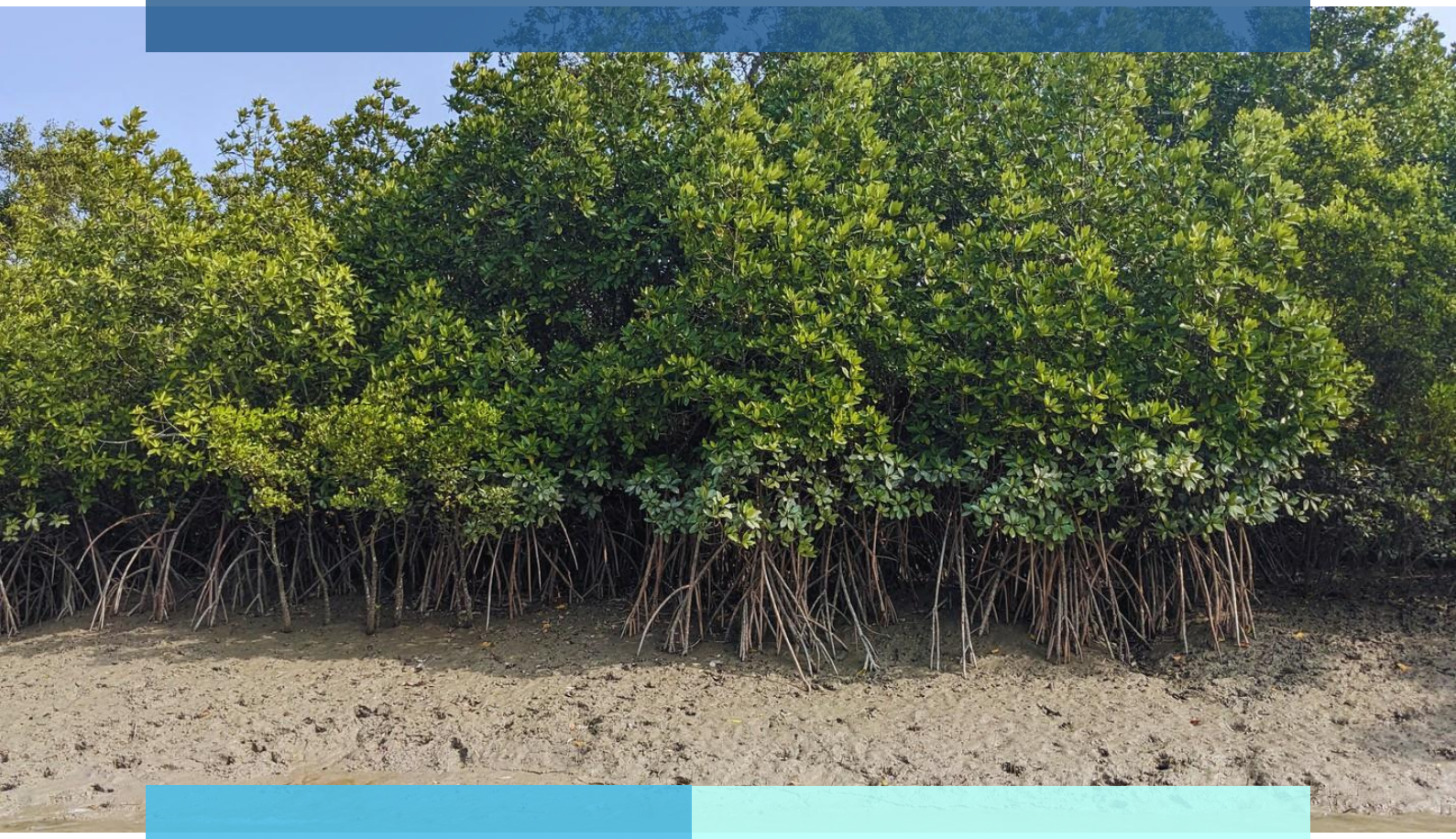
FINAL REPORT



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ECO-HYDROLOGY FOCUS ON RESTORATION IN THE SUNDARBANS BIOSPHERE RESERVE, INDIA - FOCUS ON NATURE AND PEOPLE

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SUMMARY

This comprehensive investigation into the ecohydrological dynamics of the Sundarbans Biosphere Reserve (SBR) presents a portrait of a globally significant ecosystem at a critical crossroads. The report, drawing on extensive analysis from 1990 to 2024 with projections to 2050, reveals an environment undergoing profound transformation due to a confluence of climate change, altered hydrology, and intense anthropogenic pressures. While the Sundarbans remains a vital carbon sink and a sanctuary for immense biodiversity, including iconic protected species such as the Bengal tiger and estuarine crocodile, its resilience is being tested, and its ecological functions are approaching critical thresholds. The study focuses on the vulnerable, inhabited eastern islands of Gosaba, Satjelia, and Jharkhali, which, compared to the more severely degraded western and northern parts of the SBR, possess considerable potential for restoration but face acute and growing environmental threats.

The central finding of the report is the alarming and accelerating crisis of freshwater scarcity, which fundamentally threatens the region's ecological and social fabric. The spatiotemporal analysis uncovered a catastrophic decline in surface water bodies between 1990 and 2024. On Gosaba Island, the surface water area plummeted by 80%, from 91 hectares to a mere 18.11 hectares , while Satjelia Island experienced an 89% reduction, from 137.87 hectares to just 14.85 hectares. This loss is driven by a complex interplay of factors. The region's climate is characterized by a long-term average annual rainfall of 1,754 mm, but its predominantly clay-loam soils have low permeability, causing a high proportion of this rainfall (40-70%) to be lost as surface runoff. Trend analysis further indicates a statistically significant decline in low and moderate runoff events, signaling a shift toward a more erratic hydrological regime defined by extremes. Paradoxically, essential conservation efforts have contributed to this water shortage. Extensive mangrove plantation initiatives, which successfully expanded from 15.01 hectares in 1995 to 79.84 hectares in 2023 in one restoration site on Gosaba, have been effective in stabilizing riverbanks against erosion but have simultaneously restricted the natural inflow from rivers that historically replenished these inland water bodies. Similarly, the construction of embankments to prevent saline water intrusion has severed the hydrological connectivity between rivers and inland wetlands, leaving them almost entirely dependent on seasonal monsoonal precipitation.

This scarcity of freshwater is compounded by the pervasive and intensifying threat of salinity. River salinity levels consistently reach their peak during the drier pre-monsoon months. More critically, groundwater resources are being severely compromised by seawater intrusion, a process accelerated by cyclonic storm surges and vertical and lateral seepage through the soil. The situation is particularly acute on Gosaba Island, where a staggering 44% of groundwater samples were found to be highly affected by saline water intrusion, rendering them unsuitable for drinking and agricultural use. This pervasive salinity directly dictates the patterns of human life and agriculture. On Gosaba, water scarcity forces farmers into a rain-fed monocropping system ,while Satjelia exhibits an agricultural divide: the more saline eastern part supports only a single monsoon crop whereas the western part practices intensive double cropping by tapping

into shallow freshwater aquifers. In contrast, the relative hydrological stability and better water quality in Jharkhali enable prosperous, year-round multi-cropping. In response, communities have developed sophisticated adaptation strategies, including the revival of indigenous, salt- tolerant paddy varieties like Nona Bokra and Talmugur and the maintenance of extensive, community-managed canal networks (khals) that capture and store over 1.15 million cubic meters of monsoonal rainwater across Gosaba and Satjelia, forming a critical buffer for the long dry season.
As a critical "blue carbon" ecosystem, the Sundarbans' capacity for carbon sequestration is of global importance. The report documents an impressive 96.8% growth in the region's carbon stock between 1990 and 2020, rising from 1,454.79 Mt C/ha to 2,863.61 Mt C/ha, with projections indicating further growth to 4,296.58 Mt C/ha by 2050. However, this remarkable growth is shadowed by a concerning decline in the ecosystem's net carbon sequestration efficiency. Carbon emissions from land-use change are projected to increase by 70% between 2020 and 2050 compared to the 2005-2020 period. This trend is exacerbated by a net loss of
42.74 sq. km of mangrove area between 1990 and 2024 and the impact of recent powerful cyclones, which have been shown to reduce soil organic carbon (SOC) in agricultural fields by as much as 46%. The threat is multiplied by accelerating sea-level rise. The analysis projects a net relative sea-level rise of 5.88 mm/year, which is expected to submerge 20.35 sq. km of coastal land by 2050. This will result in an estimated loss of 71.91 Mt of stored carbon, a figure that represents 10.8% of the projected net sequestration for that period, demonstrating how sea-level rise directly negates the ecosystem's climate mitigation potential.
Despite these intense and converging pressures, the ecosystem demonstrates remarkable resilience. The analysis identifies a vast area of 1,800-1,900 sq. km with strong potential for mangrove restoration, a potential that remains stable even under future high-emission climate scenarios. This inherent resilience provides a crucial window of opportunity for intervention. The report concludes that the Sundarbans are at a pivotal juncture, demanding a paradigm shift in management away from isolated actions and towards integrated ecohydrological and carbon-centric strategies. Key recommendations include the urgent implementation of water harvesting and managed aquifer recharge systems, particularly in the 3,106 sq. km identified as having moderate recharge potential. Restoration efforts must be prioritized in hydro-climatically suitable zones while ensuring the maintenance of hydrological connectivity. These technical solutions must be supported by the establishment of comprehensive monitoring networks and the fostering of community-centered governance, empowering local populations through initiatives which can provide alternative livelihoods for women, thereby reducing direct dependence on vulnerable natural resources and taking a step toward climate smart initiatives to empower local students too. By integrating scientific understanding with community- led adaptation, it is possible to safeguard the future of the Sundarbans, ensuring it continues to function as a vital ecological buffer, a haven for biodiversity, a significant carbon sink, and a lifeline for millions of people.