Geospatial Vulnerabilities in the Sundarban and Their Effect on Agriculture

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Abstract

The Sundarban delta, one of the most ecologically significant regions in South Asia, is increasingly under threat from a complex interplay of geospatial vulnerabilities. These vulnerabilities, driven by natural processes and anthropogenic activities, include sea level rise, soil salinization, land subsidence, riverbank erosion, and frequent cyclonic disturbances. Agriculture, which forms the backbone of rural livelihoods in this fragile ecosystem, is particularly sensitive to these changes. This article provides a comprehensive scientific analysis of the geospatial vulnerabilities in the Indian Sundarban—specifically the Gosaba and Basanti blocks of South 24 Parganas—and their direct and indirect implications on agriculture. Using recent literature, satellite data, and field observations, it explores how environmental stressors disrupt agro-ecological stability, reduce farm productivity, and aggravate socio-economic vulnerability. The article concludes by highlighting the need for spatially adaptive agricultural planning, community-led risk reduction strategies, and multi-stakeholder policy coordination.

Keywords: Agriculture, Adaptive Planning, Land Subsidence, Salinization, Vulnerability

1. Introduction

The Sundarban region, located at the interface of land and sea, constitutes the southernmost part of the Gangetic Delta. It spans parts of India and Bangladesh, with approximately 9,630 km² in West Bengal alone, encompassing 19 community development blocks in the South and North 24 Parganas districts. A part of the region is protected under the Sundarban Biosphere Reserve, while the inhabited areas support over 4.5 million people, most of whom are engaged in subsistence agriculture and allied activities.

Despite its ecological richness, the region is marked by extreme geophysical vulnerability. The deltaic topography, monsoonal hydrology, salinity-prone soil, and lack of infrastructure amplify the exposure and sensitivity of local agriculture to environmental hazards. With the increasing frequency of cyclones and a discernible shift in climate parameters, the vulnerability of agricultural systems is intensifying, threatening food security and sustainability in the region.

Source: Ankush Chowdhury Photography

2. Geospatial Vulnerabilities in the Sundarban

2.1. Physiographic Setting and Elevation Risks

The Sundarban delta is an intricate network of islands, creeks, and tidal rivers. Elevation in the region ranges mostly between 0 and 5 meters above mean sea level, making it one of the most low-lying coastal zones in India. Digital Elevation Models (DEMs) derived from SRTM and ASTER satellite datasets highlight large swathes of land susceptible to tidal inundation even under normal high tides, especially during lunar cycles.

2.2. Sea Level Rise and Tidal Dynamics

According to Indian National Centre for Ocean Information Services (INCOIS), the sea level in the Bay of Bengal is rising at a rate of 3.14 mm/year—higher than the global average. The cumulative effect of sea level rise and subsidence is exacerbating tidal ingress into the agricultural hinterlands, particularly in blocks like Gosaba, Basanti, and Kultali, where embankment breaches are recurrent.

2.3. Soil Salinity and Agricultural Constraints

Salinity intrusion is one of the most pressing geospatial threats to agriculture in the Sundarban. Soils affected by salinity (measured by electrical conductivity > 4 dS/m) now extend over 50% of cultivable areas in some islands. Post-cyclonic flooding, fields often remain waterlogged for weeks, leading to increased salt accumulation in root zones and reduced microbial activity. Saline toxicity adversely affects rice germination, nitrogen fixation, and micronutrient availability, resulting in lower yields.

2.4. Erosion, Accretion, and Landform Change

Spatio-temporal analysis using Landsat and Sentinel data from 1990 to 2020 shows a net loss of landmass in several islands. The erosion of riverbanks and coastal fringes, especially near the Matla and Bidyadhari rivers, has displaced families and reduced arable land. On the other hand, accretion is largely unproductive, often consisting of saline mudflats unsuitable for immediate agricultural use.

2.5. Cyclonic Activity and Climate Extremes

The Indian Sundarban is a high-impact cyclone zone. Recent super cyclones—Aila (2009), Amphan (2020), and Yaas (2021)—have devastated standing crops, saline-proof embankments, and irrigation infrastructure. The increasing recurrence of high-intensity cyclones leads to overlapping recovery cycles, where communities are unable to fully rehabilitate before the next disaster strikes.

3. Impact on Agricultural Systems

3.1. Crop Loss and Decline in Productivity

Paddy, primarily grown during the monsoon (Kharif) season, is highly sensitive to both flooding and salinity. Pre-harvest cyclone events have resulted in widespread yield losses, estimated at over 50% in some years. The productivity of traditional high-yielding varieties (e.g., IR-36, Swarna) has declined, prompting a reluctant shift to salt-tolerant but low-yielding landraces such as *Talmugur* and *Hamilton*.

3.2. Constraints in Cropping Intensity and Diversity

Due to waterlogging and soil degradation, the scope for multi-cropping and Rabi (winter) cultivation has declined significantly. Cash crops such as mustard, pulses, and winter vegetables are now cultivated in fewer pockets, primarily where fresh water and drainage are available. This has reduced both farm income and dietary diversity.

3.3. Infrastructure and Irrigation Deficiency

Traditional irrigation systems based on tidal canals are now compromised due to saline blockage and siltation. The absence of controlled freshwater sources limits year-round farming. Groundwater, though used in some areas, is increasingly saline, and tubewell-based irrigation is both costly and unsustainable.

3.4. Shift Toward Brackish Water Aquaculture

There is a noticeable trend of converting agricultural fields into shrimp farms, especially in saline-prone regions. While aquaculture offers short-term income, it renders the land uncultivable for decades due to soil toxicity and organic degradation. This shift is often driven by external investors, creating conflicts and marginalizing traditional farmers.

4. Socio-Economic Implications

4.1. Livelihood Insecurity and Migration

The declining viability of agriculture has pushed many rural households, especially landless laborers and smallholders, toward seasonal or permanent migration. Male out-migration to cities like Kolkata and Delhi has increased, leaving behind a feminized agricultural workforce burdened with both domestic and productive responsibilities.

4.2. Gendered Vulnerability

Women farmers in the Sundarban face distinct challenges, including limited access to extension services, credit, and adaptive inputs. The additional caregiving burden during disasters, coupled with inadequate land rights, constrains their ability to adopt climate-smart practices.

4.3. Institutional and Policy Gaps

While several government schemes—such as PM-KISAN, MGNREGA, and National Adaptation Fund for Climate Change (NAFCC)—are operational in the region, their implementation often lacks spatial targeting. Disaster relief, compensation, and agricultural advisories are not systematically aligned with geospatial risk zones.

5. Strategies for Resilience

5.1. Geospatial Planning and Risk Zoning

GIS-based vulnerability mapping should be institutionalized to identify high-risk agricultural zones and prioritize interventions. Participatory land use planning can help in selecting appropriate crops and designing effective embankment repair strategies.

5.2. Climate-Resilient Agriculture

The promotion of salt-tolerant rice varieties (*CSR-36*, *Lunishree*), agroforestry, and organic soil amendments (e.g., biochar, green manure) can help restore productivity. Rainwater harvesting and shallow tube wells may provide localized irrigation support.

5.3. Strengthening Community-Based Adaptation

Community seed banks, farmer field schools, and SHG-led micro-irrigation units are emerging best practices. Empowering local institutions like Panchayats and Farmers'

Producer Organizations (FPOs) to lead adaptation efforts enhances ownership and accountability.

5.4. Policy Integration and Multi-Level Governance

A regional agro-climatic policy tailored for the Sundarban should align agricultural planning with climate adaptation, disaster preparedness, and biodiversity conservation. Integration between departments—agriculture, water resources, environment, and rural development—is essential.

6. Conclusion

The Sundarban's geospatial vulnerabilities present a complex, multidimensional challenge to agricultural sustainability and rural livelihoods. Soil salinization, land subsidence, and recurrent climate hazards are not just environmental issues—they are deeply intertwined with questions of equity, governance, and resilience. Addressing these issues requires a shift from reactive relief to proactive, spatially-informed adaptation planning. A combination of modern geospatial tools, traditional ecological knowledge, and inclusive governance structures will be key to safeguarding agriculture and food security in this deltaic frontier.

References

Bhattacharyya, R., & Sarkar, S. (2020). *Cyclone and Salinity: Dual Challenge to Agriculture in Indian Sundarban*. Journal of Coastal Conservation, **24**(5), 1–14.

INCOIS. (2022). *Sea Level Monitoring Reports*. Hyderabad, India.

NRSC. (2020). *Land Degradation Atlas of India*. Department of Space, Government of India.

Ghosh, A., & Hazra, S. (2018). *Impact of Relative Sea Level Rise in the Indian Sundarbans: A Geospatial Perspective*. Journal of Environmental Management, **206**, 1093–1101.

Saha, S., & Acharya, S. K. (2021). *Agricultural Coping Strategies in Cyclone-Prone Sundarban Delta*. Indian Journal of Extension Education, **58**(1), 44–48

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