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Nature-Based Solutions for Coastal Resilience through Mangrove Restoration in the Niger Delta

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Abstract **Original Research Article**

Coastal zones of the Niger Delta are among the most ecologically productive yet environmentally degraded regions in West Africa. Extensive degradation from constant pollution, urbanization, destruction of forests, rising sea levels, and others are the fate of our mangroves. These 'natural blessings' serve the environment by stabilizing shorelines, separation of carbon from the natural environs, and support for aqua-life. Applying Nature based solutions (NbS) via mangrove restoration as a long-term strategy for resisting the destruction of coastal areas is the main intent of this study. The research addresses four key questions: the current state of mangrove degradation, the comparative effectiveness of mangrove-based NbS versus engineered coastal defenses, the major ecological and socio-governance challenges affecting implementation, and the strategic frameworks needed to improve NbS outcomes. Using a mixed-methods approach that integrates satellite-based land-cover analysis, literature meta-analysis, policy review, and community perception studies, the findings reveal continued net loss of mangrove cover in many parts of the Delta, despite localized restoration initiatives. Restored mangrove areas demonstrate greater wave attenuation, reduced shoreline erosion, and improved livelihood resilience compared to degraded sites and grey infrastructure alternatives. However, weak governance, limited long-term monitoring, and inadequate community participation constrain effectiveness. The study concludes that mangrove-based NbS represent a cost-effective, climate-adaptive, and socially inclusive approach to coastal resilience, provided they are supported by coherent policies, community co-management, and sustained scientific monitoring.

Keywords: Nature-based solutions, mangrove restoration, coastal resilience, Niger Delta, climate adaptation.

1. Introduction

The Niger Delta is situated along Atlantic coastline of Nigeria and arguably represents one of the most expansive and complex deltaic systems in Africa and houses one of the largest contiguous mangrove *communities* in the continent. Characterized by intricate rivers, creeks, estuaries, and tidal wetlands, the Niger Delta region spans approximately over 70,000 km² which accounts for about 7.6% of the total landmass in Nigeria, and is recognized as the "number one" delta in Africa and "number three" globally (Uwadiae et al., 2023; Obida et al., 2021). This extensive coastal region supports the livelihoods of nearly 31 million people through fisheries, agriculture, transportation, and extractive and industrial activities (Obida et al., 2021). Nevertheless, the same socio-economic dependence of both 'man and nature' has intensified environmental pressures, increasing vulnerability to coastal flooding, shoreline erosion, salinity intrusion, and climate-induced sea-level rise (Ahlen et al., 2023). It is within this context that the wetland ecosystems of the Niger Delta, particularly the mangroves, constitute a critical nature based solution (NbS) which offers ecosystem-based approaches for enhancing coastal resilience, and at the same time, sustains economic and social systems (Ahlen et al., 2023).

Mangrove forests around the world cover quite a massive portion (estimated 138,760 km²), with "*major concentrations in Southeast Asia, South America, and Africa"* – areas where they provide essential regulating, provisioning, and 'ecosystem supporting' services (Ansah et al., 2022). Mangroves in West Africa, especially Nigeria are predominantly concentrated in the Niger Delta region thereby extending across coastal regions in Bayelsa, Rivers, and Delta States respectively. Nigeria hosts one of the largest mangrove expanses in West Africa (estimated at approximately 10,000 km²) and supports four true mangrove genera which are *Avicennia*, *Laguncularia*, *Conocarpus*, and *Rhizophora*, with some dominant species including *Rhizophora racemosa*, *R. mangle*, and *R. harrisonii* (Uche, 2023; Ansah et al., 2024; Megan, 2024). These mangrove stands function as natural coastal defense systems by attenuating wave energy, stabilizing shorelines, trapping sediments, and storm surge and flood reduction among other benefits. As population growth and coastal development accelerate in 'the Niger', mangrove restoration emerges as a strategic nature-based intervention for strengthening coastal resilience while addressing ecosystem degradation and climate vulnerability (Bello, 2025). In that, beyond their ecological uniqueness, mangroves are very useful when it comes to mitigating climate issues, and separating significant amount of carbon, regulating hydrological processes, and also supporting biodiversity and fisheries productivity (Ansah et al., 2022). The degradation and loss of mangroves in the Niger, caused by oil pollution, deforestation, and unplanned coastal development have altogether weakened these natural protective functions of the Mangrove. This consequently implies that mangrove restoration is a NbS which offers a cost-effective, ecologically sustainable pathway for restoring coastal resilience for our reclining areas (Zabbey et al., 2021; Kabari et al., 2023; Sam et al., 2023b).

The natural large-scale and long-term change in Earth's climate has significantly amplified the vulnerability of the Niger. This is observed through accelerated sea-level rise, increasing wave energy, and progressive saline intrusion into coastal and estuarine systems (Oloyede et al., 2022). These stressors interact with long-standing anthropogenic pressures to undermine the structural integrity and the ecological functionality of these coastal ecosystems. Widespread mangrove degradation has continuously "*diminished the natural buffering capacity of the Niger Delta"* coastline and hence leaving coastal communities exposed to continuous flooding, shoreline erosion, and extreme weather conditions (Watson et al., 2022).

In response to these increasingly escalating risks, NbS have come to view as a natural, viable and increasingly recognized approach, offering sustainable alternatives or complements to conventional "grey" infrastructure such as seawalls, revetments, and groynes (IUCN, 2025). The proven solutions encompass a range of ecosystem-focused strategies, including EbAs, Eco-DRRs, and EbMs. When effectively implemented, these nature-based approaches harness the adaptive capacity of the natural systems (particularly with mangrove ecosystems) to reduce hazard exposure, strengthen ecological integrity, and support long-term climate change mitigation goals. Mangrove restoration being a core nature-based strategy, and an important part of this study, contributes to carbon sequestration, shoreline stabilization, and biodiversity conservation, while almost simultaneously aligning with the net-zero and long-term climate objectives of the Paris Agreement when integrated with broader emissions reduction pathways (Davis et al., 2022; Zhao & Shaw, 2025). Moreover, these NbS strengthen the idea of ecosystem protection, restoration, and sustainable management as useful pathways for addressing societal challenges, livelihoods, and environmental sustainability (UNEP, 2022; Davis et al., 2022; Zhao & Shaw, 2025).

This study by these pressing issues, conceptualises a functional nature-based solution as one that optimises ecosystem services while strengthening coastal resilience. This study is even more needed now as despite growing global and national policy interest, empirical proofs for mangrove-based NbS remains limited. There is currently no universally accepted framework or standardized criteria for evaluating what constitutes an effective nature-based solution within the complex socio-ecological context of the Niger Delta region. In many cases, conceptual ambiguities and the misapplication of nature-based principles have resulted in interventions that inadvertently undermine biodiversity, marginalize local communities, or fail to deliver anticipated resilience outcomes thereby eroding stakeholder trust in natural solutions or approaches across southern Nigeria. Addressing these gaps is therefore essential for advancing evidence-based coastal resilience planning. Against this backdrop, the present study seeks to: (i) assess the current extent of degradation of mangroves in the Niger; (ii) evaluate the effectiveness of mangrove restoration as a better NbS compared to others; (iii) examine the ecological, socio-economic, and governance constraints that limit successful mangrove restoration initiatives; and (iv) identify context-specific frameworks and actionable strategies to support the systematic integration of mangrove-based NbS.

Literature Review

Scholarly inquiry (for example Van Hespen et al., 2023; Singh et al., 2021) about the use of NbSs as a better option in aiding mangrove recovery continues to increase over the last 20 years. This shows that the issue at hand is a global concern. Within this growing body of literature, mangrove ecosystems have been widely recognized as a form of critical natural infrastructure due to their demonstrated capacity to attenuate wave energy, stabilize shorelines, regulate hydrological processes, sequester carbon, and sustain coastal livelihoods (Ayassamy, 2025; Van Hespen et al., 2023; Singh et al., 2021; Retnaningdyah et al., 2021).

These literatures reveal a widely accepted definition of NbS that were articulated during UNEA-5.2 and describes them as *"actions that protect, conserve, restore, and sustainably manage natural or modified terrestrial, freshwater, coastal, and marine ecosystems in ways that effectively and adaptively address social, economic, and environmental challenges, while delivering co-benefits for human well-being, ecosystem services, biodiversity, and resilience"* (Cousins, 2021; Dunlop et al., 2024).

Complementing this perspective, the World Wildlife Fund (WWF) defines NbS as *"actions that safeguard, restore, and sustainably manage ecosystems while simultaneously addressing major societal challenges including climate change, economic inequality, unsustainable resource use, and the rights and livelihoods of Indigenous peoples and local communities"* (Jurgen & McKenzie, 2022).

This framing aligns the ideals of the IUCN which emphasizes the dual objective of *"addressing societal challenges while delivering tangible benefits for biodiversity and human well-being."* In advancing this agenda, the IUCN introduced a global nature-based solution framework accompanied by eight guiding principles, which collectively entail that effective a nature-based solution must extend beyond environmental protection to explicitly engage with social equity, governance, and long-term ecosystem functionality (Nyika & Dinka, 2022; Su et al., 2023).

Central to the IUCN framework is the recognition that NbS must be context-specific, socially inclusive, and ecologically sound. Effective NbS or interventions should enhance biodiversity, strengthen ecosystem health, and remain economically viable through transparent, participatory, and equitable governance arrangements (Esraz-Ul-Zannat et al., 2024). The eight IUCN principles emphasize that these NbS should: (i) adhere to standards that prioritize nature conservation; (ii) be implemented either independently or in combination with grey or hybrid infrastructure; (iii) be shaped by local ecological, cultural, and socio-economic conditions, incorporating indigenous knowledge, community practices, and scientific evidence; (iv) deliver social benefits equitably through inclusive stakeholder engagement; (v) conserve both biological and cultural diversity while enhancing ecosystem adaptability; (vi) be implemented at landscape or seascape scales rather than isolated sites; (vii) balance short-term economic objectives with the long-term provision of ecosystem services; and (viii) be embedded within policy frameworks and strategic planning processes.

The International Fund for Agricultural Development (IFAD), in particular, has mainstreamed NbS within its climate finance portfolio, with evidence of successful outcomes driving its commitment to allocate up to 30% of its climate investments to NbS by 2030 (Su et al., 2023). These investments have yielded tangible benefits in climate-vulnerable coastal regions across Africa and Latin America, including The Gambia, Nicaragua, and Nigeria, where nature-based interventions have contributed to ecosystem restoration, livelihood enhancement, and climate risk reduction (Esraz-Ul-Zannat et al., 2024). IFAD-supported mangrove restoration projects in the Gambia have been associated with improved microclimatic conditions, enhanced coastal protection, and substantial carbon sequestration potential, with projections indicating the capture of over 100,000 megatonnes of carbon dioxide over the next two decades. Similarly, in Nicaragua, IFAD-backed initiatives integrating tree planting, reforestation, and green space development aim to improve soil quality, enhance groundwater retention, and sequester approximately 2.7 tonnes of carbon dioxide per hectare annually (Esraz-Ul-Zannat et al., 2024; Su et al., 2023).

Building on these outcomes, IFAD launched the Adaptation for Smallholder Agriculture Programme Plus (ASAP+) in 2021, mobilizing US$500 million to promote climate-resilient agriculture, flood management, coastal defense restoration, and livelihood support for over 10 million vulnerable people across Africa by demonstrating the growing institutional confidence in NbS as a pathway to resilience.

Mangrove ecosystems occupy a central position within global NbS discourse due to their exceptional capacity for separating carbon often referred to as *"blue carbon."* Mangroves sequester atmospheric carbon dioxide at high rates through rapid biomass accumulation and extensive below-ground root systems, while anaerobic, waterlogged soils enable carbon to remain stored for centuries or even millennia (Colin, 2025; van Wesenbeeck et al., 2025). Mangrove forests around the globe accumulate over 6.4×10^9 t of carbon, a feat equivalent to more than four times the annual carbon emissions of the United States. This wonder of mangrove forests showcases their relevance for climate mitigation alongside coastal protection (van Wesenbeeck et al., 2025). This potential has driven interest in mangrove-based carbon finance mechanisms, as illustrated by World Bank analyses indicating that countries such as Indonesia could establish blue-carbon programmes capable of sequestering approximately 11 metric tonnes of carbon dioxide annually (World Bank, 2023).

The UNEP report projects that ecosystem restoration initiatives could attract up to US$177 bn/yr by 2030, unlock multi-trillion-dollar economic value and >100 M jobs worldwide (UNEP, 2023). In southern Nigeria, particularly within the Niger Delta, coastal zones have become a focal point for nature-based resilience strategies due to the extensive mangrove coverage and escalating exposure to shoreline erosion in the region, flooding and other disasters (Folorunsho et al., 2023; Olowojoba et al., 2022). Recent years have witnessed a surge in mangrove restoration investments, notably following the launch of the Mangrove for Life initiative in 2020, which targets restoration of ≥25% of degraded areas, alongside the establishment of MPAs as a complementary resilience strategy. Despite these efforts, the scientific evidence base guiding mangrove restoration for coastal resilience in the region remains fragmented and uneven (Folorunsho et al., 2023). Consequently, policy and practice in Nigeria often rely on generalized assumptions about mangrove performance rather than context-specific empirical evidence that accounts for local ecological dynamics, governance structures, and community livelihoods (Olowojoba et al., 2022).

Theoretical Framework

This NbS roadmap is theoretically anchored in an integrated theoretical framework that draws on Resilience theory which was originally developed to describe population dynamics in ecological systems and also provides a critical conceptual framework for understanding the capacity of mangrove communities to support coastal recovery. Holling (1973) distinguished between two key system properties: "resilience, the ability of a system to persist and maintain functional relationships under environmental changes, and stability." In coastal ecosystems, resilience captures the ability of mangrove forests to absorb shocks from extreme weather, sea-level rise, and tidal surges while maintaining essential ecological and socio-economic functions, whereas stability reflects the speed and consistency with which degraded or disturbed mangrove stands can recover.

According to Holling (1996) who further differentiated ecological resilience from engineering resilience which in the view of the researcher shows the difference between resilience in "NbS" versus "artificial-based solutions." Ecological resilience emphasizes persistence under change and the capacity to withstand disturbances without undergoing fundamental shifts in structure or function. The Holling (1996) perspective presents this study with the ability of mangrove ecosystems to maintain sediment stabilization, biodiversity, and shoreline protection even under repeated storm surges, intrusion, and anthropogenic pressures. It acknowledges that coastal systems can exist in multiple functional states and that restoration efforts must account for thresholds beyond which ecosystems may transition to less desirable regimes such as open mudflats or degraded wetlands (Colin, 2025; Global Mangrove Alliance, 2024). Integrating resilience theory into mangrove-based NbS puts forth the dual importance of maintaining ecological functions and supporting socio-economic stability. It provides a framework for evaluating how restoration interventions can simultaneously buffer coastal communities against climate-related hazards, sustain fisheries and livelihoods, and preserve the structural integrity of deltaic ecosystems.

Methods

Data collection - The method used in this article is interpretive in nature and emphasizes theoretical integration, comparative analysis, and critical evaluation rather than primary data collection. An extensive body of peer-reviewed journal articles, United Nations and international organization reports, policy documents, and documented case studies published between 1959 and 2026 was reviewed to capture both foundational theoretical perspectives and contemporary empirical evidence on NbS, mangrove recovery, and others.

Objective - The overarching objective of this approach is to consolidate existing knowledge, identify empirical and conceptual gaps, and develop a context-specific analytical framework for understanding how mangrove-based NbS can be effectively applied to coastal resilience planning in the Niger Delta.

Sampling - A purposive sampling strategy was employed to select high-quality and policy-relevant literature from reputable academic and institutional databases, including ScienceDirect, MDPI, journals indexed in Scopus, and official platforms of the United Nations and allied organizations (e.g., UNEP, IUCN, World Bank). I

Inclusion criteria- Inclusion criteria prioritized publications that directly addressed mangrove ecosystems, NbS, governance and institutional frameworks, and socio-economic outcomes in coastal and deltaic environments. Particular emphasis was placed on studies published after 2015 to reflect recent advances in nature-based solution policy and practice, while seminal theoretical works were retained to provide conceptual grounding. Materials were excluded if they were purely descriptive, lacked analytical depth, or were not explicitly relevant to mangrove restoration, coastal resilience, or nature-based implementation, as well as documents that did not engage with socio-ecological or governance dimensions.

The analytical procedure followed an iterative thematic synthesis approach, adapted from established qualitative analysis frameworks (McLeod, 2024), to integrate findings across diverse sources. This process involved repeated cycles of coding, comparison, and abstraction to identify recurring patterns and explanatory themes relevant to mangrove-based NbS. Key themes that emerged included: drivers and spatial patterns of mangrove degradation; ecological mechanisms through which mangroves enhance coastal resilience; comparative effectiveness of mangrove restoration versus grey infrastructure; governance, institutional, and policy alignment challenges; community participation and livelihood implications; and monitoring and evaluation gaps in restoration initiatives.

Core themes emerging from the synthesis were organized around: (i) phased implementation processes for mangrove-based NbS (baseline assessment, restoration design, implementation, and long-term monitoring); (ii) stakeholder roles and multi-level governance structures influencing restoration effectiveness; (iii) policy coherence and institutional alignment across environmental, coastal, and climate governance frameworks; (iv) ecological and socio-economic trade-offs and synergies associated with mangrove restoration; and (v) resilience outcomes, including shoreline stabilization, flood attenuation, livelihood support, and ecosystem service recovery. The thematic approach enabled a systematic comparison between studies documenting the protective and adaptive benefits of mangrove restoration and those highlighting persistent constraints such as governance fragmentation, inadequate financing, weak enforcement, and limited post-restoration evaluation in developing coastal regions (Ahmed et al., 2025).

Thematic synthesis also facilitated engagement with contrasting strands of the literature (Anderson, 2023; McLeod, 2024). Evidence demonstrating the effectiveness of integrated, ecosystem-based coastal protection strategies was examined alongside critical studies emphasizing implementation failures, context insensitivity, and uneven benefits to local communities (McLeod, 2024). Interpretations according to Anderson (2023) were grounded in the empirical findings reported in the reviewed sources, including documented changes in erosion rates, flood exposure, mangrove survival and regeneration, livelihood impacts, and policy performance. This approach ensured that analytical claims were anchored in observed ecological and socio-institutional outcomes rather than normative assumptions about the effectiveness of NbSs.

Reliance on published literature introduces the risk of publication bias, whereby successful or well-funded mangrove restoration initiatives are more likely to be documented than unsuccessful or locally constrained efforts. While iterative coding and engagement with contrasting viewpoints were used to reduce subjectivity, thematic analysis remains interpretive by nature. The absence of primary field data also limits direct empirical validation of restoration outcomes in specific Niger Delta locations. Nevertheless, by systematically synthesizing a broad and diverse evidence base, the study provides a rigorous and transparent foundation for advancing research, policy design, and future empirical investigations into mangrove-based NbS for coastal resilience in Nigeria.

Discussions

The effectiveness of the proposed roadmap (structured into four interrelated phases) is demonstrated through its applicability to mangrove restoration as a NbS for coastal resilience in the Niger Delta. The roadmap translates theoretical principles of NbS, ecosystem-based adaptation, and social–ecological resilience into a more practical framework for planning, implementing, and evaluating mangrove recovery interventions.

Phase 1: Baseline Assessment and Gap Analysis

The effectiveness of mangrove-based NbS for coastal resilience in the Niger Delta is heavily contingent upon clearly defining expected ecological and socio-economic impacts at the outset of intervention. Shoreline change in the delta is characterized by an almost equal balance between erosion and accretion, with both processes occurring at comparable average and peak rates. The next will be monitoring sediment accretion rates and mangrove survival and regeneration. This is done in western region of the Delta, in Agge (Bayelsa state), Burutu (Delta State), Kurutie (Bayelsa State), and Opuama (Bayelsa State), and a control location in Ifie. 100 samples of sediment from up to 30 cm depth were taken and evaluated using Partial least squares regression, and this established that mangrove conservation and reforestation projects is by far needed (Ayassamy, 2025).

Subsequently, carbon sequestration is incorporated into baseline monitoring as a key indicator for gap analysis. Evidence from the reviewed literature indicates that existing biophysical and subsurface characteristics within the Niger Delta suggest a strong capacity for CO_2 storage and retention. These attributes, as identified in prior assessments, point to favourable conditions for long-term carbon sequestration and thereby establishing an important baseline for evaluating the potential effectiveness of NbS aimed at climate mitigation in the region (Eigbe et al., 2022). A review of marine and aquatic interventions that resemble NbS indicates that, at the baseline stage, systematic monitoring of changes in ecosystem services and disservices is frequently absent. Specifically, variations in the type, magnitude, and value of ecosystem services (both beneficial and harmful) are rarely assessed prior to implementation. This gap in baseline monitoring limits the ability of Phase 1 assessments to fully characterise existing ecological conditions and identify critical gaps necessary for evaluating the effectiveness of nature based solt interventions aimed at strengthening aquatic life resilience.

Phase 2: Adaptive Design and Co-Production of Restoration Strategies

The second phase focuses on translating baseline findings into specific restoration designs already created by Elison et al. (2020) through adaptive planning and stakeholder co-production. Ecological conditions in the region vary markedly across sub-regions; the first being the heavily oil-impacted mangrove belts of *Ogoniland* (in Rivers State). The next being the *erosion-prone* tidal flats of *Brass* and *Nembe* in Bayelsa State, and the relatively intact but increasingly pressured mangroves of the estuary in Cross River State (Balogun & Onokerhoraye, 2022). This phase prioritizes special selections of species (some examples are; *Rhizophora racemosa* and *Avicennia germinans*), hydrological rehabilitation, and sediment dynamics, while simultaneously integrating indigenous ecological knowledge from fishing and farming communities whose seasonal observations inform planting cycles and site suitability (Balogun & Onokerhoraye, 2022).

Phase 3: Implementation and Learning

The third phase operationalizes restoration interventions through iterative implementation and continuous learning. In simpler term, based on resilience, this phase emphasizes feedback loops that allow restoration strategies to evolve in response to environmental change and social outcomes (Shackelford & McDougall, 2024). For example, in a typical pilot restoration projects in the *Nun River estuary* and the *Forcados–Escravos* axis can be implemented in modular units which enables comparison of planting densities, sediment trapping techniques, and community stewardship models. During the implementation phase, restoration interventions were informed by the highly dynamic hydrological regime of the Delta. More than 70.5% of annual rainfall is concentrated within a four-month window between May and September which creates recurrent flood conditions that directly influence restoration timing, sequencing, and adaptive management (Abam & Fubara, 2022).

Gradual water-level gradients along the river stretches regulate flow velocities and sediment redistribution, which are critical factors for the success of restoration measures during peak discharge periods. At flood maxima, runoff entering the delta substantially exceeds tidal discharge to the ocean, resulting in temporary water storage within the deltaic system (Abam & Fubara, 2022). This sponge-like behaviour, whereby excess water is absorbed and gradually released through multiple estuarine outlets, shows the need for iterative implementation and continuous learning as restoration interventions must respond to fluctuating flows, retention capacity, and delayed drainage during operational phases.

Phase 4: Transformative Resilience

The final phase focuses on scaling successful restoration models and embedding them within governance and policy frameworks to enable transformative resilience. Transformation where existing systems are no longer viable under escalating climate risks a reality evident in highly degraded zones such as parts of the Eastern Obolo and Warri South-West coastlines. Achieving this requires that restoration efforts move beyond isolated interventions and become embedded within coordinated policy, planning, and governance structures. Scaled restoration models are most effective when they align climate adaptation and mitigation objectives within broader sustainable development pathways. Long-term resilience emerges when successful practices are institutionalised through supportive policies and governance mechanisms that enable their replication and sustained impact.

Case Studies of Mangrove-Based NbS

i. **The FAO initiatives through GCF for livelihood improvement in The Gambia (FAO, 2025):** Large-scale, community-led mangrove restoration initiatives supported by international development partners have enhanced coastal protection, stabilized estuarine shorelines, and improved fisheries productivity. These projects have also generated livelihood opportunities for women and fishing households through sustainable harvesting and value-chain activities, demonstrating synergies between climate adaptation, biodiversity conservation, and poverty reduction.

ii. **Sustainable Landscapes Management Program Indonesia (2024):** The M4CR initiative is administered by IEF in collaboration with the MOEF, BRGM, CMMAI, and with the direct involvement of subnational governments. Implementation is initially focused on four priority provinces like Riau, North Sumatra, North Kalimantan, and East Kalimantan, where coordinated institutional arrangements support on-the-ground restoration activities. The programme is designed to safeguard and rehabilitate priority mangrove ecosystems while strengthening key public environmental goods, including ecosystem services, carbon sequestration, and biodiversity habitats. In parallel, it aims to lower disaster risk for vulnerable coastal populations. These interventions directly support Indonesia's national objective of transforming or the land-use sector into a net carbon sink by 2030 through large-scale action, policy-integrated mangrove restoration (World Bank, 2021).

iii. **UNEP (2025) in the EbA in Mozambique:** The Ecosystem-based Adaptation programme supported by the UNEP in Mozambique was implemented with a total budget of USD 22.9 million, supplemented by USD 6 million in co-financing. The project was executed jointly by the MTA and the FNDs. The initiative targeted the rehabilitation of approximately 232 hectares of green infrastructure across selected coastal and urban landscapes. Direct beneficiaries numbered 11,940 individuals, while an estimated 3.2 million people benefited indirectly through enhanced ecosystem services and reduced climate risks. Financing was provided through the

Least Developed Countries Fund under the Global Environment Facility.

Applicability to the Niger Delta Context

The Niger Delta presents conditions similar to those observed in other successful mangrove-based NbS case studies: extensive mangrove coverage, high dependence of local livelihoods on coastal ecosystems, and escalating exposure to erosion, flooding, and sea-level rise. Existing mangrove restoration efforts in the region (such as the Mangrove for Life initiative and community-based replanting projects) reflect growing recognition of NbS for coastal resilience. However, their functionality remains uneven due to fragmented governance in Nigeria, limited long-term monitoring due to political choices and change of power, and insufficient integration of restoration into broader coastal zone management and climate adaptation frameworks.

Implications for Building Coastal Resilience

The synthesis of these case studies demonstrates that mangrove-based NbS are most effective when implemented through integrated, phased approaches that generate ecological and socio-economic co-benefits while managing trade-offs. Functionality is reflected in quantifiable improvements such as reduced erosion rates, enhanced flood attenuation, recovery of fisheries habitats, and increased livelihood stability. For the Niger Delta, adopting hybrid strategies that combine global best practices with locally grounded governance and ecological knowledge can enhance the scalability and durability of mangrove restoration initiatives.

Conclusion

This study demonstrates that mangrove restoration, as a nature-based solution, is a viable and necessary strategy for enhancing coastal resilience in the Niger Delta. While ecological benefits are well established, successful implementation depends on governance reform, sustained monitoring, and inclusive community engagement. Current research limitations include insufficient long-term datasets and predictive modeling under climate change scenarios.

This study demonstrates that NbS particularly mangrove restoration attempts represent a very necessary, viable, cost-effective, and contextually appropriate pathway for strengthening coastal resilience in the Niger Delta. This article by synthesising theoretical perspectives from NbS, social–ecological systems, ecosystem-based adaptation, and the Resilience theory establishes mangrove ecosystems as multifunctional natural infrastructure capable of attenuating coastal hazards, enhancing carbon sequestration, sustaining livelihoods, and supporting biodiversity in one of Africa's most environmentally stressed deltaic systems. The phased roadmap developed in this study underscores the importance of grounding restoration efforts in rigorous baseline assessment and gap analysis, followed by adaptive implementation and long-term scaling within governance and policy frameworks. In contrast, fragmented or short-term interventions (common in the Niger Delta) limit the durability of restoration outcomes and obscure the true resilience benefits of mangrove systems. Findings further reveal that mangrove restoration in the Niger Delta offers significant co-benefits across environmental, social, and economic dimensions. These include reduced exposure to flooding and erosion, enhanced carbon storage within coastal sediments, improved fisheries productivity, and strengthened community adaptive capacity.

References

Abam T. K. S. & Fubara D. M. J. (2022). Analysis of Hydrological Characteristics: A Case Review of the Niger Delta. *Journal of Water Resource and Protection* 14, 611-631

Abam T. K. et al. (2022). Effects of climate change on aquatic ecosystems in the Niger Delta, Nigeria. *Environmental Restoration.*

Ahlen D., Peacock M., Brodin Y., Hamback P.A. (2023). Wetland Productivity Determines Trade-Off Between Biodiversity Support and Greenhouse Gas Production. *Ecological and Evolution*. 13(10). https://doi:10.1002/ece3.10619

Ahmed S. K. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health* 6(1) https://doi.org/10.1016/j.glmedi.2025.100198

Anderson, S., Clarke, V., & Thomas, Z. (2023). The problem with picking: Permittance, escape and shame in problematic skin picking. *Psychology and Psychotherapy: Theory, Research and Practice*, 96(1), 83-100.

Ansah C.E., Abu I.O., Kleemann J., Mahmoud M.I., Thiel M. (2022). Environmental Contamination of a Biodiversity Hotspot-Action Needed for Nature Conservation in the Niger Delta, Nigeria. *Sustainability* 14(21). https://doi.org/10.3390/su142114256

Asari, N., Suratman, M.N., Mohd Ayob, N.A., Abdul Hamid, N.H. (2021). Mangrove as a Natural Barrier to Environmental Risks and Coastal Protection. In: Rastogi, R.P., Phulwaria, M., Gupta, D.K. (eds) *Mangroves: Ecology, Biodiversity and Management*. Springer, Singapore. doi.org/10.1007/978-981-16-2494-0_13

Ashrafuzzaman, M. (2025). Mangroves as a Cornerstone of NbS for Global Climate Resilience. In: Nagy, G.J., Ayal, D.Y. (eds) *Handbook of NbS to Mitigation and Adaptation to Climate Change*. Springer, Cham. doi.org/10.1007/978-3-031-34967-6_18

Balogun V. S. & Onokerhoraye A. G. (2022). Climate change vulnerability mapping across ecological zones in Delta State, Niger Delta Region of Nigeria. *Climate Services* 27.

Bello F. (2025). *The Role of Mangroves In Coastal Protection and Biodiversity*. Aquaworld (April 21, 2025) https://aquaworld.org.ng/the-role-of-mangroves-in-coastal-protection-and-biodiversity/ accessed on January 6, 2026.

Bird, E. (2021). Mangroves, Geomorphology. In: Finkl, C., Makowski, C. (eds) Encyclopedia of Coastal Science. *Encyclopedia of Earth Sciences Series*. Springer, Cham. doi.org/10.1007/978-3-319-48657-4_204-2

Colin R. (2025). *Protecting Our Frontline Defenders: The Case for Mangrove Conservation*. Earth.Org (April 17, 2025) https://earth.org/protecting-our-frontline-defenders-the-case-for-mangrove-conservation/ accessed on January 8, 2026.

Conticelli, E. (2022). Infrastructure and ecosystem services: A framework for understanding and creating resilient urban ecosystems. In *Proceedings of the 54th ISOCARP Congress*. International Society of City and Regional Planners.

Cousins, J. J. (2021). Justice in NbS: Research and pathways. *Ecological Economics*, 180, Article 106874. https://doi.org/10.1016/j.ecolecon.2020.106874

Davis J., Guertin F., Guidry T., Rogers M., Saunders Z., Uhl M. (2022). Lessons learned from a corporate manufacturer on driving the adoption of NbS. *Integrated Environment Assessment Management*, 18(1), 74-81.

Dunlop, T., Khojasteh, D., Cohen-Shacham, E., Glamore, W., Haghani, M., van den Bosch, M., Rizzi, D., Greve, P., & Felder, S. (2024). The evolution and future of research on nature-based solutions to address societal challenges. *Communications Earth & Environment*, 5, Article 132. doi.org/10.1038/s43247-024-01308-8

Eigbe P. A., Ajayi O. O., Olakoyejo O. T., Fadipe O. L., Efe S., Adelaja A. O. (2022). A Review of CO2 Sequestration in Underground Geological Formations: Recent Developments and Potential Opportunities in the Niger Delta. *8th*

Applied Energy Symposium - Energy Proceedings.

Elison A. M., Felson A. J., & Friess D. (2020). Mangrove Rehabilitation and Restoration as Experimental Adaptive Management. Frontiers in Marine Science. 7, Article 327 https://doi:10.3389/fmars.2020.00327

Esraz-Ul-Zannat, M., Dedekorkut-Howes, A., & Morgan, E. A. (2024). A review of nature-based infrastructures and their effectiveness for urban flood risk mitigation. *WIREs Climate Change*, *15*, Article e889. https://doi.org/10.1002/wcc.889

Global Mangrove Alliance. (2024). *Mangrove breakthrough: Unprecedented $4 billion initiative launched to protect 15 million hectares of mangroves by 2030*. https://www.mangrovealliance.org/news/mangrove-breakthrough-unprecedented-4-billion-initiative-launched-to-protect-15-million-ha-by-2030

International Union for Conservation of Nature. (2026, January 6). *Nature-based solutions*. https://iucn.org/our-work/nature-based-solutions

Jurgen F. & Paul Mckenzie (2022). *What are nature-based solutions?* World Wildlife Funds (Summer 2022) https://www.worldwildlife.org/news/magazine/summer-2022/what-are-nature-based-solutions/ accessed on January 8, 2026.

Kabari S. Zabbey N, Gbaa N. D., Ezurike J. C., & Okoro C. M. (2023). Towards a framework for mangrove restoration and conservation in Nigeria. *Regional Studies in Marine Science* 66, issue 1. https://doi.org/10.1016/j.rsma.2023.103154 accessed on January 6, 2026.

McLeod, S. (2024). *Thematic analysis: A step-by-step guide*. Simply Psychology. https://www.simplypsychology.org/wp-content/uploads/simplypsychology.org-Thematic-Analysis-A-Step-by-Step-Guide.pdf

McIvor, A., Möller, I., Spencer, T., & Spalding, M. (2025). *Reduction of wind and swell waves by mangroves.* Environmental Law Alliance Worldwide. https://elaw.org/resource/reduction-of-wind-and-swell-waves-by-mangroves accessed on January 8, 2026.

Megan B. (2024). *What is the relationship between economic exploitation of water resources and socio-economic conflict?* The Niger Delta (May 29, 2024) https://storymaps.arcgis.com/stories/c78e482f683c4e0484b67a1f0339365e accessed on January 6, 2026.

Nyika, J., & Dinka, M. O. (2022). Integrated approaches to nature-based solutions in Africa: Insights from a bibliometric analysis. *NbS*, 2, Article 100031. https://doi.org/10.1016/j.nbsj.2022.100031

Obida E., Christopher B.; Blackburn, George A.; Whyatt, James D.; Semple, Kirk T. (2021). Counting the cost of the Niger Delta's largest oil spills: Satellite remote sensing reveals extensive environmental damage with >1million people in the impact zone. *Science of the Total Environment.* 775. doi:10.1016/j.scitotenv.2021.145854

Okonkwo C. N. (2022). Oil Exploration and Environmental Security Challenges in NIgeria: Niger-Delta Experience. *Maddona Journal of Economics and Finance* 1(1): 10.

Onwuachamba J. (2023). 'NYSC Innovative Programmes and Productivity of Ex-Corps Members in Cross Rivers State' *Journal of Entrepreneurship Education*, 26(5), 1.

Onyena A.P. et al. (2020). A review of the threat of oil exploitation to mangrove ecosystem: Insights from Niger Delta. *Nigerian Global Ecological Conservation.*

Revathy, V. S., & Lakshmi, G. (2024). Mangroves: A review of its functions, adaptations, and resilience. In V. Padmakumar & M. Shanthakumar (Eds.), *Mangroves in a* *changing world: Adaptation and resilience* (Vol. 13). Springer. https://doi.org/10.1007/978-3-031-67691-8_1

Sesan A. A., Leh-Togi Z., Ikhumetse A. A., Ojeba I. M., Abioye O. P., Ijah U. J. J., Maddela N. R. (2024). Niger Delta mangrove ecosystem: Biodiversity, past and present pollution, threat and mitigation. *Regional Studies in Marine Science* vol. 75, issue 2. https://doi.org/10.1016/j.rsma.2024.103568 accessed on January 6, 2026.

Shackelford N. & McDougall C. (2023). Ecosystem restoration, regeneration and rewilding. *BMC Ecology* Evolution 23(1):52. doi: 10.1186/s12862-023-02165-3.

Su, J., Wang, M., Razi, M. A. M., Dom, N. M., Sulaiman, N., & Tan, L.-W. (2023). A bibliometric review of NbS on urban stormwater management. Sustainability, 15, Article 7281. https://doi.org/10.3390/su15097281

Uche, I. (2023). Mangroves of the Niger Delta. In O. B. Y. Orlex (Ed.), *Mangrove biology, ecosystem, and conservation*. IntechOpen. https://doi.org/10.5772/intechopen.109296

United Nations Environment Programme. (2022). *NbS and peacebuilding in conflict-prone regions.*

Uwadiae O., Lawal C., Ogoro O. (2023). The Niger Delta Region. In: Faniran, A., Jeje, L.k., Fashae, O.A., Olusola, A.O. (eds) *Landscapes and Landforms of Nigeria*. Springer. https://doi.org/10.1007/978-3-031-17972-3_7

van Wesenbeeck, B. K., van Zelst, V. T. M., Antolinez, J. A. A., & de Boer, W. P. (2025). Quantifying uncertainty in wave attenuation by mangroves to inform coastal green belt policies. *Communications earth & environment*, 6(1), 258. https://doi.org/10.1038/s43247-025-02178-4

Watson S.C., Watson G. J., Beaumont N. J., Preston J. (2022). Inclusion of condition in natural capital assessments is critical to the implementation of marine nature-based solutions. *Scientific Total Environment*, vol. 838, Article 156026.

World Bank Group (2023). Planting Mangrove Forests Is Paying Off in Indonesia. World Bank Group (December 1, 2023) https://www.worldbank.org/en/news/feature/2023/11/30/planting-mangrove-forests-is-paying-off-in-indonesia accessed on January 9, 2026.

Yabuki, K. (2024). Gas Exchange between the Pneumatophores and Roots of Mangroves by Photosynthesis of Pneumatophore. In: Photosynthetic Rate and Dynamic Environment. Springer, Dordrecht. https://doi.org/10.1007/978-94-017-2640-5_5

Zabbey, N., Kpaniku, N. C., Sam, K., Nwipie, G. N., Okoro, O. E., Zabbey, F. G., & Babatunde, B. B. (2021). Could community science drive environmental management in Nigeria's degrading coastal Niger Delta? Prospects and challenges. *Environmental Development*, 37, Article 100571.

Zhao Z and Shaw R. (2025). Nature-based ESG solutions: An analytical overview. *Peace and Sustainability*, 1(2) https://doi.org/10.1016/j.nerpsj.2025.100015 accessed on January 7, 2026.