Journal of Climate Change, Vol. 10, No. 3 (2024), pp. 31-42.
DOI 10.3233/JCC240021

Review on Conservation Approach Study of Largest Mangrove Ecosystem as the Mitigation of Climate Change

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Received July 12, 2024; revised and accepted July 30, 2024

Abstract: Bangladesh's complicated socioeconomic background serves as an example of the 21st-century worldwide environmental challenges. With a land area of 10,200 km^2, the 'Sundarbans' is the world's biggest mangrove forest, a hotspot for biodiversity, and home to several rare or endangered birds, reptiles, and mammals. Issues with biodiversity and climate change are linked here. Bangladesh and India share this important carbon sink ecosystem downstream of the Ganges Brahmaputra Meghna River complex. The Sundarbans are extremely beneficial to the local population because they produce beeswax, honey, and an abundance of seafood. They also prevent saltwater intrusion onto arable land, accumulate sediment as sea levels rise, and lessen the effects of seasonal droughts and monsoon floods. The mangrove is the main source of food and money for a large number of the impoverished residents that live in and around this forest, mostly from farming and fishing. The negative effects of climate change are becoming more and more evident. Preserving this worldwide treasure is of utmost importance; nevertheless, how can this forest be sustained over the long haul? In order to ensure the effective conservation of this globally significant ecosystem in the context of climate mitigation, this paper evaluates the advantages of the Sundarbans ecosystem's good ecosystem function and lays out an integrated approach at the national (Bangladesh), bi-national (India-Bangladesh), and regional (with all countries of the Sundarbans river catchment system) levels.

Keywords: Sundarbans; Climate change; Cyclones and monsoon; Mangroves; Mitigation.

Introduction

Bangladesh is a developing country with a total area of 147,570 km^2 surrounded to the west, north and east by a 4,095 km land border with India and by a land and water border of 193 km with Myanmar in the southeast. It is the eighth most populous country in the world with about 170 million people and a population growth rate of 0.95% in 2021 (United Nations 2022). It is the seventh most densely populated country, with 1,265 inhabitants per square kilometer in 2020 (Work Bank 2020). Birth rates are now declining but the population has more than doubled since the early 1980's. This population boom is generating socioeconomic and environmental challenges in terms of land planning and management, food security, health and education (Farid et al., 2011). Bangladesh is in a phase of rapid economic growth which is reducing poverty. The country converted from low- to lower-middle-income status in 2015 (Raihan et al., 2017) to the world's

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seventh fastest-growing economy in 2020 with a rate of 5% GDP annual growth, yet 21% of the population (ca 34 million people) still live below the poverty line. Most of the workforce (85%, >50 million people) is casually employed (Bangladesh Bureau of Statistics, 2020). The services sector contributed 50 to 53 % of the country's GDP in 2019, followed by industry (30 %) and then agriculture (13 %) (O'Neill, 2021). Manufacturing had a key role in recent economic growth with the main industries being textiles, clothing, tea processing, paper production, cement, chemical fertilisers, sugar and light engineering (Majumder, 2013). Bangladesh is the world's fourth biggest rice producer, and this crop is the main food source for its populace. Bangladesh is also a major producer of tea, jute, wheat, sugarcane, tobacco, spices, and fruits (Majumder, 2013). Since 2020, economic turmoil due to the COVID pandemic highlighted the strengths and weaknesses of the Bangladesh economy as an initial global trade slowdown and then acceleration impacted the clothing sector, which accounts for >80 % of exports (Bodrud-Doza, et al., 2020). Bangladesh is one of the most vulnerable countries to climate change as it is already strongly affected by seasonal droughts and floods which are increasing in severity (Rahman, et al., 2021). Bangladesh is the eighth most natural disaster-prone country in the world (Eckstein et al., 2019) and experiences cyclones, floods, landslides, earthquakes, heat waves, as well as outbreaks of dengue, cholera and other infectious diseases. During the monsoon season (Hossain et al., 2020) at least a third of the country is vulnerable to flooding which causes loss of human life, people displacement and illnesses that impact economic growth and damage assets. The frequency, magnitude and duration of floods have increased significantly and all floods that covered more than 30% of the country have occurred since 1974 (Hossain et al., 2020). In 1974, extreme events 'only' caused $600 million worth of damage in Bangladesh, in 1998 this was $3.5 billion, in 2004 $6.3 million; there was crop damage of $ 290 million in 2007 and $1.2 billion worth of damage to infrastructure in 2017 (Hossain et al., 2020; Mirza, 2003).

Bangladesh is a low-lying country, with two-thirds of its land area below sea level, making these issues particularly severe there. The Ganges, Brahmaputra, and Meghna river basins, in summary, include the majority of the nation (GBM). Since 1987, the Ramsar treaty has protected the Sundarbans mangrove forest, which spans 4,260 km^2 in West Bengal and 6017 km^2 (62%) in Bangladesh. Because of the remarkably diversified aquatic and terrestrial flora (around 5,700 angiosperm species) and rich fauna (about 700 fish species), UNESCO designated the region as a world heritage site in 1997 (Rahman, 2015). In addition to providing food and materials, the region is a global priority for the protection of biodiversity and offers shelter from storms, erosion, and flooding (Pullaiah, 2019). It contains rare and endemic animals including the Bengal tiger (*Panthera tigris*) and the Rhesus monkey (*Macaca mulata*). Of its 102 islands, 58 are inhabited. It offers a range of ecosystems, such as freshwater and saltwater Heritiera forests, low mangrove forests, and tree mangrove forests (Payo et al., 2016). The Sundarbans' species composition and community structure vary from east to west and along salinity gradients, with freshwater genera like *Heritiera, Ceriops*, and Xyocarpus coexisting with salt-tolerant genera like Excoecaria, Sonneratia, and Bruguiera (Rahman, 2015). Since 1950, over 50% of the mangrove trees have been cut down for timber, to make way for farmland and shrimp operations. The Sundarbans may disappear during the next century if predicted "under business as usual" increases in atmospheric carbon dioxide persist (Feller et al. 2010; IPCC 2022). The Sundarbans face this existential risk because there are no plans in place to allow for the natural inland retreat of the mangrove forest and sea levels are rising there at a rate of 5.5 mm/year (CEGIS, 2011 cited by Sadik et al., 2018). Global mean sea level rise is projected to be a further 2800-5500 mm higher by 2100 with 1.5 degrees C warming (IPCC, 2022).

According to Rahman (2020), freshwater marsh forests have receded from their historical range, and species including wild rice (*Potresia coarctata*), rice grass (*Leersia hexandra*), and screw pine (*Pandanus tectorius*) have gone extinct locally. As salt-tolerant species proliferate and spread throughout the forest, including the white mangrove (*Avicennia marina*), palm tree *Nipa fruticans*, and mangrove date palm (*Phoenix pelludosa*), *Heritiera fomes*, a once-abundant species, is in danger of going extinct (Khan et al., 2020). Sea level rise, saltwater intrusion, increased rainfall, storms, and temperature are all contributing to the damage of the Sundarbans (Basu et al., 2016). In addition, increased water pollution from industry and urban wastes has reduced the quality of fish habitats in the area and resulted in a decline in property values (Hoq, 2014).

The Bangladesh government has policies, laws and management plans in place to protect the Sundarbans but these regulations have been inefficient with limited knowledge regarding their significance for climate mitigation and poor coordination among government agencies and the local communities (Rahman, 2021). Many of the people who live in and around the Sundarbans depend on the region as their major source of food and income, mostly from agriculture and fishing, and are burdened by poverty and inadequate governance systems. Extortion and bribery are two instances of poor governance that worsen the overuse of Sundarbans resources, which results in serious environmental and social issues (Rahman, 2018).

Benefits of the Sunderbans Mangrove Forest

Mangroves grow along tropical and subtropical coastlines and have trees that can withstand high salinity, strong winds, high temperatures and anaerobic sediment. They take up nutrients and water from their roots to fix carbon dioxide from the air through photosynthesis in their leaves, producing carbohydrates for forest growth that are translocated into living wood tissues. Leaf and dead wood material build up muddy sediments that are rich in inorganic and organic matter (Robertson et al., 1992). In global terms, the estimated mangrove litter fall varies from 130 to 1870 g m^{-2} y^{-2} (Twilley et al., 1997). Mangroves absorb carbon up to 100 times faster than terrestrial forests and store it for millennia. They provide many other benefits (Das and Vincent 2009, Table 1) such as limiting the risk and impacts of natural hazards (Mukhopadhyay et al., 2018) which increases the value of their ecosystem services (Hilmi et al., 2023).

Material brought in by rivers and tides becomes trapped amongst the forest root system where inorganic nutrients stimulate forest growth and organic material stimulates a highly productive detritus-based food web (Twilley et al., 1997). Organic carbon can also be sequestered in anoxic layers of sediment which mangrove trees can tolerate as they have specialised aerial roots that supply buried parts of the trees with oxygen. Mangrove forests are among the most productive natural ecosystems in the world with primary productivity levels that exceed that of many agricultural systems (Mukhopadhyay et al., 2018). Mangroves help improve water quality, are important nursery and fishing areas for finfish and shellfish and are biodiverse habitats that can include numerous endangered species (Maiti & Chowdhury, 2013; Mukhopadhyay et al., 2018).

The Sundarbans mangrove forest was formed about 7,000 years ago as it colonised coastal sediment deposits from the Himalayas (Aziz & Paul, 2015). It is a biodiverse area with records of 334 plant species, 260 bird species, 210 fish species and many reptile, mammal and amphibian species (Ahmed et al., 2017). The forest plays an important role in the capture of sediments, the recycling of nutrients (Basu et al., 2016) and the sequestration of atmospheric CO_2 (Hilmi et al., 2023). It is strongly affected by the seasons, for example, *Avicennia* species of mangrove tree produce peak amounts of leaf fall and litter production after annual monsoons. The Sundarbans is one of the largest detritus-based ecosystems in the world where mangrove litter regulates the productivity of the adjacent Ganges Brahmaputra estuarine complex, which acts as an important nursery for commercially important species of finfish and shellfish (Basu et al., 2016).

According to Ahmed et al. (2017), the Sunderbans store more than 0.5 million tonnes of carbon annually at rates of between 4.7 and 6.5 Mg C $ha^{-1} \cdot y^{-1}$, which is faster than in the Amazon rainforest (Mitra et al., 2011; Ray et al., 2013). The standard measure used to price carbon is a tonne of carbon or Mg C. A Tg C is equal to 1012 g of carbon. The annual worldwide emissions of carbon are around 10 Pg C or 10 × 1015 g y^{-1}. With an estimated 56 million metric tonnes of stored carbon and ecosystem services worth between 273 and 714 million USD annually, the Bangladeshi portion of the forest covers 4415 km^2 (Aziz and Paul, 2015). According to Ray et al. (2013), the Indian portion of the Sundarbans, which spans 4264 km^2, is thought to have absorbed 2.79 Tg C, or 0.64%, of India's 2010–2011 emissions of fossil fuels. To put it another way, the Kolaghat coal-fired power station released 2.83 Tg C into the atmosphere in 2011 in order to generate 7469732 MW of energy. This amount of CO_2 was therefore sequestered by roughly 4328 km^2 of Sundarbans mangrove forest (Ray et al., 2013). Salinity and vegetation type affect how much carbon is stored in the Sunderbans. About 70% of the trees in this area are Heritiera fomes, which store the most carbon per unit area (mean 360 Mg C ha^{-1}) in the mangrove habitat. While the amount of below-ground carbon storage is highest in the high salinity zones, zones with freshwater impact have greater carbon stores (mean 336 Mg C ha^{-1}) than high salinity zones (Mizanur et al., 2015).

The Sunderbans store carbon and other greenhouse gases like methane and nitrous oxide, but they also release more of these gases into the atmosphere due to deforestation caused by prawn cultivation for export (Ahmed et al., 2017; Rosentrenter et al., 2023). During their 5-year study period, Chowdhury et al. (2019) found that planting Avicennia mangrove tree seeds into regularly spaced holes was the most cost-effective method of sequestering the highest amount of carbon in terms of restoration. However, the success rates of these plants varied depending on salinity, tidal inundation, and soil type. Mangrove preservation and sustainable use are crucial steps in reducing the negative effects of climate change locally preserving biodiversity, boosting recreational value, and promoting sustainable economic strands in the area (Hafiz Iqbal & Nur Mozahid, 2022).

Relationship between Climatic Parameters and Sundarbans

The Intergovernmental Panel on Climate Change predicts that, as a result of global climate change, there will likely be an increase in tropical storm peak wind intensities as well as an increase in tropical cyclone mean and peak precipitation intensities in some locations during the twenty-first century (Agarwal and Mitra, 2019). If severe winds and low pressure become more frequent, storm surge heights are also expected to rise. This could happen if storm frequency or intensity increases due to climate change (Mitra, 2013). Storms that are stronger and occur more frequently may cause more harm to mangroves by killing off trees and causing defoliation. Storms can change the height of mangrove sediment by soil erosion, soil deposition, peat collapse, and soil compression in addition to stressing trees and generating sulfide soil toxicity (Mitra, 2018; Mitra, 2020). Because of changes in sediment elevation and accompanying hydrology, areas experiencing widespread tree mortality with low survival of saplings and trees may undergo permanent ecological conversion (Dhar et al., 2022). Recovery through seedling recruitment may not occur in these areas. Climate change will not have an impact on other natural disasters like tsunamis, which can nonetheless seriously harm mangroves and other coastal ecosystems (see, for example, the tsunami that struck the Indian Ocean on December 26, 2004 (Guha and Mitra, 2020).

Due to climate change, there will likely be a 25% increase in rainfall worldwide by 2050. Rainfall will, however, be distributed unevenly throughout the region. It is quite probable that precipitation will increase in high latitudes and decrease in most subtropical regions, particularly along the poleward edges of the subtropics. The Sahel, the Mediterranean, southern Africa, and portions of southern Asia experienced drying, according to the Intergovernmental Panel on Climate Change's most recent assessment, which also noted notable increases in precipitation in eastern North and South America, northern Europe, and northern and central Asia. For other regions, no long-term patterns had been noted (Mitra et al., 2019; Mitra and Zaman, 2022; Biswas et al., 2020).

Mangrove growth and spatial distribution are predicted to be impacted by changes in precipitation patterns (Yadav and Majumder, 2020). Reduced rainfall and increased evaporation will increase salinity, decreasing net primary productivity, growth, and seedling survival; changing the competition between mangrove species; reducing the diversity of mangrove zones; and causing a notable reduction in mangrove area due to the conversion of upper tidal zones to hypersaline flats. These conclusions are primarily based on links observed between mangrove habitat conditions and rainfall trends (Barua and Mitra, 2024; Barua et al., 2017). Reduced precipitation means less freshwater surface water input for mangroves and less water entering groundwater, which raises salinity. Mangrove trees' increasing tissue salt levels and correspondingly decreased water availability as soil salinity rises lower productivity (Barua and Barua, 2023; Barua et al., 2023). The mangrove's susceptibility to any rise in relative sea level will be heightened by increased salinity since it would increase the availability of sulfate in seawater, which will accelerate the anaerobic breakdown of peat. Mangrove invasion of freshwater and saltwater wetlands can be caused by decreased precipitation (Barua et al., 2022; Barua and Rahman, 2022; Barua et al., 2020; Goodrich et al., 2022).

From a pre-industrial value, the atmospheric concentration of CO_2 increased by 35%, from 280 parts per million by volume (ppmv) in 1880 to 379 ppmv in 2005 (Solomon et al., 2021). CO_2 emissions have been rising over the last few decades: between 2000 and 2005, they went from an average of 6.4±0.4 GtC/yr in the 1990s to 7.2±0.3 GtC/yr. Certain mangrove species may produce more as a direct result of higher atmospheric CO_2 levels. Mangroves are expected to develop faster and regulate water loss more effectively in response to rising atmospheric CO_2 levels (Bhattachariya et al., 2022; Chatterjee et al., 2023).

Natural Resource Management in the Sunderbans

The Sundarbans, the world's biggest mangrove forest, have and require careful management because coordination between Bangladesh and India, the nations upstream of the river, is still necessary for the basin and businesses looking to make money off of the resources at their disposal. Bangladesh possesses national policies like the Convention on Biological Diversity, which it signed as a National Environment Management Action Plan, a National Conservation Strategy, and a National

Action Plan and Strategy for Biodiversity. The Ministry of Climate Change, Forests, and Environment is legal. Inadequate communication between this incoherence can be produced by ministries, as demonstrated by the prawn development policy, which is the second-largest export industry in the nation after apparel. Thousands of hectares of mangrove vegetation were devastated in Chakaria due to prawn aquaculture even though there are legal safeguards in place to protect this forest (Ishtiaque et al., 2016).

The Sundarbans have undergone strategic environmental assessments and management plans. Forestry Department to advance a more comprehensive plan that includes the indications required to make monitoring easier. Nationally, people meet the UN Sustainable Development Goals (Schnatz, 2022). Natural remedies have the potential to conservation and offer strategies for coping with difficulties related to territory and climate change (Smith et al., 2021). The mangrove ecosystem provides services to the entire community (Table 1).

Community Involvement

In order to specify actions, impacts, and outcomes, dialogue with stakeholders is required. Civil society is a part of this. All users of natural resources, including global corporations, as well as organisations and local communities. The Sundarbans ecosystem is related to livelihoods, food supply, human health, education, and transportation. Communities affected by the mismanagement of natural resources must be involved in order to determine and long-term fixes (Arruda, 2018). Without lecturing the populace, information must be disseminated in the appropriate socioeconomic context (Chowdhury et al., 2016). Participation from local communities and the exchange of traditional knowledge aid in determining appropriate policies and solutions totaling (Titumir, et al., 2020). A few crucial points regarding the conversation between traditional knowledge, science, and policy-making encompass wildlife biology, environmental science, ecological management, biodiversity conservation, weather variability, ecosystem management, and the effects of climate change (Kruskwoski and Arruda, 2017).

How to Improve the Conservation of the Mangroves in Bangladesh?

Sustainable management of the Sundarbans requires coordination between India and Bangladesh. Natural continuity, common environmental risks, and human challenges faced by both countries require improved dialogue and coordination. India and Bangladesh are both parties to the Convention on Biological Diversity and to the Ramsar Convention on Wetlands and share the UNESCO World Heritage Site. A 2011 Memorandum of Understanding on Conservation of the Sundarbans "Recogni[ses] that the Sundarban of

Table 1: The Sundarbans mangroves forest's ecosystem services

Regulating service	Oxygen production, temperature regulation, carbon sequestration, climate regulation, water and nutrient cycling, pollutant and sediment regulation. For example, they reduce the impacts of cyclones by saving human life, properties and protecting biodiversity from intense winds, waves and seawater flooding during cyclones.
Supporting service	Terrestrial and marine biodiversity maintenance & protection. Reproductive habitat for aquatic, benthic and terrestrial species. Nursery, feeding and breeding grounds for economically valuable fish and shellfish. Materials, e.g. *Nypha fruticans* leaves are widely used for thatching and *Phoenix paludosa* wood is used for building.
Provisioning service	Edible fish and shellfish, wax and honey from *Apis dorsata* bees, fruits such as Keora (*Sonneratia apetala*) and Ora (*Sonneratia caseolaris*). Raw materials e.g. wood for paper and fuel (species like *Ceriops decandra, Cynometra ramiflora, Amoora cuculatta*). Medical resources: Several biocides, food additives like alginates, and leaves of *Phoenix paludosa* are used for the treatment of ringworm and sore throats.
Cultural service	Accessible knowledge on biodiversity processes, for education and research. Spiritual values associated with the environment and rituals for religious communities. Creating job opportunities such as growing numbers of tourists joining ethnic festivals, river cruises and jungle trails.

India and Bangladesh represent a single ecosystem divided between the two countries" and established key principles, as follows: "Both Parties recognize the need to monitor and conserve the Sundarbans, which is home to rich biodiversity consisting of a large variety of rare species of flora and fauna, and acts as a vital protective barrier protecting the mainland from flooding, tidal waves and cyclones (article 1)" "They also agree to: 1. Consider and adopt appropriate joint management and joint monitoring of resources; Explore the possibility of implementing conservation and protection efforts, and encourage mangrove regeneration, habitat restoration, and rehabilitation programs, which would eventually increase the potential for carbon sequestration; 3. Develop a long-term strategy for creating ecotourism opportunities for both countries, which will create synergy and generate greater revenue (Article 2)" India and Bangladesh clearly state 'why' cooperation was needed and 'what' to do. However, 'how' to implement these activities, and 'who' will finance them is missing. Indian government legislation aims to preserve part of the mangrove forest as a national park and they created three sanctuaries to stop mangrove degradation, but, despite these efforts, the populated coastline of these protected areas is the most affected by human development and land encroachment (Abhiroop et al., 2018).

Distinguishing and separating green (terrestrial ecosystems) carbon from blue (marine ecosystems) carbon opens opportunities for future trading. The establishment of a blue carbon market could positively impact local communities and contribute to climate change mitigation and adaptation. It is important to highlight the co-benefits that can be derived from financial blue carbon activities, and how they can improve social well-being, and economic growth, and meet sustainability goals (Schindler Murray et al., 2023). For the Sundarbans, a blue carbon strategy could have positive impacts on seafood supplies, shoreline protection, and water quality. Blue carbon strategies for mangrove conservation are creating new employment opportunities linked to sustainable practices. They can be used to help local communities and strengthen Sundarbans restoration (Herr et al., 2019).

The River Basin Perspective

Of the Bangladesh fresh water input, 93% comes from abroad needing international efforts to improve water quality, reduce contamination and improve water risk management (Chowdhury 2016) this is to conserve downstream biodiversity and the mangrove ecosystem. Consideration of the entire river catchment system is needed for Sunderban conservation in the long term. The Mekong River basin in Southeast Asia is a similar case where the middle and downstream countries (Cambodia, Lao People's Democratic Republic, Thailand and Vietnam) have formed a common agreement, the Mekong River Commission (Mukhopadhay et al., 2018). This agreement does not include Myanmar or China in the upper part of the basin which is problematic as the latter has developed major hydropower infrastructure. The status of downstream biodiverse areas of Cambodia (Tonle Sap Lake) and the deltas of Vietnam are quickly deteriorating despite the MRC dialogue and strong positive efforts between member countries and international financing. Since the 1990s, there has been major dam construction in China, in the upstream part of the river, to provide electricity to support economic development (Foreign Policy, 2020). This is comparable to the Sundarbans river input decline as since the 2010s, the density of dams in tributaries of the Brahmaputra has been increasing quickly.

"Blue Carbon" as a Nature-Based Solution to Enhance Mangrove Conservation

As governments, financial institutions, and corporations become more aware of the magnitude of risks of biodiversity loss and business dependency on nature, they are updating regulations, sustainability measures and policies to extend credit, or establish new investment criteria for "ethical investment, socially responsible investment, or "impact investing". Climate funds are important as significant resources are needed to adapt to the adverse effects and reduce the impacts of a changing climate. They involve the scaling-up of resources from public, private, bilateral, multilateral, and alternative financial sources. Mobilising private climate finance is needed to address climate change because public finance alone will not be enough (Arruda and Johannsdottir, 2023). Mangroves require carbon prices to reflect their real value as these habitats store carbon, provide climate resilience and provide water, and food security. Knowledge of the drivers leading to their destruction: climate change, urban development, economic activities (rice and palm oil production, aquaculture). Environmental, Social, and Governance (ESG) goals (environmental and social issues) need to be considered when making investment decisions. Green Bonds are used to finance projects with positive environmental impacts. Sustainability bonds are used to "finance or re-finance a combination of green and social projects or activities" (La Torre and Chiappini, 2020). Sustainability-linked finance instruments have been also introduced. The most popular have been corporate sustainability-linked loans (SLLs) and sustainability-linked bonds (SLBs). For SLLs: Interest may increase if the borrower fails to achieve an agreed-upon sustainability performance target, and vice versa. For SLBs, coupon rates will increase, or the issuer may pay a penalty when the bond matures if it fails to achieve sustainability or ESG objectives or targets. Debt for nature swaps are used in many countries and can raise capital in low-income countries to address environmental and other policy challenges, but come with a range of risks and management issues (Arruda and Johannsdottir, 2023).

The co-benefits can become synonymous with "Blue Carbon" and investors might evaluate their engagement in carbon credits with the impact these services have on their supply chain (Vanderklift et al., 2019). The need for a Green Climate Fund dominated discussions at the Conference of Parties in November 2022, especially the need to scale up access to finance to developing nations. In 2022, the main target of the GCF and GEF was to promote a Long-Term Vision of Complementarity and Coherence collaboration (GEF, 2021) between the Green Climate Fund (GCF) and the Global Environment Facility (GEF) for climate change adaptation and mitigation. It created an opportunity to scale- bonds focussed on marine and ocean-based environmental initiatives. As the largest class in the global financial market, green bonds (and blue bonds as a subcategory of green bonds) can play a significant role in orienting investment to achieve the Sustainable Development Goals (SDGs) and the Blue Economy. Blue Bonds are a sector-based type of bond that can be issued by companies, financial institutions, governments, and municipalities for the protection of ocean-related assets and finance projects oriented to deliver the SDGs.

The blue bond label is an opportunity to improve ocean sustainability by addressing the risks of unsustainable business operations, incentivising corporate social responsibility, attending to the high demand for financial instruments linked to SDGs and ESG as well as financing solutions for conservation and sustainable management of ocean and coastal resources. Blue bond issuance is based on two levels of expectations (UN Global Compact (2020b) in a relevant corporate sustainability strategy in place to address the SDGs' and 'a clear target for the Bonds reflected in one or more Key Performance Indicator (KPIs'). This aligns with the Ten Principles of the UN Global Compact, the Sustainable Ocean Principles, the International Capital Market Association's Green and Social Bonds Principles as well as the criteria defined by the Tipping Points for a Healthy and Productive Ocean. The KPI needs to be clear, measurable, and aligned to the Sustainable Ocean Principles that are incorporated into the project strategy (a five-year use of proceeds blue bond to finance innovation or a three-year KPI-linked blue bond). The future of the blue bond market depends on aligning environmental incentives, objectives, innovation, infrastructure, government support, policy frameworks, standards, clear measurable key performance indicators, credibility, and transparency (Aziz et al., 2022; Rahman et al., 2020; Bhowmick et al., 2020)

Mitigation Options for Climate Change

According to Simard et al. (2019), the ecosystem carbon stocks in the afforested plantation mangroves of the Delta were similar to those in other mangrove-rich deltas in Asia (Table 2).

Abbreviation: AGB, aboveground biomass

However, they were lower than those in other geomorphic settings, indicating lower mangrove biomass carbon per hectare than in tropical humid regions and and reduced soil carbon, perhaps as a result of the Ganges and Brahmaputra Rivers' heavy sediment input (Sarwar & Woodroffe, 2013). When compared to the values in Asia, Africa, the Americas, Oceania, and the global mean values (~758 Mg C ha−1), the carbon stocks in the plantations in Bangladesh were lower than the carbon stocks reported for natural mangroves worldwide. The differences ranged from two to five times lower in Bangladesh (Donato et al., 2011; Kauffman et al., 2020; Murdiyarso et al., 2021; Rahman et al., 2015). The environmental circumstances of the plantations, which do not support the same level of productivity and carbon accumulation as natural forests in the Sundarbans—which typically tend to be less saline and less exposed to wind, waves, and currents—may be responsible for the lower carbon stock in the plantations in Bangladesh (Rahman et al., 2015). Both anthropogenic (such as land use change) and natural (such as climate) factors affect the variations in mangrove carbon stores along the Delta's coastal regions (Kauffman et al., 2020). Different regions (such as Bangladesh's East, Central, and West coasts) may have different carbon stock levels due to factors such as climate, vegetation structure, salinity regime,

Table 2: Carbon stocks by planted mangroves in mangrove-rich Asian deltas

	Carbon stock (Mg C ha^{-1})			
Region/ country	*Biomass C*	*Soil C*	*Ecosystem C*	*References*
Bangladesh	60.3	129.8	190.1	Uddin et al. (2022)
Vietnam	107 (AGB carbon)	146–159	250	Ha et al. (2018); Hien et al. (2018); Phan et al. (2019)
China	184	89	270	Yu et al. (2020)
India	91	61	152	Sahu et al. (2016)
Indonesia	49.2–168	300–450	350–600	Cameron et al. (2019); Murdiyarso et al. (2021)
Myanmar	18–43	167	185–210	Thant et al. (2012)

geomorphology, and land use change (Kauffman et al., 2020; Rahman et al., 2015). Variations in the geomorphic settings and corresponding variations in the biophysical circumstances across the coastal regions are linked to higher carbon stock values on the West coast and lower values on the Central and East coasts of the Delta (Rovai et al., 2018; Sasmito et al., 2020; Uddin et al., 2022).

The environmental factors that support higher mangrove productivity associated with freshwater influx from rivers, high levels of precipitation, lower salinity levels, and higher species richness on the West Coast are likely linked to the higher carbon stocks per hectare as well as the higher level of plantation success in the West coast of the Delta compared to the Central and East coast (Alongi, 2014; Hayes et al., 2017; Uddin et al., 2022).

In Bangladesh, planted mangroves helped remove CO_2 by about 5,417,609 mg C, or 19.9 Mt CO_2, over the course of 50 years of plantation establishment (at a rate of 114,149 mg C/year, or 0.41 Mt CO_2/year). The amount of carbon that accumulated in mangrove soils—3,660,671 mg C, or 13.5 Mt CO_2—was about 2.1 times higher than the carbon stock made up of biomass (1,756,938 mg C, or 6.4 MtCO_2). The total carbon stocks (Mg C) that have accumulated in mangrove species plantations in Sundarbans. Even though Bangladesh's current plantations are helping to mitigate climate change, more planted mangroves could be established, which would increase their contribution. However, because plantation biomass grows exponentially, the new plantations would only be fully effective 20 years after they are established. According to estimates made by the Ministry of Environment, Forest and Climate Change (MoEFCC) in 2022, the AFOLU sector in Bangladesh is expected to contribute 14.4% of the country's total GHG emissions (111,553,134 Mg C or 409.4 MtCO_2) by 2030, or 14,989,101 Mg C (or 55.01 MtCO_2) (MoEFCC, 2022).

Conclusions and Recommendations

The socioeconomics of developing countries are highly affected by the risks posed by climate change. The Sundarbans mangrove forest, in Bangladesh, provides ecosystem services that are in decline although there are opportunities to mitigate the risks of climate change, secure carbon stocks, increase carbon sequestration and improve regulating, supporting and provisioning ecosystem services as well as protecting cultural services. These are benefits to local populations that also reduce the impacts of climate change, biodiversity loss, and food chains, ameliorating negative impacts on economic and cultural activities. The benefits of the Sunderbans ecosystem functions can be better secured if long-term sustainable conservation efforts and blue carbon strategies are supported by finance mechanisms that are implemented according to an integrated and articulated 'local-global' approach. Important multiscale challenges can be addressed by interinstitutional coordination of nature-based solutions, environmental planning, sectorial conservation, and adaptive strategies oriented to scientific research, communication, education, participation, respect to environmental traditional knowledge, policies, and efficient governance systems. The Sundarbans are key to adaptation, mitigation, biodiversity conservation, carbon sequestration and ecosystem services with critical implications for the health and wellbeing of local people. If done well, the establishment of a blue carbon market would be an environmental and economic large-scale strategy to protect and restore the Sundarbans through nature-based investment funds to finance conservation enterprises, sustainable economic activity models, new technological applications that increase efficiency and scale-up bio-carbon markets, blue carbon credits and blue bonds. The preservation of mangroves, their sustainable use and the quality of maritime environments will depend on a transformative co-investment platform combined with the right alignment of socio-economic environmental policy frameworks, infrastructure, standards, measurable implementation and a long-term vision on complementarity and coherent collaboration among countries to strengthen resilience and co-management.

References

Aziz, A., Rahman, M. and Ahmed, A., 2022. Diversity, distribution and density of estuarine phytoplankton in the Sundarban Mangrove Forests. *Bangladesh Journal of Botany*, **41(2):** 87-95.

Abhiroop, A., Aliya, N., Santanu, B. and Pranabes, S., 2018. Cost–benefit analysis of Blue Carbon' sequestration by plantation of few key mangrove species at Sundarban Biosphere Reserve, India. *Carbon Management*, **9(6):** 575-586.

Agarwal, S.K. and Mitra, A., 2018. Salinity: A primary growth driver of mangrove flora. *Current Trend for Research*, **2(2):** 1-9.

Ahmed, A., Drake, F., Nawaz, R. and Woulds, C., 2018. Where is the coast? Monitoring coastal land dynamics in Bangladesh: An integrated management approach using GIS and remote sensing techniques. *Ocean & Coastal Management*, **151(2):** 10-24.

Ahmed, N., Cheung, W.W.L., Thompson, S. and Glaser, M., 2017. Solutions to blue carbon emissions: Shrimp cultivation, mangrove deforestation and climate change in coastal Bangladesh. *Marine Policy*, **82(5):** 68-75.

Akhand, A., Mukhopadhyay, A., Chanda, A., Mukherjee, S., Das, A., Das, S., Hazra, S., Mitra, D., Choudhury, S.B. and Rao, K.H., 2016. Potential CO_2 emission due to loss of above ground biomass from the Indian Sundarbans. *Journal of the Indian Society of Remote Sensing*, **30(2):** 56-65.

Alam, M.S. and Uddin, K., 2013. A study of morphological changes in the coastal areas and offshore islands of Bangladesh using remote sensing. *American Journal of Geographic Information System*, **2(1):** 15-18.

Arruda, G.M., 2018. Renewable Energy for the Arctic: New Perspectives. Routledge, Abingdon, p.115

Arruda, G.M. and Johannsdottir, L., 2023. Climate Adaptation and Green Investment: Arctic and non-Arctic World. Routledge, Abingdon.

Arruda, G.M. and Krutkowski, S., 2017. Social impacts of climate change and resource development in the Arctic: Implications for Arctic governance. *Journal of Enterprising Communities: People and Places in the Global Economy*, **11(1):** 277-288.

Aziz, A. and Paul, A.R., 2015. Bangladesh Sundarbans: present status of the environment and biota. *Diversity*, **7(92):** 242–269.

BBS, 2015. Population density and vulnerability: a challenge for sustainable development of Bangladesh, Bangladesh Bureau of Statistics, Dhaka, Bangladesh

Barua, P. and Rahman, S.H., 2022. Urban Management in Bangladesh. *In:* The Palgrave Encyclopedia of Urban and Regional Futures. *Disaster Management*, **40(3):** 60-80.

Barua, P., Saeid, S. and Rahman, S., 2020. Climate change vulnerability and responses of fisherfolk communities in the South-Eastern coast of Bangladesh. *Water Conservation and Management*, **4(1):** 20-31.

Barua, P. and Rahman, S., 2019. Sustainable livelihood of vulnerable communities in Southern Coast of Bangladesh through the utilization of mangroves. *Asian Journal of Water, Environment and Pollution*, **16(2):** 59-67.

Barua, P. and Barua, M., 2023. Indigenous knowledge practices by farmers in response to salinity intrusion in coastal Bangladesh. *IUP Journal of Knowledge Management*, **21(3):** 50-65.

Barua, P. and Mitra, A., 2024. Climate smart agriculture: Global perspective. *Journal of Climate Change*, **10(1):** 45-65.

Barua, P. and Mitra, A., 2024. Global Climate Change Vulnerabilities and Adaptation Scenarios. *In:* Saeid Eslamian, Mir Bintul Huda, Nasir Ahmad Rather, Faezeh A. Eslamian (eds), Handbook of Climate Change Impacts on River Basin Management: Case Studies. Routledge, Tailors and Francis, CRC Press.

Barua, P., Mitra, A., Mitra, A. and Eslamian, S., 2023. Resilience of Farmers in Response to Salinity Intrusion Problem in Agricultural Fields of Coastal Region of Bangladesh. *In:* Alam, A., Rukhsana (eds) Climate Change, Agriculture and Society. Springer, Cham.

Barua, P., Rahman, S.H. and Eslamian, S., 2022. Adaptation practices by the farmers for reduction of salinisation problem in the paddy fields of South-Eastern Coast of Bangladesh. *Asian Journal of Water, Environment and Pollution*, **19(6):** 37-44.

Basu, S., Dey, M., Lutful, S.M., Jahangi, S., Masum, K., German, Y., Shinji and Rubén, L., 2016. Sundarbans mangroves: Diversity, ecosystem services and climate change impacts. *Asian Journal of Medical and Biological Research*, **2(4):** 488-507.

Bhattacharyya, S., Pethick, J. and Sensarma, K., 2022. Managerial response to sea level rise in the tidal estuaries of the Indian Sundarban: A geomorphological approach. *In:* Xun, W., Whittington, D. (editors): Water Policy, Special Edition: The Ganges Basin Water Policy, **15:** 51-74.

Bhowmick, B., Uddin, Z. and Rahman, S., 2016. Salinity changes in south west Bangladesh and its impact on rural livelihoods. *Bangladesh Journal of Veterinary Medicine*, **14(2):** 251-255.

Biswas, S., Zaman, S. and Mitra, A., 2020. Development of food products from mangrove associate species: A step towards health security. *Our Heritage*, **68(8):** 69-77.

Bomer, E.J., Wilson, C.A., Hale, R.P., Hossain, A. and Rahmane, A., 2020. Surface elevation and sedimentation dynamics in the Ganges-Brahmaputra tidal delta plain, Bangladesh: Evidence for mangrove adaptation to human-induced tidal amplification, *CATENA*, **187(2):** 66-70.

CARE, 2020. Bangladesh: Monsoon Floods 2020 Coordinated Preliminary Impact and Needs Assessment -Needs Assessment Working Group (NAWG) - 25 July 2020

Chanda, A., Mukhopadhyay, A., Ghosh, T., Akhand, A., Mondal, P., Ghosh, S. and Hazra, S., 2016. Blue carbon stock of the Bangladesh Sundarban mangroves: What could be the scenario after a century? *Wetlands*, **36:** 1033-1045.

Chatterjee, M., Shankar, D., Sen, G.K., Sanyal, P., Sundar, D., Michael, G.S., 2023. Tidal 822 variations in the Sundarbans estuarine system, India. *Journal of Earth System Science*, **122(4)**: 899-933.

Chowdhury, 2010. Water management in Bangladesh: An analytical review. *Water Policy*, **12(1):** 32-51.

Chowdhury, A., Maiti, S.K. and Bhattacharyya, S., 2016. How to communicate climate change 'impact and solutions' to vulnerable population of Indian Sundarbans? From theory to practice. *SpringerPlus*, **5:** 1219.

Chowdhury, A., Maiti, S.K. and Bhattacharyya, S., 2019. How to communicate climate change 'impact and solutions' to vulnerable population of Indian Sundarbans? From theory to practice. *SpringerPlus*, **5:** 1219.

Danda, H. 2019. Environmental Security in the Sundarbans in the Current Climate Change Era: Strengthening India-Bangladesh Cooperation, ORF, Dhaka, Bangladesh.

DoE. 2015. Community Based Ecosystem Conservation and Adaptation in Ecologically Critical Areas of Bangladesh: Responding to Nature and Changing Climate. Department of Environment (DoE), Ministry of Environment and Forests, Dhaka, Bangladesh, pp x+122

Descroix-Comanducci, F., Allemand, D., Berthomieu, C., Hall-Spencer, J.M. and Ferrier-Pagès, C., 2023. The imposition of participation? The case of participatory water management in coastal Bangladesh. *Water Alternatives*, **7(2):** 342-366.

Dhar, I., Sengupta, G., Biswas, S., Sinha, M. and Mitra, A., 2021. Salinity: A major environmental factor in sustainability of the blue carbon. *J Mech Continua Math Sci*, **16(11):** 34-42.

Didar, S.M. and Hossain, M., 2018. Sundarbans mangrove forest of Bangladesh: Causes of degradation. *Environmental Sustainability*, **1:** 113-131.

Eckstein, D., Vera Künzel, H., Laura Schäfer, H. and Winges, M.W., 2019. Global Climate Risk Index 2020. Who Suffers Most from Extreme Weather Events? Weather-Related Loss Events in 2018 and 1999 to 2018, Germanwatch, Germany. Eyler, B., 2020. Science Shows Chinese Dams Are Devastating the Mekong, Foreign Policy, April 2020.

Farid, K.S., Ahmed, J.U., Sarma, P.K. and Begum, S., 2011. Population Dynamics in Bangladesh: Data sources, current facts and past trends. *Journal of the Bangladesh Agricultural University*, **9(1):** 121-130.

Feller, I.C., Lovelock, C.E., Berger, U., McKee, K.L., Joye, S.B. and Ball, M.C., 2010. Biocomplexity in mangrove ecosystems. *Annual Reviews in Marine Sciences Research,* **2(2):** 395-417.

Getzner, M., et Muhammad Shariful Islam, 2013. Natural resources, livelihoods, and reserve management: A case study from Sundarbans mangrove forests, Bangladesh. *International Journal of Sustainable Development and Planning,* **8 (1):** 75-87.

Giri, C., Pengra, B., Zhu, Z., Singh, A. and Tieszen, L.L., 2007. Monitoring mangrove forest dynamics of Sundarbans in Bangladesh and India using multi-temporal satellite data from 1973 to 2000. *Estuarine, Coastal and Shelf Science*, **73(1-2):** 91-100.

Goodrich, J., Wibisono, H., Miquelle, D., Lynam, A.J., Sanderson, E., Chapman, S., Gray, Gualberti, G., et al., 2022. Total Official Support for Sustainable Development - Data comparison study for Bangladesh, Cameroon and Colombia. *Economic Management*, **20(2):** 35-55.

Guha, T. and Mitra, A., 2020. Salinity—a crucial factor in ecological sustainability for Sundarbans Mangrove ecosystem. *In:* Mitra, A., Calma, M.M. and Chakrabarty, S.P., (eds). Proceedings: natural resources and their ecosystem services. HSRA Publication, pp. 27-35.

Hafiz, I., 2020. Valuing ecosystem services of Sundarbans Mangrove forest: Approach of choice experiment. *Global Ecology and Conservation*, **24(2):** 1-10 ,

Herr, D., Blum, J., Himes-Cornell, A. and Sutton-Grier, A., 2019. An analysis of the potential positive and negative livelihood impacts of coastal carbon offset projects. *Journal of Environmental Management*, **235 (2):** 463-479.

Hilmi, N., Benitez Carranco, M.B., Broussard, D., Mathew, M., Djoundourian, S., Cassotta, S., Safa, A., Maliki, S. and Hoq, M., 2014. Management Strategies for Sustainable Exploitation of Aquatic Resources of the Sundarbans Mangrove, Bangladesh. *In:* Faridah-Hanum, I., Latiff, A., Hakeem, K. and Ozturk, M., (eds) Mangrove Ecosystems of Asia. Springer, New York, NY

Hossain, B., Sohel, S.M. and Ryakitimbo, M.C., 2020. Climate change induced extreme flood disaster in Bangladesh: Implications on people's livelihoods in the Char Village and their coping mechanisms. *Progress in Disaster Science*, **6 (2):** 100-120.

Hossain, M., Rejaun, N.A., Mohammad, L.A. Mahmud, Md. and Mohammad, I., 2016. Ecosystem services of the world largest mangrove forest Sundarban in Bangladesh. *International Journal of Innovation and Scientific Research*, **27(6):** 9-15.

IPCC, 2022. Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [H.-O. Pörtner, D.C. Roberts, M. Tignor, E.S. Poloczanska, K. Mintenbeck, A. Alegría,

M. Craig, S. Langsdorf, S. Löschke, V.Möller, A. Okem, B. Rama (eds.)]. Cambridge University Press.

Iqbal, M.H., 2020. Valuing ecosystem services of Sundarbans mangrove forest: Approach of choice experiment. *Global Ecology and Conservation*, **24 (3):** 50-65.

Ishtiaque, A. and Chhetri, N., 2016. Competing policies to protect mangrove forest: A case from Bangladesh. *Environmental Development*, **19 (2):** 75-83.

Islam, M.M., Sunny, A.R., Hossain, M.M. and Friess, D.A., 2018. Drivers of mangrove ecosystem service change in the Sundarbans of Bangladesh. *Singapore Journal of Tropical Geography*, **39(2):** 244–265.

Islam, R., 2023. Bangladesh tries fences to tackle growing human-tiger conflict in Sundarbans. Mongabay.

Khan A., Faisal, Md., Rahman, S. and Giessen, L.Md., 2020. Mangrove forest policy and management: Prevailing policy issues, actors' public claims and informal interests in the Sundarbans of Bangladesh. *Ocean & Coastal Management*, **186 (3):** 105090.

Majumder, S., 2013. The economics of early response and resilience: Bangladesh country management: A case study from Sundarbans mangrove forests, Bangladesh. *International Journal of Sustainable Development and Planning*, **8(1):** 75-87.

Mirza, M.M.Q., 2003. Three Recent Extreme Floods in Bangladesh: A Hydro-Meteorological Analysis. *In:* Mirza, M.M.Q., Dixit, A., Nishat, A. (eds.). Flood Problem and Management in South Asia. Springer,

Mitra, A., 2013. Sensitivity of mangrove ecosystem to changing climate, vol XIX. Springer, New Delhi, Heidelberg, New York, Dordrecht, London, p 323.

Mitra, A., 2020. Mangrove forests in India: exploring ecosystem services, vol XV. Springer, p 361.

Mitra, A., Sengupta, K. and Banerjee K., 2011. Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans. *Forest Ecology and Management*, **261(7):** 1325-1335.

Mitra, A. and Zaman, S., 2022. Estuarine acidification: exploring the situation of mangrove dominated Indian Sundarban estuaries, vol XII. Springer, Chem, p 402.

Mizanur, M., Nabiul Islam Khan, M. and Fazlul, H., 2015. Carbon stock in the Sundarbans mangrove forest: Spatial variations in vegetation types and salinity zones. *Wetlands and Ecological Management*, **23 (2):** 269-283.

Mukhopadhyay, A., Andres, P., Abhra, C., Tuhin, G., Chowdhury, S.H. and Hazra, S., 2018. Dynamics of the Sundarbans mangroves in Bangladesh under climate change. *Disaster Management*, **30(3):** 489-503.

Mukhopadhyay, A., Andres, P., Chanda, A., Ghosh, T., Chowdhury, S.M. and Hazra, S., 2018. Dynamics of the Sundarbans mangroves in Bangladesh under climate change. *In:* Nicholls, R., Hutton, C., Adger, W., Hanson, S., Rahman, M. and Salehin, M. (eds). Ecosystem Services for Well-Being in Deltas. Palgrave Macmillan, Cham.

Northrop, E. and Roth, N., 2023. The blue carbon handbook: Blue carbon as a nature-based solution for climate action and sustainable development. *Wetland Management*, **30(2):** 45-65.

O'Neill, A., 2021. Bangladesh: Share of economic sectors in the gross domestic product (GDP) from 2009 to 2019. *Statista*, **20(3):** 45-65.

ORF, 2018. Background Note, Bangladesh-India Sundarbans Region Cooperation Initiative, 20p.

Payo, A., Mukhopadhyay, A., Hazra, S., et al., 2016. Projected changes in area of the Sundarban mangrove forest in Bangladesh due to SLR by 2100. *Climatic Change*, **139 (3):** 279-291.

Pullaiah, J., 2019. Global Biodiversity, Chapter III Biodiversity in Bangladesh, Apple Academic Press Inc, Dhaka, Bangladesh.

Rahman, M.M., Rahman, M.M. and Islam, K.S., 2010b. The causes of deterioration of Sundarban mangrove forest ecosystem of Bangladesh: Conservation and sustainable management issues. *AACL Bioflux*, **3(2):** 77-90.

Rahman, M.R. and Asaduzzaman, M., 2010. Ecology of Sundarban, Bangladesh. *Journal of Science and Foundation*, **8(1&2):** 35-47.

Rahman, M.A., 2018. Governance matters: climate change, corruption, and livelihoods in Bangladesh. *Climatic Change*, **147(1-2):** 313-326.

Rahman, M., 2021. Assessing the progress and pitfalls of the Ministry of Environment, Forest, and Climate Change in Achieving SDGs in Bangladesh. *Journal of Public Administration*, **29(2):** 140-158.

Rahman, M., Keshem, H., Gobhe, H., 2021. COVID-19 pandemic, dengue epidemic, and climate change vulnerability in Bangladesh: Scenario assessment for strategic management and policy implications. *Environmental Research*, **192:** 110-125

Rahman, M.H. and Miah, M.D., 2017. Are the protected forests of Bangladesh prepared for the implementation of REDD+? A forest governance analysis from Rema-Kalenga wildlife sanctuary. *Environments*, **4(2):** 43-65

Rahman, M., 2015. Causes of biodiversity depletion in Bangladesh and their consequences on ecosystem services. *American Journal of Environmental Protection*, **4(5):** 214-236.

Rahman, M.M., 2020. Impact of increased salinity on the plant community of the Sundarbans mangrove of Bangladesh. *Community Ecology*, **21 (2):** 273-284.

Rahman, M.M., Ghosh, T., Salehin, M., Ghosh, A., 2019. Ganges-Brahmaputra-Meghna Delta, Bangladesh and India: A Transnational Mega-Delta. *In:* Deltas in the Anthropocene. Springer: Cham, pp. 23-51.

Raihan, S., Lemma, A., Khondker, B. and Ferdous F., 2017. Economic Dialogue on Inclusive Growth in Bangladesh, Bangladesh Sectoral Growth Diagnostic, the Asia Foundation, Dhaka, Bangladesh. .

Ray, R., Ganguly, D., Chowdhury, C., Dey, M., Das, S., and Dutta, M.K., 2011. Carbon sequestration and annual increase of carbon stock in a mangrove forest. *Atmospheric and Environmental Sciences*, **45(2):** 5016-5024.

Ray, C., Chowdhury, N., Majumdar, M.K., Dutta, S.K., Mukhopadhyay, T.K. and Jana, S. 2013. Biogeochemical cycle of nitrogen in a tropical mangrove ecosystem, east coast of India. *Marine Chemistry*, **167(2):** 70-95.

Sadik, M.S., Shaw, R., Rahman, M.R., Nakagawa, H. and Kawaike, K., 2017. Event-consequence chain of climate change-induced salinity intrusion in Sundarbans mangrove socioecological system, Bangladesh. *Disaster Management*, **20(3):** 33-55.

Schindler Murray, L., Miligan, B., Ashford, O., Bonotto, E., Cifuentes Jara, M., Howard, J., Landis, E., Schnatz, J., and Guerrero-Ruiz, H., 2022. Aligning development co-operation to the SDGs in lower middle-income countries : A case study of Bangladesh. *Social Change*, **20(2):** 55-75.

Shah, M.A. and Datta, D.K., 2010. A quantitative analysis of mangrove forest resource utilization by the dependent livelihoods. ISEE conference on Advancing Sustainability in a Time of Crisis. *Journal of Sustainable Environment*, **209(2):** 45-65.

Smith, A.C., Tasnim T., Irfanullah, H.Md., Turner, B., Chausson, A. and Seddon, N., 2021. Nature-based solutions in Bangladesh: Evidence of effectiveness for addressing climate change and other sustainable development goals. *Frontiers in Environmental Sciences*, **9(1):** 56-65.

Solomon, S., Qin, D., Manning, M., Alley, R.B., Berntsen, T., Bindoff, N.L., Whetton, P., Wood, R.A. and Wratt, D., 2018. Technical summary. *In:* Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K.B., Tignor, M., Miller, H. L. (Eds.), Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Goodrich, J., Wibisono, H., Miquelle, D., Lynam, A.J., Sanderson, E., Chapman, S., Gray, T.N.E., Chanchani, P. and Harihar, A., 2022. *Panthera tigris*. The IUCN Red List of Threatened Species 2022. IUCN 2022: T15955A14862019.

Titumir, R.A.M., Afrin, T. and Islam, M.S. 2020. Traditional Knowledge, Institutions and Human Sociality in Sustainable Use and Conservation of Biodiversity of the Sundarbans of Bangladesh. *Wetlands,* **34(2):** 80-95.

Twilley, R.R., Pozo, H., Garcia, H.G., Rivera-Monroy, V.H., Zambrano, H., and Bodero, H., 1997. Litter dynamics in riverine mangrove forests in the Guayas River estuary, Ecuador. *Oecologia*, **111 (2):**109-122.

Uddin, M.M., Hossain, M.M., Aziz, A.A. and Lovelock, C.E., 2022. Ecological development of mangrove plantations in the Bangladesh Delta. *Forest Ecology and Management*, **517(2):** 120-150.

Uddin, M.M., Mahmud, M.A.A. and Jannat, M., 2019. Impacts of mangrove plantations on land stabilization along the coastline in Bangladesh. *American Journal of Earth and Environmental Sciences*, **2(1):** 1-8.

Uddin, M.M., Rahman, M.S., Hossain, M.K. and Akter, S., 2014. Growth density and regeneration of afforested mangroves at Mirersarai forest range in Bangladesh. *Forest Science and Technology*, **10(3):** 120-124.

Yadav, S.K. and Majumdar, K., 2020. Mangrove associated seaweeds in Sundarban biosphere reserve, West Bengal, India. *International Journal of Advanced Research in Biological Sciences,* **7(12):** 53-62.