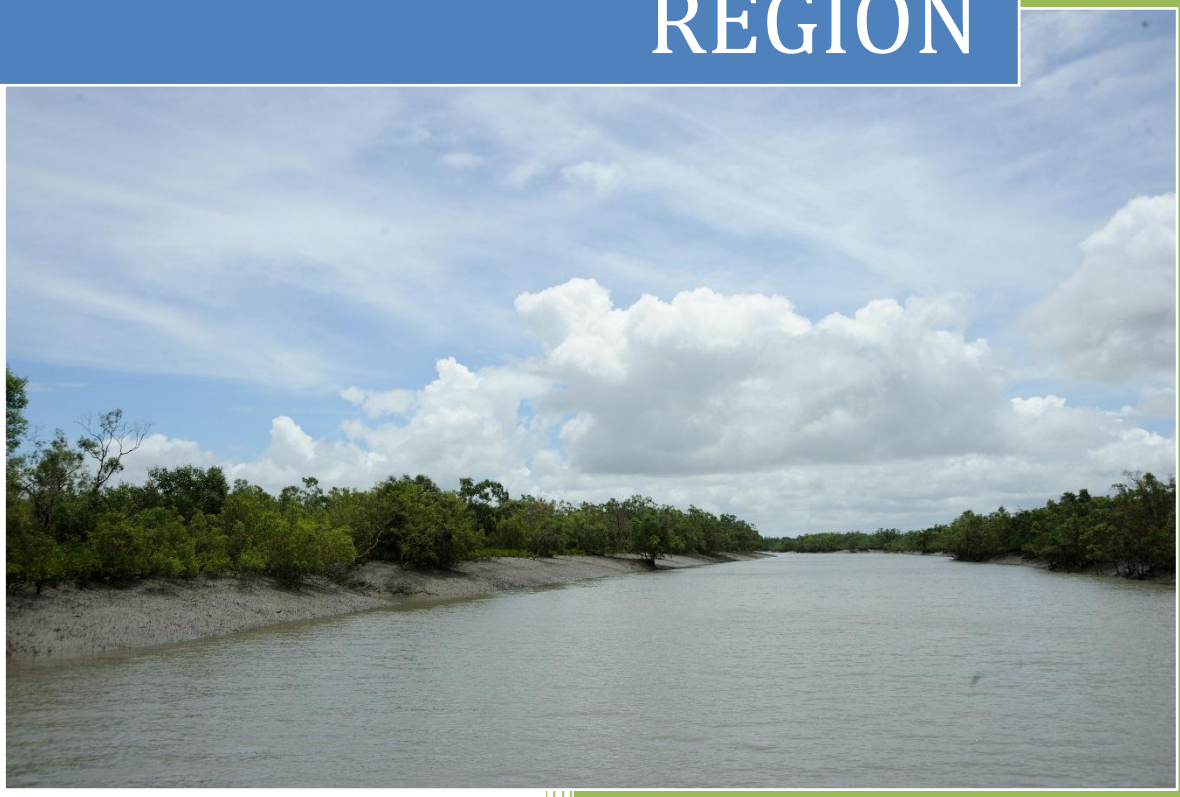
2017

VISION FOR THE SUNDARBAN REGION



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1. Preamble

There is evidence from around the world that periods of regional prosperity and well-being have coincided with periods of close economic, political and cultural relationships between countries in that region. In the context of South Asia, strengthening existing relationships and envisioning contexts for new relationships designed to address emerging challenges and opportunities will pave the way for mutual prosperity. Shared ecological habitats and natural resources presents a unique opportunity for cooperation and joint action. In the future, the regions' dependence on shared natural resources such as forests, rivers and other ecological habitats will increase but so will be the threats these resources are exposed to. Preserving the ecological integrity of these resources that transcend sovereign borders through joint action is thus of critical importance in South Asia, for both human and national security.

The fifth assessment report of the Inter-governmental Panel on Climate Change (IPCC) observes that projected sea-level rise in the Asian region is likely to result in significant losses of coastal eco-systems and that millions of people in South and South East Asia will be exposed to the risk of flooding.[1] It cautions that changes in the climate will impinge on the sustainable development of most developing countries of Asia as it would compound the pressure on natural resources and environment associated with rapid urbanization, industrialization and economic development. According to the report, vulnerability of settlements and society to climate change was greater in high risk locations particularly coastal and riverine areas. The report highlights that mangroves, salt marshes and sea grass beds could decline unless they move inland and that coastal freshwater swamps and marshes are likely to be exposed to seawater intrusion with rising sea levels. While the report expects bio-diversity to increase at temperate latitudes as warm-water species expand their ranges northwards, it anticipates a decrease in biodiversity in the tropics if thermal tolerance levels are exceeded.

Given its long coastline, Bangladesh is one of the most vulnerable countries to the impact of climate change not only in South Asia but also in the world. This poses a significant risk to the economic development of the country. According to the Asian Development Bank (ADB), the country will experience loss of about 2 percent of its GDP due to climate change by 2050. To address climate change impact Bangladesh was among the countries that developed early responses such as the Climate Change Strategy and Action Plan in 2009 (BCCSAP, 2009). The country also has developed Nationally Appropriate Mitigation Action (NAMA) and National Adaptation Programme (NAP) under the UN Framework Convention on Climate Change (UNFCCC) process. The latest action is the development of the Intended Nationally Determined Contribution (INDC) in 2015 which has automatically transitioned to Nationally Determined Contribution (NDC) of the country on ratification of Paris Agreement on 21st September 2016 by Bangladesh. Bangladesh NDC and all ongoing and planned activities to counter climate change adopts a two pronged strategy which focuses on increasing the resilience of the population through adaptation measures under NAP and set out a number of mitigation actions that will help limit the country's Green House Gas (GHG) emissions. The NDC targeted to reduce GHG emissions by 5 percemt from business as usual (BAU) levels (234 MtCO2e) in 2030 in the power, transport, and industry sectors from its own finance and reduce GHG emissions by 15 percent from BAU levels in 2030 in the power, transport, and industry sectors with the financial support from global climate financing institution.

[1] Hijioka, Y., E. Lin, J.J. Pereira, R.T. Corlett, X. Cui, G.E. Insarov, R.D. Lasco, E. Lindgren, and A. Surjan, 2014: Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change[Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi,Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370.

Adaptation is a key priority in the ongoing development plan and also in future. NDC and BCCSAP and the main areas of interventions to address adverse impact of climate change that has been identified in the NDC are:

a) Food security, livelihood and health protection (including water security)
b) Comprehensive disaster management
c) Coastal Zone Management including Salinity intrusion control
d) Flood control and erosion protection
e) Building climate resilient infrastructure
f) Increased rural electrification
g) Enhanced urban resilience
h) Ecosystem based adaptation (including forestry co-management)
i) Community based conservation of wetlands and coastal areas
j) Policy and Institutional capacity building

The action priorities identified in the NDC relevant to conservation of Sundarban also include Biodiversity and ecosystem conservation, research and knowledge management and capacity building at individual and institutional level to plan and implement adaptation programmes and project in the country.

India was also among the first few countries to develop action plans to address challenges posed by climate change. In the section on climate change adaptation, India's INDC states that India's coastline of 7517 km (including island territories) encompasses a total 73 districts in the 9 maritime states and 2 Union Territories. It observes that the coastal districts house 14.2 percent of India's total population. It states that India has been identified as one of the countries which is most vulnerable to the impact of accelerated sea level rise due to global warming.

The document states that India has responded by demarcating vulnerable areas on the coasts by declaring them as Coastal Regulation Zone (CRZ) with restrictions imposed on setting up and expansion of industries, operations and processes in these areas. It notes that India is also implementing programmes for Integrated Coastal Zone Management (ICZM). According to India's INDC, the vision of the project is to

a) build national capacity for implementation of comprehensive coastal management through ecological management, conservation and protection of critical habitats, coastal geomorphology and geology of coastal and marine areas, coastal engineering, socio-economic aspects, policy and legal issues and other related fields in the area of coastal governance.
b) Map and demarcate coastal hazard lines for development of emergency response plans which is an effort that is ongoing in all the coastal states and union territories.

India's INDC also refers to the Mangroves for the Future (MFF) initiative which aims to protect coastal livelihoods that is coordinated by International Union for Conservation of Nature (IUCN) in India.

It observes that not unlike the Small Island Developing States, the 1,238 Indian islands are vulnerable to loss of coastal wetlands including mangroves and salt water intrusion in fresh water aquifers. It states that with changing climate, islands are highly susceptible to frequent and more intense tropical cyclones and associated storm surge, droughts, tsunamis and volcanic eruptions, which would have an adverse impact on economy of these islands and health of their inhabitants.

It further states that the Indian government has notified the Island Protection Zone (IPZ) in 2011 with the objective of ensuring livelihood security to the local communities, conserving and protecting coastal stretches, and promoting development in a sustainable manner. The IPZ focuses on disaster risk reduction through bio-shields with local vegetation (mangroves) and other soft protection measures, and the conservation of beaches and sand dunes.

All the measures listed above have close relevance to the Sundarban region, the world's largest contiguous mangrove ecosystem shared roughly equally between Bangladesh and India. The Sundarban is one of the World's most bio-diverse ecosystems and is home to numerous threatened species. The Bengal tiger and several species of river dolphins are examples of the most well-known of these but there are numerous less known species such as butterflies and birds for which the Sundarban is a unique habitat. The Sundarban delta (including inhabited parts and wildlife zones in Bangladesh and India) is about 19,288 km^2 (19,288,00 hectares [ha]). The Sundarban Biosphere Reserve (SBR) in India is about 9630 km^2 (9,63,000 ha) of which 4260 km^2 (4,26,000 ha) is forested and 5370 km^2 (5,37,000 ha) is inhabited. In Bangladesh 6017 km^2 (6,01,700 ha) is forested while 3641 km^2 (3,64,000 ha) known as Sundarban Impact Zone (SIZ) inhabited.[2]

The broader context for forging a partnership to sustain human and ecological habitats in the Sundarban has already been established. Bangladesh is of strategic importance in the context of India's 'Look East' policy. The centrality of Bangladesh in India's 'Look East' policy is highlighted by the fact that India shares a 4,060 kilometre border with Bangladesh, India's longest with any country. The 'Look East' and 'Act East' policies have paved the way for an integrated 'Neighbourhood First' policy under the current government. The visit of the Indian Prime Minister to Bangladesh in June 2015 has resulted in major agreements under the head of 'Notun Projonmo' or 'Nayi Disha' which focus on building partnerships and cooperation on various economic, strategic and ecological issues.

Despite a few cases of divergence in interest, India's relationship with Bangladesh is among the most enduring since the birth of Bangladesh as an independent nation in 1971. Post 1991, both the nations have witnessed enhanced level of cooperation and success in the area of trade, resource mobilisation, development projects, energy conservation and cultural exchange. The Bay of Bengal Initiative for Multi-Sectoral Technical and Economic Cooperation (BIMSTEC) and the South Asian Free Trade Agreement (SAFTA) introduced by SAARC has led to an increase in trade activity and has opened up avenues for incorporation of bilateral free trade agreements in near future.

Power trade between the countries is progressing with current operating capacity of 500 Megawatt (MW) that is likely to increase to 1000 MW in the future. Grid connectivity with India has opened up possibility for power trade between Bangladesh, Nepal and Bhutan. Additionally, power trade is facilitating new investments from India's private sector into Bangladesh. India has allowed Bangladesh duty free access to its market barring a few products on the negative list. During the June 2015 visit of the Indian Prime Minister to Bangladesh, the two countries renewed the Protocol on Inland Water Transit and Trade. Agreement was also reached to allow India access to the Chittagong and Mongla sea ports of Bangladesh. Another positive development is the Motor Vehicles Agreement (MVA) reached in Thimpu in July 2015 for seamless movement of people and goods through roadways by Bangladesh, Bhutan, Nepal and India. The most recent visit of the Prime Minister of Bangladesh to India in 2017 ended in agreements that included but not limited to an agreement between the Energy Efficiency Services Ltd (EESL) of India and Sustainable and Renewable Energy Development Authority (SREDA) of Bangladesh, signing of an MOU between Petrobangla and Petronet for the setting up of a Joint Venture regasification Liquid Natural Gas (LNG) terminal at Kutubdia island as well as an inter-governmental agreement for cooperation in the field of civil nuclear energy.

In the context of the Sundarban, a memorandum of understanding (MOU) between the Government of India (GOI) and Government of Bangladesh (GOB) on the Conservation of the Sundarban was signed in September 2011 (hereinafter referred to as the 2011 MOU) in recognition of the potential of the Sundarban for sustaining ecological and human habitats. As per the provisions of the MOU, both the Indian and Bangladesh governments agreed to adopt appropriate joint management & monitoring of

[2] Geological Survey of India

resources, promote joint research to develop a understanding of the impacts of climate change along with adaptation strategies, foster information exchange programmes, effective patrolling in respective border areas and promote capacity building.

Article II in the 2011 MOU emphasises development of a long term strategy for creating ecotourism opportunities for both countries for increasing revenue generation within the region. In this context the signing of an MOU on passenger and cruise vessels on coastal and protocol routes between Bangladesh and India during the April 2017 visit of the Prime Minister of Bangladesh to India is significant as it sets framework under which cross border eco-tourism can be developed in the Sundarban region.

Article III of the 2011 MOU points out that both parties will map and delineate the human settlements living around Sundarban region on respective sides so that a better understanding emerges of the relationship between human settlements and the ecosystems, and also to develop a management plan to address issues of livelihoods through information collected.

2. Issues for Long Term Action through Joint Framework

2.1.Increasing Salinity in the Sundarban Region

SWAGAT BAM, INDIA

The Province of Bengal, comprising West Bengal and Bangladesh, forms a distinct geographical unit in the eastern extremity of the Indian Subcontinent. It is also a distinct geological unit, underlain by the Bengal Sedimentary Basin for the most part. On the surface Bengal is demarcated in the east by the Indo-Burmese ranges and the Chittagong Hill Tracts; in the west by the Chhota Nagpur Plateau which separates it from the Indian Craton; in the north by the Eastern Himalayas, the Shillong Plateau and its associated hills; and in the south by the Bay of Bengal. The Bengal Basin is an asymmetric sedimentary basin which largely follows the surface boundaries of the province. Whereas topographical expressions demarcate the province on the surface, the subsurface is constrained by faulting to the east, to the west and to the north. The southern boundary is marked by the continental shelf extending into the Bay of Bengal. The mostly low-lying, deltaic, alluvial land of Bengal is a direct product of its early geologic history, with an overlay of its recent geologic history, the combined effect of which define the prevailing natural framework of the province today.

6.1.1 Early Geologic History

In the Permian Period (290 to 256 million years before present or mybp) land masses on the earth were amalgamated into two super-continents: Gondwanaland in the southern hemisphere and Laurasia in the northern hemisphere. India, along with Australia, Antarctica, Madagascar and Africa formed the southern super-continent. Rifting of lithospheric plates led to the initial breakup of Gondwanaland in the Early Triassic Period, around 225 mybp. The Indian Plate, following its full detachment in the Early Cretaceous Period (142 to 99 mybp) drifted northward across the Indian Ocean, colliding first with the Eurasian Plate near Tibet to the north and then rotating eastwards to collide with the smaller Burmese Plate to the east. This is believed to have taken place in the Early Eocene Epoch around 55 mybp. The northward and eastward thrusting on account of subduction of the Indian Plate below the Eurasian Plate gave rise to the Himalayan orogeny in the north and the Indo-Burmese orogeny to the east. These two ranges constitute the major surface boundaries of Bengal today. Of the other topographic features demarcating Bengal, The Chhota Nagpur Plateau to the west is part of the Indian Craton of Pre-Cambrian age (over 600 mybp). It is extensively weathered and denuded and is geologically quiescent. The Shillong Plateau is believed to have risen more or less contemporaneously with the collision event in the Mid Eocene; however its geological origin is still a subject of active research today. The three uplifted areas, i.e. the Himalayas, the Indo Burmese Ranges and the Shillong Plateau have been geologically dynamic from the Eocene till the present.

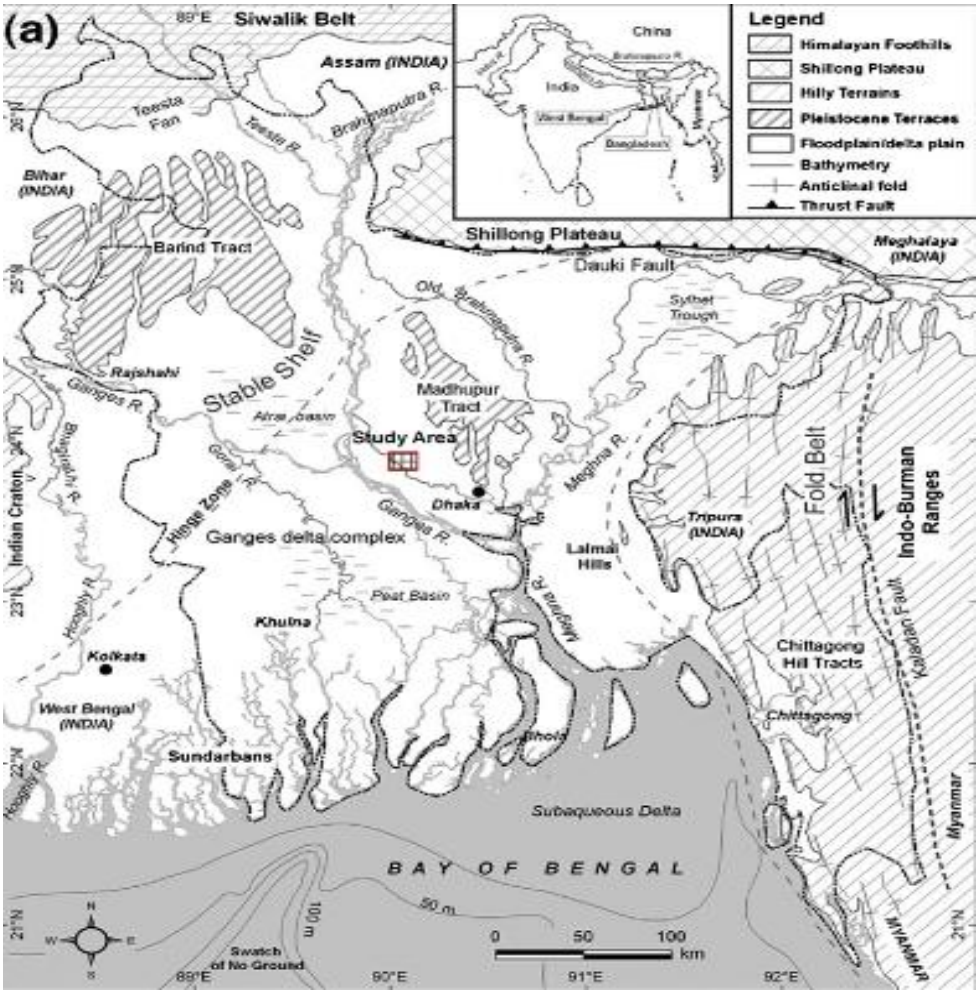
These events have caused the Bengal Basin to be a zone of geologic instability, with manifestations of crustal flexing, extensive linear faulting, magmatic lava flows, volcanism and seismicity. The Basin is classified as foreland basin, which developed as a crustal depression posterior (i.e. westward) of the subduction zone of the Indian Plate. As a result, the Bengal Basin has served as a massive sediment repository since the Oligocene Epoch (24 to 34 mybp), the time at which major collision-related uplifting of the Himalayas took place. Sedimentary volumes deposited since the Oligocene can be 16km to 18 km thick, which are considered to be the thickest in the world in that timeframe.[3] The proto-Ganges and the

[3] Roy, A.B. and Alokesh Chatterjee, 2015, "Tectonic framework and evolutionary history of the Bengal Basin in the Indian Subcontinent". Current Science, vol. 109, no. 2.

proto-Brahmaputra river systems had begun to take shape and drain the newly uplifted Himalayas and Indo–Burmese ranges by the Late Oligocene.

The predominant sedimentary supply to the Bengal Basin was therefore contributed by these two uplifted areas. Lesser contributions came from the Indian Craton, the Shillong Plateau, and via marine transgression. Thus the present-day distribution patterns of land and sea masses and of surface topographical features were largely in place by the beginning of the Miocene Epoch (24 mybp) which followed the Oligocene. It may be noted that the early geologic history of Bengal created the enduring physical features that we see today. An amalgamation of the early and the more recent geologic histories will provide an insight into the modern dynamic processes that shape the province: the topography, the climate, the geography, the hydrography, the pedology, the flora, and the fauna, human settlement and other factors that influence the Sundarbans in the present time.

MAP 1: TECTONIC MAP OF BENGAL[4]



Simplified geological map of the Bengal Basin. Ganges, Brahmaputra and Meghna rivers form one of the largest deltaic systems, occupied by Bangladesh and West Bengal, India.

6.1.2 Recent Geologic History (Holocene Epoch)

Bengal's Holocene geologic history (12,000 years before present, or ybp, to present), is key to the processes that are relevant to the BI-SRCI project (approximately 50 year timescale). Fluctuating global

[4] Shamsudduha, M., A. Uddin, J.A. Saunders, M-K Lee, 2008, "Quaternary stratigraphy, sediment characteristics and geochemistry of arsenic-contaminated aquifers in the Ganges-Brahmaputra floodplain in central Bangladesh". Journal of Contaminant Hydrology, vol. 99 (1-4)

cooling and warming episodes of the preceding Pleistocene Epoch (2mybp to 12,000 ybp) resulted in four major periods of glaciation, and up to nine minor ones worldwide. The coldest period of the Pleistocene Epoch was the last glacial episode, peaking around 20,000 ybp and ending 12,000 ybp. During the glacial maxima large quantities of water were locked in continental glaciers that covered much of the northern hemisphere. Continental shelves were emergent at this time, including the shelf extending south of the present-day Bengal coastline.

Sea level rise has been a continuous, ongoing process in the Holocene Epoch, rapid at first then followed by a general slowing. Glacial melting 12,000 years ago produced rapid eustatic rise. Stratigraphic, paleontological and palynological studies in the Bengal offshore indicate the rise to have been around 9 mm/yr from 9,800 ybp to 5,000 ybp (Hait et. al. 1996). This is thrice the rate of the average worldwide rise today (3 mm/yr). This slowed to 7 mm/yr between 6,200 ybp and 4,700 ybp, slightly more than twice today's rate. Concurrent to the Holocene sea level rise the Ganges-Brahmaputra Delta started to assume its present shape, prograding southward, and by about 5,000 ybp it was more or less as we see it today.

Today's estimates of regional sea level rise over the length of the Bengal coastline is in the range of 3-8 mm/yr. The worldwide average is 3 mm/yr. The variation in Bengal is due to three primary factors superimposed on each other: transgression of the sea and asymmetric tectonic settling of the Bengal Basin (both factors leading to sea level rise); and sedimentary deposition of fluvial and marine origin (working to lower it). Secondary factors such as local sediment compaction rates also play a role. Sea level rise is noted to be higher in the eastern part of the coastline due to basal tectonic settling of the Bengal Basin in an easterly direction. This is notwithstanding the fact that the eastern coastline also hosts the major river Mouths with the highest sediment discharge loads, resulting in high depositional build-up.

The coastal island systems offshore Bengal are much more transient in nature, accreting and eroding in response to localized depositional and erosional patterns.[5] The rapid Holocene sea level rise over the past 12,000 years has effectively trapped unconsolidated sediment delivered by the Delta close to its Mouth, resulting in easily shifted silt, sand and clay. The aggregate effect of these disparate dynamic processes working in tandem defines the coastline of Bengal today.

The dynamic processes influencing coastal Bengal overall are also evident in the Sundarban region. Due to tectonic tilting in an eastward direction, river systems have shifted eastward over time. This has produced a more active geological regime in the east, with higher sediment discharge, higher basinal settling and net higher sea level rise. The western part of the Sundarbans, like West Bengal, is geologically more passive and as a result exhibits lower levels of sea level rise.

6.1.3 River Systems

The Sundarban region is located in the inter-tidal floodplain of the tropical coastline of Bengal. Approximately half of the area covering the Sundarban region is affected by the tidal regime of the Bay of Bengal.[6]

The major river systems flowing into the Sundarban region in Bengal are, from west to east, the, Muriganga, Shaptamukhi, Thakuran, Matla, Biyadhari, Gosaba, Haribhanga, Raimangal, Kopotakho, Mathabhnga, Gorai, Nabaganga, Madhumati, and Baleswar. These may be classified as secondary rivers of Bengal. The channels of the four primary rivers, the Hooghly, the Ganges, the Brahmaputra and the Meghna bypass the Sundarban region. The rivers that enter the Sundarban region are in a state of continuous hydrologic flux, controlled by variable replenishment from the upstream (the primary source being the Ganges).

[5] Hazra, Sugata, T. Ghosh, R. Das Gupta and G. Sen, 2002, "Sea level and associated changes in the Sunderbans". Science and Culture, vol. 68, no. 9-12.

[6] Ibid.

Anthropogenic factors have been of increasing importance with population growth over the past two centuries. Human habitation has heightened demand for water use in agriculture, industry and domestic use. Modification of flow channels through constructions of barriers, diversions and other civil works, choking and fouling of rivers due to waste disposal, and similar activities have altered flow patterns on a regular basis.

6.1.4 Salinity in the Sundarban Region: India

The Sundarban region contain the largest brackish-water mangrove forests on earth with the highest species diversity of flora and fauna. It is also one of the most biologically productive wetlands on earth (Gupta and Sarkar, 2014). In West Bengal, out of a total area of 9630 sq. km., 4262 sq. km. of the Sundarban is reserve forest. This comprises 2195 sq. km. of wetlands/mangroves and 2069 km. sq. of tidal river. Reclaimed land of 5366 km. sq. is used for human settlements and agriculture. This was earlier forest area within the Sundarban.[7]

Terrestrial and aquatic biota in the Sundarbans, and fertility of agricultural land, are sensitive to saline incursion of marine and brackish waters inland.

Changes in salinity stress the cellular equilibrium of flora and fauna, primarily by disrupting internal ionic and osmotic balances. Resultant effects include stunting, deformation, and other negative effects on organisms. Stress is imposed on the population and the diversity of the biota. Output from agriculture and fishing diminishes. Potable water sources are reduced. Therefore factors promoting salinity changes need to be tabled as a first step in addressing the problem.

In West Bengal, the Sundarban emergent plain lies greater than 6m above mean sea level for the most part.[8] The net sea level rise (3-8 mm/yr) identified in Bengal suggests that eustatic sea level will not on its own cause major inundation in the time scales under consideration in this report (say 50 years). Sea level rise may prove to be a more challenging issue in the longer term of 100 years or more as the present rate could double due to global warming by that time. This however is in the scope of ongoing scientific studies and long-term trends are still being determined.

An important cause, perhaps the most important in increasing salinity are the storm surges that travel inland from the cyclonic storms generated in the Bay of Bengal. These storms are perennial features and their generation is dependent on land and sea distribution patterns in the region of the Subcontinent along with the temperature regime and marine and atmospheric circulation in the Bay of Bengal and Indian Ocean. These features (including the Asian monsoon) were initiated in the Miocene and were established in their present form by the mid Holocene, 5,000-6,000 ybp. The frequency of the highest-intensity cyclonic storms in the Bay of Bengal, considered to be the most powerful in the world, is about 9 per decade. The triangular shape of the Bay of Bengal produces funnelling and concentration of storm energy in a northerly direction towards the apex, with landfall typically in Bangladesh, West Bengal and Myanmar.

The tidal regime of the Bay of Bengal impacting the Bengal coastline and estuarine mouths has a typical range of 3.7 to 5 m, a very high value for unrestricted waters. High tides result in saline water being pushed in a landward direction, a process that is ongoing on a daily basis. Due to the narrowing and shallowing of fluvial channels upstream from the estuarine mouths, development of tidal bores is common. The bores gets accentuated as they moves inland Tidal bores are known to reach a height of over 7 m. (Tide Table of Hoogly River, 1984), promoting the ingress of saline waters inland . The tides and

[7] ibid.

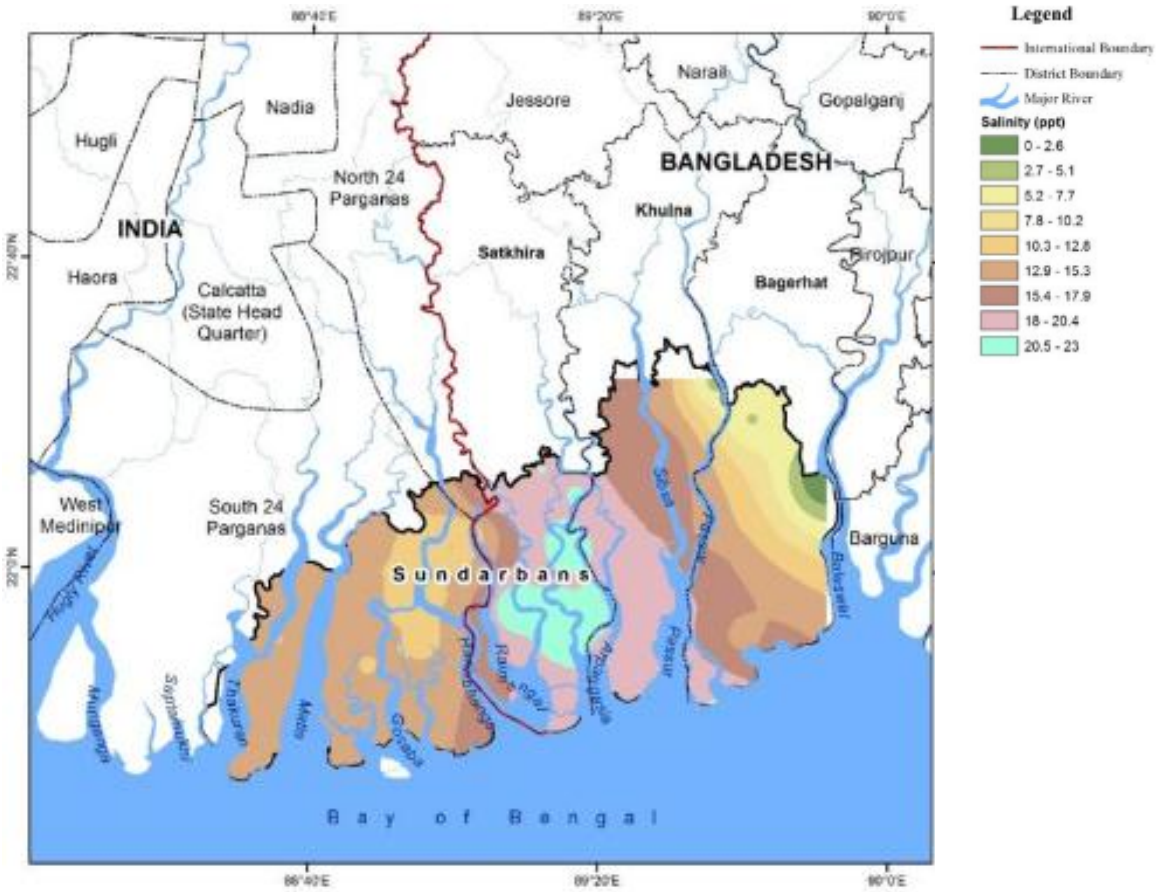
[8] Gupta, Shubhadip and Gargi Sarkar, 2014, "Climate change and economic adaptability of the Indian Sunderban". International Journal of Science and Research, vol. 3 issue 10.

the tidal bores not only regularly inundate the low-lying coastline 3-8m above sea level but are also a prime factor in the erosion of transitory emergent islands.

Changes in certain global weather and current patterns, documented over past quarter century, have had a bearing on fresh water supply in coastal Bengal, including the Sundarban region. There have been 12 episodes of El Nino (preferential warming of surface waters) in the equatorial and southern Pacific Ocean since 1980, with the most severe appearances being in 1982-83, 1997-98 and 2015-16. The regional effect of El Nino on Asia is weakened precipitation accompanied by drought in many areas. The resultant reduced rainfall inadequately replenishes the catchment areas of the Ganges and Brahmaputra river systems. The flushing and diluting function of fresh water on saline incursion is therefore impaired.

Changing river courses in the Holocene Epoch have been a common feature of the Bengal Delta due to prevailing geological conditions. The Bengal Basin has been tilting gradually in an eastern direction due to sediment loading and tectonic subsidence.[9] Over time river courses have shifted in a downdip, eastern direction. Localised geological features including faults, escarpments, hinges, etc, add their effect by providing pathways of lesser, or greater resistance to flow. As a result, eastern Bengal is more riverine than the western part. The Sundarban region, on the central and south-western coast of Bengal, are largely bypassed by the main rivers of the delta, limiting fresh water input.

MAP 2: SALINITY MAP OF SUNDARBAN REGION[10]



Source: CEGIS, Centre for Environmental and Geographic Information Services, Dhaka

[9] Morgan, James P. and William G. McIntire, 1959, "Quaternary geology of the Bengal Basin, East Pakistan and India". Bulletin of the Geological Society of America, vol. 70 no. 3

[10] IWA, "Sundarban Joint Landscape Narrative (draft) 2016

Change in river courses have also been exacerbated by human settlement and intervention in land and river use patterns since the early 19th century. Construction of dams, barrages and embankments, diversion for water for agriculture and habitation purposes, blockage of channels due to waste disposal and other such activities have disproportionately affected the smaller distributaries that flow into the Sundarbans. Many of these rivers have been deprived partially, or sometimes wholly, of freshwater supply from their mother channels (mainly the Ganges-Hooghly system). Chief among the affected rivers are the Saptamukhi, the Thakuran, the Bidyadhuri, the Matla, the Kopothako and the Mathabhanga. The ability of these rivers to contribute fresh water to the Sundarban ecosystem has been greatly reduced over the past two hundred years.

Due to the heavy sediment load of the Himalayan rivers that erode the young Himalayan ranges, sedimentary deposition rates (siltation) in river channels reduce the flow gradient, thereby causing alternate alignment. New alignments frequently result in reduced, or lost connection between mother channels and their daughter channels, rendering the distributaries less effectual in combating saline incursion. Additionally, weakening of river gradients due to sedimentation promote new alignment. The ability to displace saline waters ingressing from the coastline into the Sundarbans due to tides or storm surges is correspondingly reduced.

The variation in replenishment of the Ganges and the Brahmaputra river systems over time has a corresponding effect on energy levels of fluvial flow. Higher energy waters will result in linear flow trajectories whereas lower energy waters will promote meandering and will be subject to local surface and subsurface geological factors. The most significant change of this kind in the Holocene has been in the course of the Brahmaputra which used to enter Bengal from east of the Shillong Plateau near Sylhet. The Brahmaputra now enters Bengal from west of the Plateau, and flows south where it joins the Ganges. Although this flow pattern differs from the otherwise general trend of eastward shift of river channels, it illustrates the manner in which river courses can change, prompted by energy levels of the water resulting in new pathways.

In summary, it may be seen that the primary factors raising salinity levels in the Sundarbans are storm surges and tidal effects. Fresh water supply into the region that counteracts this stands reduced. It may be mentioned that many of the major natural processes of the earth such as tectonic settling, subduction, eustatic sea level rise, cyclone generation, seasonal rainfall, and like are beyond direct human control. Nevertheless the pathway remains open to moderating their effects. Astute land and water management practices, effective civil engineering, and more favourable patterns of human settlement and intervention on the ecosystem could all be addressed.

6.1.5 Salinity in the Sundarban Region: Bangladesh

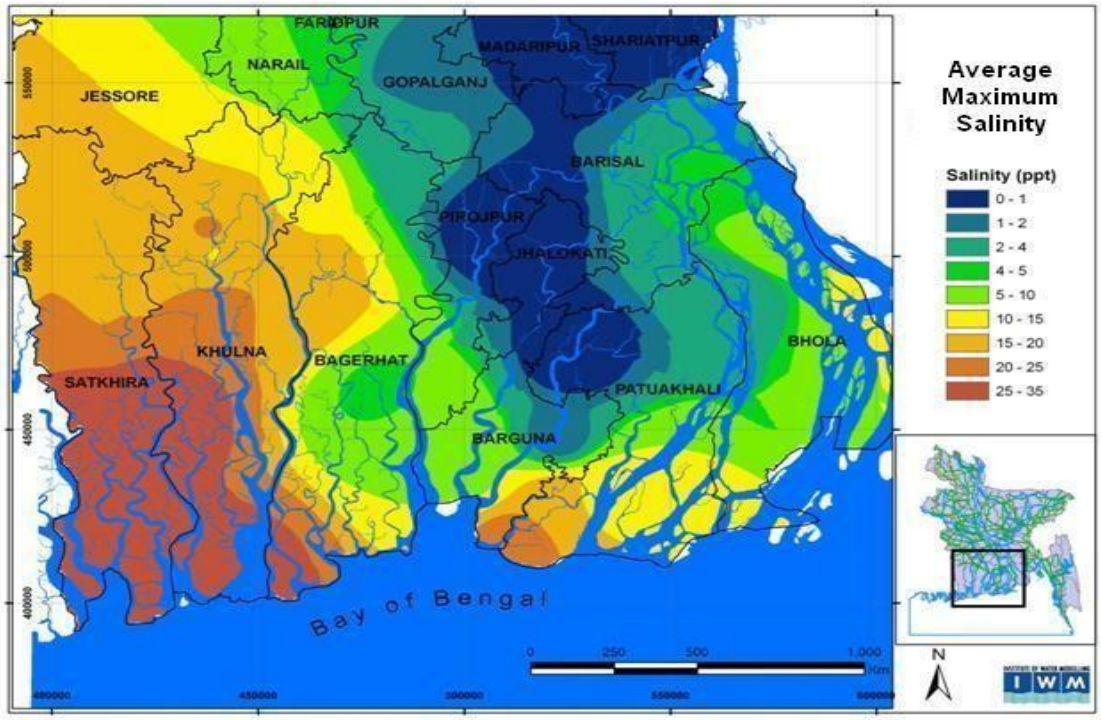
ANSARUL KARIM, BANGLADESH

Salinization of the river water and the soil in the Sundarban is the most widely discussed research subject in the Sundarban. Being placed in the interface between land and the coast, salinity in the Sundarban depends on the freshwater flow from the upstream surface runoff from the rainfall events through the river systems and the tidal dynamics of the Bay of Bengal. Due to the seasonal distribution of the rainfall salinity of the rivers shows seasonal pattern, low saline condition during the wet months and high salinity during dry months. In addition to temporal variation, there is pronounced spatial variation in river salinity. Tidal waves from the Indian Ocean travel through the deeper part of the Bay of Bengal and approach the coast of Bangladesh from the south.

Sundarban is bounded by Baleswar River in the east, Raimongal River, and the border with India in the west. The Gorai River, a distributary of the Ganges, is the main source of freshwater for the eastern part of the Sundarban which is dependent on the supply of freshwater from the Ganges River. Spatial variation of

river salinity within the Sundarban, depends on tidal amplitude, the extent of landward penetration of tides, and the volume of freshwater flow from the upstream rivers. Thus salinity in the rivers increases from east to west and south to north.

MAP 3: SPATIAL VARIATION OF THE MAXIMUM RIVER SALINITY LEVEL DURING 2011–2012 IN THE SUNDARBAN



Source: Institute for Water Modelling (IWM), Bangladesh

The most recent evidence suggests that global Sea Level Rise (SLR) could reach one meter or more during this century[11],[12],[13]. These results focus on the dynamic implications of ice sheet instability and produce estimates significantly beyond the upper limit of the range cited by IPCC AR4 (IPCC 2007a): a 90 percent confidence interval of 18 to 59 cm based principally on thermal expansion, with an additional 10 to 20cm allowed for a potential dynamic response from the Arctic and Antarctic ice sheets.

Area estimates indicate the following changes from the baseline (March 2012) to the best and worst case future scenarios (March 2050)

- "Slight saline" river area is likely to decrease from 22 percent at the baseline to 16 and 13 percent in the best and worst case scenarios, respectively.
- "Slight to moderately saline" river area is likely to decrease from 35 percent at the baseline to 30 and 21 percent in the best and worst case scenarios, respectively.

"Moderate to high saline" river area is likely to increase from 8 percent at the baseline to 17 and 27 percent in the best and worst case scenarios, respectively.

[11] Hansen, J.E., and M. Sato. 2011. Paleoclimate Implications for Human-made Climate Change. NASA Goddard Institute for Space Studies and Columbia University Earth Institute.

[12] Pfeffer, W. T., J. T. Harper and S. O'Neel. 2008. Kinematic constraints on glacier contributions to 21st-century sea-level rise. Science, 321: 1340-1343.

[13] Dasgupta.S, Istiak Sobhan Wheeler, D (2016). Policy Research Working Paper 7736, World Bank Group, Development Research Group Environment and Energy Team June 2016.

- "Highly saline" river area is expected to increase from 35 percent at the baseline to 38 and 40 percent in the best and worst case scenarios, respectively.

Mangroves of the Sundarban are adapted to variable saline condition and so expected increase in river salinity is likely to trigger changes in the ecosystems of the Sundarbans mangrove forest. The most commonly found trees in the Sundarbans are Sundari (Heritiera fomes), Gewa (Excoecaria agallocha), Guran (Ceriops decandra), Baen (Avicennia officinalis) Keora (Sonneratia apetala), Kankra (Bruguiera sexangula) and Garjan (Rhizopohora mucronata). Among these, Sundari is the single most dominant and important species of Sundarbans, with the highest market value. The diameter and height of the trees decreases steadily with salinity increase and shows a dramatic decline when salinity is more than 25 parts per thousand (ppt). Gewa the second largest coverage tree also reduces in stature but can thrive in higher salinity. Goran grows better with increasing salinity. Even if greenhouse gas emissions were to be stabilized today, it is virtually certain that SLR will continue beyond 2100. Probably it is *fait accompli* that increase in salinity with the change in climate and SLR is inducing an overall shift from Sundari dominance to lower value species (Gewa and Guran) even extinction of the globally endangered Sundari plant in Sundarbans.

Expected increase in river salinity is likely to change the aquatic eco-systems as well. Saline intrusion into freshwater habitats of fish is likely to change the composition of capture fishery during the dry season. Habitats of freshwater loving fish are likely to decline in the wild. Reductions in the wild are also expected for small indigenous freshwater fish species, for example Bacha (*Eutropiicthyys vacha*), Bata (*Mugil parsia*), Batashi (*Pseudeutropicus atherinoides*), Chela (*Salmostoma argentea*, *Salmostoma phulo*, *Salmostoma bacaila*), Darkina (*Esomus danricas*, *Rasbara daniconius*, *Rasbara rasbora*), Kajuli, Baspata (*Ailia coila*, *Ailicthys punctate*), Kash Khaira (*Chela laubuca*), Kholisha (*Colisa fasciatus*), and Tengra (*Mystus tengra*).

The optimum level of surface water salinity is less than 4 ppt for Golda/giant freshwater prawn (Macrobrachium rosenbergii) and ten to 20 ppt for brackish water Bagda/Black Tiger shrimp (*Penaeus monodon*). Spawning grounds for Golda prawn are likely to move upstream as freshwater is essential for Golda juveniles. Golda production in the wild is expected to decrease and Bagda production on monoculture farms is expected to increase[14].

2.2. Increasing Pollution in the Rivers and Sediments

2.2.1. Bangladesh

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Within the Sundarbans Reserve Forest (SRF) there is little human activity other than seasonal fishermen at Dubla and visit by the tourists. The Mongla Port located at the vicinity of the SRF that uses the Passur River for maritime and inland vessel movement is the source of pollution. There are also several cement factories, LPG plants at the bank of the Passur River which discharges wastes in to the Passur River. Pollution may also originate from the Mongla Export Promotion Zone, Special Economic Zones planned to be established at Satkira and Mongla with the Indian Government Finance and also the industrial activities that are concentrated along the roads between Kushtia-Jessore-Khulna and along the rivers flowing in to the Sundarban.

Movement of Vessels at present is not significant with only 500 vessels per year but it is likely to increase significantly when the port will be used by India as per the recently signed Coastal Shipping Protocol and Inland Water Transport Protocol and also transportation of bulk coal for the Bangladesh India Friendship Coal Power Plant. The number of other vessels (mechanized, passenger, fishing, etc.) has been reported to

[14] Dasgupta.S, Istiak Sobhan Wheeler, D (2016). Policy Research Working Paper 7736, World Bank Group, Development Research Group Environment and Energy Team June 2016.

be on the increase in last 10 years. Bilge water and crude oil slicks derived from mechanized boats, fishing trawlers, goods carrying vessels and passenger launches travel along the Pasur river at a distance of about 100 km via the SRF to Mongla port and affects a considerable part of the Sundarbans.

There are reports about mortality of seedling, fish, shrimp and other aquatic animals from the oil spill. Oil spills cause damage to mangroves by coating roots, limiting the transport of oxygen to underground roots. Mangrove communities including invertebrates, fishes, and plants are also highly susceptible to damage from petroleum products. Dredging and filling activities of the port causes flooding of mangrove habitat. Standing water covers the aerial roots, making it impossible for oxygen to reach these specialized roots as well as the underground root systems. Eventually this leads to the death of mangrove trees.

In the recent past there were about 165 industries in Khulna, located in Rupsha, Khalispur and Shiromony industrial zones. Some of them have closed in recent years, but approximately 150 exist presently. The polluting industries of Khulna such as chemical complexes, fish processing plants, steel mills, paper mills, rayon mill complexes, cement factories, paint and dye manufacturing plants, several soap and detergent factories and a number of light industrial units directly discharge untreated toxic effluent into Bhairab-Rupsha river system. These industries discharge more than 4500 m^3/ha waste water in the Rupsha River, which ultimately carried out to the Sundarbans through Bhairab-Rupsha River system. Goalpara power station, some jute mills, match factories in the Khalispur industrial belt also discharge their untreated waste into Bhairab river. The pollutants find their way to the SRF wetlands through the Pasur-Sibsa river system. Discharge of waste water from the shrimp culture ponds in to the rivers also threatening the aquatic ecology of the Sundarban.

Presently in Bangladesh, the use of chemicals is increasing. About 20 insecticides, 18 fungicides and 2 rodenticides are being used in the country. These agrochemicals eventually drain into the adjacent water bodies and are carried downstream in the SRF through the river waters. Their subsequent incorporation into the food chain, with biological magnifications at higher tropic level, risks the stability of the biota itself and result in the disruption of the biochemical cycles of the ecosystem. Monitoring and surveillance facilities are not available to quantify the extent of the pollution. However, sporadic researches indicated the presence heavy metal pollution in the aquatic organism of the rivers[15].

It is known that the fine grained anaerobic sediments, characteristic of mangrove forests, severely reduce the rate of microbial breakdown of oil. Burrowing activities of crustaceans, a characteristic of mangrove forest, can lead to persistence, high levels of oil contamination, not only on the soil surface but also deep in the sediments in the mangrove root zone. The light fraction of the oil, considered to be the most toxic, generally evaporates or degrades rapidly. Hence, the heavier fraction is the cause of most of the chronic impacts. Chronic exposure to oil residues results in damage to aerial roots, reduction in litter fall, and reduced survival and deformation of seeding.

Coastal and marine fisheries are affected quantitatively and qualitatively with a reduction in the nutritional value of fish. The thin layer of oil on the water affects the multiplication of planktonic organisms and interferes with the growth and reproduction. Fish can also absorb oil directly with their feeding, resulting in the tainting of fish tissue. Also, the aromatic hydrocarbons present in the crude oil are persistent and carcinogenic. Since they have tendency to be biologically accumulated in fish tissue, they can pass it on into organisms of higher tropic levels in the food chain.

An increased amount of heavy metals in the sediment of top dying affected areas has been reported from the Sundarban and relates to cause of 'top-dying' of the Sundri trees a major cause of decline of Sundri[16].

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[15] Samad M.A.,, Mahmud Y, Adhikary R.K., Rahman S.B.M., Haq M.S., Rashid H. (2015) American Journal of Environmental Protection, 2015, Vol. 3, No. 6, 180-186.

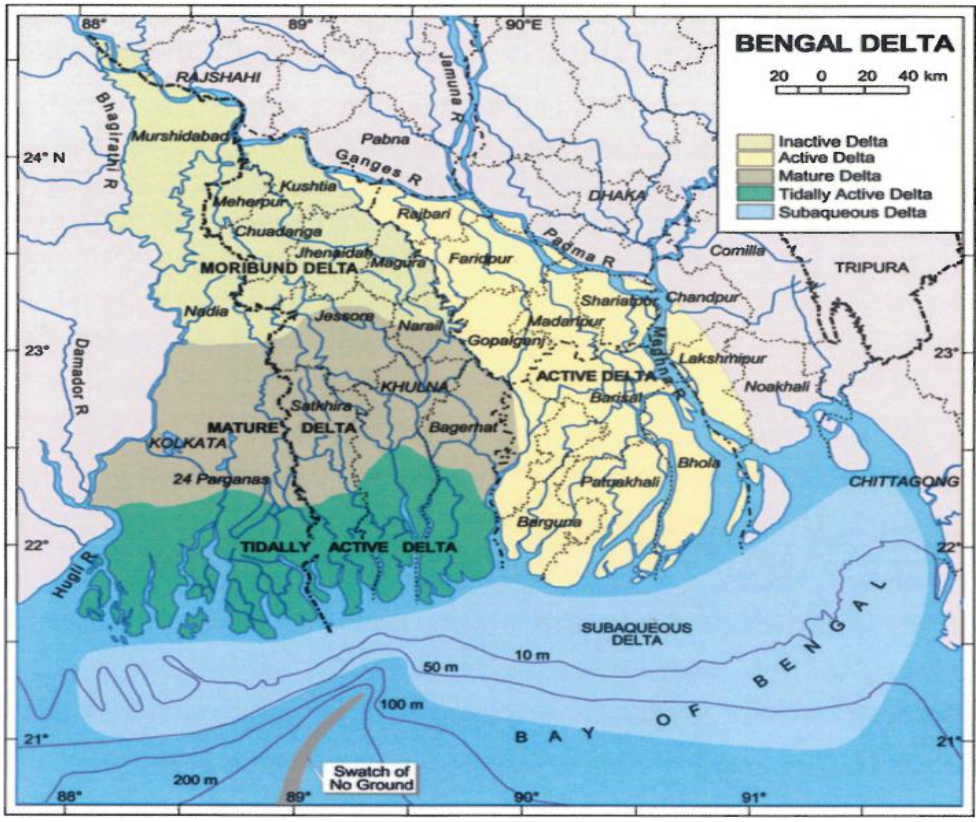
[16] Awal, Mohd. Abdul (2014) Analysis of causes of disease in Sundarbans natural mangrove. American Journal of Bioscience and Bioengineering. 2(2): 18-32.

2.2.2. India[17]

Seven rivers flow through the Sundarban. In the western part of the Sundarban are the Hooghly river and the Muriganaga which originate from the Ganges river. In the western part the five rivers that flow through it are Saptamukhi, Thakuran, Malta, Gosaba and Harinbhanga also had upstream connection with the Ganges. Due to heavy siltation and disposal of solid waste from adjacent cities, the rivers in the western part of the Sundarbans no longer receive fresh water from the upstream Ganges and are totally tidal fed. However, these rivers do receive fresh water during monsoon which lasts for the period from May to October. Due to continuous tidal activity, the surface water in Sundarbans is saline and unusable for human and livestock consumption. Sweet water or potable water is drawn from aquifers at depths 200 to 400m.

The Sundarban delta has been formed by the continuous deposition of silt carried down by the Ganges and Bramhaputra river system into the Bay of Bengal for more than 70 million years. The silt load carried by the Ganges and Bramhaputra varies from 1 to 1.67 billion tonnes annually. A large part of the sediment reaches the sea through two marginal estuaries-Hooghly in the west and Padma-Meghna in the east. But the tide pushes back a portion of sediment load through creeks and rivers. The silt-laden water spills over the flood plain during high tide and recedes during low tide and thus land along the flood plain of these rivers gets elevated. The Sundarban area is thus identified as an active delta. The part of the delta that is elevated above highest high water level is identified as matured. This area gets sediment deposit only during flood. When the river area is decayed, the area is described as moribund delta. The sub aqueous delta, as seen in the satellite image shown in MAP4 extends far south from the coastline into the Bay of Bengal.

MAP 4: Satellite Image of Bengal Delta



Source: Government of West Bengal

[17] West Bangal State Action Plan on Climate Change, Government of West Bengal

Despite receiving such sediment load, there has been no appreciable growth of new land along the coast during last three centuries. There are various factors which are together responsible for this condition of the delta. It is reported by experts 'delta building' is impeded by siphoning of sediment away from the coast through the 'Swath of No Ground'[18] or the submarine canyon of the Bay Bengal. In addition, destructive waves continuously attack the southern littoral tract and erode land. Slow subsidence due to auto-compaction of newly deposited sediment surpassing the effect of accretion is also among causes for inadequate growth of the delta.

Between 1777 and 1971, continuous deforestation and land reclamation activities were carried out in the Sundarban region in the once densely forested mangrove area for agriculture by the British. Clearing of forests did not however, facilitate beginning of agriculture on the flood plain which tended to be submerged under saline water during high tides. Therefore a 3500 km long embankment was built along the bank of creeks and along the sea shore to prevent the ingress of saline water. Thus the spill-over of silt-laden water on floodplains was assumed to be restricted.

However, the embankment impeded the dynamics of sedimentation. It trapped silt within the embankments and the river beds got filled with silt, making the channels increasing shallow. As a result, the riverbeds got elevated but the flood plains remained at the same height. Consequently, rainwater falling on the floodplains remains stagnant for a long periods of time and the tidal inflow has been transformed into a tidal bore which breaches the embankment often.

2.3.Habitat degradation (Terrestrial and Aquatic)

2.3.1. Bangladesh

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A habitat is an ecological area that supports or is inhabited by a species or groups of animals and plants species or other type of organisms naturally. The Sundarban is a unique mangrove ecosystem in the sense that no other mangroves in the world provide habitats for unique plants and animals that are not seen in any other mangroves in the world.

Historically, it is the last habitat of Royal Bengal Tiger which cannot be found in any other mangroves in the world and also an orchid which is endemic to the Sundarban. At present Sundarban is the last remaining habitat of the most endangered plant the Sundri (*Heritiera fomes* Buch Ham) and last viable population of most endangered species *Panthera tigris.* It is also the habitat for the endangered Gangetic dolphin. Despite its terrestrial and aquatic biodiversity, the region has not received the attention that it deserves. Habitat for all those species in the Sundarban is seriously degraded and predicted to continue to degrade under the present human development and climate change scenario threatening the existence of all those globally significant species.

In the geological past the Sundarban has evolved in an abundance of freshwater as a landscape of the river dominated delta of the distributaries of the three mighty rivers the Ganges, the Brahmaputra and the Meghna. The biota of this delta and its estuaries also adapted to freshwater dominating to low saline hydro geomorphology from the apex of the delta to the tide dominated coast. Currently hundreds of millions of people occupy the upper part of delta landscape and human engineering is now a major influence on the growth and evolution of the delta, through control of the flow path of distributary channels, and mitigation of the seasonal flood wave with concomitant change in the delivery of sediment load. Understanding of habitat change in the Sundarban must be seen through the pre-anthropocene ecology of the delta.

[18] The Swatch of No Ground is a shelf canyon that deeply incises the Bengal shelf near the Ganges-Bramhaputra river mouth, cuts the forest beds of the sub aqueous river delta and acts as temporary depocenter between river mouth and Bengal fan. Sedimentation rates in the Swatch of No Ground are highest near the canyon head

Degradation of the mangrove habitat is the consequence of over-exploitation (legal and illegal) of the mangrove wood products by human and also indirectly through change in hydrodynamics of the rivers flowing through the Sundarban. Besides the increasing impact of salinization and pollution load of the rivers as described in the previous section, changes in land use in the watershed area of the rivers obstruct or modify the flow regime. Geological subsidence accompanied by increasing SLR risk further degradation of the habitat. Literature on the habitat assessment of the Sundarban is very limited. However considering that high mangrove forest characterized by high vegetation consisting of multi layered forest structure is the most desired habitat condition, it has been shown that Sundarban is heading towards an uncertain future probably risking the extinction of more plant and animal species in the near future. Limited studies available to track the changing dynamics of habitat of selected mangrove species reveal that *H. fomes*, is estimated to have declined by 76 percent since 1959 and about 70 percent of the remaining *H. fomes* trees are affected by the 'top dying' disease. Dramatic declines in other dominant mangrove species (e.g. *E. agallocha* and *X. mekongensis*) have also been reported.

In response to the serious depletion of forest timber resources the Government of Bangladesh has put a moratorium on timber extraction from the Sundarban in 1989. In spite of such a ban there had been continuous decline of Sundri and Gewa tree coverage. A recent study detected the 8.4 percent decline of Sundari cover during the period from 1989 to 2000. Area of Kankra increased and bush land was introduced within this 11 years period. Almost all the rivers in the study area have increased their width within the respective period revealing the bank erosion in the rivers[19]. Data in the table below shows changes in the area of forest cover classes between the year 1989 and 2000.

TABLE 2: CHANGES IN AREAS OF FOREST COVER CLASSES BETWEEN THE YEAR 1989 AND 2000

Classes	1989-2000		change 1989-2000		Net Gain-Loss	
	Hectares	percent Area	Hectares	percent Area	Hectare	percent
Sundri	23027.8	52.0	19308.5	43.6	-3719.3	-8.4
Gewa	15184.4	34.3	15828.4	35.7	643.3	1.4
Kankra	190.6	0.4	1906.1	4.3	1715.5	3.9
Keora	43.8	0.1	81.7	0.2	37.9	0.1
Bush land			386.7	0.9	386.7	0.9
Shrub	569.5	1.3	463.3	1.0	-106.3	-0.2
Marshy Grassland	558.7	1.3	772.2	1.7	213.6	0.5
Water	4726. 6	10.7	5581.0	12.6	854.4	1.9

The decrease of Sundari habitat condition is attributed to the unsustainable harvesting practices, both legal and illegal[20], increased salinity in the river and soil, micro topographic variation of the substrate condition

[19] Mariam Akhter (2006) Remote sensing for developing an operational monitoring scheme for the Sundarban Reserved Forest, Bangladesh. Thesis submitted for the degree of Doctor of Natural Science (Dr. rer. nat.) of Technische Universität Dresden, Germany

[20] Canonizado JA, Hossain MA (1998) Integrated forest management plan for the Sundarbans Reserved Forest (Final Draft). Mandala Agricultural Development Corporation and Forest Department, Ministry of Environment and Forest, Bangladesh

affecting inundation regime and nutrient availability[21,22,23,24,25,26,27]. The conclusions of these studies should be considered as a "wake up call" for those who have serious concern about the conservation of the Sundarban.

2.3.2. India[28]

The forest area of Sundarban covers an area 4265 km^2 and is reserved for conservation. It is observed that there is 5 percent loss of forest cover in 20 years (1989-2009). The forest area is divided into five distinct categories based on different mangrove associations (Table 3).

- Deforested mangrove swamp: found mostly in the western and central parts of Sundarban;
- Dense mangrove forests: currently found only in the south- eastern part;
- Tall & dense mangroves: these are restricted to the eastern part of Sundarban and are comprised of Heritiera forms;
- Brakish water mixed Heritiera sp. Forests: these are rare and largely confined to the north – eastern part;
- Palm swamps dominated by Phoenix paludosa: these have scattered distribution and are found throughout the Sundarban forest.

TABLE 3: THE RESERVED AREA OF INDIAN SUNDARBAN

Designated Areas	Zoning	Designation	Area (sq.km.)	Remarks
Sundarban Tiger Reserve:2585 sq.km	Core Zone	Sundarban National Park	1700	An area of 124.4 sq km preserved as "Primitive Area"for gene pool preservation
	Buffer Zone	Sajnekhali Wild Life Sanctuary	362	
		Designated Reserve Forest	523	
Reserve Forest of South 24-Pgs: 1680 sq.km (Western side of Matla River)	Manipulated Zone	Lothian Wild Life Sanctuary	38	Limited human intervention allowed
		Haliday Island Wild Life Sanctuary	6	
		Designated Reserve Forest	1636	

The Sundarban, in its eastern side, has an area of 2585 km^2 demarcated for conservation of tiger, with a core zone of 1700 km^2 known as the Sundarban National Park and is surrounded by a buffer zone covering 885 km^2 that houses the Sajnekhali Wild Life Sanctuary, and a clear area within the forest is demarcated for preservation of the gene pool. No human intervention is allowed on this side of the Sundarban.

[21] Chaffey DR, Miller FR, Sandom JH (1985) A forest inventory of the Sundarbans, Bangladesh, Main report. Overseas Development Administration, Land Resources Develop- ment Centre, England.

[22] Karim A (1988) Environmental factors and the distribution of mangroves in the Sundarbans with special reference to Heritiera fomes Buch.-Ham. PhD Thesis, University of Calcutta, Calcutta, India

[23] Karim A (1995) Report on mangrove silviculture, vol 1. Inte- grated Resource Development of the Sundarbans Reserved Forest, Bangladesh. FAO/UNDP Project BGD/84/056

[24] Karim A (1994) Vegetation. In: Hussain Z, Acharya G (eds) Mangroves of the Sundarbans vol 2: Bangladesh. IUCN

[25] Siddiqi NA (1994) Natural regeneration. In: Hussain Z, Ach- arya G (eds) Mangrove of the Sundarbans, vol 2: Bangladesh. IUCN, Bangkok, Thailand

[26] Iftekhar M.S. and Saenger P. 2008. Vegetation Dynamics in Bangladesh Sundarbans Mangroves: a Review of Forest Inventories. Wetlands Ecol. Manage 16: 291-312.

[27] Sarker, S. K. et al. Are we failing to protect threatened mangroves in the Sundarbans world heritage ecosystem? Sci. Rep. 6, 21234; doi: 10.1038/srep21234 (2016).

[28] This section is based on the 2012 State Action Plan on Climate Change of the Government of West Bengal

An additional 1680 km^2 in the western side of Sundarban, has the Lothian Wild Life Sanctuary, the Haliday Island Wild Life Sanctuary and a designated Reserve Forest. This area allows limited human intervention for extracting non timber forest products.

The soil of the region can be generally classified in five groups, namely, clay soil, heavy soil, sandy loam, sandy soil and silty soil. The entire area may be divided into low salinity up to 8 parts per thousand (ppt) and moderate to high salinity from 8 ppt to 20 ppt. The salinity has seasonal variation with minimum from July to October, moderate during November to February and highest during March to June. On the whole, the soils of the region are fertile and suitable for productive agriculture but optimum use is constrained by poor drainage conditions during wet season and lack of irrigation in the dry season.

TABLE 4: ENDANGERED PLANTS SPECIES OF SUNDARBANS

Name	Current Stresses
Amoora Cucullata	Alteration of habitat changes and environmental changes
Cynometra iripa	Environmental changes
Heritieria fomes	Biotic pressure and environmental change
Intsia bijuga	Over exploitation
Kandelia candel	Change of Environment
Merope angulate	Habitat Change and environmental change
Rhizophora apiculate	Exploitation due to medicinal properties
Srcolobus griffithi	Over exploitation and habitat changes
Phoenix paludosa	It is a back mangrove species, and is therefore particularly vulnerable to coastal development and sea-level rise

The Sundarban mangrove forest, the mangrove swamps, and backwaters of Sundarbans form a barrier to cyclones and tropical storms originating mainly in the Bay of Bengal and to tidal surges, providing protection to a large part of inhabited areas inland and to the coastal fringes. The mangrove forests, mangrove swamps, and backwaters of Sundarbans form a productive and protective margin of coastal Sundarbans. The mangrove are characterised by the presence of pneumatophores, salt glands, and lateral and tilt roots and crypto-viviparous germination. This unique ecosystem provides a wide range of important environmental services and due to the nutritional inputs provided by the mangroves to the adjacent coastal water, this region has become a unique nursery and breeding ground of aquatic and marine fauna such as finfish and shellfish.

Several key biodiversity species have become extinct or are in the verge of becoming extinct in this region. The current stress factors include alteration in habitats, environmental changes, biotic pressure, over exploitation of the natural resources in the region including that of medicinal plants etc. The list of endangered species is given in Table 4.[29]

Mangrove vegetation of the Indian Sundarban comprises an area of 2120 km^2.[30] It is one of the 19 Sub-State Sites identified in the National Biodiversity Action Plan (NBAP). According to the survey carried out by Botanical Survey of India (BSI) in 2002, the Sundarban forest held 61 of the 68 mangrove species found in India. These are unique plant species growing and surviving in swampy and marshy inter tidal areas.

[29] Department of Sundarban Affairs Government of West Bengal, accessed from www.DSAepartmentwb.org/Distribution of Land.htm on 25 March 2012

[30] A K Raha, Indian Sundarban: An Overview, Report on Sundarban, Biosphere Reserve, West Bengal Forest Department, 2004

Even under submergence of sea water for long hours these species are able to survive. See Table 5 for the list of endemic mangrove species of Sundarban.[31]

More than 1692 faunal species are present in this ecosystem. These comprise of faunal groups like:

- Invertebrates: Aquatic and inter-tidal forms such as crabs and mussels.
- Vertebrates: Fish, Reptiles and Amphibians, Birds & Mammals.

A good number these species are classified as special status under the Indian Wildlife Protection Act (1998) and are classified as rare and endangered. The most noted species of the wild life of the region are Royal Bengal Tiger, Spotted Deer, Wild Boar and Estuarine Crocodiles. These are on the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) list, or are classified as rare & endangered species. The endangered list also includes River Terrapin, Ganges & Irawady Dolphins and varieties of migrants & resident avifauna. One of the living fossils viz. Horse Shoe Crab inhabits in this region. At least three species of marine turtle and several species of cetaceans exist in this coastal habitat.

TABLE 5: ENDEMIC PLANT SPECIES OF SUNDARBAN

Common Name	Scientific Name	Description
Sundari Tree	Heritiera fomes	H. fomes is a major timber-producing tree of Sundarbans. Large Sundarban trees with 2m girth were found earlier but have been heavily harvested. Now trees over 1 m in girth are no longer common. Height of H Fomes ranges from 15 to 25 m and d.b.h. from 2.5 to 38 cm depending onsite quality. It is an evergreen tree, thrives at 7.22 ^{0}C to 37.78 ^{0}C and heavy annual rainfall of 1600 mm to 5334 mm. In the Sundarbans, it is the climax species in newly formed inlands with sweet, brackish, and saline water. It is dominant in the slightly saline and moderately saline zone and thrives in a well drained soil inundated by tidal water of a low degree of salinity.
Mangrove apple	Sonneratia apetela	It is a small to medium size columnar mangrove tree, which can attain a height of about 20 m and a girth for about 2.5 m. The tree occurs on newly accreted soil in moderately to strongly saline areas and is considered as a pioneer species in ecological succession.
Sea Date/ Khadi Khajur	Phoenix paludosa	Paludosa (paludosa, Latin, swampy) or Mangrove Date Palm is a species of flowering plant in the palm family. Clustering, to 5 m high, usually forming dense thickets, the leaves are 2 to 3m long and re-curved.

There are several species of these microbial elements such as algae, bacteria, fungi, plankton and micro-Fauna in the Sundarban estuary with the support of ocean current, water temperature, and salinity, biotic & abiotic substrata in this ecosystem. These microbiological elements are important in their contribution to high primary productivity and are crucial components of the ecosystem. These also maintain the balance of food chain. However the populations and distribution of Phytoplankton & Zooplankton are very sensitive to seasonal variations and on the trends of fluctuations in environmental parameters.

Studies carried out over a period of 27 years indicate changes in the properties of water in and around Sundarbans is also one of the key drivers towards the changing bio-diversity in the area.[32]

[31] Sourced from: http://www.portal.gsi.gov./portal/page pageid= 127,723772& dad= portal& schema=PORTAL & LINKLD=1213

[32] Mitra Abhijit Mta, Avijit Gangopadhy, Anumeha Deb, Andre K Schmidt, and Kakoli Banerjee. 2009.Observed changes in Water Mass Properties In the Indian Sundarbans (North western Bay of Bengal) during 1980-2007. Current Science, vol 97, no.10, November 25, 2009.

There are studies that have concluded that between 1980 and 2007 waters in the Sundarban are gradually warming up at an average rate of 0.5°C per decade, with warming being more in the western parts of Sundarban region than in the eastern parts. The warming observed in Sundarban waters is higher than the observed global sea surface temperature warming of 0.06°C per decade and the warming of the Indian Ocean at the rate of 0.2°C per decade.

The warming of the sea has implications on aquatic life, as warmer ocean water absorbs less CO_2. However rapid increase in sea surface temperature further compounds the effect, especially in the Sundarban area, where the impact is likely to be on the nutrient rich waters affecting both the mangroves and the other aquatic fauna that thrives on this nutrient rich waters such as fish. Further, the water in the western sector of the Sundarbans shows a higher pH with respect to the water in the eastern side of the region. This indicates influx of fresh water in the western river systems of Hooghly and Muriganga flowing through the Sundarbans. These rivers are a continuum of the Ganges and the fresh water in these river systems is attributed to influx of fresh water in the Ganges due to recession of the Gangotri glacier[33] from which it originates.

An analysis of the dissolved oxygen (DO) in the two regions indicate that in the eastern sector of the Sundarban the DO has increased by +0.3 ppm/decade and in the eastern sector the DO has decreased by -0.4ppm/decade. Increase in DO is attributed to fresh water influx in the western rivers, and decrease in DO in the western rivers are due to increase in salinity due to siltation, mixing with ocean water and possibly due to high evaporation rates as the surface air temperature increases.

Similarly, the transparency of the eastern region water has increased with respect to the western region. Consequently the western region waters have improved in water quality than in the eastern region of Sundarbans and the trend continues to increase in both the sectors. Because of their location at the interface between land and sea, mangroves are likely to be one of the first ecosystems to be affected by global changes. As the mangrove systems are very specialized, and may live close to their tolerance limits, they are particularly sensitive to minor variation in hydrological or tidal regimes.[34]

Reduced runoff in the eastern region of the Sundarban would increasingly produce higher salinity and greater sea water-sulphate concentrations. Both would decrease mangrove production.[35] The most important effects, however, would come from rising sea levels, but responses will vary among locations and will depend on the local rate of the rise and the availability of sediment to support reestablishment of the mangroves.[36,37,38]

At continuous submergence in higher water depth, the plants would have:

- significantly lower rates of photosynthesis and growth;
- be shorter and narrower;
- have fewer branches and leaves;
- and have more acid-sulphide in their soils.

Increased mangrove growth rates predicted for increasing atmospheric CO_2 may be offset by decreased growth resulting from changes in tidal regimes.

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[33] As per the reports of the Working Group on Himalayan Glaciers of the International Commission for Snow and Ice (ICSI, 1999) and the World Wide Fund for Nature Report, Climate Change In Sundarbans, 2007

[34] Blasco, F., Saenger, P.and Janodet, E.(1996). Mangroves as indicators of coastal change. Catena 27 (3-4) 167-178

[35] Snedaker, S.C.(1995). Mangroves and climate change in the Florida and Caribbean region: Scenarios and hypotheses. Hydrobiologia 295 (1-3), 43-49.

[36] Pernetta,J.C.1993. Mangrove Forests, Climate Change and Sea Level Rise: Hydrological Influences on Community Structure and Survival, with Examples from the Indo-West Pacific. IUCN, gland.

[37] Parkinson, R.W.Delaune, R.D. and White,J.R. (1994).Holocene sea-level rise and the fate of mangrove forests within the wider Caribbean region. Journal of Coastal Research 10, 1077-1086.

[38] Woodroffe,C.D.(1999). Response of mangrove shorelines to sea level change. Tropics 8 (3), 159-177.

The mangrove-associated fauna would be affected both directly by climatic changes and indirectly by changes in the mangroves.[39] Species that are tolerant of increasing temperatures (e.g., fish, gastropods, mangrove crabs and other crustaceans) may adjust rapidly to the changes. In contrast, soft-bodied animals and bivalve molluscs would be very sensitive to higher temperatures. Desiccation that would accompany increasing temperatures would harm many marine species associated with mangroves.[40] For mangrove-dependent species, however, the most serious consequences of a changing climate would likely be the loss of habitat as the mangrove forests decline.

Non Timber Forest Products (NTFPs) is an essential component of the livelihood of the people living within the Sundarbans mangrove area. A study carried out in 2010[41] concludes that about 79 percent of the livelihood earnings of the people from this region comes from NTFP. The NTFPs include tannin bark from most Sundarban species like Ceriops decandra, Ceriops myrobalans, Phoenix paludosa which yield around 30-42 percent tannin; Nypa Fruticans (Golpata), natural honey from Apis Dorsata, cultured apiary honey and bee wax from Apis Indica; fuel wood and small poles and boles; fish, prawn crab, shrimps; and lime (manufactured from jorgran, kastura and jhinuk). However, as many of the mangrove species are becoming endangered they are falling under the purview of conservation and therefore their extraction is now restricted, affecting the earnings of the people.

A number of individual, groups of commercial fishermen and multinational corporations are collecting large-scale commercial catch from the coastal, estuarine and deep sea zone of Sundarbans throughout the year. Fishing is done through collection of prawn post larvae and aqua-culture in coastal swamps; Intensive fresh water mono-culture of shrimp is practiced in some parts especially at the mouth of the estuary where salinity is lowered by fresh water discharge through river's paddy cum fish cultivation. Commercial fishing is undertaken in estuaries and deep sea zones.

Overfishing in the contemporary decade has come to generate tremendous pressure on the Sundarban economy and environment as it has led to the decline of many species, especially of the tiger prawn. Collection of seeds of Panaeus monodon (tiger prawn) is one of the main sources of earning for the small and landless fishermen and women. During collection of economic prawn seeds, the rural people segregate the Panaeus monodon seeds and destroy other 90 to 95 percent of fish and prawn seeds, which is among the most important reason for the destruction of large number of estuarine species. The fishermen live in poor conditions and are prone to climate vulnerabilities and therefore get roped easily in unjust market trends. Poor infrastructure and minimal land holdings force fishermen into the trap of unjust economic practices. A large section of women and children from poor households are also involved in catching tiny prawn seedlings. The estimated value of shrimp trade from the delta, including exports, is worth over Rs.1 billion. However, the real beneficiaries are mostly the middlemen and exporters.

Large scale mechanization has boosted export-based fishing economy, but this is degrading the sensitive aqua-mangrove ecosystem of the Sundarban due to unsustainable practices. Intensive prawn culture in paddy cum fish areas is endangering the indigenous varieties of fish such as Vada, Khalisa, Mourala, Nados, Chanda, Khaira, etc. Further, frequent oil leakage and regular washing of fishing vessels is causing water pollution near local sand heads leading preventing the aggregation of fish.[42]

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[39] Sayed, O.H.(1995) Effects of the expected sea level rise on Avicennia marina L: A case study in Qatar. Qatar University Science Journal 15 (1), 91-94

[40] Kjerfve, B.and Macintosh, D.J. (1977). Climate change impacts on mangrove ecosystems. In "Mangrove Ecosystem studies in Latin America an d Africa"(B.Kjerfve, L.D. Lacerda and S.Diop, eds), pp.1-7.UNESCO, Paris.

[41] Anshu Singh, Prodyut Bhattacharya, Pradeep Vyas and Sarvashish Roy; 2010.Contributiion of NTFPs in the livelihood of Mangrove forest dwellers of Sundarbans, Journal of Human Ecology, 29 (3), 191-200.

[42] Mahua Das, 2007. Impact of Commercial Coastal Fishing on the Environment of Sundarbans for Sustainable Development; Asian Fisheries Science 22 (2009):157-167; accessed from www.asianfisheriessociety.org on 25th March 2012

2.4.Illegal Wild life Poaching and Trade

2.4.1. Bangladesh

ANSARUL KARIM, BANGLADESH

Sundarban is the habitat for a diverse wildlife including a number of globally endangered animal species. Of particular importance are the Royal Bengal Tiger (*Panthera tigirs*), Spotted Deer (*Axix axis*), Wild Boar (*Sus scrofa*), Monkey (Macaca mullata), Monitor Lizard (Varanus spp.), Turtles (both fresh and marine water), Snakes, Dolphins especially the Gangetic Dolphin (*Platanista gangetica)*, Otter (*Lutra perspicillata*), and the Saltwater Crocodile (*Crocodylus porosus*), which are diverse examples of rich wildlife spectrum requiring urgent management attention and intensive conservation action. The tiger is part of the inseparable legend attached to the Sundarbans and the species occurs throughout the SRF. Sundarban mangrove forest is the single largest home of the Royal Bengal Tiger (*Panthera tigris*) and only mangrove forest in the world having the tiger as its indigenous population. Tidal mangrove forest is a rare habitat for the species where it has been pushed due to habitat shrinkage. In many ways, mangrove has proved to be an unusually secure abode for the tiger, in spite of the fact that the species is listed in the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) as endangered species as per the Red List of Threatened Species listed by the International Union for Conservation of Nature (IUCN) also known as the IUCN Red List or Red Data List.[43] The occurrence of barking deer (*Muntiacus muntjak*) appears to be limited to the north and the north-east in the SRF. Wild boar (Sus scrofa) occurs throughout the SRF including the off-shore islands. Monkey occurs throughout the SRF and is a common sight with greater incidence in the south. Some 35 species of reptiles have been recorded in the SRF. The Marsh Crocodiles (*Crocodylus porosus*), once abundant, is now quite rare. At least 30 species of snakes are reported to have found in the SRF but there has been a general decline in densities, especially over the last 15 years[44]. The Rock Python (Python morulus) is listed as a vulnerable by IUCN and is another valuable species which is said to have declined over recent years and is rarely encountered.

The wetlands in the SRF and coastal waters are suitable habitats for a large number of Ganges River dolphins (or Shushuks), Irrawady Dolphins and Finless Porpoises. As in case of vegetation, the salinity gradient partitions Cetaceans'(marine mammals) abundance in the SRF and the interface landscape: i) Shushuks found in mangrove channels with high freshwater inputs, ii) Irrawaddy Dolphins in more saline mangrove and in open estuarine waters where freshwater inputs are reduced but still fairly high, and iii) Indo-Pacific Humpback Dolphins and Finless Porpoises in moderately saline, nearshore waters affected by freshwater inputs.

Bangladesh has taken a number of measures for protecting wildlife in the Sundarban. The Bangladesh Forest Department published the Bangladesh Tiger Action Plan in 2009 as a step towards tiger conservation in the country. World Bank-funded IDA (US$36 million) Project `Strengthening Regional Cooperation for Wildlife Protection (SRCWP)' is under implementation. Some sections of the Passur and Shela river have been declared as dolphin sanctuary. Enactment of the new legislation has been followed by social campaigns to protect tigers from poachers. Notably, Bangladesh is advancing work with local communities through compensating for human-tiger conflict, forming co-management organizations in villages around the Sundarban and deploying village response teams to manage tigers that stray into villages so they are not killed. Bangladesh has also recruited 100 new officers and staff to be deployed in the Sundarbans to enhance protection there, and is piloting 'smart' patrolling systems, with regular patrolling. National and international commitments have been constituted for monitoring smart patrolling schemes.

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[44] IFMP. 1998. Integrated Forest Management Plan. Forest Department, Dhaka, Bangladesh.

Despite all the national and international conservation efforts, illegal wildlife trade is growing and the wildlife population is declining due to habitat destruction and poaching. According to 2004 census tiger population of about 440 were counted which distributed throughout the 6017 km^2 area. Probably it is the single largest population in the world[45,46]. Recently, however, Bangladesh forest department conducted a census, which confirmed that only 106 tigers were left in the area, showing a sharp decline in tiger's number[47]. Tiger poaching had been identified as a significant threat for the tigers in Bangladesh[48],[49]. Depletion of prey for the tiger has already been documented[50]. Prey may be poached from any part of the Sundarbans due to the widespread distribution of forest users and the current limited protection capacity of the forest department (Ahmad et al. 2009).

The overall tiger-poaching scenario in the Bangladesh Sundarbans is surreptitious. A recent study on the poaching of tigers in the Sundarban[51] revealed interesting results on the presence of a local trade of tiger parts in the villages around the Bangladesh-Sundarban where tiger parts are traded via local middlemen or local people in need of money. Five groups were identified that are involved in tiger killing: villagers, poachers, shikari (local hunters), trappers, and pirates. Villagers kill tigers in the village predominantly for safety, while other groups kill inside the forest professionally or opportunistically. Poachers kill tigers purely for money, but the diverse incentives for the other groups are more complex. Shikari's motives are multi-faceted, encompassing excitement, profit, esteem, and status arising from providing tiger parts for local medicine. Pirates, on the other hand, not only kill tigers for profit and safety, but also as a 'protection service' to the community. The results further illustrate that each group that engages in the killing of tigers submit tiger parts to the commercial trade in exchange for money. Non-local Bangladeshi traders from other cities come and buy the bones from the tiger killers.

International enforcement, for tracking the illicit value chain of wildlife poachers, traffickers and consumers is also hindered by gaps in data sharing among agencies and countries. This poses a potential threat to the success of the anti-poaching campaign which depend upon accessible information flows among diverse parties including governments, international agencies, research institutions, local communities and industry. Bangladesh and India have recently signed an MOU on information sharing and joint census of tigers using uniform methodology.

2.4.2. India

JAGDISH KISHWAN, INDIA

Tiger population in Bangladesh has come down drastically from 440 in 2010 to 106 in 2016.[52] The reasons for sharp decline range from unscientific estimation in the past to illegal killing of the animal by local hunters. There have been reported instances of poaching of tiger in Bangladesh. For example, The Hindu reported in August 2015 death of 6 tiger poachers in gunfight with Bangladesh Police. It also reported

[45] Barlow, Adam C. D. 2009. The Sundarbans Tiger Adaptation, Population Status, And Conflict Management. PhD Thesis. The Faculty Of The Graduate School Of The University Of Minnesota.
[46] Barlow,A., Ahmad.I., Smith, J 2013 Profiling Tigers (Panthera tigris) to formulate management response to human killing in the Bangladesh Sundarban. Wildlife Biology in Practice,9(2).30-39
[47] Dey,T.K., Kabir.M.J.,Islam,M.M., Chowdhury,M.M.R, Hassan,S., Roy,M.(2015). First phase tiger status report of Bangladesh Sundarbans,2015. Wildlife Institute of India and Bangladesh Forest Department, Minstry of Environment and Forests, Government of Peoples Republic of Bangladesh
[48] Ahmad,I.U., Greenwood, C.J, Barlow, A.C.D.,Islam, M.A, Hossain, A.N.M., Khan M.M.H., et al (2009) Bangladesh Tiger Action Plan, Dhaka, Bangladesh Forest Department.
[49] Aziz,A., Barlow,A, Greenwood,C & Islam,A. (2013) Prioritizing threats to improve conservation strategy for the tiger Panthera tigris in the Sundarbans Reserve Forest of Bangladesh. Oryx,47(4),510-518
[50] Jagrata Juba Shangha (JJS) 2002. Study on human-wildlife interactions in relation to Sundarbans Reserve Forest. Paper presented at the SBCP Workshop on Wildlife Management Planning in Sundarban, Dhaka, 24-25 November 2002.
[51] Salf,S.& MacMillan,D.C.(2016) The Geography of Environmental Crime.DOI 10.1057/1978-1-137-53843-7_2
[52] Alison Harley Senior Communications Manager WWF Tx2 Tiger Initiative Version: 22nd March 2016

that five policemen were also injured in the gunfight, and four guns, three pistols and three pieces of tiger hide were also seized from the scene. The incident shows that tiger poaching does take place in Bangladesh Sundarban.

Samia Saif in her PhD study[53] revealed the local use of, and belief in, the medicinal values of tiger parts is diverse (e.g. medicinal uses, as protection from "dangers" in the forest, and to enhance personal social status and/or wellbeing), and that virtually all parts of the tiger are used including teeth, bones, meat, tongue, genital organs, claws, furs, and whiskers. This is a shocking revelation as most people believed that the tiger parts were consumed in China and some South East Asian countries. The general impression till recently was that there was no local market for tiger parts in Bangladesh. The incident quoted above contests this idea.

Indian Sundarbans also are not free from instances of illegal hunting. The Times of India in February 2013 reported arrest of three Kakdwip residents for poaching of deer. So, both sides (India and Bangladesh) have problem of poaching of tiger and deer, and may be other animals also by the local poachers. Since the boundary between the Sundarbans of both the countries is porous, there is continuous movement of animals from one country territory to the other. Possible movement of poachers crisscrossing the pervious international boundary cannot be ruled out. Poachers from either country, targeting tigers and other wild animals in the Sundarban areas of the other country is a distinct possibility.

Since the population of tigers worldwide is small and is also showing a downward trend, it is imperative that both the countries collaborate on sharing of information, data, and other details to check poaching of tiger and other wild animals in Sundarban landscape spanning the territories of the two countries. Such information and details should relate to history sheeters, poachers, instances of poaching, mode of operation of poachers, and real-time movement of suspicious persons, etc in the tiger habitats. This will call for an information and intelligence sharing mechanism at the local level between the forest and enforcement authorities of the two countries.

It is suggested to set up a transboundary information and intelligence sharing mechanism/network involving the government authorities on both sides of the boundary for control of poaching in Sundarbans landscape covering the territories of India and Bangladesh.

The legal mandate of management of Bangladesh Sundarban lies with the Directorate of Forest under the Ministry of Environment and Forest. Chief Conservator of Forest is responsible for the administration of the Sundarban Management through a number of subordinate officers located at Khulna and Sundarban proper. The day to day affairs of administration is discharged by Conservator of Forest, Khulna Forest Circle; two Divisional Forest Officers one designated as DFO Planning and the other as DFO Wildlife works under the Conservator of Forest at Khulna. The direct administrative head of the Division is the Divisional Forest Officer, based at Khulna, who has a number of professional, sub-professional field and support staff to assist him. The field and support staff provide necessary logistic and enforcement support for implementation of management and administrative activities. The Bangladesh part of the Sundarbans forest falls under two forest divisions, and four administrative ranges. 17 (Seventeen) forest stations and 72 (seventy two) forest camps are also located in different ranges of Sundarban forests. Range offices and forest stations are involved with revenue collection, administration, patrolling, law enforcement, and patrol monitoring, whereas camps carry out patrolling and law enforcement only. Moreover about 32 Coast Guards are working in 6 Camps namely at Kachikhali, Supati, Alorkol, Kagadobeki, Dobeki and Kokilmony. Bangladesh border guard post also have been established in Kachikata to prevent illegal activities in the Sundarban. Forest Department has introduced 'Special Monitoring and Reporting Tool (SMART)' patrolling system to protect wildlife and other biodiversity resources of the Sundarban.

[53] Investigating tiger poaching in the Bangladesh Sundarbans. Thesis submitted for the degree of Doctor of Philosophy to Durrell Institute of Conservation and Ecology, University of Kent, UK in June 2016

Bangladesh Forest Research Institute (BFRI) also maintains Mangrove Silviculture (growing and cultivation of Trees) Division at Khulna to provide necessary research supports for Sundarban management.

Indian Sundarban are administered by the Directorate of Forest, West Bengal. Chief Conservator of Forests (South) and Director, Sundarbans Biosphere Reserve is the administrative head of the park at the local level. He is assisted by one Deputy Field Director, and one Assistant Field Director. The administrative management units further down the official hierarchy, are broken down into forest ranges with each range manned by a Range Officer. The park receives financial aid from the State Government as well as from the Ministry of Environment, Forest and Climate Change under various Plan and Non-Plan Schemes. Additional funding is received under the Project Tiger from the Central Government.

It is the considered view that both sides of the governance structures in the two countries are inadequate to check the ever presence threat of poaching of tiger and other wild animals. The field formations need to be strengthened, and better equipped to enforce the law. There is need to involve the local communities in enforcement as well as in intelligence gathering to control poaching.

It is suggested to strengthen the field formations of the forest department of the two countries in the Sundrban landscape by inducting more staff, improving the knowledge and skills of the existing staff, and also enhancing their mobility and communication abilities. Local communities need to be engaged more actively in protection and management of the Sundarbans, as well as in intelligence gathering to help in control of poaching in the landscape. A suitable governance mechanism for the purpose, needs to be put in place for engagement of the local communities.

2.5.Poverty Eradication and Livelihood Generation[54]

The estimated population of the Indian Sundarban region today is about 4.1 million people. This represents a doubling of the Population since 1971 when the population was just over 2 million[55] and an increase of a quarter of a million people since the previous decade when the population was estimated at 3.76 million.[56] Population growth is driven in large part by demographics as there seems to be relatively little significant migration to or from the Sundarbans area according to census data.

Most of the recent population growth has occurred on the West Bengal side, where the decadal population growth rate of about 14 percent in the area is similar to that for the state of West Bengal, but below India's decadal population growth rate of 18 percent.[57] By contrast, the Bangladesh part of the Sundarban experienced a much smaller decadal population growth rate of 1.34 percent according to the 2011 Population and Housing Census. The population density is also lower in the Bangladeshi portion of the Sundarban, ranging from 369 inhabitants per square kilometre in Bagerhat district to 844 in Pirojpur district. In comparison, the population density in West Bengal portion of the area is estimated at 2,462 persons per square kilometre in North 24 Parganas and 998 persons in South 24 Parganas.

Estimates indicate that about 94 percent of the population of the Sundarbans is rural. Living conditions are generally very poor, and are exacerbated by the area's high exposure and vulnerability to natural

[54] This section replicates text from Carolina Martin, Carrie May, Anna O'Donnell and Quentin Wodon, Ecological, Historical and Socio-Economic Context in Anna O'Donnell & Quentin Wodon (ed.) Climate Change Adaptation and Social Resilience in the Sundarbans, Routledge, London, 2015.

[55] Planning Commission, 1981, Report on Development of Coastal Areas affected by Salinity, National Committee on the Development of Backward Areas, Government of India, New Delhi Planning Commission

[56] Department of Sundarban Affairs, undated, Action Plan for Conservation of Biodiversity and Socio-Economic Development of Sundarbans Region, Government of West Bengal, India.

[57] Government of India, 2011, Census of India, 2011 Ministry of Home Affairs, Office of the Registrar General and Census Commissioner, New Delhi, India.

disasters. According to household survey results, over half the population in North and South Parganas in West Bengal, India live below the poverty line, with 10 percent being classified as extremely poor. The poverty rates are similarly high in the Bangladesh portion, half of the population in 17 districts that share borders with the Sundarban Impact Zone (SIZ) having consumption levels below the upper poverty line. The area's physical infrastructure is inadequate and contributes to limiting access to markets as well as basic services such as electricity. The physical geography of the area greatly limits road construction; boats of varying sizes represent a key mode of transport.

Data from the household surveys carried out in 2011 in both the Bangladesh and West Bengal portions of the Sundarban confirm that the population continues to be very poor. Very few households have a car, truck or motorcycle. Some have a bicycle or a boat, but many do not. Only one in four households has a radio and less than one in five has a television. Cell phones are more prevalent, with more than half of the households in West Bengal using them and up to three-fourths of households in Bangladesh. But other amenities such as refrigerators, air conditioners, and sewing machines are rare, which is not surprising given that only one in six households has access to electricity. Modern sanitation and access to water are limited as well. Dwellings are very small, with an average of only 1.2 to 1.3 rooms per dwelling. Mud floors are the rule rather than the exception. Land ownership is also limited, especially in West Bengal where the population density pressure is stronger.

The main livelihood activity is single-crop rain-fed agriculture, with fishing, forestry, and tourism also offering sources of income. Paddy is the main agricultural crop. The predominance of agriculture results in part from previous periods of reclamation in the late nineteenth and early twentieth centuries, when exploitation of forest resources and taxation of agricultural produce drove many of the Sundarbans blocks to be settled. Under current conditions, these activities have, at best, a modest effect on poverty reduction; profits made from selling crops, fish, or other goods are limited in part because of the Sundarban's physical isolation from larger markets.[58] With inadequate infrastructure and limited modes of transportation, many local residents are unemployed or underemployed. In addition nearly 80 percent of households pursue livelihood options that involve inefficient production methods in agriculture, fishing, and aquaculture. Such practices, combined with a reliance on a diminishing natural resource base and a host of environmental challenges, threaten the ecological integrity of the Sundarbans and, in turn, the well-being of the population. Impacts of past environmental degradation are estimated as equivalent to 14 percent of the gross domestic product of the Sundarbans.

Two key challenges to agricultural productivity are the area's aging embankment system and a lack of freshwater resources. In the nineteenth century a 3,500-Kilometer system of river embankments was constructed to allow for more human settlements in the Sundarbans and to prevent saline tidal water intrusion from impacting rain-fed rice cultivation on enclosed areas of land. Centuries of altering natural patterns of sediment deposits have taken a toll on the system. Large sediment loads in the river systems now enclosed by the embankment system have effectively raised riverbeds and made embankment breaches common. Flooding from frequent embankment breaches has had devastating impacts on agricultural production, inundating farmlands with saline waters, destroying crops, and rendering soil infertile in some areas.

As shown in Table 6 a majority of households surveyed for the above quoted study declared that they suffered from a decline in crop production and livestock over the five years preceding the survey. In the case of crops, the main reasons for the decline were saline water staying in fields, poor soil quality, changing weather conditions, and the lack of fresh water. For livestock, the main reasons were animal diseases, cyclones, losses during floods, and the shortage of fodder. The waterways that run through and

[58] Danda, A.A.,2007, surviving in the Sundarbans: threats and Responses. An Analytical Description of Life in an Indian Riparian Commons. Ph.D. thesis, University of Twente at Enschede, Netherlands.

border the Sundarbans are brackish and the persistent lack of access to freshwater resources poses challenges to agricultural production. Non-saline aquifers can be accessed only through deep tube wells at great expense, and shallow tube wells accelerate the penetration of saline prisms into the aquifers.[59] For households who declared that they suffered from a decline in crop production and livestock over the five years preceding the survey, salinity is a key issue.

Those who own agricultural land are at risk of losing their ability to farm because of saline intrusions from neighbouring fish and shrimp farms. Over the past decades, agricultural land has been lost to the commercial fishery and shrimping industries. Large tracts of land have undergone controlled inundation, sometimes without the consent of farmers who own the land. As a result of loss of land without proper monetary compensation, some farmers have had no other option but to exploit the natural resources of the area for their livelihood.

TABLE 6: REASONS FOR DECLINING CROPS AMONG HOUSEHOLDS DECLARING A DECLINE[60]

Reasons for the decline	Bangladesh	West Bengal (India)
Saline water staying in fields	33.85	43.51
Poor soil quality	24.38	23.39
Changing weather conditions	19.49	1.12
Not enough fresh water available	7.94	22.69
Pest attack-infestation	5.87	4.88
Other reasons	5.55	1.41
Fertilizer too expensive	1.17	0.89
Not enough fertilizer available	0.71	0.67
Not enough seeds available	0.68	0.45
Seeds too expensive	0.36	0.02
Crops stolen from fields		0.98

At the same time there are also challenges to commercial fishing and shrimp production. These are growing activities in the region, but while some have benefited, others have not and the activities represent a threat to the health of the aquatic ecosystem. Lack of industry regulation has intensified problems of erosion downstream in the coastal areas. Shrimp-fry (larvae form) collection methods being used are ecologically damaging and have led to a loss of species of aquatic organisms. Furthermore, because the Sundarban is the aquaculture nursery for the Bay of Bengal, a potential future decline of aquatic organisms could result in loss of traditional livelihoods for thousands of families dependent on artisanal and industrial fishing.

Forests also play a role in local livelihood strategies. Many in communities surrounding the Reserve Forest in both countries derive occupations from fishing in its rivers and tributaries, collecting shrimp fry, harvesting wood and timber, and collecting non-timber forest products such as honey, palm fronds, bamboo, and medicinal plants. However, forest resources are being depleted rapidly. The forest department of Bangladesh has restricted forest access in efforts to manage the rate of resource depletion, yet many users circumscribe these mandates and resort to illegal and unreported forest activity.

[59] DDP (Development and Planning Department, Government of West Bengal), 2009, District Human Development Report: South 24 Parganas, Kolkata: Saraswaty Press Ltd.

[60]

Investments in human capital are also limited, in large part because of the lack of resources of the population. Basic data on school enrolment rates at the primary and secondary levels in both countries illustrate poor outcomes in terms of human capital. While enrolment rates at the primary level are high, they are much lower at the secondary level. By and large, at the secondary level in both countries the main reasons mentioned for a child not pursuing his or her education were that the school was too expensive, or that the child had to work for the family. Both responses underscore the fact that the population is poor, which also limits investment in education, limiting future options for children due to a lack of mobile human capital.

A confluence of natural and social factors has created conditions of poverty that are difficult to escape. With poor access to services, human development levels are low. Livelihood activities are fraught with challenges and continued dependence on them for survival is proving to be increasingly precarious. Large areas have been extensively exploited for timber, fish and prawns, fodder, or converted for paddy and aquaculture. Changes in land use, water management, and resource extraction practices have contributed to the disappearance of many species and have threatened extinction for others.[61] The area's biodiversity is also under threat from human activity and exploitation methods undermine the productive capacity of the land.[62]

The likelihood that climate risks over the next several decades will increase does not bode well as present-day weather shocks already severely undermine the well-being of households. Cyclonic storms in the Sundarbans often devastate communities along the coastline and other low-lying areas. Available climate change models suggest that the intensity of these events will increase. Rising sea levels associated with changes in climate and ongoing hydrologic processes also threaten the local population's livelihoods and the very existence of the Sundarban in its current from. The impact of these stresses on both the natural and social worlds is unfolding at a rapid pace. The picture of the Sundarbans today and projections for its future are dreary.

Yet at the same time inhabitants have demonstrated, over centuries, their ability to adapt. The governance challenge for the inhabited parts of the Sundarban in Bangladesh and West Bengal is to ensure that the adaptation capabilities of the households are strengthened so that they are able to cope with the destruction caused by weather shocks and adapt to a changing environment, either by themselves or with the help of their community and government.

2.6.Socio-economic Challenges: Indian Sundarban[63]

The Indian administrative region of Sundarban lies within the state of West Bengal, and spreads over an area of 9630 sq km from 20°30'to 21°15'N and 88°10'to 89°10É. Of this 5363, km^2 is reclaimed area and 4267 km^2 has been declared as the Sundarban Biosphere Reserve. The entire mangrove area protects the inland area from the recurrent cyclonic disturbances and storm surges that occur in this area.

The area of 5364 km^2 of non-protected area covers 54 islands and a part of the mainland as well, and has dense human settlement. Around 1780s, human settlement in this region took place through clearing mangrove forests and constructing a 3500 km long earthen embankments or dyke to protect the islands from tidal waters. The human settlements in Sundarbans area covers the sub divisions of Kakdwip,

[61] Ghosh, A. and A.A.Danda, 2001, Case Study on the Sundarbans, Centre for Environment and Development, Regional Awareness Workshop on Global Environment Facility, Indian Institute of Management, Calcutta, January 2001

[62] DDP (Development and Planning Department, Government of West Bengal), 2010, District Human Development Report: South 24 Parganas, Kolkata: Saraswaty Press Ltd.

[63] This section is based on the Report 'West Bengal State Action Plan on Climate Change, 2012' brought out by the Government of West Bengal

Baruipur, Diamond Harbor, and Canning in South 24 Parganas district, and Bashirhat in North 24 Parganas district and is divided into 19 blocks of which 6 are in North-24 Parganas and 13 are in the South-Parganas districts having 190 Gram Panchayats and 1064 villages.

Major land use in the Sundarban region is for agriculture and homestead garden purposes, which is around 304,834 ha and 41,812 ha respectively and together constitute 65 percent of the total area under Sundarbans-about 18 percent is classified as residual area by the Department of Sundarban Affairs Department (DSA), which includes the continuous land building and destructing process in the region. There is seasonal migration of substantial population to the other parts of the country seeking employment. As per government statistics, in 2009, the availability of agricultural land in the Sundarbans was around 1691.246 sq km.[64] 61 percent of the area is in the low lying areas, the medium and upland areas are 26 percent and 11 percent respectively of the total area available for cultivation.

The agricultural system of the region is centred on two main cultivating seasons. In the 'khariff' or monsoon season between June to September and 'aman' (winter). In addition, some high value vegetables like okra, ridge gourd, bitter gourd, beans snake gourd and water melons are grown in uplands and field bundhs. In the 'rabi' season between November to June paddy is cultivated in irrigated condition which extends only to 12 percent of the total cultivated area. In this season pulses like khesari and moong and oil seeds like sesame, mustard and sunflower and some vegetables are also grown. Only 16 per cent of the cropped area is irrigated. Even so the average productivity of paddy is higher than in West Bengal. Most farmers are engaged in subsistence agriculture and the typical landholding size is less than 1 hectare per family (2011).

Mono-crop agriculture contributes to 77.55 percent of the local economy directly or indirectly. Other than crop husbandry, people of the Sundarban also have fishing as a livelihood and collect Non-Timber Forest Produce (NTFPs) from forests. According to the GOWB agricultural area has shrunk between 2002 and 2009 from 2149.615 sq km to 1691.246 sq km. The average paddy yield is around 2,037 tonnes/ha in this area between 2009-10, and the cropping intensity is very low, raining between 1.5 to 2 tonnes/ha. The low intensity of cropping is because (i) only mono cropping of rice is practiced in the 'kharif' season and in the 'rabi' season horticultural crops are grown; (ii) also because, agriculture is mainly rain fed, with only 12 percent of the cropped area being irrigated through rain fed ponds, tanks and canals; and (iii) because of high levels of salinity of the soils due to high tides, cyclones and storm surges, and problems of water stagnation, even beyond monsoon seasons at times. With continuous increase in population, agriculture production in the region has not been able to meet demand. Frequent damage to property and crop failure due to cyclones and thunderstorms has rendered a large population poverty ridden. As a result, high levels of migration to cities is reported.

Higher temperatures may lower yields which already are not enough for the burgeoning population of the region. Also with more and more area getting inundated by cyclones and higher storm surges, agriculture is likely to be affected in the flood plains of Sundarban as the salinity in the soil rises (the recent example being the impacts during cyclone Aila).

Coastal fishery of the east in India is dependent upon Sundarbans as it owns nearly 90 percent of the aquatic species of the eastern coast. Fisheries in Sundarban are also based upon both inland and marine fisheries resources and fishing communities are engaged in the collection of fish seeds and adults, along with species of prawns and crabs. For many households it is the sole livelihood means. A total of 172 species are hauled out from a variety of sources, 20 identified species of prawns and 44 species of crabs including two edible ones. The mangrove swamps acts as a crucial abode to many of the aquatic species. In the South 24 Parganas district of West Bengal, India there are at present fourteen landing centres to

[64] http:// www.the hindubusinessline.com/industry-and-economy/agri-biz/article2950858.ece uploaded on March 1, 2012, based on the CSE report brought out by CSE; accessed on 25th March 2012

capture fisheries and among them some important ones are Kakdwip, Diamond harbour, Namkhana, Gangasagar, Beguakhali, Mayagoalini ghat for catching throughout the year and Kalisthan, Frazerganj baliara and Gangasagar west for seasonal fishing.

People of Sundarbans are primarily affected by water and vector borne diseases while air borne diseases like Acute Respiratory Infections are a perpetual occurrence. Chronic malnutrition has also been observed among the children under the age of 5 years and women. The diarrhoeal prevalence peaks when cyclones strike. The cyclones also bring exacerbate the occurrence of water-borne diseases (e.g., gastro-enteric diseases) as people have no choice but to consume contaminated water. In addition, snake bites, accident injuries, skin related problems, and vector-borne diseases (such as, malaria) are also prevalent in Sundarbans.

Poor socio-economic indicators and environmental conditions result in perpetual morbidity and malnutrition. Inadequate and contaminated water supply, lack of sanitation and low level hygienic condition cause diarrhoeal diseases, dysentery, jaundice and worm infection. Sundarbans is also experiencing a rise in vector borne diseases particularly malaria. Kala-azar and encephalitis are also found in some blocks which are possibly a result of migration. There are instances of other diseases like goiter.

Majority of the people of Sundarbans are dependent on natural based livelihoods and occupation which lead to different health hazards. Women engaged in shrimp larvae collection in the rivers suffer from dermatological diseases and gynaecological problems and urinary tract infections due to long time immersion in saline water. The farmers, fishers and forest product collectors are under constant threat to animal attacks particularly snake, crocodile, tiger, shark, etc. The cause of the prevalence of infections includes contaminated water used for drinking. Water logged conditions also increase incidences of dengue in urban centres of Sundarbans and lead to increase in malaria vectors in the mangrove forests, thereby increasing incidences.

The public health facilities include two sub-divisional, nine rural hospitals (RH), ten block primary health centers (BPHCs) and 47 primary health centers (PHCs). The block level facility (BPHC/RH), in addition to playing a role of a referral unit, acts as a hub of all primary health care activities within a block. The sub-centers are adequate in number if one goes by the usual standard (5000 population per sub-centre), but the number of PHCs, are inadequate by the same standard (30,000 per PHC).The inadequacy is more prominent in South Sundarban especially in some blocks (Gosaba, Canning I and II, Patharpratima, and Kakdwip).[65] An inter-regional disparity has been analysed in the Human Development Report of West Bengal (2009)[66], which clearly indicates the lower level of infrastructure including patient care in the Island area with respect to mainland areas of the Sundarban. The difficult terrain and isolation denies the people of Sundarbans quick access not only to the nearby facilities but also to the facilities outside this region. Such inaccessibility to health facilities have resulted in the obvious emergence of quacks and registered medical practitioners (RMPs).

With the eastern region of the Sundarbans receiving sweet water from the Ganges and the western region becoming more and more saline, availability of potable water in the long run is likely to be an issue for both the human settlements and wild habitats in the western region of the Sundarban. Further with increase in intensity of cyclones, potable water stored in sand dighis (ponds) are likely to be impacted even in the eastern region for longer periods of time as volume water incursion will be higher as higher heights of storm surges enter inland covering larger areas.

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[65] Barun Kamjilal, Papya Guha Majumdar, Maumita Mukherjee, Swadhin Mondal, Debjani Burman, Sneha Singh and Arnab Mandal; 2010. Health care in the Sundarbans India-Challenges and plan for a better future. Accessed from http://www.futurehealthsystems.org/publications/health-care-in-the -sundarbans-india-challenges-and-plan-for.html: 25th March 2012.

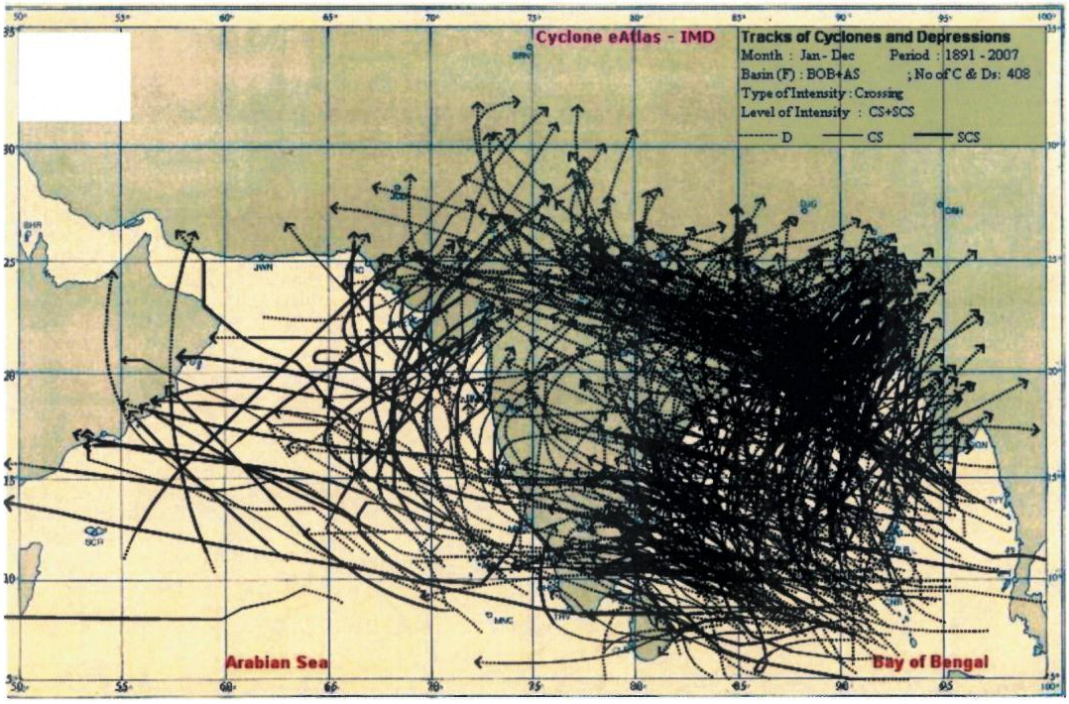
[66] Human Development Report-West Bengal 2009. Accessed from wbplan.gov.in/ Human Dev/DHDR/24percent PGSsOUTH/Chapterpercent2009.pdf, 25th March 2012

The electricity supply from all sources (grid, renewable energy sources including solar home lighting systems and diesel generators) in Sundarbans is estimated to 262.8 million units/year. Around 3.5 percent of total supply is contributed by the renewable source of energy. As of 2010, 120,000 households were reported to be electrified. The per capita electricity consumption in Sundarbans is much lower compared to that of India and West Bengal respectively at 58.4 kWh/ year as compared to 550 kWh/year in West Bengal and 1000 kWh/year at an all India level. The increase in demand for electricity in 2020 is expected to be 7.5 to 15 times that of the present demand.

Due to proximity to the sea, the temperatures throughout the year in Sundarbans are moderate though it is situated in the south of Tropic of Cancer. Average annual maximum temperature is around 35°C. The summer extends from middle of March to mid-June, and the winter is from mid-November to February. The monsoon sets in the middle of June and continues to up to October. It experiences cyclonic disturbances between May to November, with some of the cyclones maturing into severe cyclones. The average annual rain fall is 1920 mm, most of which falls between May to October, Sundarban area is cyclone-prone, monsoonal and low-lying. This area experiences slightly more than 4 cyclonic events per year of varying wind forces.

Cyclonic depressions in the Indian ocean, bringing in high winds, heavy rainfall and strong tidal surge, occur between May to November. Though the number of depressions are the highest in the month of August, maximum number of them develop into cyclonic storm in the month of October, and the number of severe storms formed were 284 in number, out of which 94 intensified up to the stage of Severe Cyclonic storms (33 percent) in Severe Cyclonic storms (57 percent). The intensification of the systems is stronger during the epoch II than the epoch I even though there is a decrease in the total number of cyclonic storms over Bay of Bengal from epoch I to epoch II (see Chart 12)

CHART 12: Cyclonic Storm Tracks in Bay of Bengal between 1891-2007



Source: Government of West Bengal

Further examination of the data sets on the decadal scale showed that 35 cyclonic storms formed in the Bay of Bengal during the decade 1981-1990 out of which 22 (63 percent) intensified in to Severe Cyclonic Storms and during the decade 2001-2010, 32 cyclonic storms formed in the Bay of Bengal out of which only 11 (34 percent) intensified in to Severe Cyclonic Storms. This general analysis points towards the fact

that the cyclonic storm hitting the Sundarbans area have increased in intensity between 1951 and 2010. The increase in intensity is attributed to the increase in Sea Surface Temperature.

Cyclonic storms are the highest in the month of November.[67] The tracks of storms in the Bay of Bengal region between1891-2007, indicate a substantial number of them hitting the Indian Sundarbans area.[68] Studies have observed that about 44 cyclonic disturbances have crossed the Sundarbans area between 1891 and 2006, of which 35 were severe cyclonic storms. In some cases when the cyclonic events having wind force more than 100 km per hr they are synchronized with the high tides, the waves influenced by storm surge hit the river embankments causing breaches and flash flood due to sea water ingress.

Along the Sundarban Delta the tidal amplitude ranges between 3.7 to 5.0 m above mean sea level. The higher tidal amplitude occurs in monsoon months mostly in August – September. Due to progressive sedimentation and swallowing of channels, the tidal amplitude becomes as high as 6 m along the coast line and further inland it increases to around 7 m. Surface waves in this coastal area are mainly due to wind action. Waves become destructive during cyclonic storm. When the Cyclonic incidences coincide with tides, wave height rises over 5 m and above the mean sea level.

Due to heavy loads of siltation, water levels in many embanked creeks remain at least two meters above the adjoining flood plains during high tides. The tidal waves often breach the embankment and the severity of breaching and extent of damage increases when cyclones strike.

The storm surges during cyclones have taller wave height and as a result other than breaching the embankment, they also ride over it and enter the plains flooding large areas, creating water logging and making the soil more saline than its natural state. For example, during Cyclone Aila in 2009, a 400 km stretch of embankment was breached and the waves crossed over the height of the embankment at many other places and entered the flood plains. The sea water got logged in the plains and more than two million people were marooned for several days affecting not only agriculture but also drinking water supply. Most of the thatched houses were damaged. The farmland became non-productive due to salt water incursion in the soils.

According to the Human Development Report (HDR 2009), five of the thirteen Sundarban blocks in South 24 Parganas are entirely or mostly constituted by islands which do not have a direct road link with the mainland. These are Gosaba, Basanti, Kultali, Patharpratima and Sagar. For these blocks the only connecting point with the mainland as well as with other islands is through long journeys via river channels. In Sundarbans the plight of people in most of the islands is a source of concern due to severed links with the mainland, absence of ‘pucca’ (robust) roads and well-maintained jetties. Sundarbans being riparian, the primary means of transportation is through the watercourses. In comparison to the roadways which are full of discomforts the water transport is slightly better but insecure. Navigable rivers and creeks form the principal means of communication in the Sundarbans. Most of the people rely on boat services for their daily movements but due to siltation of watercourses services continue to be inadequate. Only few islands have inland transport in the form of cycle-van, while others do not have any mode of transport at all. The 'van-rickshaw' is essentially a tricycle with a flat wooden platform to carry load and passengers. The modern van-rickshaw has a small diesel engine fixed to it and is known as the 'engine-van', but they are also prone to accidents, due to imbalance and slippery roads when rain pours and erodes the ‘kaccha’ (crude or unpaved) roadways. For the success of any region, transport plays a significant role, which however is inadequate in Sundarban and affects the prosperity of the region.

[67] Recent and Current Activities of the RSMC New Delhi. 2009. Paper submitted in the sixth Tropical Cyclone RSMC/TSWCs, technical Coordination Meeting, Brisbane,Australia, 2-5th Nov 2009. WMO, tcm-v/Doc.3.2 (3) (19.X.2009), item 3.2
[68] Hatawar et al., Challenges in Tropical cyclone forecasting, 2010. Accessed from: www.nidm.gov.in/idmc2/PDF/Presentations/Cyclone/Pres8.pdf

Unsatisfactory road network acts as a stumbling block to movement of Sundarbans locals and commodities. It has prevented growth of markets and obstructs timely marketing of perishable goods and supply of inputs. The lack of permanent shelters and inadequate number of motor launches too are major constraints of the development of river transport. Rural electrification has not made much headway. The absence of infrastructural provisions heightens the impoverishment in the delta. Also sharp deficit in infrastructural development has led to the burning issue of inadequate economic progress and better livelihood.

Large scale of migration of working adults have taken place and not of the households as a whole. Of those who remain in the islands, take care of the land left and other assets during and post cyclone Sidr and Aila. The loss of land resulted in the decreased size of the Sundarbans which forced some to desert their homelands. Migration outwards appears to be of great concern in Sundarbans region. People from the Sundarbans are forced every day to leave home to distant locations due to adverse climatic conditions and absence of security and alternative livelihoods. Inadequate development planning is forcing people in this fragile region to migrate to other parts of India in search of livelihoods, while the number of climate refugees in the area swells and vast swathes of agricultural land is either devoured by the encroaching sea or rendered unfit for cultivation.

2.7.Disaster Management: The Sundarban Region[69]

As observed earlier, in the Sundarban, cyclones are a common occurrence and their likelihood and severity may increase further with climate change. While the literature suggests that Bangladesh has been successful in establishing well-functioning early warning systems, thanks in part to networks of volunteers ready to communicate with households at the village level, similar networks are just being developed in West Bengal.

Effective early warning systems have the potential to significantly reduce the loss of lives and assets due to cyclones and storm surges.[70] In the period 1956-2005, the number of disasters and related economic losses from weather-related hazards increased by nearly tenfold and the increase for water and climate-related hazards was even larger. However, the reported loss of life decreased from 2.66 million over the decade 1956-65 to 0.22 million over the decade 1996-2005, thanks in part to better early warning systems that help in reducing fatalities from natural disasters.[71]

Effective early warning systems require strong technical foundations and good knowledge of the risks. But they must also be strongly “people centred”- with clear messages and dissemination systems that reach those at risk, and practiced and knowledgeable responses by risk managers and the public.[72]

In Bangladesh, a cyclone with wind speeds measuring 62 m/sec and accompanied by storm surges of 6 to 9 meters in height made landfall in 1970, killing an estimated 350,000 people. In the aftermath of this disaster, a volunteer-based Cyclone Preparedness Programme gained the endorsement of the Government of Bangladesh.[73] Two further catastrophic natural disasters, including a cyclone in 1991 that killed around

[69] This section is from O’Donnel, Anna and Quentin Wodon, ‘Early warning systems’ in Anna O’Donnell & Quentin Wodon (ed.) Climate Change Adaptation and Social Resilience in the Sundarbans, Routledge, London, 2015

[70] UNISDR,2010, Early Warning Practices can Save Many lives: Good Practices and Lessons Learned, United Nations Secretariat of the International Strategy for Disaster Reduction, Bonn, Germany

[71] World Meteorological Organization,2009, Weather, Water and Climate Information Provide Early Warnings that Save Lives. Fact Sheets: Early Warning, Geneva.

[72] United Nations, 2006, global Survey of Early Warning Systems: As Assessment of Capacities, Gaps an d Opportunities toward Building a Comprehensive Golbal Early Warning System for all Natural Hazards. Report prepared at the request of the Secretary-General of the United Nations, New York: United Nations.

[73] Government of Bangladesh, 2010, Standing Orders on Disaster, prepared by the Disaster Management Bureau under the Ministry of Food and
Disaster Management, Government of the People’s Republic of Bangladesh, Dhaka

140,000 people, served as catalysts to improve the early warning system and preparedness, with an approach focused more on people.[74] Today, the country has a well-functioning 48-hour early warning system in place that allows people to evacuate to safe cyclone shelters hours before any cyclone makes landfall. This has drastically reduced the death toll from cyclones-from over 350,000 deaths from Cyclone Bhola in 1970 to 3,300 deaths from Cyclone Sidr in 2007.

In West Bengal, India, by comparison, early warning systems are still in their infancy, perhaps because the state has experienced far fewer deadly cyclones than Bangladesh. Nevertheless, the state's coastal area remains at risk of high intensity cyclones. As recently as 2009, a category 5 cyclone made landfall in West Bengal, causing widespread devastation through storm surges and embankment breaches.

Since the 1980s Bangladesh has adapted to dealing with recurrent cyclones and succeeded in significantly reducing cyclone-related deaths. Much of the reduction in lives lost can be attributed to an improved and modernized early warning system, as well as to the construction of multipurpose cyclone shelters, coastal embankment systems that have the ability to reduce the impacts of storm surges, the regeneration and conservation of the coastal forest cover, as well as campaigns to raise awareness at the community level. Today, Bangladesh's early warning system, although not without its problems, is cited as a premier example of a 'people centred approach' building on community engagement and delivering messages in a culturally appropriate and sensitive manner to ensure that warning sand messages are understood.

The Bangladesh early warning system is governed by the Standing Orders on Disasters, which lay out the roles and responsibilities of each agency and line ministry with respect to pre-disaster, during disaster, and post-disaster events. Under the institutional arrangements laid out in the Standing Orders, the Bangladesh Meteorological Association is responsible for monitoring and warning about weather events. The Bangladesh Meteorological Department (BMD) has three radar stations in Dhaka, Khepupara, and Cox's Bazar that transmit minute-by-minute weather updates. The Department also receives information from the National Oceanic and Atmospheric Administration in the United States and from Japanese satellite via the Bangladesh Space Research and Remote Sensing Organization.

When cyclones form in the Bay of Bengal, the BMD monitors their intensity and projected landfall, and issues daily bulletins. These bulletins are transmitted to the Prime Minister's office and relevant line ministries, as well as to the public and media outlets. The coordinating body for disaster management at the national level is the Disaster Management Bureau (DMB), which is placed under the Ministry of Food and Disaster Management. Established in 1993,the DMB aims to create public awareness regarding disasters, formulate training programs and projects on disaster preparedness, coordinate all activities related to disaster management from the national to the grass-roots level, and coordinate functions of disaster management with government agencies, donors, and non-governmental organisations (NGOs).

The Bangladesh early warning system fully incorporates the role of local communities, and was established originally through a Red Crescent Society program called the Cyclone Preparedness Programme (CPP). Established in the aftermath of Cyclone Bhola in 1970, the project was initiated to develop an early warning system using the existing structures at the village level.[75] Today, the program covers 13 districts in the coastal areas and benefits from the contribution of 49,215 cyclone response volunteers. Using radio networks, megaphones, hand sirens, and public address systems, the volunteers provide the public with the latest weather bulletin information in advance of a cyclone landfall. The volunteers implement

[74] Government of Bangladesh, 2007, Interim Report: Bangladesh Progress Against HFA Priority action. Report prepared by the Ministry of Food and Disaster Management, Government of Bangladesh, Dhaka.
[75] IFRC, 2010, Empowering Communities to Prepare for Cyclones, Geneva: The International Federation of Red Cross and Red Crescent Societies.

evacuation orders and direct the public to established cyclone shelters. The volunteer networks also perform rescue, first aid, and emergency relief tasks.[76]

The CPP ensures the transmission of weather alerts to coastal communities to promote awareness and disseminate early warnings. The CPP has a direct link to the BMD that directly disseminates information to the CPP headquarters in Dhaka, as well as to 6 zonal offices and 30 sub-district (upazila) offices over high frequency radio. There is a direct chain of communication from the sub-district to the unions (village level) through very high frequency radios. At the village level, between 10 and 15 volunteers constituting a unit team spread out to issue cyclone warnings. Each unit serves one or two villages with a population of about 2,000 to 3,000. Cyclone warnings are issued almost door to door, using megaphones, hand sirens, and public address systems, including through mosques (BDRCS) 2002.[77] More recently, text message early warnings to registered cell phone users have been piloted. The effectiveness of the CPP in warning, evacuation, and post-disaster reconstruction is often credited with reducing the number of lives lost during cyclones in Bangladesh, as well as for reducing the number of lives lost during cyclones in Bangladesh, as well as for reducing the time needed to recover from cyclones.

By contrast, in West Bengal and India more generally, the Disaster Management Framework remains significantly more vertically integrated and centralized, with a comparatively weaker interface with communities that would facilitate volunteer engagement. Cyclone forecasts are provided through six cyclone warning centers located in Kolkata, Bhubaneswar, Visakhapatnam, Chennai, Mumbai, and Ahmedabad. The center located in Kolkata is responsible for early warnings for the Bay of Bengal. Cyclones are tracked through radar as well as meteorological observations, including weather reports from ships. Cyclone warnings are issued to the All India Radio and the Doordarshan for broadcast/telecast in different languages. Cyclone warnings are also given to a control room and Crisis Management Group in the Ministry of Agriculture, which has final responsibility for coordinating the various activities of center and state governments as well as other agencies with respect to cyclone warnings. Forecasts and warnings are simultaneously communicated to the states and the districts likely to be affected. Ports, airports, and other user agencies also receive the forecasts and warnings at the same time.[78]

Cyclone warnings are then disseminated through telegrams, telecasts, radio broadcasts, bulletins to the press, broadcasts through the Department of telecommunications, coastal radio stations to ships in the high seas and coastal areas, the INSAT-based Disaster Warning System, and point-to-point direct channels to the central and state government functionaries and other user agencies. On receipt of warnings, government officials and other authorities are expected to take measures to safeguard lives, if necessary by evacuating people from vulnerable areas to safer place.[79] In West Bengal specifically, the communication of cyclone events to communities is expected to be coordinated at the district level through the District Magistrates office and through local authorities. Once a cyclone makes landfall, the State Relief Commissioner, the district administration, and local authorities are expected to take the lead on recovery efforts, although the role of NGOs and community groups is also acknowledged in the stat's Standing Orders on Disasters. However, the state's Standing Orders on Disasters do not appear to have a clear mechanism either for warning communities or ensuring the coordination of relief efforts, and there appears to be no equivalent to the well-organized volunteer structure and village level as well as door-to-door communication efforts that are found in Bangladesh. The question is whether this structure in Bangladesh makes a difference. The evidence suggests that it does indeed.

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[76] Webster, P.and B.Webster, 2011 Bay of Bengal Tropical Cyclone sand Convective Systems: Predictability, Prediction and the Impacts of Climate Change. Draft report submitted to the World Bank under Climate Change Adaptation, Socio-Economic Development & Biodiversity Conservation in the Sundarbans: A Non-Lending Technical Assistance.

[77] BDRCS,2002, Cyclone Preparedness Programmed (CPP) at a Glance. Bangladesh Red Crescent Society (BDRCS).Paris: UNESCO.

[78] Arya, N.2011, Brief note on forecasting and Warning Systems of Cyclone in India, mimeo.

[79] Government of West Bengal, 2008, West Bengal State Disaster Management Policy & Framework. Department of Disaster Management, Government of West Bengal.

As shown in Tables 7 & 8, it turns out that among those affected by a cyclone or a flood in Bangladesh in the five years preceding the survey, 73.2 percent of households were warned of the event beforehand, versus only 3.6 percent in West Bengal. The tables provide some details on how households have been warned, according to various categories of households.

TABLE 7: Channels of information for warnings, Bangladesh (%)

All	
Television	12.37
Radio	19.47
Mobile phone	3.32
Newspapers	0.67
Union Parishad	4.09
Neighbours	12.75
DMC	20.48
No info	26.84

TABLE 8: Channels of information for warnings, West Bengal (%)

All	
Television	0.26
Radio	1.86
Newspapers	0.09
Panchayat	0.73
Neighbours	0.62
No info	96.43

In the case of Bangladesh, seven different possibilities for being warned are distinguished in the questionnaire: television, radio, mobile phone, newspapers, Union Parishad, neighbours, and the Disaster Management Committee (DMC). Television is the main source of information for the wealthier quintiles, the DMC is the primary source of information, followed by neighbours. This suggests that the efforts to mobilize local communities have been highly effective in warning households, and especially the poor. Mobile phones and newspapers are less effective in warning households, but the Union Parishad does contribute on top of the main sources of warning. In West Bengal, five sources of information for early warnings are identified: television, radio, newspapers, the Panchyat, and neighbours. Only radio is marginally more effective in reaching the population affected by cyclones and floods, and more so among the better off than among the poorest.

Even though Bangladesh's early warning system seems to function reasonably well, there are differences between urban and rural locations, as well as between districts. Urban households are more likely to be warned than rural households, and among districts, while Bagerhat and Barguna tend to do well, followed by Khulna and Pirojpur, Satkhira lags behind ,so that there is still scope for improvement.

The results suggest that an overwhelming majority of households in both countries have been affected by cyclones and floods in the five years preceding the survey; yet it is only in Bangladesh that a majority of households were warned ahead of time of the cyclones. The better performance of the early warning system in Bangladesh can be traced back to a number of efforts implemented in the last few decades, especially with the support of networks of volunteers at the village level. These networks have been

especially beneficial in warning the poor, who tend to be less likely to be warned through television, radio, or mobile phones.

Still, even in Bangladesh there are differences between districts in the probability of being warned, as well as by level of well-being, so that additional gains could be achieved. In West Bengal, even if cyclones have admittedly been less devastating, substantial efforts are needed to be able to warn populations ahead of time of imminent cyclones.

During the floods in 2015 heavy rainfall accompanied by high tides and huge discharges from dams caused extensive floods in 12 districts of West Bengal. Huge loss of crops, agricultural land, horticulture, fisheries and plantation produce, roads, bridges, houses and other infrastructure was reported. So far, damages have been assessed at over Rs 240 billion. According to the GOWB extensive relief and rescue operations were carried out. Repair and reconstruction work has also been initiated.

According to the Climate Action Plan of the GOWB it has cooperated extensively with neighbouring Nepal and Odisha in relief and rehabilitation activities after the recent natural calamities. The GOWB has established an Emergency Operation Centre (EOC) at the Disaster Management Department which is operational 24X7, 365 days and responds to any natural disaster anywhere in the State and outside also in quick time. The Department has developed SMS based Early Warning System through the IT Department for alerting all the mobile users in the districts of the State regarding advent of natural calamities like cyclone, tsunami, heavy rainfall, etc. Early Warning SMS service for the government officials at state, district, block and up to Gram Panchayat level are operational. The Department is constructing 225 Multi-Purpose cyclone Shelters at the coastal districts of North 24 Parganas, South 24 Parganas and East Medinipur, out of which 30 have already been handed over to the District Authorities. The Department has constructed 334- Flood Shelters (from State Fund) and 99 are under construction. 221 Relief Godowns have been constructed and 45 are under construction in the districts, sub divisions and blocks of the state.

The Department of Sundarban Affairs (DSA) has emphasized on connectivity in the Sundarban region by adopting several kilometres of Brick-Paved Roads, Bituminous & Concrete Roads, a number of reinforced Cement Concrete Jetties and some reinforced Cement Concrete Bridges. In the area of South 24 Parganas district in the Sundarbans irrigation sources are primarily from harvesting of rain water in pond, tank, khal, canal etc due to salinity problem in ground and surface water. 47 such water bodies have been re-excavated including a 110 km Khal with sluice gate covering command area 2253 ha. Three more such projects are reported to be in progress. According to the climate action plan of the GOWB, one of the mechanisms to address the salinity problem is the environment flows assessment for ensuring sustainable management of rivers and riverine ecosystem. The report says that in the Sundarban the estimation of environmental flows to maintain the salinity level within 15 ppt is essential. The basis for this level is not elaborated.

2.7.1. Climate Change Adaptation Strategies of the GOWB

The state action plan on climate change lists a number of initiatives that it either recommends or is already carrying out. Listed below are a selection of activities from the action plan that are relevant for the Sundarban region.

Protection against Increase in intensity of cyclones

Cyclones are projected to become less in number with respect to their current frequency, but their severity will most likely intensify, meaning that wave heights will increase making ingress of sea water deeper inland. Therefore the entire Sundarban region and all its sectors are highly vulnerable to climate change. Increase in intensity of cyclone will mean, devastation of human habitats, in accessibility to potable water, loss in communication and transport. It will also lead to adverse and may be irreversible

damages to the flora and fauna, as the seawater ingresses inside the creeks and inland, leading to high levels of salt ingression.

Proposed Adaptation action in the context of severe cyclones:

- Undertaking a study to generate low, medium and high scenarios of impacts of climate change on cyclones, for 2030s, 2050s, and 2080s to enable informed decision making and implementation of measures towards adaptation. The projections will give the likely return periods, trace the paths of cyclones and storm surges to track the likelihood of land fall along the Sundarban coast, the maximum and the minimum heights of the sea surges/ wages during cyclones even when they ride over high tides, and an assessment of the spatial extent to which the waves can carry salt water inland.
- Identifying the level of tolerance of the various existing mangrove species to the different level of projected salinity an d flood water depth.
- Identifying the type and density of the mangroves required to act successfully as the first level of defence and accordingly, the mangrove plantation can be taken over.
- Identifying the endangered species of fauna and building up strategies for conservation & protection of faunal species.
- Constructing and retrofitting the embankment along the sea as well as along the rivers based on the likely return periods and maximum heights of storm surges that can occur.
- Raising the level of existing houses in vulnerable areas on tilts based on the level of flood water height likely to ingress in the future based on scientific studies.
- Identifying safe areas and building / strengthening cyclone shelters for people as well as livestock.
- Mobilising communities to take action rapidly and cyclone proof themselves when early warnings are sounded by authorities vis a vis moving people and livestock and their valuables to safer places. *Early warning systems, though in place, does not seem to be effective, as witnessed during cyclone Aila in 2009*.
- Strengthening communication especially roads and telephony.
- Identifying key sectors of livelihoods, building up strategies for sustainable use of natural resources, construction of infrastructure to support sustainable livelihoods, insurance coverage to the stakeholders of key livelihood sectors.
- Improving general health care services to ensure full coverage of the population; building up sources for sustainable and safe drinking water to all.
- Developing rehabilitation strategies and packages for post disaster renovation supported with social services and alternative livelihoods.

Protecting agriculture productivity and livelihoods:

- Improving height and quality of embankments that play an important role in protecting agriculture in the region from additional salinity in soil due to projections of increasing intensity of cyclones.
- Introducing thermal resistant and salt tolerant rice cultivations
- Promoting commercial level coconut plantations in saline areas
- Promoting horticulture vegetable crops
- Providing access to markets through construction of roads
- Providing storage, marketing & processing facilities
- Providing crop insurance for cereals & commercial / plantation crops

Promoting alternate livelihood opportunities:

- Promoting inland and marine fisheries as an alternative livelihood, in addition to cropping.

- Formulating a fishery policy around conservation vis a vis climate change impacts.
- Providing early warning systems for fish catch availability in marine areas through modelling. *In this context, modelling capacity to map fish catch on a real time basis needs to be developed.*
- Providing insurance to fishermen against calamities.
- Promoting animal husbandry & poultry/ duckery as alternative livelihood with market support & insurance coverage.

Enhancing the access to drinking water:

- Supplying piped water to all households. *This can be done by drawing water from the western rivers in Sundarbans as they are likely to have more fresh water in the near future*. *Also the potable water supply can be augmented through more exploitation of ground water in the areas*. *Further, rain water harvesting of water and storing it in overhead tanks at higher levels can be thought of as an additional option to keep water clean and potable. Introduction of rooftop rainwater harvesting in community buildings to be introduced.*

Improving accessibility to health facilities:

- Bridging the existing health infrastructure and health service delivery gaps.
- Enhancing health service delivery quality through community approach.
- Developing telemedicine facilities.
- Developing rapid transport for the critically injured by pressing in helicopter services.
- Developing disaster preparedness to abate disease outbreaks and undertake regular drills.

Conserving biodiversity:

- Ensuring stricter pursuance of regulations and policies of the Forest Department
- Improving research to understand the nature of impacts of climate change on mangroves in terms of its floral and faunal biodiversity
- Planning for afforestation measures and conservation of fauna as per the dictates of the changing climate scenarios, which can be implemented in the 13th plan.

2.8.Information Generation and Sharing: Bangladesh

2.8.1. Bangladesh

ANSARUL KARIM, BANGLADESH

Creating evidence and communicating evidence-based information to the public and to policy makers plays an important role in the sustainable management of the natural resources. Sundarban is a complex ecosystem and its various components interact at different spatio-temporal scale. Research on the Sundarban is resource demanding and difficult due to the muddy substrate with fluctuating tidal rhythm and the presence of man eating tiger. The research information on the Sundarban ecosystem functioning is very scanty and almost absent for the Bangladesh part. Some information is available from the Inventory of Forest Timber resources made for preparing Forest Working Plan at an interval of 25-28 years and also short term consultancy reports which are rarely publicly available. A separate division of Mangrove Silviculture destined to conduct research is located at Khulna, used to carry out some research tree Silviculture under various aid programme. That also could not generate much information that contributed towards improved management of the Sundarban ecosystem goods and services. Whatever published

research available mostly done by the enthusiastic academics from the universities both within the country and abroad[80,81,82,83,84,85,86,87].

Government of Bangladesh and India signed an MOU with India which recognizes the Sundarbans as a single ecosystem straddling two countries. Important synergies can be realized through collaboration between two countries to develop a harmonious approach for integrated ecosystem management. In this respect information is the panacea for enhanced communication and collaboration.

One of the objective of the proposed Joint Platform could be to facilitate research and share information through a system of research network. Proposed Joint network can build more effective knowledge systems for sustainability of the Sundarban.

2.8.2. India

P.K. GHOSH

The Sundarban region, offers unique opportunities to both incumbent countries India and Bangladesh, to cooperate and collaborate for the improving the ecological and social habitats of the region. In this context it affords the coordination and implementation of the SDGs of both countries as well as the realisation of the commitments in the NDCs such as protection of coastal communities and conservation of mangrove forests. It is noteworthy that the potential of this cooperative approach has already been codified in an overarching MOU signed in 2011 but it is yet to show progress on taking forward some of the provisions of the MOU partly on account of divergent perspectives of governments at the central and state level.

While the MOEF&CC sees the region as a bio sphere reserve forest and a bio diversity zone with a mandate towards enhancement of scientific management- the state government supports a different perspective. For the GOWB the area comprises of 19 blocks with an approximate population of over 4 million most of whom live below poverty line. Thus, development and associated activities like building infrastructure, promoting livelihood opportunities such as eco-tourism etc form its prime criteria. Even though within the GOWB there exists a Sundarban Affairs Department headed by a Minister of State, the department is handicapped by lack of resources – both human and financial. Hence, one of the basic requirement is to either cooperate or to develop the region as a whole, rests on raising awareness levels considerably at various levels of operations and amongst stake holders. Sustained cooperative efforts could address poverty eradication concerns as well as sharpen response strategies and regional resilience to natural disasters and those related to climate in the context of SDGs and NDCs. The above stated objectives can be achieved only if there is horizontal and vertical communication between the

[80] Sarker, S. K. et al. Are we failing to protect threatened mangroves in the Sundarbans world heritage ecosystem? Sci. Rep. 6, 21234; doi: 10.1038/srep21234 (2016).
[81] Salf,S.& MacMillan,D.C.(2016) The Geography of Environmental Crime.DOI 10.1057/1978-1-137-53843-7_2
[82] Gain, A.K., Giupponi, C., 2014. Impact of the Farakka Dam on thresholds of hydrologic flow regime in the Lower Ganges River Basin (Bangladesh). Water, 6(8), 2501-2518. doi:10.3390/w6082501
[83] Islam, M.S.N. 2008 Cultural landscape changing due to anthropogenic influences on surface water and threat to mangrove wetland ecosystem :A case study on the Sundarbans,Bangladesh. Ph.D. Thesis. Brandunberg University of Technology, Cottbus
[84] Iftekhar M.S. and Saenger P. 2008. Vegetation Dynamics in Bangladesh Sundarbans Mangroves:a Review of Forest Inventories. Wetlands Ecol. Manage 16: 291-312.
[85] Awal, M. A (2014) Analysis of causes of disease in Sundarbans natural mangrove. American;Journal of Bioscience and Bioengineering. 2(2): 18-32.
[86] Karim A (1988) Environmental factors and the distribution of mangroves in the Sundarbans with special reference to Heritiera fomes Buch.-Ham. PhD Thesis, University of Calcutta, Calcutta, India
[87] Mukhopadhyay, A., Mandal,Pl, Barik,J Chowdhury,S.M., Ghosh, T., and Hazra, S. (2015) Changes in mangrove species assemblages and future prediction of the Bangladesh Sundarbans using Markov chain model and cellular automata...Environ. Sci.: Processes Impacts, 2015,17, 1111-1117,DOI: 10.1039/C4EM00611A

various stakeholders. In effect developing the region will not only be beneficial for the locals but provide a bond between the two neighbouring countries and help in reaching their commitments under NDCs.

2.9. Institutional Mechanism for Addressing Challenges in the Sundarban Region

2.9.1. Bangladesh

ANSARUL KARIM, BANGLADESH

Salinity regime in the Sundarban is influenced by a complex set of natural and anthropogenic factors. Upstream fresh water flow through the rivers interacting with tidal mixing from the Bay of Bengal. Increased freshwater flow pushes the saline front downstream. The natural flow of freshwater depends on precipitation and glacier melting of the Himalayas which flows through the Ganges. Most of the rivers flowing through the Sundarban used to be distributaries of the river Ganges are now disconnected or connected during the monsoon only. Variation in hydrological flow is caused by numerous human interventions including direct water abstraction from surface and groundwater bodies, and due to flow diversion by the barrage at Farakka. However, population growth and rapid economic development in the upper catchment area will impose increased pressure on surface and groundwater resources. As discussed earlier anthropogenic activities combined with ingress of tidal water due to increased SLR have significant transboundary consequences. Ecosystem degradation including: degradation of habitat, losses of species and reduced biodiversity affect the Sundarban ecosystem as a whole covering both the countries. Unfortunately there is not much data available in the Sundarban as no multidisciplinary studies have been carried out in this field. However, it can be assumed that increased salinity in rivers has a negative effect on both terrestrial and aquatic component of the Sundarban mangrove ecosystems if they are above a certain threshold. At the same time decreased flow in rivers decreases the dilution of pollutants reducing carrying capacity. If discharge standards are not met this can cause further adverse effects on the environment and humans.

Deterioration of water quality in the upstream of the rivers has significant transboundary consequences particularly within and downstream of the Sundarban. This can be confirmed by the presence of chemical compounds of anthropogenic origin in water quality of the Sundarbans in both countries although information on the transboundary sections of the rivers as well as in bottom sediments is inadequate. Water pollution in the rivers comes from a number of land based sources including industrial and port sites, agricultural lands, households in rural areas and untreated wastes from the municipalities. Wastewater treatment facilities are absent in most municipalities. But there is no monitoring system in place due to poor planning and inadequate finance. This has resulted in issues relating to data reliability and availability.

The main environmental impacts of surface and groundwater contamination can be summarized as follows:

- Land contamination by polluted waters including accumulation of heavy metals in soil and in plants
- Degradation of aquatic ecosystems
- Degraded fish stocks.
- Pollution of water-marsh ecosystems and wetlands
- Pollution of the coastal zones

The main socio-economic consequences of surface and groundwater contamination are:

- Contamination of drinking water supply (surface and ground water supplies) and consequently population health hazards
- Increase in potential water-borne diseases
- Reduced water availability and product quality in the aquaculture sector

- Reduced land productivity and agriculture products quality due to the use of polluted irrigation water
- Reduced attraction of the territories for recreation and the tourisms.

The Department of Forest which is legally mandated for the management of the SRF has no jurisdiction over the water resource management in the upstream. Regulating the water quality standards is the task of the Department of Environment and Pollution Management of the Port is the responsibility of the Mongla Port Authority. Management of fisheries at the coastal region is the responsibility of the Fisheries Department. Past Forest Management Plans attempted to address the Forestry issues. After nineties the concept of Management of the Sundarbans although centred on integrated management of the resources but none of the Management Plan was implemented due to the lack of adequate financing and institutional weakness. Though the recent Integrated Resource Management Plan (2010-2020) for the Sundarban recognizes the problem of pollution it lacks any guidance or activities for establishing an ecological monitoring system in the Sundarban which is persistently sought out by UNESCO from the Sundarbans of both India and Bangladesh.

For the last several years UNESCO has been advocating establishment of an ecological monitoring system for the Sundarban World Heritage Sites as per the requirement of WH charter. This can be an action point for joint platform

Causal Chain analysis shown in Annexure 1 shows that causes of deterioration of Sundarban are linked to human activities and biophysical processes ranging from local, national and regional level. Mitigation of the problems requires to be addressed at those levels. Present management actions do not match with the scale of the biophysical and socio-ecological processes which maintain the ecosystem integrity of the Sundarban.

Sundarban ecosystem is an interface ecosystem developing under the dynamic changes of geological and climatic change and mediated through human activities and will continue to do so. Current piecemeal or silo approach to management is inadequate to successfully support healthy ecosystem and sustainable human livelihoods. An approach of ecosystem management that practices adaptive response and adjustment under the dynamic changes is ideal for the Sundarban ecosystem management. Creating an institutional and management structure that encompasses the scale that nearly corresponds to functional process of Sundarbans socio-ecological condition is necessary.

The underlying cause of salinity increase in the Sundarban is partly man-made and partly natural. Inadequate knowledge base on the natural flow requirement of the rivers for conserving ecosystem integrity of the Sundarban has led to decisions that are ecologically unsustainable. In order to ensure ecosystem integrity of the Sundarban requires coordinated actions between the two countries. Taking the advantage of historical MOU signed between governments of the two countries proposed platform can make a soft start on advocacy to implement ecosystem management of the Sundarbans. Implementing WH charter to generate ecological information involving scientific community of two countries can be a first step towards promoting unified data gathering protocol and establishing an ecosystem view of the Sundarban.

2.9.2. India

2.9.2.1. Uninhabited Mangrove Forests

In 1840, the British colonial administration promulgated the Crown Land (Encroachment) Ordinance that targeted forests in Britain's Asian colonies, and vested all forests, waste lands, unoccupied and uncultivated lands to the crown. The Imperial Forest Department was established in India in 1864. British state's monopoly over Indian forests was first asserted through the Indian Forest Act of 1865. This law

simply established the government's claims over forests. Sir Dietrich Brandis, who joined British Service in 1856 and Dr. Hugh Cleghorn, the man behind the mobilization of opinion leading to the introduction of systematic management in the Indian forests, were jointly appointed the first Inspectors General of Forests in India in 1864. Sir Brandis, the father of the Scientific Forestry Regime in India, continued his ground-breaking work of forestry administration in India. The Indian Forest Act, 1865, was passed by the colonial government to provide legislative back-up to the upcoming forestry regime.

The first national forest policy had been announced in 1894. During the decade of the 1950s, a new Forest Policy was formulated in 1952. The national interests of defence and industries were given priority. It also stated that one-third of the total land should be brought under forests. Concept of sustained yield and conservation management continued. The Estate Acquisition Act was promulgated in 1953. Through this Act the forests of south West Bengal (lateritic tract) under private (zamindar) ownership became vested to Government and were given to the Forest Directorate for management.

In the early 19th century, the British government set aside all unleased mangrove areas under protection and conservation.[88] A separate agency for governance of Sundarban was felt and a 'Sundarban Commissioner' was put in charge. However in Independent India the developmental needs of the region was being monitored by the normal established administrative set up (24-Parganas District administration) till 1972. In 1972 wildlife and forest protection legislations were formulated.[89] This legal protection is seen as the basis for governance of the mangrove forests. However, scholars believe that 'economic reasons such as high land use conversion costs (due to tidal, saline environment and the presence of the Royal Bengal Tiger have become more important in preventing large-scale destruction of the mangroves than administrative regulations. Moreover very clear demarcation of forest boundaries along rivers and the Bay of Bengal have also contributed to the protection of the forest.

Since the 1970s, the Indian Sundarban mangroves have been protected under various legal measures which were established primarily to protect and help increase the threatened tiger population. In 1984 a (subordinate) protection of the forests came into law with the establishment of the 1330 km^2 Sundarban National Park, designated as a UNESCO World Heritage Site in 1987, and a biosphere reserve in 2001, where no human interference is permitted. In addition there are less strictly administered wildlife sanctuaries namely, Sajnekhali (362 km^2), Lothian (38 km^2) and Haliday (6 km^2) and the Sundarban Reserve Forest, where limited human use is allowed. In total, the protected forest covers an area of about 4260 km^2. Additionally, the government of India established a National Mangrove Committee within the Ministry of Environment and Forests in 1979, with the mandate to manage, protect, and re-afforest the areas. Consequently, despite the high population density, the areal extent of the Indian Sundarban mangrove forest remained more or less stable.[90]

West Bengal Forest Department[91]

In West Bengal, concept of preservation of wild life and its habitat was well established since the 1940s. With promulgation of the Wildlife (Protection) Act, 1972, the preservation of floral and faunal biodiversity got high importance and got statutory support during this decade. Forestry was State subject under Constitution of India till 1976. By an amendment to the Constitution of India in 1976, Forests became a Concurrent subject. Thus both Union Parliament and State Legislature have jurisdiction to regulate forests. The National Commission on Agriculture submitted its report on Forestry in 1976. Two interim reports came before that. One report dealt with social forestry the other report dealt with manmade forests of commercial value. In order to get institutional finance and for rapid conversion of

[88] Aditya Ghosh, Susanne Schmidt, Thomas Fickert and Marcus Nüsser The Indian Sundarban Mangrove Forests: History, Utilization, Conservation Strategies and Local Perception Diversity 2015, 7(2), 149-169
[89] ibid
[90] ibid
[91] http://westbengalforest.gov.in/history.php

forests, Forest Development Corporations were created in all states of India including West Bengal. The West Bengal Forest Development Corporation started functioning from 1974 on forest land in Darjeeling hills leased out by the Forest Department of this state.

The West Bengal Panchayat Act, 1973 introduced three-tier system of Panchayat in the state. The Panchayat bodies took up work to motivate and educate local committees on forestry activities. These Panchayat bodies had great contribution in successful implementation of social forestry and Joint Forest Management (JFM) in the later decades.

Box 1: ***Classification of Recorded Forest Land (legal status)***

Reserved Forest
An area notified under the provisions of Indian Forest Act or State Forest Acts having full degree of protection. In Reserved Forests all activities are prohibited unless specifically permitted.
Protected Forest
An area notified under the provisions of the Indian Forest Act or State Forest Acts having limited degree of protection. In Protected Forest all activities are permitted unless prohibited.
Unclassed Forest
An area recorded as forest but not included in Reserved or Protected forest category. Ownership status of such forests varies from state to state.

The Forest Conservation Act (FCA), came into force in 1980 and was amended in 1981. The most important provision of the Act was that no forest land could be cleared of trees which have grown naturally in that land. Deviations could be permitted with prior approval of central Government. The FCA 1980 has been used effectively to reduce deforestation for revenue or for local development projects. Though the National Commission on Agriculture recommended social forestry in the mid-seventies, it got real boost in West Bengal from 1981. The IDA supported West Bengal Social Forestry Project initiated a new approach to deal with problem of biotic interference on forest land. The idea was to grow trees by villagers on their own land lying unproductive. Forest Directorate distributed seedlings free of charge to farmers for planting trees.

The West Bengal Forest School, Dowhill established in 1907 to impart in-service training to foresters of this state, was expanded in 1980s. Imparting forestry knowledge to Forest Guards was also felt necessary and therefore a Forest Guard Training Centre was opened at Jhargram in 1984.

The National Forest Policy was formulated in 1988. It outlined for the future a new strategy of forest conservation and maintenance of natural environment. It gave strategies on matters of afforestation, social forestry, management of state forests and the rights and concession of tribals etc. It contained a new provision of restriction of felling of natural forests, development and protection of forest and meeting the need of forest fringe dwellers.

The Sundarban Biosphere Reserve

The Sundarban Biosphere Reserve was constituted by the GOI in 1989 and it received the recognition of UNESCO under its Man and Biosphere (MAB) Programme in November, 2001. The Sundarban National Park , forming the core area of Sundarban Tiger Reserve, received recognition as World Heritage Site by UNESCO in 1987.

It has been nominated by GOI for recognition as Ramsar Site (a wetland of international importance). Sundarban Tiger Reserve was constituted by GOI under Project Tiger scheme, in 1973. Sundarban is the only mangrove forest in the world which is the home of Tigers. Sundarban Tiger Reserve has the highest tiger population in the world.

The Sundarbans Biosphere Reserve has three main objectives:

I. Restoration of the unique mangrove ecosystem of Sundarban and conservation of its biodiversity.
II. Development of sustainable economic, social activities of the population living in the Biosphere Reserve.
III. Facilitating research, monitoring, education and training to perpetuate the achievements made.

The total area of this Biosphere Reserve has been divided into the following inter-related zones:

I. The core zone is a compact block of R.F. covering approximately 1700 sq. km. lying in the eastern portion of Sundarban adjoining Bangladesh border and is bounded by Matla river in the west and butts into the Bay of Bengal . This fully protected area containing the Sundarban National Park is devoted to conservation of bio-diversity, including primitive area which has remained free from any external disturbances for a long time. Nature in pristine glory exists here.
II. The buffer zone comprises majority of mangrove areas including reserved forests areas adjoining area surrounding the above core zone and includes portion of the buffer zone of tiger reserve, Sajnakhali Wild Life Sanctuary and compact R.F. blocks lying between Matla and Thakuran under 24-Parganas (South) Forest Division.
III. The Transition zone : Covers the balance of the Biosphere Reserve area, which contains mangrove areas mostly in non-forest areas and reclaimed areas with agriculture.

Participatory or Joint Mangrove Management (JMM) is the basis of sustainable Conservation of Mangrove Eco-system in the Sundarban. On the basis of the experiences of peoples' participation in forest management in Southern West Bengal, the Forest Department of the GOWB has issued orders facilitating the formation of Forest Protection Committees (FPC) around the Reserved/ Protected Forests, and Eco-Development Committees (EDC) around the National Park and Sanctuaries of Sundarban region also. So far 52 FPCs and 14 EDCs have been registered in Sundarban.[92]

Members of the FPCs and EDCs participate in protection of the forests against exploitations. However, since large population in the fringe villages are intensively dependent on the resources of the mangrove eco-system, the effort to create "alternate livelihood options" for these target groups and dilute the biotic pressure on the ecologically fragile mangrove ecosystem is being pursued.

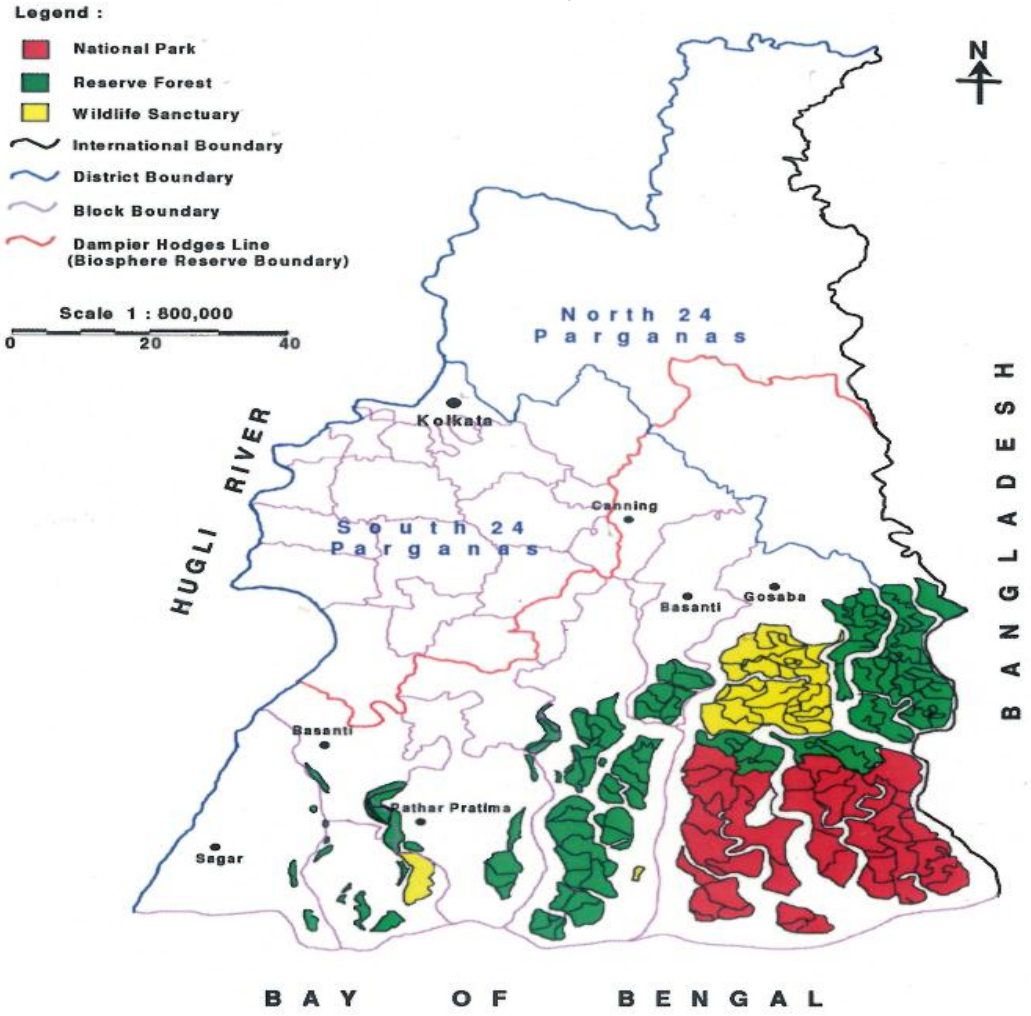
The website of the Sundarban Biosphere Reserve says that ‘meagre development funds available for the forest fringe villages, are utilized for creating resources through the process of Micro-level Planning and participatory implementation’. The FPC/EDC members are said to be encouraged to create Community Fund, through their contributions from the benefits derived out of JFM support services, which will help to sustain the development activities in the villages even after the withdrawal of the Fund from various schemes.

Transboudary Projects

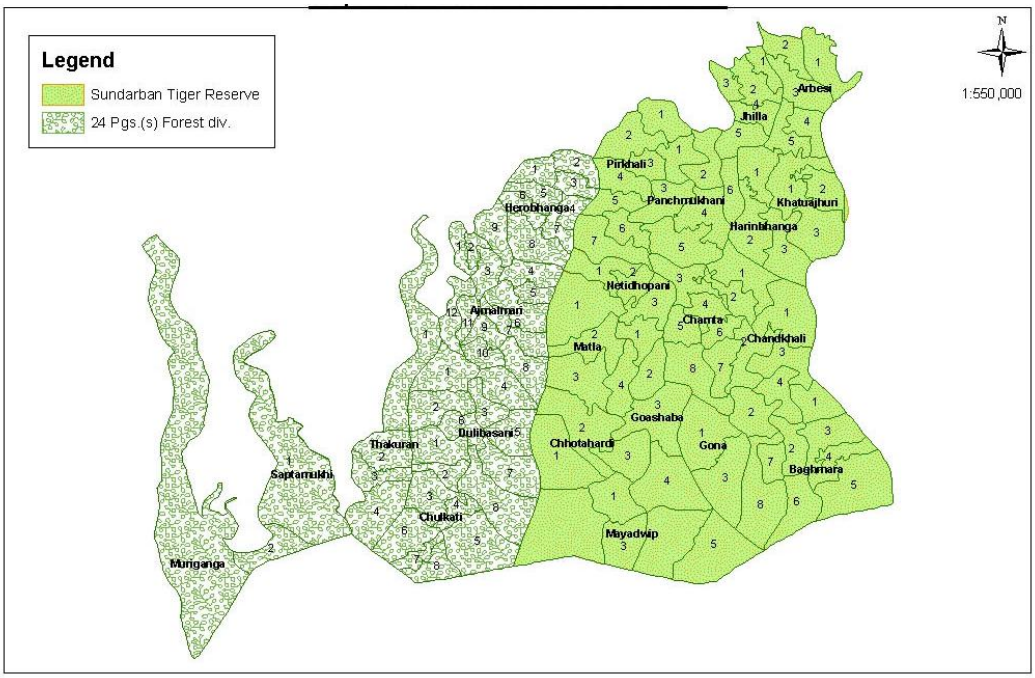
According to the website of the Sundarban Biosphere Reserve (India) the MOEF&CC, GOI and the Department of Economic Affairs, had approved implementation of a Preparatory Phase Project on "Conservation of Biodiversity in Indian Sundarbans through two-country approach" with fund support from United Nations Foundation (UNF) routed through UNDP - India and UNDP - Bangladesh. Under the project, Director, Sundarban Biosphere Reserve was appointed as National Project Coordinator(NPC) for India . NPC of the two countries had prepared a Joint Project Document on "Conservation of Biodiversity in Sundarban through-two country approach" and the same was submitted to UNDP / India and UNDP / Bangladesh for seeking further fund support for implementation of the project.

[92] http://www.sundarbanbiosphere.org/html_files/management_indian_sunderban.htm

MAP 5: Sundarban Biosphere Reserve



MAP 6: Sundarban Reserved Forest



Source: http://www.sundarbanbiosphere.org/html_files/photos_all/map/sundarban_7_1.htm

2.9.2.2. Inhabited Areas of the Sundarban

a. The Irrigation & Waterways Department

The irrigation department is among the oldest bureaucratic bodies with a mandate of governance of the Sundarban as it was set up in 1920 by separating it out from the Public Works Department. However it was named Irrigation & Waterways Department (IWD) only in 1946. According to publicly available information on the department[93], in the pre-plan period i.e., prior to 1951, irrigation was effected through diversion schemes on the rivers Kangsabati and Damodar. The department is currently entrusted with the task of providing irrigation facilities, offering reasonable protection against flood, alleviating drainage congestion, arresting erosion, maintaining internal navigation channels and up-keeping the natural waterways in the state. The department is in charge of the embankment schemes, town protection schemes, drainage schemes, anti-river bank erosion schemes and anti-sea erosion schemes. The department works with central institutions such as departments such as the Central Water Commission (CWC) and the India Meteorological Department (IMD).

44 inhabited islands that have 3500 km long embankments surrounding and protecting them. Since the 1960s when the zamindari system was abolished, the protection and maintenance of the embankments has been the responsibility of the IWD. The IWD is under the charge of two full-fledged cabinet ministers, one to head the department and the other functions as the Minister of State for Irrigation. It has an elaborate bureaucratic structure with a Secretary who occupies a position subordinate to that of Ministers and is responsible for the running of the directorate and also the administrative head of the department.

Chart 13: Organization Structure of the Irrigation and Waterways Department

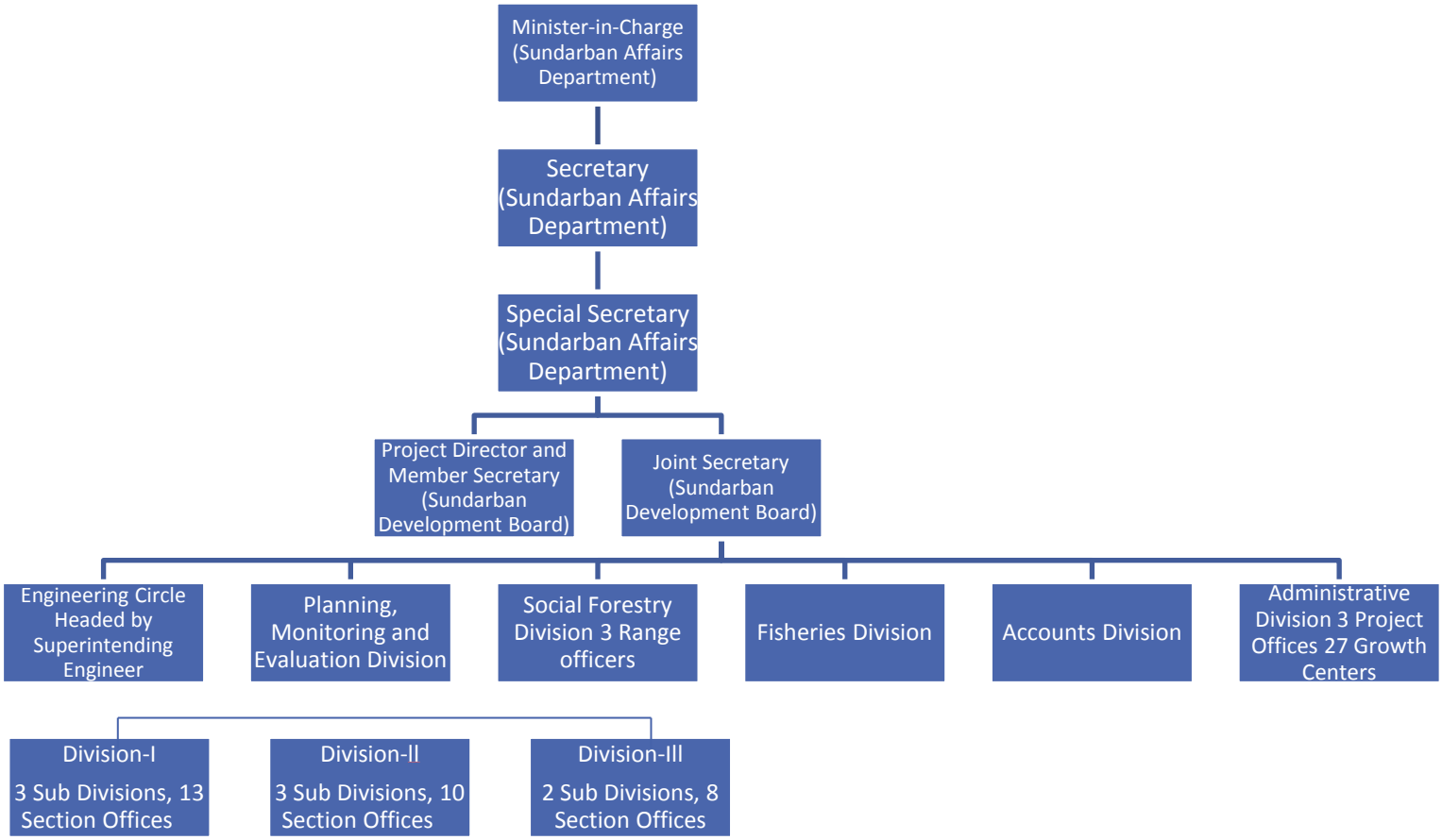
[93] http://www.wbiwd.gov.in/index.php/applications/about

Key decisions on the embankments are made by a host of civil and mechanical engineers. Embankments in the Sundarbans comes under the Eastern Circle with a Superintendent Engineer in charge of each circle.[94]

Department of Sundarban Affairs

In January 1994, the Department of Sundarban Affairs (DSA) was created to give an impetus to the development efforts in the Sundarban region and the Sundarban Development Board (SDB) has been placed under this Department. The DSA implements developmental activities through Sundarban Development Board.

Chart 14: Organization Structure of the Sundarban Affairs Department



The department promotes social, economic and cultural advancement of people residing in the Sundarban areas of the districts of North & South 24 Parganas, co-ordinates development schemes and projects in the area, provides infrastructural facilities through improvement of rural communication, water resources, preservation of ecological balance, provides facilities for the development of the agriculture including minor irrigation and drainage system and allied matters. In terms of Rules of Business framed under Article 166(3) of the Constitution of India, the Department of Sundarban Affairs is to perform the following functions of the Government:

- Promotion of Socio-economic and Cultural Advancement of people residing in the Sundarban areas of the District of North 24 Parganas and South 24 Parganas; and financing, regulation and inspection of bodies established for the purpose.

[94] This paragraph is based on insights from Mukhopadhyay, Amites. Living with Disasters: Communities and Development in the Indian Sundarbans, Cambridge University Press, 2016

- All matters in connection with or in relation to the Constitution and functioning of the Sundarban Development Board.
- Co-ordination of development schemes and projects such as i) Livelihoods: Agriculture, Pisciculture, Forestry; ii) Water supply and sanitation; iii) Disaster risk management and erosion control ; iv) Energy ; v) Transportation; vi) Biodiversity conservation; vii) Education; viii) Awareness creation etc in the Sundarban areas of the District of North and South 24 Pgs.

All matters connected with infrastructural facilities through improvement of rural communications, water sources, and preservation of ecological balance, socio-economic and allied development programmes etc. in the Sundarban area of the Districts of North & South 24 Parganas.

The Sundarban Development Board

Constitutionally, it is a distinct development agency guided by the decisions of a Board comprising elected representatives (MLAs / Sabhadhipaties), Administrators (District Magistrates of the two districts), noted Social Workers and Non-Government Organisations (NGOs) and representatives of State Govt. Depts. Functionally, however, it is a Directorate, erstwhile under the Sundarban Area Branch of the Development & Planning Department, and since 1994 under the Sundarban Affairs Department of the State Government.

In pursuance of the State Government policy of entrusting the planning and co-ordination of development activities in the backward region to specified agencies, the Sundarban Development Board under the Development& Planning Department was set up in 1973 for the socio-economic development of the Sundarban.

The functions entrusted to the Sundarban Development are:

- Formulation of integrated programme for effective utilization of the resources placed at its disposal from various sources.
- Co-ordination of execution of plans for the development of the region.
- Supervision of the execution of any project for the development of the region as a whole or part of it.
- Review and evaluate the progress of implementation and make adjustment in policies and measures as the review may indicate.

The constitution of the Board at the initial stage was (a) Minister-in-Charge of Sundarban Area Branch of - Chairman Development & Planning Department (b) Vice-Chairman of the West Bengal State Planning - Member (Ex-officio) Board (c) Three M.L.A.s of Sundarban nominated as Member (Ex-officio) by State Government. The Executive head of Sundarban Development Board is designated as Member Secretary.

2.9.3. Academic and Scientific Bodies

Central Soil Salinity Research Institute (CSSRI) is a premier research institute dedicated to interdisciplinary research on salinity/alkalinity management and use of poor quality irrigation waters in different agro-ecological zones of the country. In 1970 the Central Rice Research Station, Canning Town, West Bengal was transferred to CSSRI Karnal to conduct research on problems of coastal salinity.

The CSSRI organises a number of courses, seminars and workshops that routinely include participants from Bangladesh. For example, experts from Bangladesh participate in the International Training Workshop on 'Approaches for Integrated Analysis of Agricultural Systems in South Asia: Field to Farm to landscape scale' jointly organized by CSSRI, the Indian Council of Agricultural Research (ICAR) and the Mexico based International Maize and Wheat Improvement Centre (CIMMYT) at Karnal, Haryana, India in May 2015. The Centre of CSSRI based in Canning Town is partner along with institutions in Bangladesh on an international collaborative research project on Cropping System Intensification in Salt Affected Coastal Zones of Bangladesh and West Bengal, India organised by the Commonwealth Scientific and Industrial

Research Organisation (CSIRO) and Murdoch University, Australia. It is also partnering with the Bangladesh Agricultural Research Institute, Bangladesh Rice Research Institute and Khulna University on collaborative research on Cropping system intensification in salt affected coastal zones of Bangladesh and West Bengal. A number of joint papers on problems of salinity in the Sundarban region are also available.

ANNEXURE

Causal Chain Analysis Matrix of the Perceived Problems of the Sundarban Ecosystem proposed by Resource Persons in Bangladesh

	Problem	Immediate Cause Onsite	Management Jurisdiction	Impact local/ national	Secondary/ Intermediate Cause	Root cause	Institution/ Stake holders	Probable Solution/ National	Trans-boundary Impact	Probable Solution/ Regional
1	Increased Salinization	Reduced freshwater inflow	FD No jurisdiction	Loss of biodiversity, loss of forest production, Loss of livelihood, Reduction of forest structure, decline in protection services against cyclone and disasters	Obstruction/abstraction of freshwater in the upper catchment area of rivers passing through the Sundarban	Socioeconomic development/ Food security, lack of planning and control	FD,WDB, Agriculture Department, LGED, No effective regional coordination	Measures to increase freshwater in local watershed/catchment area of the rivers	Decline in Sundarban Ecosystem Values and Services, Tension between neighbors for competing freshwater use	Resurrection of historical water flow Regime from the Ganges and Ganges linked distributaries, Fare share and wise use framework for freshwater flow in the rivers, Increased participation of Civil Society and INGOs
		Increased ingress of Seawater	FD No jurisdiction		Sea level rise	Climate change	FD, Climate Change Unit, NGOs ,INGOS,	Restore sediment supply through rivers	Loss of biodiversity value of the Sundarban Ecosystem, Loss of protection value of the Sundarban from sea level rise and storm surges	Joint strategy for adaptation mitigation, Increased participation of Civil Society and INGOs

2	Alteration in freshwater flows and sediment loads from rivers	Change in sedimentation, increased sediment load during rainy season, silting up of the river bed	FD No jurisdiction	Changes in geomorphic pattern with corresponding changes in biota, unpredictable changes in ecosystem services	Obstruction in upper catchment, obstruction in local watershed areas through polder construction, reduced base flow from the watershed areas	Demand for increased food security, protection from flooding	FD,WDB, Agriculture Department, LGED, No effective regional coordination	Measure to establish natural flow	Loss of biodiversity value of the Sundarban Ecosystem, Loss of protection value of the Sundarban from sea level rise and storm surges	Resurrection of historical water flow Regime from the Ganges and Ganges linked distributaries, Fare share and wise use framework for freshwater flow in the rivers, Increased participation of Civil Society and INGOs
3	Pollution	Increased Pollution load, lack of information, lack of awareness	FD No jurisdiction	Loss of biodiversity, loss of fisheries production in the rivers and oceanic areas, Loss of livelihood, increased health deterioration due to food chain contamination , Sanitary and health	Industrial development, Urbanization, Agricultural pesticide and fertilizer use, discharge of shrimp farm wastes, Increased port activity	Socioeconomic development/ Food security, lack of planning and control, lack of waste management culture in the municipalities	FD, Department of Industries, Department of Agriculture, Department of Fisheries, Department of Environment, Ministry of Port and Shipping, Ministry of Energy, Ministry of Land	Regional Pollution prevention policy and strategy	Cross border pollution of rivers & marine areas, decrease in marine and artisanal fisheries production, loss of ecosystem integrity of the Sundarban and adjoining marine areas, concern for human health of the resource dependent local community and distant market places of the Sundarban product, Decline of Tourism Revenue	Joint strategy for pollution prevention, Mandatory Regional Environmental Impact Assessment in mega project Implementation, Increased participation of Civil Society and INGOs

4	Habitat degradation (Terrestrial)	Salinity increase, legal and illegal over exploitation of plant products, increased submersion rate and duration, lack of research information and monitoring, indulgence of local people in forest fire, poaching of timber and other forest product	FD Management plan in operative or inadequate, limited capacity to sustain local pressure	Loss of ecosystem integrity/resilience, decline of wildlife population,	Lack of well motivated protection team, unsustainable intervention of the natural water flow, Corruption in SB Management Hierarchy	Dependence of local people livelihood on Forest product, corruption in SB Management Hierarchy	FD, Research Organization, WDB, Department of Environment, Mongla Port Authority, BEPZA and BSEZA, Law enforcing agencies,	Sundarban Forest Habitat Improvement Plan of Action and Implementation	Loss of regional and global biodiversity value of the Sundarban	Integrated Regional Plan For Sundarban Habitat Improvement Plan Implementation, Formal Intergovernmental Consultation Structure, Increased participation of Civil Society and INGOs
	Habitat degradation aquatic	Salinity increase, over exploitation of plant products, increased submersion rate and duration, lack of research information and monitoring, use of bio toxic chemicals for fishing	FD no Management Plan, donor driven adhoc census and community mobilization for tiger only, no management intervention for other aquatic wildlife population	loss of aquatic biodiversity, decline of endangered aquatic wild life (mammals, amphibians, shell fish etc)	Lack of well-motivated protection staff, increased pollution load from local river watershed and upper catchment area of the Ganges, Corruption in SB Management Hierarchy	Dependence of local people livelihood on aquatic resources(fish, shrimp, bivalves etc, corruption in SB Management Hierarchy	FD, Fisheries Department, WDB, Department of Agriculture, Department of Environment, Ministry of Industries , Ministry of Shipping, Ministry of Energy, Prime Minister's Office(BEPZA and BSEZA)	South West Regional Pollution Control Plan of Action	Loss of marine and riverine fisheries resources	Formal Intergovernmental Consultation Structure. Increased participation of Civil Society and INGOs
5	Illegal Wildlife Poaching and Trade	Weak anti poaching capacity of the FD, lack of local people's participation	FD limited response capacity, participation of local community an adhoc donor based recent	Loss of endangered wildlife species,		Extreme poverty, organized national and international wildlife trade due to high international market demand	FD, Ministry of Commerce, Police Department, Coast Guard, RAB, BGB and all other law	Plan for poverty reduction, strengthen anti poaching squad at	Loss of globally significant endangered wildlife	Formal Intergovernmental Consultation Structure, Increased participation of Civil Society and INGOs

			initiative, no sustained indigenous plan for protection				enforcing agency	national and local level		
6	Sicio-economic Vulnerability and dependency on Sundarban Resources									
7	Climate Change Adaptation and Mitigation									
8	Civil Society participation related to management of Sundarban									
9	Information Generation and Sharing									