

The Impact of Climate Change on Coastal Erosion: A Case of Bonny and Okrika Communities in Rivers State, Nigeria.

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ABSTRACT

Coastal erosion is a major environmental and disaster-risk concern in the Niger Delta, where low elevation, tidal channels, mangrove ecosystems, rapid development and hydrocarbon-related activities interact with climatic and geomorphic processes. This paper examines the impact of climate change on coastal erosion in Bonny and Okrika, Rivers State, Nigeria, using a secondary-data and geospatial evidence-synthesis design. Evidence was assembled from peer-reviewed shoreline-change studies, climate assessments, GIS-based coastal-vulnerability studies and recent Bonny-specific remote-sensing research. The evidence shows that global mean sea level increased by 0.20 m between 1901 and 2018 and that the rate rose from 1.3 mm yr⁻¹ during 1901–1971 to 3.7 mm yr⁻¹ during 2006–2018. Niger Delta shoreline studies demonstrate strong spatial heterogeneity: Afolabi and Darby (2022) found nearly equal shares of erosion and accretion across the wider delta, while recent Bonny-specific work reported net land loss over 2000–2020. A 2024 Rivers State vulnerability assessment ranked Bonny as the most vulnerable assessed coastal area and Okrika third. The paper argues that climate change is a risk multiplier rather than a standalone cause: sea-level rise operates together with subsidence, altered sediment supply, dredging, reclamation, mangrove loss, infrastructure and urbanisation. A publication-grade research protocol is proposed using Landsat/Sentinel-2, DSAS, MNDWI, DEMs, GNSS/InSAR and field validation to quantify shoreline retreat and relative sea-level effects. The study recommends integrated coastal-zone management, mangrove restoration, coastal setbacks, continuous geospatial monitoring, climate-resilient infrastructure and risk-based decisions between protection, accommodation and managed retreat.

Keywords: Climate change; coastal erosion; sea-level rise; shoreline change; Bonny; Okrika; Niger Delta; GIS; remote sensing; coastal vulnerability; adaptation

INTRODUCTION

Coastal zones are dynamic interfaces between land and ocean where sediment supply, waves, tides, river discharge, vegetation, morphology and human activities interact. Climate change is modifying this system primarily through sea-level rise and changes in coastal extremes. The Intergovernmental Panel on Climate Change (IPCC) reports that global mean sea level increased by 0.20 m between 1901 and 2018 and that the rate increased from 1.3 mm yr⁻¹ during 1901–1971 to 3.7 mm yr⁻¹ during 2006–2018 (IPCC, 2021).

These changes are particularly consequential for low-lying deltas. The relevant local quantity is relative sea-level change, which combines ocean-level change with vertical land motion. Subsidence can therefore amplify the effect of global sea-level rise. In deltaic environments, this interaction can increase the frequency of inundation, alter tidal penetration and place shorelines closer to critical thresholds for erosion and flooding.

The Niger Delta is an especially important setting for this problem. Its extensive tidal creeks, mangroves, barrier islands, estuaries and low-elevation settlements support large populations and economically strategic infrastructure. Previous studies have shown that shoreline change in the delta is spatially heterogeneous and that both erosion and accretion occur, with strong dynamics near river mouths (Afolabi & Darby, 2022).

Bonny and Okrika provide contrasting but complementary cases. Bonny occupies a low-lying coastal island environment and is a major oil and gas centre, while Okrika is an island/estuarine urban community within the wider Port Harcourt coastal system. A Rivers State GIS-based vulnerability assessment ranked Bonny first and Okrika third among assessed coastal areas (Igbokwe et al., 2024).

The central proposition of this paper is that climate change should be treated as a risk multiplier. Sea-level rise raises the baseline exposure, while geomorphology, subsidence, sediment disruption, mangrove degradation and human modification determine how much of that climatic pressure becomes shoreline retreat and community impact.

Study Aim and Objectives

The aim is to assess how climate change contributes to coastal erosion risk in Bonny and Okrika communities and to develop an evidence-based framework for monitoring and adaptation.

Specific objectives are to: (1) synthesize evidence linking climate change and coastal erosion; (2) compare published vulnerability evidence for Bonny and Okrika; (3) examine shoreline-change evidence for Bonny and the wider Niger Delta; (4) identify climatic, geomorphic and anthropogenic drivers; (5) develop a rigorous remote-sensing and GIS methodology for future field validation; and (6) recommend climate-resilient coastal management measures.

Research Questions and Hypotheses

RQ1: What evidence links climate change, relative sea-level rise and coastal erosion in Bonny and Okrika? RQ2: What is the spatial and temporal character of shoreline change in the study region? RQ3: How do subsidence and human coastal modification interact with climate-driven processes? RQ4: Which community demonstrates greater published vulnerability? RQ5: What adaptation options are appropriate?

H01: Climate-related variables are not significantly associated with coastal erosion vulnerability in Bonny and Okrika. H11: Climate-related variables are significantly associated with coastal erosion vulnerability. H02: There is no significant difference in coastal vulnerability between Bonny and Okrika. H12: A significant difference exists. These hypotheses should be tested with original transect-level and field data in a subsequent empirical phase.

LITERATURE REVIEW

4.1 Climate change and sea-level rise. Sea-level rise is a well-established consequence of anthropogenic warming. IPCC AR6 attributes observed twentieth- and early twenty-first-century sea-level acceleration primarily to human influence since at least 1971. Projections indicate continued rise throughout the twenty-first century, with the magnitude depending on emissions and ice-sheet response (IPCC, 2021).

4.2 Shoreline dynamics in the Niger Delta. Afolabi and Darby (2022) analysed satellite-derived shorelines from 1986–2019 and found that erosion and accretion occupied nearly equal shares of the wider delta (50.3% and 49.7%), with mean maximum rates of approximately 3.9 and 4.0 m yr⁻¹ respectively. The authors emphasized spatial heterogeneity and stronger dynamics near river mouths. This finding is important because it cautions against treating the entire Niger Delta as uniformly erosional.

4.3 Bonny Island evidence. Bisong and Abija (2025) analysed Landsat imagery for 2000, 2005, 2010, 2015 and 2020. They reported land losses of 1.37 km² from 2000–2005, 0.05 km² from 2005–2010 and 2.55 km² from 2010–2015, followed by 1.05 km² of gain from 2015–2020. Overall, they reported 2.04 km² of net land loss over 2000–2020. Their findings reinforce the value of repeated shoreline mapping while also demonstrating that erosion and accretion can alternate through time.

4.4 Rivers State vulnerability. Igbokwe et al. (2024) used GIS, remote sensing and analytical hierarchy process modelling to classify coastal vulnerability in Rivers State. The high-vulnerability zone covered 545.29 km² (6.38% of the assessed area). Bonny accounted for 139.28 km², followed by Degema at 111.28 km², Okrika at 71.73 km² and Andoni at 62.20 km². Bonny was ranked first and Okrika third.

4.5 Anthropogenic amplification. Coastal erosion cannot be attributed to climate change alone. Dredging, reclamation, vegetation clearing, infrastructure and urbanisation can alter sediment transport and tidal pathways. A Bonny Island study focusing on urbanisation found both erosion and accretion along the studied shoreline, illustrating the need to separate climatic forcing from local land-use effects. Similarly, regional shoreline studies identify river-mouth processes and sediment supply as important controls.

4.6 Remote sensing and DSAS. Satellite imagery provides repeated, spatially consistent observations of shoreline position. DSAS can derive end-point rate (EPR), linear regression rate (LRR), net shoreline movement (NSM) and shoreline-change envelopes. For a Bonny–Okrika study, these methods should be combined with tidal-stage screening, cloud masking, DEM analysis, field GPS/drone surveys and vertical-land-motion measurements.

Study Area

Bonny and Okrika are coastal communities in Rivers State in the eastern Niger Delta. Bonny is located at approximately 4.44°N, 7.23°E, while Okrika is approximately 4.64°N, 7.08°E based on published place-coordinate sources. Both settings are low-elevation coastal/estuarine environments with extensive tidal-water connections. Their exposure is therefore controlled by both marine and estuarine processes.

Bonny's strategic role in oil and gas makes coastal erosion a critical infrastructure-risk issue as well as a community and ecosystem problem. Okrika's proximity to Port Harcourt and its urban-industrial setting create additional pressures associated with settlement expansion, transportation, coastal modification and pollution.

MATERIALS AND METHODS

6.1 Research design. This manuscript uses a structured secondary-data and geospatial evidence-synthesis design. It does not claim new household survey results or new shoreline measurements. Published results are clearly distinguished from the proposed empirical protocol.

6.2 Data sources. Recommended satellite sources include Landsat 5/7/8/9 and Sentinel-2. Ancillary datasets should include DEMs, tide-gauge or satellite-altimetry records, GNSS/InSAR vertical-land-motion estimates, wave/tidal data, land-cover products and field GPS/drone observations.

6.3 Shoreline extraction. The Modified Normalized Difference Water Index (MNDWI) is recommended: $MNDWI = (Green - SWIR)/(Green + SWIR)$. Water-land boundaries are extracted after cloud masking and tidal-stage screening. The same projection and shoreline definition should be maintained across all years.

6.4 DSAS analysis. EPR is calculated as NSM divided by the elapsed time. LRR estimates a regression slope from multiple shoreline positions. NSM quantifies the total displacement between two shoreline dates. Transects should be spaced at a consistent interval and reviewed for intersections with channels, structures and vegetation boundaries.

6.5 Vulnerability analysis. A Coastal Vulnerability Index should integrate shoreline-change rate, coastal slope, elevation, relative sea-level change, tidal range, wave height, geomorphology, vegetation condition and exposure. AHP or another transparent weighting method may be used, with sensitivity analysis to test the effect of weighting choices.

6.6 Statistical analysis. Correlation and multiple regression can be used to examine relationships between erosion rate and candidate drivers. Spatial autocorrelation should be assessed because neighbouring transects are not independent. Confidence intervals should be reported for rates where uncertainty can be estimated.

6.7 Validation and limitations. Shoreline positions should be validated with RTK-GPS or drone observations. Tidal stage and seasonal differences should be documented. Optical shoreline extraction may be affected by turbidity, mangroves, clouds and mixed pixels. These uncertainties should be reported rather than hidden.

Results and Evidence Synthesis

The evidence synthesis shows three consistent patterns. First, global sea-level rise is accelerating. Second, Niger Delta shoreline behaviour is spatially heterogeneous, with both erosion and accretion. Third, Bonny is repeatedly identified as a high-vulnerability area, while Okrika also ranks highly in Rivers State assessments.

IPCC observations show the global mean sea-level rate increasing from 1.3 mm yr⁻¹ in 1901–1971 to 3.7 mm yr⁻¹ in 2006–2018. This establishes a strong climatic background condition for coastal risk.

Afolabi and Darby (2022) found 50.3% of analysed Niger Delta shoreline segments to be erosional and 49.7% accretional during 1986–2019. Their mean maximum rates were 3.9 m yr⁻¹ for erosion and 4.0 m yr⁻¹ for accretion, demonstrating the dynamic nature of the delta.

For Bonny, Bisong and Abija (2025) reported 2.04 km² of net land loss over 2000–2020 after accounting for alternating periods of erosion and accretion. This result is especially relevant to climate adaptation because it demonstrates that long-term net change can coexist with substantial short-term spatial variability.

Rivers State vulnerability mapping identified 139.28 km² of high vulnerability in Bonny and 71.73 km² in Okrika. These figures should be interpreted as outputs of the cited GIS/AHP model, not as direct measurements of annual shoreline retreat.

Taken together, the evidence supports a compound-risk interpretation: climate change increases the baseline pressure, while geomorphology, elevation, sediment dynamics, land motion and anthropogenic modification shape the local response.

DISCUSSION

The findings are consistent with the broader understanding of deltaic coastal systems. A delta can experience both erosion and accretion because sediment deposition may offset marine erosion in some cells while other cells retreat. Consequently, climate attribution requires local measurements rather than simply observing that a shoreline moved landward.

Sea-level rise nevertheless changes the boundary conditions of the system. Higher mean water levels permit tides and extreme water levels to penetrate farther inland and reduce the elevation margin available to low-lying coastal land. In subsiding terrain, the effective rate of relative sea-level rise can be higher than the geocentric ocean-level trend.

Bonny's vulnerability is also influenced by its strategic industrial role. The potential consequence of shoreline retreat is not limited to lost beach or wetland area; it includes exposure of transport corridors, industrial facilities, pipelines, power systems, jetties and settlements. Okrika similarly requires an integrated approach because urban and industrial development can modify coastal processes.

The management implication is that climate adaptation should not rely solely on seawalls. Nature-based solutions, sediment management, setbacks, resilient infrastructure and managed retreat may be more sustainable in different shoreline cells. Hard structures should be supported by hydrodynamic and sediment-transport studies to avoid transferring erosion to adjacent areas.

Climate-Resilient Coastal Management Framework

Short term: establish shoreline-monitoring transects; undertake annual satellite analysis; identify critical infrastructure; enforce temporary development setbacks in erosion hotspots; restore degraded mangroves; and establish community reporting mechanisms.

Medium term: establish GNSS/InSAR subsidence monitoring; conduct drone and RTK-GPS shoreline surveys; develop coastal vulnerability maps; incorporate sea-level scenarios into engineering design; and regulate dredging, reclamation and sand extraction.

Long term: establish an integrated Bonny–Okrika coastal observatory; adopt adaptive coastal-zone plans; develop managed-retreat criteria; maintain sediment budgets; integrate climate projections into infrastructure master plans; and institutionalise periodic revision of vulnerability maps.

CONCLUSION

Climate change is a significant risk multiplier for coastal erosion in Bonny and Okrika, but the evidence does not support attributing all observed shoreline movement to climate change alone. Global sea-level rise provides an increasingly important boundary condition, while local subsidence, sediment supply, river-mouth processes, mangrove condition, dredging, reclamation, urbanisation and infrastructure modify the response.

Published GIS evidence places Bonny among the most vulnerable coastal areas of Rivers State and also identifies Okrika as a major vulnerability hotspot. Bonny-specific satellite research reports net land loss over 2000–2020, while wider Niger Delta studies show that erosion and accretion coexist spatially and temporally.

A defensible publication-grade empirical study should therefore combine multi-temporal satellite imagery, DSAS, DEMs, field validation and vertical-land-motion measurements. The resulting evidence should guide a differentiated strategy of protection, accommodation, ecosystem restoration and managed retreat rather than a uniform hard-engineering response.

RECOMMENDATIONS

(1) Establish a Bonny–Okrika coastal monitoring programme using Landsat and Sentinel-2; (2) install or integrate GNSS/InSAR measurements of vertical land motion; (3) create legally enforceable coastal setback zones; (4) restore and protect mangroves; (5) regulate dredging, reclamation and sand mining; (6) require coastal-climate risk assessments for major infrastructure; (7) use living-shoreline approaches where geomorphically suitable; (8) design hard protection only after hydrodynamic and sediment-transport assessment; (9) establish community-based early warning and shoreline reporting; and (10) develop managed-retreat plans for locations where erosion exceeds economically or environmentally sustainable protection thresholds.

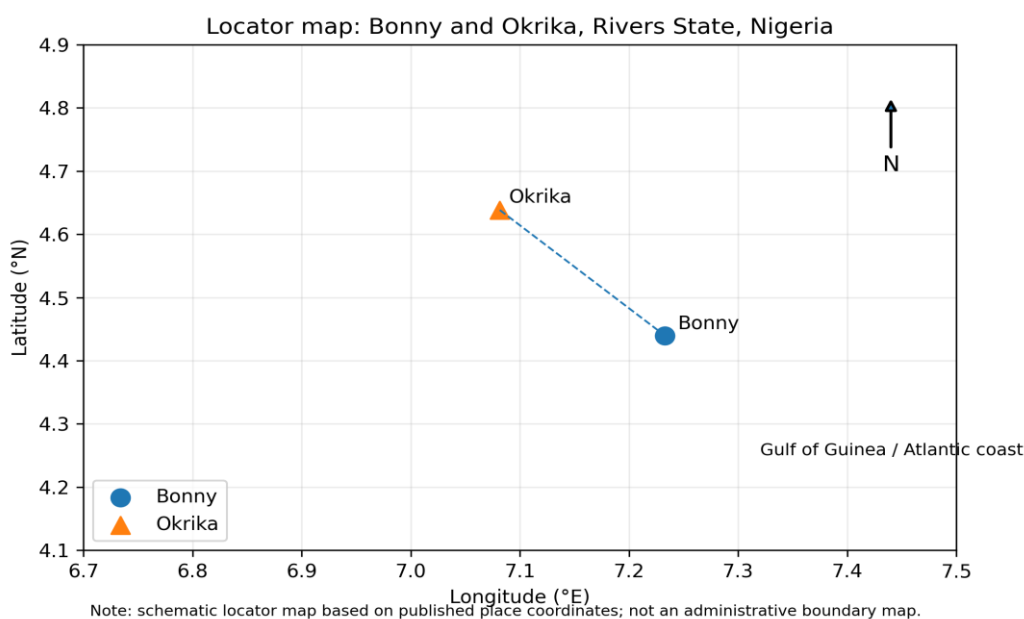


Figure 1. Locator map of Bonny and Okrika.

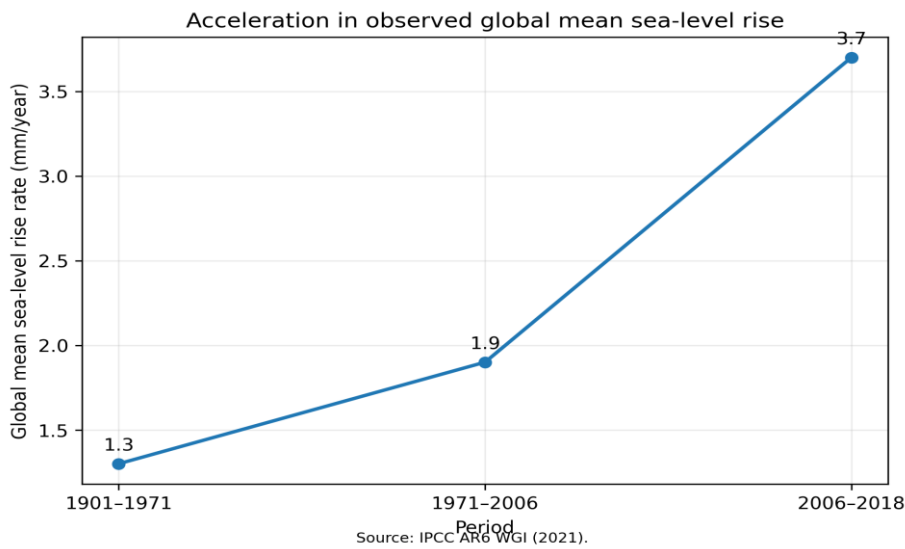


Figure 2. Acceleration in observed global mean sea-level rise.

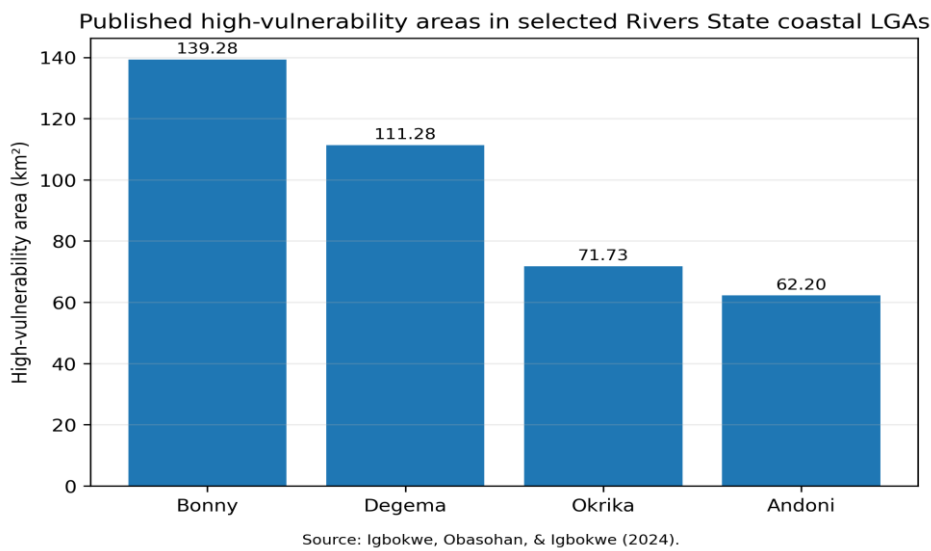


Figure 3. Published high-vulnerability areas in selected Rivers State coastal LGAs.

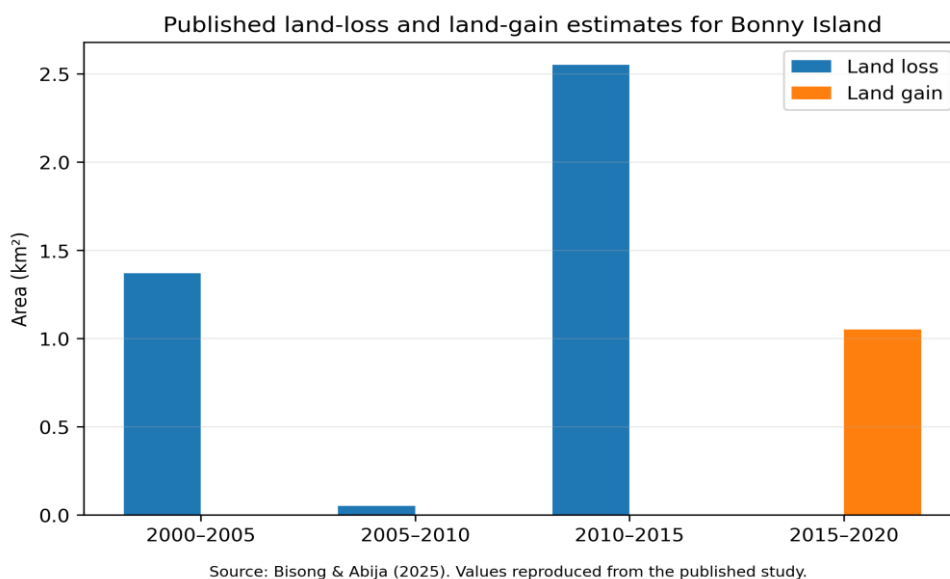


Figure 4. Published land-loss and land-gain estimates for Bonny Island.

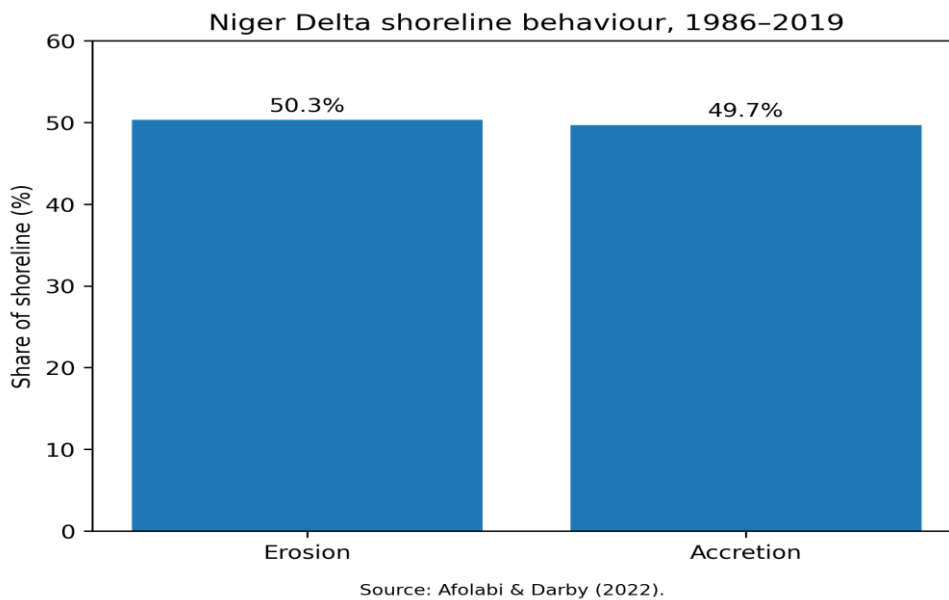


Figure 5. Niger Delta shoreline erosion/accretion proportions, 1986–2019.

Table 1. Published comparative vulnerability evidence

Location	Published high-vulnerability area (km ²)	Rank	Source
Bonny	139.28	1	Igbokwe et al. (2024)
Degema	111.28	2	Igbokwe et al. (2024)
Okrika	71.73	3	Igbokwe et al. (2024)
Andoni	62.20	4	Igbokwe et al. (2024)

Table 2. Global mean sea-level rise rates reported by IPCC AR6

Period	Rate (mm yr ⁻¹)
1901–1971	1.3
1971–2006	1.9
2006–2018	3.7

Table 3. Bonny Island published land-change evidence

Period	Land loss (km ²)	Land gain (km ²)
2000–2005	1.37	0
2005–2010	0.05	0
2010–2015	2.55	0
2015–2020	0	1.05
2000–2020 net	2.04	—

Table 4. Proposed data and analytical framework

Variable	Primary data	Method	Output
Shoreline position	Landsat/Sentinel-2	MNDWI + DSAS	EPR, LRR, NSM
Elevation	DEM + RTK-GPS	Terrain analysis	Elevation/slope
Vertical land motion	GNSS/InSAR	Time-series analysis	Subsidence rate
Sea level	Tide gauge/altimetry	Trend analysis	Relative/absolute trend
Mangrove condition	Sentinel-2/Landsat	NDVI/MVI	Vegetation change
Exposure	Buildings/infrastructure GIS	Overlay analysis	Assets at risk
Community vulnerability	Survey/interviews	Index/statistics	Social vulnerability

Table 5. Climate-resilient adaptation framework

Time horizon	Priority actions	Lead actors	Performance indicator
0–2 years	Monitoring, hotspot mapping, setbacks, mangrove protection	Rivers State agencies, LGAs, operators, communities	Annual shoreline dataset
2–5 years	GNSS/InSAR, drone/RTK surveys, coastal vulnerability maps	Universities, survey agencies, government, industry	Validated vulnerability atlas
5–10 years	Integrated coastal-zone management, resilient infrastructure	Government, communities, industry	Reduced exposure of critical assets
Long term	Adaptive protection/retreat and ecosystem restoration	State/Federal institutions and communities	Reduced residual risk

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