COMMENTARY

Save the Sundarbans

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The Sundarbans is the largest mangrove forest in the world, covering a total area of 10,200 km^2, of which 42% is in India and the remaining is in Bangladesh. It is located in the Gangetic Delta, the world's largest wetland with the highest sedimentation. It is the only mangrove–tiger kingdom in the world and is internationally recognized as a 'World Heritage Site' of UNESCO and a Ramsar Site. The Sundarbans is a crucial biodiversity hotspot, offering unique habitats for terrestrial and marine wildlife, as it is located between land and sea. It is a 'heaven' for globally threatened species such as tigers, fishing cats, Gangetic dolphins, Irrawaddy dolphins, estuarine crocodiles, horseshoe crabs, water monitor lizards, sea turtles, otters and river terrapins. Several species have already become extinct in the Sundarbans, e.g. Javan rhinoceros, water buffalo, swamp deer, hog deer and marsh crocodile. Covering 42% of mangrove cover, the Sundarbans is the largest mangrove area in India, supporting 28 mangroves, 55 mangrove associates and 2628 fauna, and the organisms are remarkably adapted to rigorously fluctuating tidal conditions[1,2].

The Sundarbans is a vital coastal asset with an annual economic value of Rs 2114 crores, far greater than any other coastal and marine ecosystem[3]. It is a dense mangrove forest, unique in extending 100 km inland from the seafront. It provides home, food, and livelihood to 5.2 million people and protects the climate-vulnerable population from floods, storm surges and other natural calamities. Honey from the Sundarbans is a highly precious product of medicinal value, which was given as an Indian gift to the world leaders during the G20 meeting held in New Delhi in 2023. The Sundarbans is a well-protected wetland, managed with legal systems, such as Reserve Forest, Protected Areas (PAs), National Park and Wildlife Sanctuary. It was the first in the world to implement management of mangrove plantations on a commercial basis as early as 1759 (ref. 2).

The Sundarbans is an 'endangered ecosystem' under the IUCN Red List. It is the most stressful environment with rise in sea-surface temperature (SST), sea-level rise, salinity, erosion, accretion and natural disasters. There is no trend of significant increase in mangrove cover, as evidenced by the loss of 200 ha between 2017 and 2019 (ref. 4). Hence, it is crucial to understand the current status of the Sundarbans.

Salinity is a primary cause of mangrove degradation through reduced levels of nutrients and increased levels of sulphide and sand[5]. There has been an increase of 29% in salinity since 1990 (ref. 6). As a result, the mangrove species composition is being altered by reducing the population of salt-sensitive species like *Heritiera fomes*, *Nypa fruticans*, *Xylocarpus* and *Phoenix paludosa*, which are how replaced by salt-tolerant species like *Avicennia*, *Excoecaria agallocha* and members of Rhizophoraceae[6].

Mangroves are degraded due to the reduction of freshwater inflow by constructing barrages and tectonic tilting of the Ganges plain, in addition to groundwater extraction and heavy siltation of distributory rivers. Monsoons are erratic by providing heavy rainfall or longer periods of drier monsoons, resulting in low productivity in agriculture, fisheries and forestry. In this regard, the Water Resources Department, Government of West Bengal has excavated the creek to a length of 650 km to harvest rainwater, which is used for agriculture and aquaculture, through the active participation of local communities. The Department supplied brooder fishes to women for spawning and raising juveniles to adults and also encouraged them to cultivate black tiger shrimp and giant freshwater prawns in the rainwater-harvested ponds.

The Sundarbans is considered to be the 'cyclone capital of India'. There has been about 29% increase in severe storms in the past 120 years. The recent cyclone events – 'Amphan', 'Yaas', 'Aila' and 'Bulbul' – caused high tidal surges, erosion and land loss. The land loss has doubled in the past decades at the annual rate of 2.9–5.5 km^2 (ref. 7). About 80% of the coastline in the Sundarbans got eroded, which is the highest record among the coastal states of India[8]. There is a need for continuous monitoring, assessing, analysing and predicting the monsoonal changes.

SST increases at the rate of 0.5°C per decade against the global average of 0.06°C (ref. 7). This alters phenology in terms of flowering, migration and egg-laying, resulting in loss of overall productivity, including fish catch reduction.

Sea-level rise is a serious threat. It was 3.7 mm/yr during 2006–18 against 1.9 mm/yr during 1971–2006 (ref. 7). However, mangroves can adapt to sea-level rise by elevating soil substrate through sediment accretion and also by migrating landward to elevated areas for colonization, if there are no barriers. As a matter of fact, many islands like Sagar, Bishalakshmipur, Lohachara and Ghoramara are facing the threat of submergence. Sagar Island is sinking at an alarming rate; about 50 years back, it was 15 km^2 and now only 3.5 km^2 (ref. 9). Ghoramara Island experienced a 50% loss of land. Haldia Port is affected due to changes in the course of river flow, flooding, sinking or destruction of river banks[9].

Sea-level rise causes coastal erosion. In erosion-prone areas, mangrove survival is extremely poor. In such situations, protective structures can be used for protection from the sea waves. In addition, growing native grasses will strengthen the mudflats for natural mangrove regeneration and further mangrove planting.

Embankments are constructed to prevent seawater from entering human dwellings during high tides. These are often damaged by sea-wave attacks, and the constructions have reduced inter-tidal space from rivers and decreased mangrove colonization. In this regard, the Water Resources Department, Government of West Bengal has undertaken an innovative initiative of developing a 'green–grey hybrid' by combining a hard engineering structure with soft mangroves under the aegis of the World Bank. This hybrid model is a nature-based solution, which is likely to create habitat by sedimentation for the natural regeneration of mangroves; besides supporting fish production, carbon sequestration and coastal protection, as well as reducing the maintenance cost of embankments, it has been proven successful in Indonesia, Thailand, Guyana, Suriname and Vietnam[9]. For instance, in Vietnam, a sea dyke with 100 m length of mangroves was intact for 50 years, but the same dyke without mangroves was damaged by waves within five years.

Biodiversity loss occurs due to habitat loss and phenological changes, as evident by the fast disappearance of mangrove species and the presence of threatened species (10 reptiles, three birds, and two mammals).

Olive Ridley turtles, found laying eggs in great abundance, could not be seen in recent years due to island submergence. There are several rare mangrove species that deserve attention for their recovery. There is an urgent need to eradicate invasive species like *Prosopis juliflora* and *Derris trifoliata* to save the mangrove biodiversity.

The high-species-diversity sites are more stable and resilient to disasters than the low-diversity sites. Hence, it is necessary to have biodiversity plantations for preserving genetic diversity by collecting propagules, not from a single source, but at individual trees separated by >10 m from each other, and by undertaking cross-pollination for *Bruguiera gymnorrhiza* and *Avicennia* spp. Genetic gardens for all the mangroves and associates need to be established in different blocks of the Sundarbans. Captive breeding has to be undertaken for the fast-disappearing otters, lesser cats and river terrapins, in addition to estimating the natural populations of major wildlife species, which will help us understand the prey–predator ratios for maintaining the ecological balance.

The Sundarbans has a dense human population of 1000 people/km^2 in 54 islands outside the Tiger Reserve[7]. It is noteworthy to mention that households are mostly headed by women. However, about 50% of the people are landless labourers, forcing them to be over-dependent and take to illegal harvesting of mangrove resources, especially illegal fishing, poaching and wildlife trafficking, as well as large-scale collection of prawn and mullet seed. During this process, many fish species are discarded as by-catch, which results in the loss of fish biodiversity. In order to save resources, fishermen are not allowed to use nets of less than 16 mm mesh thickness; they use a square mesh codend to reduce the by-catch.

Pollution affects the environment due to draining a large volume of sewage from the city of Kolkata, West Bengal, the discharge of industrial wastes with arsenic pollutants from the River Hooghly and the dumping of plastic waste. However, there is no pollution and water quality monitoring network in the estuaries. In general, infrastructure facilities in the Sundarbans are inadequate for water, education, transportation and health of the people.

Man–animal conflicts exist. Crocodiles attack women who are collecting prawns at night. Sometimes, deer hunting also takes place. There has been no report of tigers killing humans in the last decade since nylon net fences have been installed in 181 km of the Sundarbans Biosphere Reserve to prevent the entry of tigers into human localities. The tigers are predicted to disappear from the Sundarbans by 2070 due to habitat loss due to the combined effect of climate change and sea-level rise[10]. Moreover, the current census reveals that the tiger population has crossed the 100 mark, as there is no dearth of prey diet to feed the existing tiger population.

A strong collaboration is essential among the Forest Department, civil government, NGOs and academic institutions for better management of resources. More corporate social responsibility activities are necessary for joint forest management. Local people are supported by apiculture, saline water-resistant agriculture/horticulture, fuelwood, fisheries/aquaculture and ecotourism. There are increasing opportunities for livelihoods in nursery raising, wildling planting, grass transplantation for mudflat stabilization, desilting canals, eco-friendly embankment construction, erosion/flood/wind/tide control, fish aggregation devices for fisheries enrichment, fruit/fodder/fuelwood species planting, weed removal, crab fattening and also in the construction of deep tube wells for drinking water and of jetty and brick path for transportation.

Participatory management must be given the top priority by involving the local community, especially women. For example, women were the main players in a massive planting of 20 crore mangrove propagules in 2020–21. This effort by the Government of West Bengal generated employment for 26 lakh people during the worst period of the COVID-19 pandemic. Another example is the NGO NEWS (Nature Environment & Wildlife Society), which inspired a women's self-help group to take up mangrove conservation in the villages near Ghormara and Sagar islands that faced severe river erosion. As a result, since 2013, the villagers have conserved the mangrove area, which has increased from 65 to 1100 ha. Also, about 125 households have started earning Rs 10–15 crores annually through fishing and crab farming and selling fish products and organically produced chicken, eggs and vegetables by women through the Badaban Farmers Products Cooperatives.

Mangrove restoration programmes have largely failed in the past due to a lack of scientific approach to ecology, social acceptability and cost-effectiveness. Degraded mangroves can be restored better, first by identifying the physico-chemical barriers (hydrology, salinity and sediment supply), biological barriers (seed supply and dispersal) and process barriers (grazing, competition and succession). After the identification of the barriers, appropriate remedial measures can be undertaken. For example, when grazing is a barrier, fencing around the degraded mangroves can be installed to prevent cattle grazing to facilitate the natural regeneration of the mangroves. When sediment supply and drainage are the problems, hydrological connectivity needs to be restored. After undertaking the interventions, regular monitoring is required to understand the changes in the naturally regenerated or planted stocks, soil characteristics, faunal density and social benefits in terms of coastal protection, fish catch and carbon sequestration.

Aquaculture is an important livelihood of the Sundarbans, with the traditional practice of 'Bhery culture' or 'Bhasa-badha fisheries', wherein fish and rice are cultured together in the mangrove areas. This was doubly profitable because it yielded both rice and fish. In the 1970s, this traditional practice was converted into an input-intensive culture with the introduction of commercial shrimp farming methods. However, this venture was not successful. Therefore, integrated mangrove aquaculture (IMA) is now considered the only option to promote culture fisheries in an ecosystem-based approach as a climate-adaptive livelihood, in addition to conserving ecology. This is promising for the Sundarbans as 17,000 ha of brackishwater bodies are readily available for implementing IMA, as identified by the NEWS team[9]. This can further be integrated with chicks and ducks by nurturing them in floating cages to add nutrients by faecal droppings uniformly throughout the pond system. IMA does face challenges, such as the inadequate supply of pathogen-free seeds and a lack of proper facilities for cold storage, transportation and marketing. Fish waste dumped in the riverine systems, leading to water pollution, can be profitably converted into wealth through value-addition. Short-term fish cropping with multiple stockings will help overcome the problem of inundation of low-lying ponds. There is a need for a suitable land-use policy for implementing IMA and more investments by the Government and the private sector.

A database with regular updating is required for the Sundarbans. Data are not available for tidal fluctuations, sediment load in suspensions, salinity and soil composition profiles in different estuaries and islands. The dynamically changing coastal

zone needs to be mapped at regular intervals to identify the silted land blanks for plantation and the vulnerable areas for protection, especially outside the PAs.

Mangroves are carbon-rich powerhouses, indispensable for climate change mitigation[2]. In the Sundarban deltas, carbon storage and sequestration are higher as the river continuously deposits sediment carbon. The massive planting drive will increase the potential for monetizing India's carbon credits through carbon trading.

The Sundarbans has relatively low funding support despite its extraordinary environmental benefits. It has a great promise for capital investment from global financial institutions, as it is a low-cost solution to build resilience, and reduce physical and financial risks for coastal communities. The Sundarbans can generate profitable financial returns for capital investment through blue carbon, ecotourism, honey collection, and sustainable aquaculture and fisheries, for which business models must be developed to attract global grants.

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