality exposes residents to waterborne diseases. This not only affects community health but also increases healthcare costs and reduces productivity.

Although wetland conversion has contributed to the creation of employment opportunities through urban and industrial development, these benefits are unevenly distributed. In many cases, local populations do not fully benefit from these opportunities, while simultaneously bearing the environmental costs.

Additionally, displacement of communities due to land conversion has resulted in loss of ancestral lands and resettlement difficulties. This is further compounded by social and cultural disruption, as wetlands that once supported traditional practices and cultural identity are lost.

Table 5: Socio-Economic Impacts of Wetland Conversion in Bonny Local Government Area

Socio-Economic Impact	Description	Key Consequences
Loss of Livelihoods	Decline in fishing, farming, and mangrove resource use due to wetland loss	Reduced household income, increased poverty levels
Increased Flooding Costs	More frequent flooding is affecting homes and infrastructure	Property damage, displacement, and higher expenditure on repairs
Public Health Challenges	Deterioration in water quality due to pollution	Increased waterborne diseases, higher healthcare costs
Employment Opportunities	Growth in jobs from urban and industrial development	Improved income for some, but unequal benefit distribution
Displacement of Communities	Conversion of land for development projects	Loss of ancestral lands, resettlement challenges
Social and Cultural Disruption	Loss of wetlands with cultural and traditional value	Erosion of indigenous knowledge, weakened social cohesion

3.2. Discussion

- Spatial and Temporal Changes in Wetland Extent

In relation to spatial and temporal changes in wetland extent, the study reveals a clear pattern of wetland decline, particularly between 2015 and 2025. This trend reflects increasing anthropogenic pressure and is consistent with global and regional observations of wetland loss. Wetlands are known to provide critical ecosystem services, including flood regulation, biodiversity support, and water purification [3,4]. Their decline, therefore, signifies not only land cover change but also the loss of essential ecological functions. The observed wetland fragmentation and reduction further align with findings by Garba et al. [31], who linked wetland degradation in Africa to population growth and expanding human settlements.

- Drivers of Wetland Conversion

Regarding the drivers of wetland conversion, the results clearly indicate that urban expansion, industrial development, and land reclamation are the dominant factors. This is consistent with previous studies identifying anthropogenic activities as the primary causes of wetland loss [12], [13]. In the context of the Niger Delta, these drivers are particularly significant due to the presence of oil and gas infrastructure. As noted by Toochi [32], coastal wetlands in the region are highly vulnerable to industrial activities and land reclamation. Similarly, Numbere and Maduike [33] emphasised that unsustainable exploitation of natural resources has contributed to widespread environmental degradation in the Niger Delta. The findings of this study therefore reinforce the role of human activities as the central drivers of landscape transformation.

- Environmental Impacts of Wetland Degradation

In terms of environmental implications, the study highlights increased flooding, biodiversity loss, declining water quality, and habitat destruction as major consequences of wetland degradation. These impacts are well supported in the literature. Wetlands function as natural flood control systems, and their loss increases flood risk in low-lying areas [16]. Additionally, wetlands serve as critical habitats for diverse species; their degradation leads to significant biodiversity loss [7]. The decline in water quality observed in this study is also consistent with previous findings that wetlands act as natural filters, improving water quality by trapping pollutants. The environmental impacts identified, therefore, reflect the loss of key ecosystem services and reduced ecological resilience [8].

- Socio-Economic Impacts on Local Communities

With respect to the socio-economic impacts on local communities, the findings indicate that wetland conversion has resulted in loss of livelihoods, increased flooding costs, health challenges, and displacement. These outcomes highlight the dependence of local populations on wetland resources. Das and Mallick [34] emphasised that communities reliant on ecosystem services are particularly vulnerable to environmental degradation. Similarly, Ibama and Nengi [17] reported that wetland reclamation in the Niger Delta often leads to socio-economic challenges, including displacement and increased vulnerability. Although urbanisation and industrial development have created employment opportunities, these benefits are often unevenly distributed [5], leaving many residents disproportionately affected by environmental change.

4. Conclusion

This study has demonstrated that Bonny Local Government Area has undergone substantial land use/land cover changes between 2005 and 2025, characterised by rapid urban expansion and significant loss of wetlands and mangrove/vegetation cover. The classification and spatial analysis revealed that built-up areas have become the dominant land cover, increasing markedly over the study period, while natural ecosystems have declined considerably.

The change detection analysis confirms that urban expansion is the primary driver of land transformation, supported by industrial development, land reclamation, agricultural activities, and population growth. These drivers have collectively accelerated the conversion of wetlands and vegetated areas into built-up land, particularly in the later years of the study.

The study further establishes that wetland degradation has resulted in serious environmental consequences, including increased flooding, biodiversity loss, declining water quality, and habitat destruction. In addition, the socio-economic assessment indicates that local communities have been adversely affected through loss of livelihoods, increased exposure to environmental hazards, health challenges, and social disruption.

Although urbanisation and industrialisation have contributed to economic development, the associated environmental and social costs are significant and, in many cases, outweigh the benefits. The findings, therefore, highlight the urgent need for sustainable land use planning and effective environmental management strategies that balance development objectives with ecosystem conservation.

5. Recommendations

Based on the findings of this study, the following recommendations were made:

1) Comprehensive land use planning frameworks should be developed and effectively implemented to ensure that urban expansion is properly regulated and aligned with wetland conservation policies.
2) Existing environmental policies should be strengthened and strictly enforced to control land reclamation, industrial development, and other activities contributing to wetland degradation.
3) Immediate measures should be taken to protect remaining wetlands, while degraded areas should be restored through ecological rehabilitation strategies such as mangrove reforestation.
4) Industries operating within the study area should adopt environmentally sustainable practices and comply with environmental impact assessment (EIA) requirements to minimise ecological damage.
5) Local communities should be actively involved in wetland management, and alternative livelihood options should be promoted to reduce dependence on wetland resources and enhance resilience.

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