WWF

PAPER

IND

2017

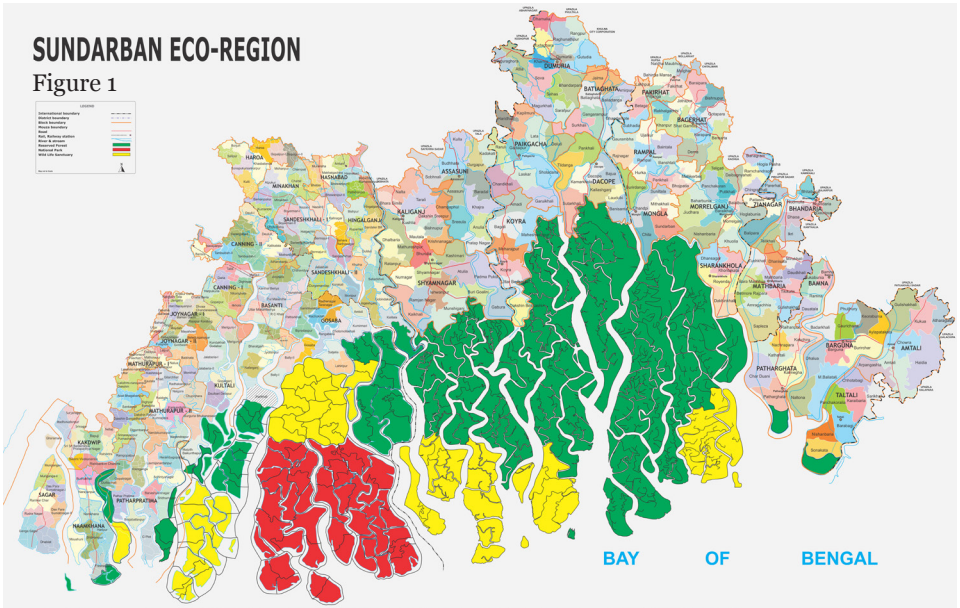
DISCUSSION PAPER

SUNDARBAN IN A GLOBAL PERSPECTIVE: LONG TERM ADAPTATION AND DEVELOPMENT

THE SUNDARBAN LANDSCAPE IN A GLOBAL SETTING

The Sundarban landscape/eco-region formed by the Rivers Ganga, Meghna and Brahmaputra is the tidally active lower part of the largest delta in the world consisting of a warren of rivers, creeks, marshes and alluvial floodplain. Morphological zones of this lower part of the delta are the Ganga tidal plain (West) between rivers Hugli and Baleswar, the Ganga tidal plain (East) between rivers Baleswar and Tetulia, and the Meghna deltaic plain stretching from river Tetulia until Chittagong coastal plain. At the confluence of the delta and the Bay of Bengal, is the single largest mangrove patch of the world spread across about 10,300 sq km of which about 60 percent is in Bangladesh and the rest in India. This mangrove patch is acknowledged worldwide for its outstanding biodiversity, including the Bengal Tiger, and designated as World Heritage Site in both the countries. This littoral mangrove forest besides serving as the habitat for about 200 tigers, accounting for five percent of the global population in the wild, also imparts protection from storm surges caused by tropical cyclones by attenuating the impact of cyclones that recur on sub-decadal time scales in the Bay of Bengal.

For the purpose of this discussion paper, the Sundarban landscape/eco-region encompasses the Sundarban Reserve Forest (SRF) of about 6000 sq km (including 1397 sq km of Protected Area (PA)) and the Sundarban Impact Zone (SIZ) in Bangladesh, and parts of Barguna and Perojpur districts outside the SIZ due to their similar characteristics because of presence of tidal channels (Figure 1). The SIZ, as defined by the Bangladesh Forest Department (BFD) is the inhabited area within 20 km of the forest where most of the Sundarban resource users live. This covers an area of 3641 sq km (Hussain, M.Z. 2014). In India, the Sundarban region, designated as Sundarban Biosphere Reserve comprises of an area of about 9,630 sq km of which around 4260 sq km is under Reserve Forests (including about 2300 sq km of PA). In totality, the geographical area of this region is about 19271 sq km with 19 percent as Protected Area (3697 sq km) and 47 percent inhabited (9011 sq km), spread over parts of seven adjoining districts (24-Parganas South and North, Satkhira, Khulna, Bagerhat, Perojpur and Barguna) covering 40 sub-districts encompassing 327 village clusters known as Union Porishod in Bangladesh and Gram Panchayat in India with a population of over7.2 million, largely dependent on agriculture, fisheries and the collection of minor forest produce. To put it in perspective, the landscape holds 0.1 percent of the global population, 137 countries/territories have population less than the Sundarban, 67 countries/territories are smaller in size, and only 29 nations and territories have a higher population density. The region therefore, is globally significant not only for the natural area and biodiversity, but also for the number of people who inhabit.



Officially, the landscape/eco-region is defined somewhat differently. The SIZ for example, is a 20 km band from the forest in Bangladesh that does not take into account natural features of the inhabited area. On the Indian side, the inhabited part of the eco-region is defined by the extent of forest in the 1830s. There have been significant alterations since that time and 29 percent of the Gram Panchayats no longer bear the defining characteristics of the eco-region– tidal channels –and could be considered to be outside the eco-region. On the other hand, in Bangladesh, because of the fixed distance from forest, Unions in Upazilas that have tidal channels have been left out, for example Amtali, Taltali, Barguna, Patharghata and Bamna in Barguna District, Mathbaria, Bhandaria and Zianagar (renamed Indurkani in January 2017) in Perojpur District. The table in Annexure 1 lists the eco-region based on presence of tidal channels and embankments.

LAY OF THE LAND, SEDIMENT DYNAMICS, COMPACTION AND TROPICAL CYCLONES

Deltas are coastal complexes characterized by the interplay between rivers, lands, and oceans and influenced by a combination of river, tidal, and wave processes, that combine natural systems in diverse habitats (e.g., tidal flats, salt marshes, mangroves, beaches, estuaries, low-lying wetlands) and human systems (e.g., houses, agriculture, aquaculture, industry, and transport). These are low-lying coastal landforms, formed by riverine sediments in the areas around river mouths, mostly during the last 6000-8000 years of relatively stable sea. These low-lying coastal landforms have a population density more than 10 times the world average (Ericson et al., 2006; Foufoula-Georgiou et al., 2011). As low-lying plains, deltas are highly sensitive to changes in the sea level and are subject to impacts from river flows from upstream (e.g., freshwater input) and the oceans (e.g., sea level changes, tidal waves) as well as within the deltas. At the same time, these are affected by human activities such as land use changes, dam construction, irrigation, mining, extraction of subsurface resources, and urbanization (Nicholls et al., 2007).

Sea-level rise from a warming climate threatens to inundate coastlines around the world but some of the world's most vulnerable coasts are the ones fringing flat delta plains, and face the far more immediate threat of sinking land(Renaud et al., 2013). Induced mainly by human activities on a local rather than global scale, this phenomenon, known as land subsidence, can outpace sea-level rise substantially (Schmidt, 2015).Unlike rocky continental coasts, delta plains tend to be soft and easily compressed. These are often propped up by underlying oil, gas, or fresh groundwater that flows through the pores of sediment deposits. As these resources are extracted, sediments compress, and the land shrinks like a dried sponge (ibid).

Elevation of a delta above the sea level depends on four interrelated factors: the ocean's global volume, aggradation, sediment compaction, and vertical movements resulting from plate tectonics and other geophysical processes. Aggradation has been severely limited by alteration of sediment flows by dams, levees, and embankments that trap sediments and starve deltas of new sediments. The GBM delta is a case in point (Schmidt, 2015). Syvitski et al. 2009, estimate that aggradation rate of the Ganga Delta has reduced by one mm per year between early 20th century and 21st century and classify it as a delta in peril (4 on a scale of 5) characterised by reduction in aggradation and accelerated compaction in a class of five, ranging from deltas not at risk to deltas in greater peril. Although annual sediment delivery by the Ganga and Brahmaputra rivers to parts of the Bengal margin has kept pace with sea level rise since the mid Holocene (Rogers et al, 2013), an abandoned

portion of the delta west of Baleshwar river (Ganges Tidal Plain (West)) is no longer connected to significant upstream river sources. This western portion of the lower delta has been thought to be sediment starved. The biggest threat is that a delta will tip toward a collapsed state, meaning that it will likely never be restored to anything remotely similar to its natural condition. The Ganga-Brahmaputra Delta is one of several delta regions around the world that is sinking. Time-variable relative sea level rise in the region has been 8-18 mm/year, the range covering either different times or different areas of the delta (Syvitski et al., 2009). The larger part of the landscape is within this abandoned western portion including SBR in India encompassing 19 sub-districts (Blocks) with 190 village clusters (Gram Panchayats), and a population of over 4.4 million as per Census 2011, on the Bangladesh side, seven sub-districts (Upazilas) with 75 village clusters (Unions) with a population of over 1.7million.

There are marked differences between the western and eastern sides of the delta. The western parts of the delta are starved of sediment (Schiermeier, 2014), whereas net sedimentation on the eastern part of the delta (Meghna Deltaic Plain; further east of Sundarban region) traps about 10 percent of annual Ganga-Brahmaputra sediment load, with accretion rates roughly equivalent to the mean regional rate of relative sea-level rise (RSLR) of about 1.0 cm/yr. If these sedimentation rates are representative of longer-term trends and subsidence rates remain stable over the next century, the eastern lower delta plain may continue to maintain its elevation and stability despite documented mangrove retreat around its seaward edges (ibid).

Average global temperature in 2016 was 1.38°C above levels experienced in 1880 when modern record keeping began. In the Sundarban region average warming has been to the tune of about 1.0°C. Although the world aspires to restrict global warming to 2.0°C, it could be closer to 3.0°C with implementation of Paris Agreement commitments at the end of this century. Without mitigation global average warming is likely to be 4.5°C. See the map series in Annex 2 for corresponding sea level rise in the Sundarban region. Notice that in the eastern part of the forest there is still some refugia even at 4.0°C warming.

Embankments have reduced tide-related sediment deposition on the delta's surface resulting in siltation within tidal creeks and sediment starvation inside the embankments. Earthen embankments were built around low-lying plots of land at different times since the 1770s to hold back tidal water and create land for agriculture. The entire inhabited area in Bangladesh SIZ is embanked (in the districts of Satkhira, Khulna, Bagerhat, and parts of Pirojpur and Barguna) while 15 of the 19 sub-districts in SBR are embanked to the extent of 33 percent or more. The embankments blocked replenishment of the delta

with river sediment carried downstream by the annual monsoon floods. Consequently, the embanked land have subsided and the islands have since lost elevation measuring in metres. Within-channel aggradation rates can be high (>60 mm yr–1), creating channels super-elevated above their surrounding flood plains and increasing the flood risk (Vörösmarty et al, 2009).

The Sundarban' position north of the Bay of Bengal makes it vulnerable to large tropical cyclones that frequently form in the Bay from October to December and April to May, The Bay of Bengal has been called a "breeding ground" for tropical cyclones due to the broad shallow shelf, warm sea surface temperatures and funnel shape of the Bay and its numerous inlets (Murty et al, 1986). Storm surges have been documented up to 12 m high along the Bengal coast (Rogers & Goodbred, 2014).

Early indications suggest that the magnitude and frequency of hurricanes and cyclones might increase along with the onset of more intense precipitation events (Lambert et al, 2008). Although humans have largely mastered the everyday behaviour of lowland rivers, they seem less able to deal with the fury of storm surges that can temporarily raise sea level by 3 to 10 m. Storm surges can travel several kilometres up estuarine channels, and may cause deep subaqueous scour at the base of peninsular islands. It remains alarming how often deltas flood, whether from land or from sea, and the trends seem to be worsening (Overeem et al, 2009).

Although the Bay of Bengal is not traversed by the maximum number of tropical cyclones on the planet, in terms of storm surges the maximum impact seems to occur here. The storm surge impact is a composite index of lives lost, all other damage, and includes the ability of the region to return to normal (economically and socially) within a reasonably short period. Storm surges in the Bay of Bengal are a serious hazard along the coasts of Bangladesh and India, particularly in the Sundarban landscape.

The reasons for the disproportionately large impact of storm surges on the coast of Bangladesh in particular, and West Bengal are the following: (1) The phenomenon of recurvature of tropical cyclones in the Bay of Bengal; (2) Shallow continental shelf, especially in the eastern part of Bangladesh; (3) High tidal range; (4) Triangular shape at the head of Bay of Bengal; (5) Almost sea level orography of the Bangladesh coast, coupled with many inlets and some rivers and estuaries; (6) High density of population, especially on low lying islands. The first five parameters would not matter if the region were bereft of population. For example, in the northern regions of Canada, large amplitude storm surges occur, but these do not receive any attention because very few people live there.

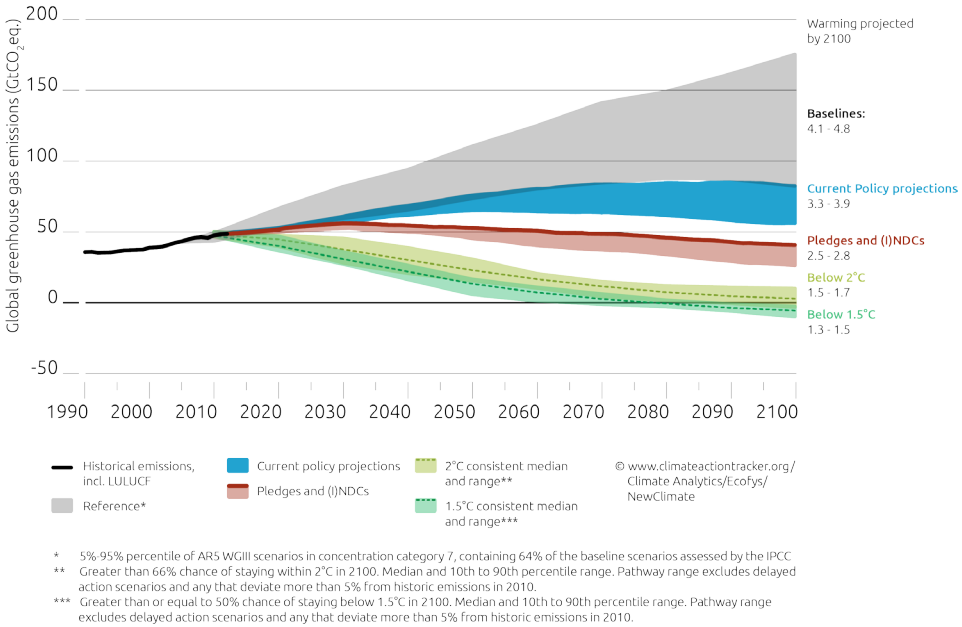
The phenomenon of recurvature of tropical cyclones in the Bay of Bengal is the single most cause of the disproportionately large impact of storm surges on the Bangladesh and West Bengal coast as most of the land is flat. Many places, although 160 km from the sea, are not more than 9 m above sea level (elevation in the western part of the delta is lower, particularly the inhabited polders and islands). A rise of a few decimetres in sea level can submerge large areas of land (Gill, 1975).

Another peculiar problem is the topographic changes that appear to occur in decadal periods in the courses of the rivers and tributaries. The storm surge problem became worse after the Assam earthquake of August 1950 because millions of tons of material from the mountains were dislodged by the earthquake, which ultimately found its way into the river systems and caused raising of the bottom by as much as 4.3 m in certain locations (Murty and Flather, 1994). The embanked areas are now far more vulnerable to storm surges that can damage or breach the embankments, effectively creating lakes that can last for years. In 2009 Cyclone Aila struck Sundarban Region and the resultant flooding marooned over two million and displaced more than one lakh people in the worst hit areas. The storm also inundated islands with fresh silt, in some places reaching a depth of 70 cm, (Auerbach, et al., 2015) reflecting the system's ability to replenish itself, if allowed.

TEMPERATURE PROJECTIONS AND RELATIVE SEA LEVEL RISE

Progressive layering of sediment over time results in the build-up of delta land mass that will continue to build seaward as long as rates of erosion do not exceed rates of sedimentation (Reker et al. 2006). Ganga delta in Bangladesh has experienced sediment reduction to the extent of 30 percent over the past 50 years and distributary channel reduction of 37 percent which prohibits river flooding onto the delta plain thus delta aggradation (Syvitski et al, 2009). On the Indian side, accretion rates could be between 20 and 50 percent of the rate on the eastern side in Bangladesh.

Deltas are now sinking at rates many times faster than global sea level is rising. Ganga delta is in peril due to reduction in aggradation plus accelerated compaction overwhelming rates of global sea-level rise. Natural compaction and accelerated compaction reduce the volume of deltaic deposits. Natural compaction involves natural changes in the void space within sedimentary layers e.g. dewatering, grain-packing realignment, and organic matter oxidation. This is typically ≤ 3mm/year. Accelerated compaction is the anthropogenic contribution to volume change as a consequence of subsurface mining (oil, gas or groundwater), human-influenced soil drainage and



* 5%-95% percentile of AR5 WGIII scenarios in concentration category 7, containing 64% of the baseline scenarios assessed by the IPCC

** Greater than 66% chance of staying within 2°C in 2100. Median and 10th to 90th percentile range. Pathway range excludes delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.

*** Greater than or equal to 50% chance of staying below 1.5°C in 2100. Median and 10th to 90th percentile range. Pathway range excludes delayed action scenarios and any that deviate more than 5% from historic emissions in 2010.

accelerated oxidation, and can exceed natural compaction by an order of magnitude (Syvitski et al, 2009). All trends point to ever-increasing areas of deltas sinking below mean sea level (Syvitski, 2008).

Higher level of subsidence in the eastern part of the Bengal basin at a rate of approximately 6 mm/year (Milliman et al., 1989) as opposed to the average rate of up to 4 mm/year of subsidence in the Delta (Goodbred and Kuehl 1999) is thought to be due to neo-tectonic movements during 10th-12th century AD that caused the Bengal basin to tilt eastward. However, it has been observed that annual sediment delivery by the Ganga and the Brahmaputra rivers to the Bengal margin has kept pace with sea level rise since the mid Holocene, sustaining sub-aerial growth of the delta with half of the mass deposited sourced directly from seasonal flood pulse and the remaining half from older reworked sediments (Rogers et al, 2013). If these sedimentation rates are representative of longer-term trends and subsidence rates remain stable over the next century, the eastern lower delta plain may continue to maintain its elevation and stability despite documented mangrove retreat around its seaward edges (Schiermeier, 2014).There are reports of net land loss of over 250 sq km in SBR during the period 1969 through 2015 (SoS, JU,

2016). The IPCC in its AR5 has also marked out the Delta for high risk of coastal flooding and wetland loss in the 21st century (IPCC, 2014). See map series in Annexure 2 for the anticipated extent of coastal flooding on account of sea level rise at the end of this century based on projected temperature rise of 1, 2, 3, and 4°C.

In the absence of policies global warming is expected, to reach 4.1°C-4.8°C above pre-industrial by the end of the century. The emissions that drive this warming are called Baseline scenarios ('Baselines' in the figure below; http://climateactiontracker.org/global.html), taken from the IPCC AR5 Working Group III. Current policies presently in place around the world are projected to reduce baseline emissions and result in about 3.6°C warming above pre-industrial levels. The unconditional pledges or promises that governments have made, including NDCs as of 1 November 2016, would limit warming to about 2.8°C above pre-industrial levels, or in probabilistic terms, likely limit warming below 3.1°C.

Since there remains a substantial gap between what governments have promised to do and the actions they have undertaken to date, the Sundarban landscape could very likely witness sea level rise associated with about 3°C at the end of the century. Moreover, both the current policy and pledge trajectories lay well above emissions pathways consistent with the Paris Agreement long-term temperature goal. Amongst the largest emitters, China, European Union, and India have submitted pledges that are not consistent with limiting warming below 2°C while what the Russian Federation has pledged is inadequate, meaning if all governments were to put forward inadequate positions, warming would likely exceed 3-4°C. Limiting warming 1.5°C above pre-industrial by the year 2100 means that the emissions of greenhouse gases need to be reduced rapidly in the coming years and decades, and brought to zero around mid-century.

For the Sundarban coast the maximum centennial-scale Relative Sea Level Rise (RSLR) is estimated to be of the order of 0.9 ± 3.3 cm/yr based on subsidence rates obtained through the dating of buried salt kiln sand mangrove root horizons (Hanebuth et al., 2013).Future rates of sea level rise are expected to exceed those of recent decades (see WGI AR5 Section 13.5.1), increasing coastal flooding, erosion, and saltwater intrusion into surface and groundwater. Beaches may erode, and mangroves and salt marshes will decline, unless they receive sufficient fresh sediment to keep pace or they can move inland (Gilman et al., 2008; Bezuijen, 2011; Kintisch, 2013; see WGII AR5 Section 5.3.2.3). Neither of these is likely to occur unless planned deliberate actions are initiated. It is less likely that sediment flow can be restored due to extensive development of water resources management infrastructure upstream in the Ganga basin which is a cause of concern

(Milliman and Farnsworth, 2011; and Syvitski, 2008).Unless mangroves can move inland, the globally significant natural area and the only mangrove tiger habitat is under severe threat, as is the northern Bay of Bengal fishery.

SCALE OF IMPACT OF TEMPERATURE RISE AND SEA LEVEL RISE

The coastal zone of Bangladesh is a disaster prone area. Cyclones, storm surges, droughts, floods, water-logging and salinity intrusion have a huge impact on people and their livelihood. Poor communication, inadequate education and health care facilities, prolonged absence of safe drinking water, insufficient cyclone shelters contribute and multiply the dimension of vulnerability. Furthermore, increasing population pressure increases the competition for limited resources.

The large population in the Sundarban is dependent on – climate-sensitive sectors – agriculture, fishing, fishery and collection of minor forest produce; half the population is below the poverty line. The subsistence economy is turning into a remittance economy since the people and the productivity of their holdings are under increased threat from deltaic subsidence, sea level rise, and increased cyclone intensity as climate change and decay of the 18th century embankments take their toll. Climate change adversely impacts farmers and fishermen alike; unpredictable rainfall patterns continue to make traditional crop production difficult for farmers. Moreover, the ecosystem is being adversely impacted by significant increases in salinity due, in part, to sea level rise as well as reductions in freshwater flows to the delta. Rising sea levels place more pressure on agriculture as land continues to be lost to sea. Entire islands have disappeared under the sea necessitating human relocation. Residents express concern that the frequency and intensity of storms and cyclones have increased overtime in the region.

To hold back the sea and create more land for agriculture, concrete and earthen embankments were built around low-lying plots of land known as polders during the 1960s in Bangladesh (formerly East Pakistan). The embankments blocked replenishment of the delta with river sediment carried downstream by the annual monsoon floods, and the islands have since lost 1-1.5 m of elevation. According to Kimberly Rogers, a research associate at the University of Colorado, Boulder, these are now far more vulnerable to storm surges that can damage or breach the walls around the polders, effectively creating lakes that can last for years. Cyclone Aila struck West Bengal and southwest Bangladesh in 2009, and the resultant flooding displaced more than 100,000 people in the worst hit areas. But the storm also inundated the islands with fresh silt, in some places reaching a depth of 70 cm, (Auerbach et al, 2015) reflecting the system's ability to replenish itself, if permitted.

Diking huge stretches of delta shoreline would likely be problematic, as indicated by Bangladesh's experience with polders. Dikes allow the land they protect to subside, Syvitskiopines that these must be routinely elevated to keep pace with steadily rising seas.

These examples illustrate the challenges of addressing a creeping problem that is barely perceptible to the population in real time. It is hard to notice a drop in land elevation of a few centimetres per year until its consequences materialize in a catastrophic event, such as a devastating flood. Yet over time, these declines become significant. Where sea level is rising by an estimated 32 cm per century, land subsiding by 10 cm per year will sink that far in just over three years. Although sea-level rise gets most of the attention, for vast numbers of people worldwide, subsidence is by far the more immediate problem. But because subsidence is a local problem, local solutions are needed to keep it bay.

Occupational and/or physical displacement is already a reality but the current proportion of population or absolute number is not so large so as to draw significant attention. With accelerated sea level rise and erosion this could change rapidly displacing two million in the medium term (Danda et al., 2011and Hussain, 2014). About 22 nation states have populations smaller than the anticipated displacement figure in the Sundarban. Unless handled proactively, individual and institutional capacities will be overwhelmed. Displacement could also be across political boundaries, complicating matters further.

The Sundarban, compared to other mangroves in the world is rich in terms of flora and harbours about 44 percent of global mangrove species. The floristic elements of the Sundarban are usually divided into mangroves and mangrove associates. Beside mangrove species, there are some associate species like herbs, cyano-bacteria, fungi, algae, moss, epiphyte, climber, and lichens (Siddiqui and Baksha2001, Alongi 2009). While most major mangrove formations support only a handful of plant species, Prain (1903) identified a total of 334 species of plants, of which 27 were common trees belonging to 245 genera of spermatophytes and pteridophytes from the Sundarban and adjoining areas. Greenwood et.al. (2009) identified 165 species of algae and 13 species of orchids.

The most common tree species occurring in the Sundarban are Heritierafomes, Excoecariaagallocha and Ceriopsdecandra in that order. The other common species are *Avicennia officinalis, Bruguiera gymnorrhiza, Rhizophora mucronata, Sonnerratia apetala and Xylocarpus mekongensis*. Another species that exists in the Sundarban Delta is nipa palm (*Nypa fruticans*), which grows extensively on the bank of rivers, canals and creeks with freshwater flows. However, increasing sea levels are known to cause changes in mangrove systems. Gilman et al. (2007) found a reduction in mangrove area

with SLR, with the observed mean landward recession of three mangrove areas over four decades being 25, 64, and 72 mm/yr, 12 to 37 times faster than the observed rate of SLR. Significant interactions exist between climate change and coastal development, where migration shoreward depends on the extent to which coastlines have been modified or barriers to successful migration have been established.

The Sundarban also harbours a rich and varied array of faunal assemblages which includes economically significant fisheries. The species of global significance include the Royal Bengal Tiger, River Terrapin, Olive Ridley Turtle, Masked Finfoot, Spoon-billed Sandpiper, White-rumped Vulture, Greater Spotted Eagle, Lesser Adjutant, Fishing Cat, Ganges River Dolphin, amongst others. A number of lizards and snakes are present, such as the water monitor, (*Varanus salvator*), and the rock python, (*Python molurus*). The estuarine crocodile (*Crocodylus porosus*), is also a prominent resident of the delta. A number of amphibian species, including the common toad (*Bufo melanostictus*) and the skipper frog (*Rana cyanophlyctis*) are also present (Chaudhuri and Choudhury 1994, Sanyal 1999). The Sundarban is the only mangrove habitat where tiger exists giving it the status of Level I Tiger Conservation Unit.

As with most mangrove ecosystems, crab species in the Sundarban are a common and significant feature. The ubiquitous fiddler crabs (Uca spp.) are some of the most important contributors to the ecosystem, forming a biomass of 3,000 kg/km^2 (Sanyal 1999). Prawn species found include the commercially important tiger prawn, Penaeus monodon, and freshwater prawns, *Macrobrachium rosenbergii*. A range of mollusc and barnacle species are also present. The Sundarban holds a rich and diverse fisheries system with several hundred different species of freshwater, estuarine and marine species. This includes a number of marine species that migrate up river to freshwater habitats to breed, such as the highly economically and culturally significant Hilsa (*Hilsa ilisha*), or that only visit estuarine areas to breed, such as Arius and Osteoganiosus species. Freshwater species that migrate to estuarine habitats to breed include catfish (Pangasius species) and a number of eel species. Sharks and rays are also present and genera represented include Scoliodon, Pristis, Sphyrna, Rhinobatos, Dasyatis and Aetobatus (Chaudhuri and Choudhury 1994). Bird communities of the Sundarban Delta are a dynamic mix of resident species, summer visitors, breeding birds and winter migrants. Common residents include herons, cormorants, egrets, kingfishers, storks and darters (Chaudhuri and Choudhury 1994, Sanyal 1999). Migrant birds that winter in the Sundarban include certain species of: raptor, plover, sandpiper, gull, babbler and flycatcher (Chatterjee 2004). A number of eagle and owl species are also reside or visit the area, such as the white-bellied sea eagle (*Haliaeetus leucogaster*) and the brown fish owl (*Bubo*

zeylonensis). With sea level rise, increased sea surface temperature and acidification, all of these could be adversely impacted. Loucks et al. (2010) predict a 96 percent decline in tiger habitat in Bangladesh's Sundarban mangroves with a 28 cm sea level rise if sedimentation does not increase surface elevations.

Biodiversity in tropical regions such as the Sundarban may fall if, as evidence suggests, tropical species are already near their thermal maxima (Cheung et al., 2009, 2010; Nguyen et al., 2011). Individual fish species are projected to shift their ranges northward in response to rising sea surface temperatures. The combined effects of changes in distribution, abundance, and physiology may reduce the body size of marine fishes, particularly in the tropics (Cheung et al., 2013). Acidification is also expected to have negative impacts on other calcified marine organisms (algae, molluscs, larvalechinoderms) (Branch et al., 2013; Kroeker et al., 2013).

With rising sea levels, coastal freshwater wetlands may be vulnerable to saltwater intrusion, but in most river deltas local subsidence for non-climatic reasons will be more important (Syvitski et al., 2009) and Sundarban may be no different. Current trends in cyclone frequency and intensity are unclear but a combination of cyclone intensification and sea level rise could increase coastal flooding (Knutson et al., 2010) and losses of mangrove forests would exacerbate wave damage (Gedan et al., 2011).

Rising sea level impacts marine ecosystems by drowning some plants and animals as well as by inducing changes of parameters such as available light, salinity, and temperature. The impact of sea level is related mostly to the capacity of animals and plants to keep up with the vertical rise of the sea. Mangroves and coastal wetlands can be sensitive to these shifts and could leak some of their stored compounds, adding to the atmospheric supply of greenhouse gases.

Warmer temperatures have direct impacts on species adjusted to specific and sometimes narrow temperature ranges. They raise the metabolism of species exposed to the higher temperatures and can be fatal to those already living at the upper end of their temperature range. When atmospheric carbon dioxide is absorbed into the ocean, it reacts to produce carbonic acid, which increases the acidity of seawater and diminishes the amount of a key building block (carbonate) used by marine 'calcifiers' such as shellfish to make their shells and skeletons and may ultimately weaken or dissolve them. Ocean acidification has a number of other impacts, many of which are still poorly understood.

The biggest threat, Syvitski says, is that a delta will tip toward a collapsed state, meaning that it likely will never be restored to anything remotely similar to its natural condition.

There the scale of impact is not restricted to few million people but to a natural system unlike any other. In other words, the scale of impact is not only global but in certain ways immeasurable.

TOWARDS SUSTAINABLE AND RESILIENT DEVELOPMENT

Sustainable development requires managing many threats and risks, including climate change. Because climate change is a growing threat to development, sustainability will be more difficult to achieve for many locations, systems, and populations unless development pathways are pursued that are resilient to effects of climate change.

The links between sustainable development and climate adaptation and mitigation are cross-cutting and complex. First, the impacts of climate change, and ill-designed responses to these impacts, may derail current sustainable development policy and potentially offset already achieved gains. These impacts are expected to affect sectors such as agriculture and fishery; threaten coastal zones; and pose critical challenges to governance and political systems (World Bank, 2010, pp. 39-69; Adger et al., 2011; IPCC,2012). Effects of climate change on key ecological resources and systems can jeopardize sustainable development in systems closely dependent on natural capital as in the Sundarban owing to lower adaptive capacity (World Bank, 2010; Lemos et al., 2013). Second, mitigation has the potential to keep these threats at a moderate rather than extreme level, and adaptation will enhance the ability of different systems to cope with the remaining impacts, therefore modulating negative effects on sustainable development (IPCC, 2007).

Third, many of the conditions that define vulnerability to climate impacts and the ability to mitigate and adapt to them are firmly rooted in development processes (e.g., structural deficits and available as set sand entitlements) (Brooks et al., 2005; Lemos et al., 2013). Indeed, climate change will act as a threat multiplier and will enhance poverty. Fourth, because several of the desirable characteristics of climate responses and sustainable development may overlap (e.g., implementation of no-regrets options, equitable distribution of resources, increased adaptive capacity and livelihood capitals, functioning ecosystems and maintained biodiversity), systems that prioritize sustainable development may be better at designing and implementing successful mitigation and adaptation (Forsyth, 2007).

Finally, climate mitigation and adaptation, if planned and integrated well, have the potential to create opportunities to foster sustainable development. Under the threat of

climate change, sustainable development depends on changes in social awareness and values that lead to innovative actions and practices, including increased attention to both disaster risk management and climate change adaptation in anticipation of (and in response to) changes in climate extremes (IPCC, 2012). Enhancing resilience to respond to effects of climate change includes adopting good development practices that are consonant with building sustainable livelihoods and, in some cases, challenging current models of development (Boyd et al., 2008). Challenging current thinking and models of development in the Sundarban is necessary to not only usher in sustainable development but also be future ready in terms of dealing with impacts of climate change on natural and social systems.

In the Sundarban, the relationship between vulnerability to climate impacts and development is very close and mutually dependent as low per capita income and inequitable distribution of resources; inadequate or inappropriate education, health care, and safety; and weak institutions and unequal power relations fundamentally shape sensitivity, exposure, and adaptive capacity to climate impact. Here, reducing risks that affect resource-dependent communities is necessary but insufficient way to tackle the myriad problems associated with climate change impacts. Building the capacity of individuals, communities, and governance systems to adapt to climate impacts is both a function of dealing with developmental deficits (e.g., poverty alleviation, reducing risks related to food insecurity, enabling/implementing public health and mass education and literacy programs) and of improving risk management (e.g., alert systems, disaster relief, crop insurance, seasonal climate forecasts, risk insurance) (Mirza, 2003; Schipper and Pelling, 2006; Warner et al., 2012).

OPTIONS FOR RESILIENT AND SUSTAINABLE DEVELOPMENT

The options for resilient and sustainable development will depend on either the time horizon or on the future emission scenario. Given that there is no temporal certainty about when temperature thresholds will be crossed it might be prudent to think of the options in terms of temperature scenarios given that the average temperature in the region is about a degree higher than pre-industrial times, and that the world is locked in for an average decadal temperature rise of 0.2°C for the next two decades due to historical emissions irrespective of current climate action and future pathway. The temperature scenarios that appear logical at this point in time are 1.5°C and 2°C. The anticipated inundation due to sea level rise beyond 2°C appears so severe and widespread (see map series in Annexure 2) that it might not be worthwhile trying to identify options.

Resilient and sustainable development under climate change may be thought of as preparing for, coping with, or adjusting to climate changes and their associated impacts. To be able to do so, in a biodiversity rich area such as the Sundarban, a methodology needs to be identified that will allow selection of options keeping in mind direct trade-off between human activities and biodiversity conservation. The Portfolio Decision Analysis (PDA) framework offers that opportunity. The approach is similar to optimising financial portfolios, where natural resources and the built environment are considered natural and human assets respectively and allocation of management actions are optimised to maximise natural assets while minimising impact on human assets. Because the region in question is the Sundarban, despite the large human population, allocation of management actions are optimised to maximise natural assets. It is accepted that this is a value judgement and that others might wish to maximise human assets while minimising impact on natural assets.

The value of each asset varies over time as a function of climate conditions (sea level rise in this case) and management actions. Venturing into the details of the PDA framework is not intended here but the general steps are mentioned to serve as reference while evaluating the options for resilient and sustainable development. In general, the steps are: 1) identify natural and human assets of interest, 2) determine vulnerabilities of and risks to assets, 3) identify potential management action, 4) quantify the effectiveness value of management actions, 5) determine costs of management actions, and 6) determine an optimal set of management actions given costs and budget constraints. Steps 4 through 6 have been kept out of the ambit of this discussion paper.

In the case of the Sundarban, at the broadest level, the assets of interest are the tiger habitat that makes this mangrove patch unique in the world, and the adjoining human inhabited areas. For both the asset categories, vulnerability emanates mainly from sea level rise and the risk is permanent inundation accentuated by the possibility of more severe storms. Regarding protection from storm surges, Odd (1980) mentioned that it would be impractical to build embankments high enough to contain the waters from a peak surge occurring with spring tides. Instead, he proposed that each polder should contain special low lengths of embankments, which could be allowed to spill waters into the polders so that damage caused is reduced. In the villages prone to storm surges on the Arakan coast of Burma, artificial earthen mounds have already been constructed. Cyclones and storm surges, although not preventable, can at least be made less harmful and the suffering they inflict can be considerably diminished by timely action (Khalil, 1992).

At 1.5°C of warming Namkhana, Patharpratima, Hingulganj sub-districts (blocks) in India and Shyamnagar, Koyra and Dacope sub-districts (upazilas) appear to bear the brunt (Annex 2). A more detailed study would allow identification of affected Gram Panchayats and Union Porishods, and thus identification and quantification of the population at risk (Sub-districts marked in Orange in Annexure 1). Tiger habitat does not appear to be greatly affected so as to necessitate management action at this stage.

Given that the afore described scenario is decades away and the recorded rates of sea level rise is 18 mm/year at its highest and elevation recovery if permitted is higher by a factor of 10, elevation recovery in the sub-districts may be possible through controlled embankment breaches. Controlled breaching of embankments has been reported to restore elevation and relieve environmental problems in some sites in Bangladesh but there has not been a detailed scientific study of this process. Post Aila, Polder 32 (Dacope) experienced tidal flooding for two years resulting in a mean annual accretion rate of about 18 cm/yr. Of course, the sustained human suffering during the process and period of elevation recovery will have to be addressed. Also it has to be borne in mind that unless drastic mitigation action is implemented globally, greater inundation is in store at 2°C of warming towards the close of the century or after.

Multi Criteria Decision Analysis (MCDA) would be a valuable tool to decide whether elevation recovery as opposed to brackish water culture fishery and tourism is a better option (a separate discussion paper on tourism is available), while building homes and public infrastructure on artificially raised land or on stilts. Should culture fishery be the more optimal option, retraining the population and concerted support all along the value chain will have to be provided. Also, mangrove regeneration will have to be supported at strategic locations to serve as storm surge barriers

At 2°C of warming not only the extent of inundation of inhabited areas is much greater (apparently more in Bangladesh than in India), about half of the tiger habitat on the Indian side and about a quarter on the Bangladesh side are no longer available for tigers. It may be possible to create large mounds from dredge material in forested and no longer human inhabited areas for tigers to take refuge. The human dimension acquires a much bigger scale in this temperature scenario and planned retreat may be the most viable option. This of course raises questions regarding host locations for the displaced population and their livelihoods. Rapid urbanization and orienting to an urban way of life is possibly the way forward but it has to be carried out in a manner that the wellbeing of the displaced is improved and that of the host population is not compromised at the least.

While anticipating the future and preparing for it is necessary, current development deficit needs to be addressed as well. Service delivery is inadequate for the population to be productive up to its potential and the economy too small to support the population. Productive potential can be enhanced through better hygiene and health care delivery, and education. Water, sanitation and waste management are crucial for improving public and personal hygiene. These as of now are non-existent and are more of infrastructure requirements. Healthcare and education infrastructure exits but needs improvement. In both these sectors the human dimension is of greater significance. The current socio-cultural ecosystem is unattractive for health and education professionals to locate themselves in the Sundarban and the required ecosystem change is an intractable challenge as of now. The solution then lies in application of technology for bridging the distance.

The main economic activity being rain-fed paddy agriculture on degrading and shrinking land, remittances play an important role although it is not enough to transform wellbeing of the population. Agriculture output has to be and can be doubled provided land can be put to use during dry winter months which is currently constrained due to unavailability of irrigation. Rain water harvesting has been promoted by the government but this route cannot meet the demand for all the agricultural land that remains fallow during winter months. Desalinisation of either shallow subsurface water provided it does not result in greater subsidence or of creek water, and efficient irrigation could be a set of option but input costs would be higher and therefore high value crops rather than paddy has to be promoted. Support for the entire value chain has to be in place. This will expand the economy but bearing in mind that the region has between a few to several decades before sea level overwhelms the place, it would be worth investing in human capital that will provide not only immediate benefits but also in the long run. This has the added advantage of not only pulling people out of poverty but also physically out of a very vulnerable place. The urban places suggested earlier for hosting the displaced population could be the human capital building sites not only for the people of the region but from afar. One of the typical features of comprehensive development in Smart Cities identified by the Ministry of Housing and Urban Affairs, GoI is giving an identity to the city. For the Sundarban region, identity of these new habitations could be based on building human capital. In these habitations, homes and public infrastructure should be built on artificially raised land to deal with periodic flooding with rising sea level and more intense storms. Nearer to the coast, conserving and planting trees could create a buffer against storm surges. (Schiermeier, 2014).

DO THE OPTIONS NECESSITATE TRANS-BOUNDARY COOPERATION?

The options discussed in the preceding section can be categorised as under

Sl. No.	Options	Category
1	Storm surge management in polders and embanked islands	Physical
2	Elevation recovery through controlled breaching of embankments	Physical
3	Building homes and public infrastructure on artificially raised land or on stilts	Physical
4	Creating tiger refugia by raising land in forested and vacated islands and mangrove regeneration	Physical
5	Building human capital development sites	Physical
6	Building adequate infrastructure for brackish water aquaculture value chain	Physical
7	Retraining the population for commercial scale brackish water culture fishery	Capacity
8	Practice of brackish water culture fishery instead of paddy agriculture as predominant economic activity	Livelihood
9	Practice of tourism as predominant economic activity	Livelihood
10	Raising high value crops during placid dry winter months using desalinisation of either shallow subsurface water or creek water and efficient irrigation	Livelihood
11	Application of technology for enhanced service delivery in health and educations sectors	Miscellaneous
12	Addressing current development deficit	Miscellaneous

Strictly speaking, barring trans-boundary tourism as the predominant economic activity, and creating tiger refugia, joint management of the landscape is not a necessary precondition to resilient and sustainable development in the region. However, trans-boundary cooperation on all of the above would result in transformative benefits given relative strengths in different sectors in the two countries.

CO-MANAGEMENT/JOINT MANAGEMENT/SEPARATE MANAGEMENT (UNDER JOINTLY AGREED GUIDING PRINCIPLES) OF THE SUNDARBAN LANDSCAPE

The people of the Sundarban are among the most disadvantaged in West Bengal and in Bangladesh, as is evident from incidence of poverty, and delivery of public services. Nevertheless, over the past decade and a half, socio-economic indicators, public service delivery, and infrastructure have shown general improvement both in West Bengal and in Bangladesh. These gains are quickly lost in case of high intensity weather events as evidenced in the aftermath of cyclones Sidr and Alia. In times such calamitous events it is also evidenced that people informally cooperate across the border with supplies and knowhow. For instance, paddy seed varieties and cultivation practices besides materials of immediate relief are unselfishly shared. The Sundarban identity and solidarity is an asset that the two countries could leverage for wider consolidation of mutually beneficial relationship. Moreover, co-management/joint management or even separate management of the landscape under jointly agreed guiding principles of natural and cultural resource management, visitor use and interpretation, science and research, as well as relations with local populations would be beneficial for the currently disadvantaged people of the Sundarban.

Further reasons for cooperation are: (a) The Sundarban eco-region is globally significant and unlike any other mangrove site in the world because of the presence of Bengal Tigers and thus World Heritage on both side of the border. This makes it obligatory for the two countries to do all that they can for the maintenance of healthy and functioning ecosystems, which will become increasingly challenging due to high density settlement in the northern part of the landscape, and ongoing and projected relative sea level rise, likely to result in coastal squeeze unless jointly addressed; (b) Besides intrinsic value of healthy and functioning ecosystem, the goods and services derived are of great significance to the fishing community of the Sundarban that engage in estuarine/riverine fishing. The other valued resources are crabs, shrimp fry, honey and wax. In terms of services, Sundarban serves as the nursery for the northern Bay of Bengal fishery benefiting fishermen operating in open waters. The wave attenuation capacity of mangroves is well documented and in the absence of the vast mangrove forest spread over 10000 sq km the cost of protection of urban areas in the delta will be exorbitant; (c) It is not only the urban areas in the delta that are threatened but the development gains achieved in the rural areas particularly in the last decade and a half will likely be lost if the Sundarban cannot be co-managed; and (d) While mitigation efforts are being ramped up it must be

understood that mitigation only has the potential to keep these threats at a moderate rather than extreme level and therefore effects of climate change cannot be avoided which will pose critical challenges to governance and political systems that must be addressed jointly and proactively to avoid the catastrophic consequences of mass movement of distressed people that this part of the world has witnessed repeatedly in the not too distant past.

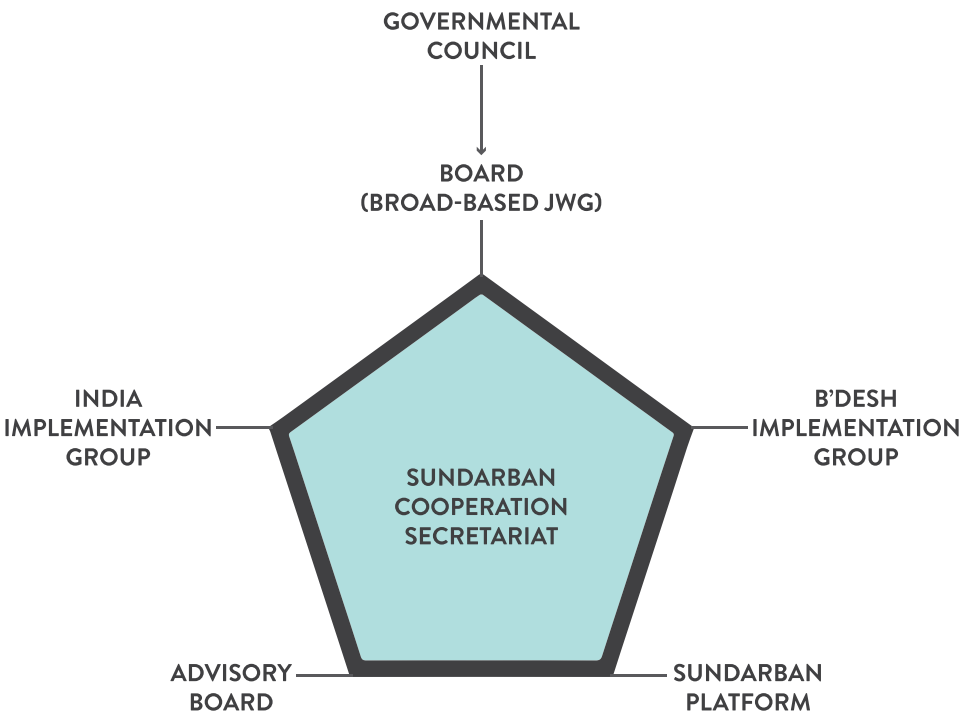
MECHANISM FOR CO-MANAGEMENT/JOINT MANAGEMENT/SEPARATE MANAGEMENT (UNDER JOINTLY AGREED GUIDING PRINCIPLES) OF THE SUNDARBAN LANDSCAPE

The proposed cooperation mechanism takes into account that (a) Primacy of the State is maintained; (b) Policy arm and implementation arm are separate; (c) Implementation arm is embedded in the respective Government machinery; and (d) A multi-tiered structure to account for the federal structure in India.

Mandate of the cooperation mechanism is to guide bilateral cooperation, precipitate and sustain joint action on (a) conservation of Sundarban to tackle endangerment and extinction, and to serve as vital natural protective barrier against flooding, tidal waves, and cyclones; (b) sustainable exploitation of natural resources for development and poverty alleviation; and (c) development of management plan(s) to address livelihood issues, flooding, climate related disasters, human-wildlife conflict, pollution, resource depletion etc.

Geographical scope of the cooperation mechanism encompass natural area of the Sundarban spanning Bangladesh and India consisting of Wildlife sanctuaries, Ramsar sites, National Park, Tiger Reserve, World Heritage sites, and jointly delineated human settlement areas adjoining natural areas (Article III of MoU 2011).

Memorandum of Understanding between the Government of the Republic of India and the Government of the People's Republic of Bangladesh on Conservation of the Sundarban was signed on 06 September 2011 which needs to be followed up by a cooperation agreement/treaty for the establishment of a bilateral institutional mechanism for cooperation and coordination, and financial commitments to fund the bilateral institutional mechanism.



The proposed structure/mechanism comprises of:

a. Governmental Council composed of Ministers of MoEFCC and MoFA Bangladesh, and MoEFCC and MEA India. The Council is meant to provide political/policy leadership; set boundary conditions; seek synthesised information; and provide resources. The council is meant to be the bilateral decision-making body on the Sundarban Landscape, maintaining primacy of the sovereign states.

b. Board/JWG+/Broad-based JWG composed of Secretaries of MoEFCC and MoFA Bangladesh, and MoEFCC and MEA India, Secretaries of other relevant ministries as decided by the Council, and five members biennially elected from among the Sundarban Platform for variety and to influence the direction of decision making. The Board will set the rules and standards, define activities, responsibilities, and timelines, adopt strategies, allocate resources, oversee operational and advisory

entities, ratify outcomes, and appoint key personnel of the Sundarban Cooperation Secretariat. The Board is meant to provide operational leadership to the Secretariat and monitor without active involvement. The Board will seek synthesised information from the Secretariat, and provide feedback to the Council.

c. The Secretariat is essentially the coordinating body staffed by professionals. It will receive directions from the Board, develop work plans in consultation with national Implementation Groups, and coordinate with these entities for implementation of work plans. It is meant to support the Board and the Council, communicate and coordinate with the Advisory Board as directed by the Council and Board. It will communicate and coordinate with national implementation groups, make reports and plans available for public consideration and deal with public concerns, as well as provide financial management services in case of third party funding that two governments agree to seek/receive. The Secretariat will bring together relevant local actors to the Platform from different sectors to develop context-specific approaches to deal with climate impacts on the Sundarban Landscape. The Secretariat will commission and coordinate collaborative research, seek information from the Platform on science, practices, debate outcomes and concerns, and provide synthesised information to the Board. It will produce policy documents/briefs and guidelines for national implementation groups as directed by the Board. It will admit members to the Platform, renew annual membership of Platform members, conduct biennial elections for non-state members of the Board (broad-based JWG), and convene half-yearly Platform meetings. The Secretariat will be tasked with the responsibility of organizing the biennial Sundarban Conference for the Council.

d. National Implementation Groups are to be composed of officials at the sub-national level (state and division respectively; e.g. West Bengal in India, and Khulna and Barisal Divisions in Bangladesh) from relevant government departments and other government entities including Panchayati Raj Institutions and their counterparts in Bangladesh. The groups are meant to implement the workplans developed by the Secretariat on the direction of the Board.

e. Sundarban Platform will be composed of elected representatives at the national and sub-national levels representing the Sundarban region (jointly delineated human settlement areas adjoining natural areas), as well as registered organizations with self-defined interests in the Sundarban Landscape, paying Annual Membership Fee, and admitted by the Secretariat after due diligence. The Platform is meant to share knowledge, science, and practices; undertake collaborative research; develop

context-specific approaches to deal with climate impacts; debate issues admitted by the Secretariat and advise the Secretariat.

f. Sundarban Advisory Board will be composed of domain experts to advise the Council and the Board when called upon.

Human history is replete with examples of institutions meant to manage the natural environment. However, the climate change problem calls for a continuously responding society. Societies will have to anticipate and respond to changes faster than before. Therefore, institutions need to allow and encourage society to continuously adapt to climate change. Institutions need to respond at a speed commensurate with changing climate. Thus, unlike in the past, the proposed structure provides space for active participation of interest groups (to influence the direction of decision making, and to develop context-specific approaches). Interest groups self-define themselves. The structure can accommodate views from the top (direction of cooperation, and boundary conditions) as well as from the grassroots (demand for certain actions and approaches), besides fostering collaboration and sharing of knowledge, science and practices. The structure is based on equal financial contribution from the two countries in the main, as well as annual contribution from interest groups.

The proposed structure is a balanced blend of hierarchical and horizontal arrangements. While hierarchical arrangements provide leadership (in the form of policy goals and resources), these may ignore new knowledge and innovative ideas. Horizontal arrangements on the other hand, lack authority but encourage different actors to collaborate and learn, and create opportunities to promote a variety of solutions to an identified problem. The structure brings together state and non-state actors in decision making but ensures that sovereign prerogative to set the agenda is not compromised.

Studies have found that for increasing institutional adaptive capacity, a combination of decentralized, participatory approaches with more top-down methods is useful (Gupta et al., 2016). However, it must be recognised that institutions/organisations are inherently change averse and unless deliberately designed with certain criteria these will not be able to deliver at a rate commensurate with the rate of environmental change. The institution/organization then, should be able to define systems of rules, decision-making procedures, programmes that give rise to social practices, assign roles to participants in these practices, and guide interactions among the occupants of the relevant roles (IDGEC, 1999). Institutions/organizations generally evolve over the long run but the current need is to be able to respond at a speed commensurate with changing climate. It is therefore proposed that the organization (Sundarban Cooperation Platform) encourage

variety (make space to incorporate different problem frames and solution strategies), allow for reflection and learning based on past experiences (mechanism for policy monitoring and revision), create room for autonomous change, encourage leadership for social responses (both long-term visionary leadership and pragmatic day-to-day entrepreneurial leadership), facilitate the generation of financial resources, help to establish a fair governance system taking into account legitimacy, equity, responsiveness and accountability.

The criteria for each of the six characteristics are:

Characteristic	Criterion	Definition
1. Variety	a) Variety of problem frames	Room for multiple frames of references, opinions and problem definitions
	b) Multi-actor, multi-level, multi-sector	Involvement of different actors, levels and sectors in the governance process
	c) Diversity of solutions	A wide range of different policy options to tackle a problem
2. Learning capacity	a) Trust	Mutual respect and trust among parties, levels and sectors
	b) Learning	Learn from past experiences and improve, ability to change assumptions
	c) Discuss doubts	Openness
	d) Institutional memory	M&E of experiences
3. Autonomous change	a) Continuous access to information	Access to institutional memory and early warning
	b) Act according to plan	Plans and scripts for action
	c) Capacity to improvise	Foster social capital, allow individuals to self-organise and innovate

Characteristic	Criterion	Definition
4. Leadership	a) Visionary	Space for long-term vision
	b) Entrepreneurial	Space for leaders who stimulate actions and undertakings
	c) Collaborative	Space for leaders who encourage collaboration among different actors, adaptive co-management
5. Resources	a) Authority	Legitimate forms of power
	b) Human resources	Availability of expertise, knowledge and human capital
	c) Financial resources	Availability of financial resources to implement policy measures
6. Fair governance	a) Legitimacy	Public support
	b) Equity	Fair institutional rules
	c) Responsiveness	Respond to societal requirements
	d) Accountability	Provide for accountability procedures

Given the pace of change in the Sundarban Landscape, attributed to impacts of climate change and other stressors, the proposed organizational structure for guiding bilateral cooperation on the Sundarban Landscape and precipitating/sustaining joint/common action would be an institution capable of responding at commensurate speed, and takes into account the six characteristics and the criteria under each.

The Joint Platform has to be agreed upon by the two governments (6a, 5a) and mandated to provide political/policy leadership (4a); set boundary conditions (4a); seek synthesised information (3a); and provide resources equally (5c, 6b). At the apex, this could be in the form a Governmental Council composed of ministers of MoEFCC and MFA, Bangladesh, and MoEFCC and MEA, India. At the next level could be a Board/Broad-based JWG to provide governance (6b, 6c, 6d), prepare, and adopt implementation strategy (3b),

oversee operational and advisory bodies, and appoint key personnel of Sundarban Cooperation Secretariat, the coordinating operational entity, at the level below. The Board could/should be composed of Secretaries MoEFCC and MFA, Bangladesh; MoEFCC and MEA, India, and 5 members elected biennially from among the Sundarban Platform (1a, 1b, 1c, 2c); to be chaired by the senior most Secretary by date of appointment irrespective of country, based on mutual trust (2a).

The Governmental Council and Board are essentially decision making entities. The decisions need to be implemented in the two countries either jointly or simultaneously (4c) which will require communicating and coordinating with the respective national implementation arms comprising of State/District level line departments and PRIs (in India) and their equivalent in Bangladesh. The coordinating entity may be termed as the Sundarban Cooperation Secretariat.

REFERENCES

Adger, W.N., K. Brown, D.R. Nelson, F. Berkes, H. Eakin, C. Folke, K. Galvin, L. Gunderson, M. Goulden, K. O'Brien, J. Ruitenbeek, and E.L. Tompkins, 2011. Resilience implications of policy responses to climate change. Wiley Interdisciplinary Reviews: Climate Change, 2(5), 757-766.

Alongi, D.M.,2009. The Energetics of Mangrove Forest. Springer, Netherlands

Auerbach, LW, et al., 2015. Flood risk of natural and embanked landscapes on the Ganges-Brahmaputra tidal delta plain. Nature Climate Change, 5(2):153-157; DOI: 10.1038/nclimate2472.

Bezuijen, M.R., 2011.Wetland Biodiversity & Climate Change Briefing Paper: Rapid Assessment of the Impacts of Climate Change to Wetland Biodiversity in the Lower Mekong Basin. Basin-Wide Climate Change Impact and Vulnerability Assessment for Wetlands of The Lower Mekong Basin for Adaptation Planning, RFP No. 10-240, Prepared for the Mekong River Commission (MRC) by the International Centre for Environmental Management (ICEM), Hanoi, Vietnam, 37 pp.

Boyd, E., H. Osbahr, P.J. Ericksen, E.L. Tompkins, M.C. Lemos, and F. Miller, 2008. Resilience and climatizing development: examples and policy implications. Development, 51(3), 390-396.

Branch, T.A., B.M. De Joseph, L.J. Ray, and C.A. Wagner, 2013. Impacts of ocean

acidification on marine seafood. Trends in Ecology and Evolution, 28(3), 178-186.

Brooks, N., W.N. Adger, and P.M. Kelly, 2005. The determinants of vulnerability and adaptive capacity at the national level and the implications for adaptation. Global Environmental Change Part A, 15(2), 151-163.

Chatterjee, S.,2004. Bird status survey of Sundarban Tiger Reserve. Naturalist, Journal of Prakriti Samsad. Vol 3: 51-68.

Chaudhuri, A.B. and Choudhury, A.,1994. Mangroves of the Sundarban, Volume 1: India. IUCN, Bangkok. 247 pp.

Cheung, W.W.L., V.W.Y. Lam, J.L. Sarmiento, K. Kearney, R. Watson, and D. Pauly, 2009. Projecting global marine biodiversity impacts under climate change scenarios. Fish and Fisheries, 10(3), 235-251.

Cheung, W.W.L., V.W.Y. Lam, J.L. Sarmiento, K. Kearney, R. Watson, D. Zeller, and D. Pauly, 2010: Large-scale redistribution of maximum fisheries catch in the global ocean under climate change. Global Change Biology, 16(1), 24-35.

Cheung, W.W.L., J.L. Sarmiento, J. Dunne, T.L. Frölicher, V.W.Y. Lam, M.L.D. Palomares, R. Watson, and D. Pauly, 2013. Shrinking of fishes exacerbates impacts of global ocean changes on marine ecosystems. Nature Climate Change, 3(3), 254-258

Danda, A.A., Gayathri Sriskanthan, Asish Ghosh, Jayanta Bandyopadhyay and Sugata Hazra, 2011.Indian Sundarban Delta: A Vision. New Delhi, World Wide Fund for Nature-India.

Ericson, J.P., C.J. Vorosmarty, S.L. Dingman, L.G.Ward, and M. Meybeck, 2006. Effective sea-level rise and deltas: causes of change and human dimension implications. Global Planet Change, 50, 63-82.

Forsyth, T., 2007. Promoting the “development dividend” of climate technology transfer: can cross-sector partnerships help? World Development, 35, 1684-1698.

Foufoula-Georgiou, E., J. Syvitski, C. Paola, C.T. Hoanh, P. Tuong, C. Vörösmarty, H. Kremer, E. Brondizio, Y. Saito, and R. Twilley, 2011. International Year of Deltas 2013: a proposal. Eos, Transactions of American Geophysical Union, 92, 340-341.

Gedan, K.B., M.L. Kirwan, E. Wolanski, E.B. Barbier, and B.R. Silliman, 2011. The present and future role of coastal wetland vegetation in protecting shorelines: answering recent

challenges to the paradigm. Climatic Change, 106, 7-29.

Gill, S.M., 1975. The Discovery of Bangladesh. Melksham, U.K.: The Offington Press, 138p.

Gilman, E., J. Ellison, and R. Coleman, 2007. Assessment of mangrove response to projected relative sea-level rise and recent historical reconstruction of shoreline position. Environmental Monitoring and Assessment, 124(1-3), 105-130.

Gilman, E.L., J. Ellison, N.C. Duke, and C. Field, 2008. Threats to mangroves from climate change and adaptation options: a review. Aquatic Botany, 89(2), 237-250.

Goodbred Jr., S.L., Kuehl, S.A., 1999. Holocene and modern sediment budgets for the Ganges-Brahmaputra river system: evidence for high stand dispersal to flood-plain, shelf, and deep-sea depo centers. Geology27 (6), 559-562.

Greenwood, C. J., Barlow, A. C. D., Ahsan, M. M., Islam, M. A., 2009. Sundarban Reserved Forest Protection Assessment: Target State, SEALS DPP preparation document, Wildlife Trust of Bangladesh and Zoological Society of London.

Gupta, J., Bergsma, E., Termeer, CJAM.,Biesbroek, GR., Van Den Brink, M., Jong, P., Klostermann, JEM., Meijerink, S &Noote boom, S. 2016. 'The adaptive capacity of institutions in the spatial planning, water, agriculture and nature sectors in the Netherlands' Mitigation and Adaptation Strategies for Global Change, vol 21, no. 6, pp. 883-903. DOI: 10.1007/s11027-014-9630-z

Hanebuth, T.J.J., Kudrass, H.R., Linstädter, J., Islam, B., Zander, A.M., 2013. Rapid coastal subsidence in the central Ganges-Brahmaputra Delta (Bangladesh) since the 17th-century deduced from submerged salt-producing kilns. Geology. http://dx.doi.org/10.1130/G34646.1.

Hussain, M.Z., 2014. Bangladesh Sundarban Delta Vision 2050: A first step in its formulation - Document 2: A Compilation of Background information, IUCN, International Union for Conservation of Nature, Bangladesh Country Office, Dhaka, Bangladesh, viii+192 pp

IDGEC Scientific Planning Committee, 1999. Institutional Dimensions of Global Environmental Change. IHDP Report No. 9, Bonn.

IPCC, 2007: Climate Change 2007: The Physical Science Basis. Contribution of Working

Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M.C. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, 1008 pp.

IPCC, 2012: Summary for Policymakers. In: Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 1-19.

IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1132 pp.

Khalil, G.M., 1992. Cyclones and storm surges in Bangladesh: Some mitigative measures. Natural Hazards, 6(1), 11-24.

Kintisch, E., 2013. Can coastal marshes rise above it all? Science, 341(6145), 480-481.

Knutson, T.R., J.L. McBride, J. Chan, K. Emanuel, G. Holland, C. Landsea, I. Held, J.P. Kossin, A. Srivastava, and M. Sugi, 2010. Tropical cyclones and climate change. Nature Geoscience, 3(3), 157-163.

Kroeker, K.J., R.L. Kordas, R. Crim, I.E. Hendriks, L. Ramajo, G.S. Singh, C.M. Duarte, and J.-P. Gattuso, 2013. Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. Global Change Biology, 19(6), 1884-1896.

Lambert, F.H. and M.J. Webb, 2008. Dependency of global mean precipitation on surface temperature. Geophysical Research Letters, 35.

Lemos, M.C., A. Agrawal, O. Johns, D. Nelson, and N. Engle, 2013. Building adaptive capacity to climate change in less developed countries. In: Climate Science for Serving Society: Research, Modeling and Prediction Priorities [Asrar, G.R. and J.W. Hurrell (eds.)]. OSC Monograph Reviews, Springer Science, Dordrecht, Netherlands, pp. 437-458.

Loucks, C., S. Barber-Meyer, M. Hossain, A. Barlow, and R. Chowdhury, 2010. Sea level rise and tigers: predicted impacts to Bangladesh's Sundarban mangroves. Climatic Change, 98(1-2), 291-298.

Milliman, J.D. and K.L. Farnsworth, 2011.River Discharge to the Coastal Ocean: A Global Synthesis. Cambridge University Press, Cambridge, UK, 384 pp.

Milliman, J.D., James M. Broadus and Frank Gable, 1989. Environmental and Economic Implications of Rising Sea Level and Subsiding Deltas: The Nile and Bengal Examples. Ambio, 18 (6), 340-345.

Mirza, M.M.Q., 2003. Climate change and extreme weather events: can developing countries adapt? Climate Policy, 3, 233-248.

Murty, T.S., Flather, R.A., and R.F. Henry, 1986. The storm surge problem in the Bay of Bengal. Progress in Oceanography, 16 (4), 195-233.

Murty, T.S. and Flather, R.A., 1994. Impact of storm surges in the Bay of Bengal. Journal of Coastal Research,12, 149-161.

Nguyen, K.D.T., S.A. Morley, C.-H. Lai, M.S. Clark, K.S. Tan, A.E. Bates, and L.S. Peck, 2011. Upper temperature limits of tropical marine ectotherms: global warming implications. PLoS ONE, 6(12), e29340, doi:10.1371/journal.pone.0029340.

Nicholls, R.J., P.P. Wong, V.R. Burkett, J.O. Codignotto, J.E. Hay, R.F. McLean, S. Ragoonaden, and C.D. Woodroffe, 2007. Coastal systems and low-lying areas. In: Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Parry, M.L., O.F. Canziani, J.P. Palutikof, P.J. van der Linden, and C.E. Hanson (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 315-356.

Odd, N. 1980. Mathematical Model Studies of the Irrawaddy Delta. Wallingford, U.K.: Hydraulics Research Station, 7p.

Overeem, I. and J.P.M. Syvitski, 2009. Dynamics and Vulnerability of Delta Systems. LOICZ Reports & Studies No. 35. GKSS Research Center, Geesthacht.

Prain, O. 1903.The flora of Sundarban. Records of the Botanical Survey of India 114: 231-272.

Reker, J.; Van Winden, A.; Braakhekke, W.; Vermaat, J.; Eleveld, M.; Janssen, R.; De Reus, N.; Omzigt, N. 2006. Deltas on the move: Making deltas cope with climate change. (Institute for Environmental Studies IVM VrijeUniversiteit, Amsterdam (Netherlands));

National Research Programme Climate changes spatial Planning (KlimaatvoorRuimte), p/aVrijeUniversiteit, Amsterdam (Netherlands).

Renaud,Fabrice G., James PM Syvitski, Zita Sebesvari,Saskia E Werners, Hartwig Kremer, Claudia Kuenzer,

Ramachandran Ramesh, Ad Jeuken and Jana Friedrich, 2013. Tipping from the Holocene to the Anthropocene: How threatened are major world deltas? Current Opinion in Environmental Sustainability, 5:644–654.

Rogers, K.G., Steven L. Goodbred Jr., Dhiman R. Mondal, 2013. Monsoon sedimentation on the 'abandoned' tide-influenced Ganges-Brahmaputra delta plain. Estuarine, Coastal and Shelf Science131, 297-309.

Rogers, K.G. and Steven L. Goodbred Jr., 2014. The Sundarban and Bengal Delta: the World's Largest Tidal Mangrove and Delta System in V.S. Kale (ed.) Landscapes and Landforms of India. Springer, New York.

Sanyal, P., 1999. Sundarban – the largest mangrove diversity on the earth. In: Sundarban Mangal. GuhaBakshi, D.N., Sanyal, P. and Naskar, K.R. (eds). Naya Prakash, Calcutta, India, pp. 428–427.

Schiermeier, Q. 2014. Holding back the tide. Nature, 508, 164-166.

Schmidt, C.W, 2015. Delta subsidence: an imminent threat to coastal populations. Environmental Health Perspectives 123.8 DOI: http://dx.doi.org/10.1289/ehp.123A204

Schipper, L. and M. Pelling, 2006. Disaster risk, climate change and international development: scope for, and challenges to integration. Disasters, 30(1 SI), 19-38.

School of Oceanographic Studies, Jadavpur University, 2016. Zones of Erosion In Indian Sundarban (1970 – 2015). Poster at India Pavilion at UNFCCC COP 21.

Siddiqi, N.A. and Baksha, M.W. (eds.). 2001. Mangrove Research and Development, Bangladesh Forest Research Institute, Chittagong.

Syvitski, J.P.M., 2008. Deltas at risk. Sustainability Science, 3, 23-32.

Syvitski, J.P.M., A.J. Kettner, I. Overeem, E.W.H. Hutton, M.T. Hannon, G.R. Brakenridge, J. Day, C. Vörösmarty, Y. Saito, and L. Giosan, 2009. Sinking deltas due to human activities. Nature Geoscience, 2(10), 681-686.

Vörösmarty, C., Syvitski, J. P. M., Day, J., Paola, C. & Serebin, A.,2009. Battling to save the world's river deltas. Bulletin of the Atomic Scientists. 65, 31–43.

Warner, K., S. Kreft, M. Zissener, P. Höppe, C. Bals, T. Loster, J. Linnerooth-Bayer, S. Tschudi, E. Gurenko, A. Haas, S. Young, P. Kovacs, A. Dlugolecki, and A. Oxley, 2012. Insurance Solutions in the Context of Climate Change-Related Loss and Damage. Policy Brief No. 6, The Munich Climate Insurance Initiative (MCII), hosted by the United Nations University Institute for Environment and Human Security (UNU-EHS), UNU-EHS, Bonn, Germany, 48 pp.

World Bank, 2010: Economics of Adaptation to Climate Change: Bangladesh, Vol. 1, Main Report. The World Bank Group, Washington, DC, USA, 102 pp.,climatechange.worldbank.org/sites/default/files/documents/EACC_Bangladesh.pdf.

ANNEXURE 1: GRAM PANCHAYAT/ UNION PARISHAD LEVEL HOUSEHOLD AND POPULATION OF SUNDARBAN LANDSCAPE

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
Satkhira District			
04- Assasuni Upazila	15- Anulia Union	5508	24710
	17- Assasuni Union	5432	23624
	25- Baradal Union	6520	28037
	34- Budhhata Union	6903	29540
	43- Durgapur Union	4021	16200
	56- Kadakati Union	3239	14120
	60- Khajra Union	5743	26046
	69- Kulla Union	5957	24562
	77- Pratap Nagar Union	6562	29250
	86- Sobhnali Union	6306	26703
	94- Sreeula Union	5846	25962
47- Kaliganj Upazila	13- Bhara Simla Union	5749	24621
	15- Bishnupur Union	4777	21927
	23- Champaphul Union	4357	16468
	31- Dakshin Sreepur Union	4478	17661
	39- Dhalbaria Union	4848	19840
	47- Krishnanagr Union	5573	25428
	55- Kushlia Union	5311	22955
	63- Mathureshpur Union	6040	26352
	71- Mautala Union	4189	18899
	79- Nalta Union	8270	34719
	87- Ratanpur Union	5628	23901
	94- Tarali Union	5689	22118

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
86- Shyamnagar Upazila	11- Atulia Union	6693	30412
	15- Bhurulia Union	4513	20039
	23- Buri Goalini Union	5760	24913
	31- Gabura Union	6762	31115
	39- Ishwaripur Union	7518	32831
	47- Kaikhali Union	5815	24608
	55- Kashimari Union	6452	26657
	63- Munshiganj Union	7206	31832
	71- Nurnagar Union	4003	18034
	79- Padma Pukur Union	5495	24653
	87- Ramjan Nagar Union	5045	21931
	94- Shyamnagar Union	7017	31229
Khulna District			
12- Batiaghata Upazila	11- Amirpur Union	3884	16282
	23- Baliadanga Union	4027	16813
	35- Batiaghata Union	4710	19460
	47- Bhandarkote Union	3966	15834
	59- Gangarampur Union	4651	18168
	71- Jalma Union	13243	59025
	83- Surkhali Union	6298	26109
17- Dacope Upazila	10- Bajua Union	3577	15753
	13- Banisanta Union	3398	14606
	21- Laudubi Union	2042	9222
	42- Dacope Union	1825	7047
	52- Kailashganj Union	3443	14516
	63- Kamarkhola Union	3559	13897

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	69- Pankhali Union	3735	15570
	73- Sutarkhali Union	7463	30060
	84- Tildanga Union	4095	17006
30- Dumuria Upazila	11- Atlia Union	7612	32236
	13- Bhandarpara Union	4077	16749
	20- Dhamalia Union	5170	22240
	27- Dumuria Union	6635	29242
	33- Gutudia Union	5971	26143
	40- Kharnia Union	4987	20585
	47- Magurkhali Union	3214	13891
	54- Maguraghona Union	5373	23115
	61- Raghunathpur Union	5935	25817
	67- Rangpur Union	4105	18053
	74- Rudaghara Union	5404	23148
	81- Sahas Union	4498	18647
	88- Sarappur Union	4122	16101
	94- Sova Union	4806	19708
53- Koyra Upazila	10- Amadi Union	7460	33184
	11- Bagali Union	8881	34477
	22- Dakshin Bedkashi Union	3881	16755
	55- Koyra Union	7788	33230
	72- Moharajpur Union	7156	31068
	78- Maheshwaripur Union	6911	29992
	94- Uttar Bedkashi Union	3673	15225

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
64- Paikgachha Upazila	16- Chandkhali Union	8963	37734
	27- Deluti Union	3817	15554
	33- Gadaipur Union	4802	19669
	39- Garuikhali Union	5620	22805
	44- Haridhali Union	5855	23415
	50- Kapilmuni Union	8230	33011
	61- Laskar Union	4590	20463
	67- Lata Union	2636	10856
	83- Raruli Union	6500	26152
	89- Sholadana Union	5072	22307
Bagerhat District			
08- Bagerhat Sadar Upazila	17- Baraipara Union	5991	25610
	25- Bemarta Union	5935	24595
	34- Bishnupur Union	5020	21593
	35- Dema Union	3825	15777
	51- Gotapara Union	5507	23155
	60- Jatrapur Union	4657	18899
	69- Karapara Union	7921	34127
	77- Khanpur Union	4169	16610
	86- Rakhalgachhi Union	3341	13428
	94- Shat Gambuj Union	5674	23522
34- Fakirhat Upazila	10- Bahirdia Mansa Union	3535	14673
	21- Betaga Union	3414	13447
	31- Fakirhat Union	6205	25076
	42- Lakhpur Union	4808	20415
	52- Mulghar Union	3414	14919

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	63- Naldha Maubhog Union	3691	16559
	73- Piljanga Union	4565	18975
	84- Subhadia Union	3501	13725
58- Mongla Upazila	23- Chandpi Union	4248	17662
	27- Burirdanga Union	3827	15311
	29- Chila Union	4362	17607
	59- Mithakhali Union	4292	17139
	83- Suniltala Union	2439	8832
	89- Sundarban Union	4277	16834
60- Morrelganj Upazila	10 - Baharbunia Union	4117	15889
	11 - Balaibunia Union	3195	11697
	17 - Banagram Union	2823	11126
	23 - Baraikhali Union	6484	22869
	29 - Chingrakhali Union	4472	15929
	35 - Daibagnyahati Union	4492	16790
	41 - Hoglabunia Union	5068	19910
	47- Hogla Pasha Union	2922	11861
	53 - Jiudhara Union	6183	22958
	59 - Khuolia Union	6605	27841
	65 - Morrelganj Union	2990	12530
	71- Nishanbaria Union	6460	27029
	77 - Panchakaran Union	3944	14945
	83 - Putikhali Union	3731	15065
	89 - Ramchandrapur Union	4337	15875
	95 - Teligati Union	3075	10521

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
73- Rampal Upazila	10- Baintala Union	5223	20639
	11- Banshtali Union	3435	13923
	17- Bhojpatia Union	2031	8078
	41- Gaurambha Union	4555	18794
	47- Hurka Union	1606	6283
	53- Mallikerber Union	2560	10348
	71- Perikhali Union	3641	14515
	77- Rajnagar Union	2612	10689
	83- Rampal Union	5895	24276
	94 -Ujalkur Union	6615	27420
77- Sarankhola Upazila	19- Dhansagar Union	4890	20821
	38- Khontakata Union	7622	31950
	57- Royenda Union	7601	32604
	76- Dakhinkhali Union	6179	24980
Barguna District			
09-Amtali Upazila	13-Amtali Union	5565	24155
	15-Arpangashia Union	3534	14873
	23-Atharagasia Union	5349	23444
	47-Chowra Union	4741	20802
	63-Gulishakhali Union	6457	28458
	71-Haldia Union	6836	29727
	87-Kukua Union	5652	24028
Taltali Upazila	39-Barabagi Union	4321	18399
	43-Chhotabagi Union	2932	13197
	79-Karaibaria Union	3095	12920

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	91-Nishanbaria Union	3226	12928
	94-Panchakoralia Union	2704	11490
	95-Sarikhali Union	1812	7804
	96-Sonakata Union	2921	11266
19-Bamna Upazila	23-Bamna Union	4694	20085
	47-Bukabunia Union	5453	21400
	71-Dauatala Union	5278	20693
	95-Ramna Union	4112	17386
28-Barguna Sadar Upazila	17-Aylapatakata Union	4730	19782
	19-Badarkhali Union	6390	26201
	28-Barguna Union	4742	20599
	38-Burirchar Union	6949	29542
	47-Dhalua Union	6082	25700
	57-Phuljhury Union	3251	13205
	66-Gaurichana Union	6483	27675
	76-Keorabunia Union	4185	17755
	85-M.Baliatali Union	7093	28944
	95-Naltona Union	4828	19705
85-Patharghata Upazila	11-Char Duani Union	6576	24563
	23-Kakchira Union	5650	20720
	35-Kalmegha Union	6939	25894
	47-Kathaltali Union	5137	19788
	59-Nachnapara Union	3251	12484
	71-Patharghata Union	7242	28491
	83- Raihanpur Union	3833	14810

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
Pirojpur District			
14 - Bhandaria Upazila	11 - Bhandaria Union	5722	25782
	23 - Bhitabaria Union	3732	15361
	35 - Dhaoa Union	4380	19481
	47 - Gauripur Union	4625	20408
	59 - Ikri Union	5183	21070
	71 - Nudmulla Union	5353	22355
	83 - Telikhali Union	5343	23702
58 - Mathbaria Upazila	15 - Amragachhia Union	5110	21090
	17 - Bara Machhua Union	2778	11808
	25 - Betmore Rajpara Union	4777	19873
	34 - Daudkhali Union	5036	20983
	43 - Dhanisafa Union	6110	28206
	51 Gulishakhali Union	4760	21096
	60 - Mathbaria Union	5166	22067
	69 - Mirukhali Union	5523	23402
	77 - Sapleza Union	7468	32469
	86 - Tikikata Union	6123	25585
	94 - Tushkhali Union	4006	17887
90 - Zianagar Upazila	15 - Balipara Union	6528	30399
	43 - Parerhat Union	4280	18488
	51 - Pattashi Union	6391	28330
			4068237

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
South 24 Parganas District			
Canning-I	Dighirpar	7390	33667
	Itkhola	6406	32587
	Matla-I	3588	15960
	Nikarighata	6810	34025
Canning-Ii	Atharobanki	6403	33459
	Kalikatala	4999	26397
	Motherdighi	9396	46403
Mathurapur-I	Abid Bhagabanpur	3406	16747
	Lakshmi-Narayanpur Dakshin	4844	24118
Jaynagar-Ii	Chuprijhara	9625	49107
	Monirhat	4647	22682
	Nalgora	2088	10373
Kultali	Deulbari Debipur	5182	26377
	Gopalganj	7238	35782
	Gurguria Bhubaneswari	6023	28079
	Jalaberia-I	4125	20138
	Jalaberia-Ii	3748	19203
	Kundakhali Godabar	5270	27916
	Maipith Baikunthapur	5178	26241
	Merigunj-I	2318	12908
	Merigunj-Ii	6017	32409
Basanti	Amjhara	5903	30237
	Basanti	6265	29320
	Bharatgarh	6681	30568
	Charavidya	5112	25056

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	Chunakhali	5494	26285
	Ful Malancha	7920	39230
	Jharkhali	5412	22343
	Jyotishpur	4103	19010
	Kanthal Beriya	5715	29240
	Masjid Bati	3515	15526
	Nafarganj	3602	15958
	R C Khali	6493	32719
	Uttar Mokamberiya	4603	21225
Gosaba	Amtoli	4140	17447
	Bally-I	3313	13124
	Bally-Ii	4308	18069
	Bipradaspur	4003	17226
	Chotomollakhali	4799	20236
	Gosaba	4485	18254
	Kachukhali	3357	13256
	Kumirmari	4344	17451
	Lahiripur	5531	22108
	Patharkhali	3403	16405
	Radhanagar Taranagar	5282	23953
	Rangabelia	3409	14706
	Sambhunagar	3471	16282
	Satjelia	4352	18081
Mathurapur-Ii	Dighpar Bakultala	3869	18168
	Gilarchhat	7739	36847
	Kankandighi	5368	24919
	Kautala	2855	13589
	Kumrapara	3654	17682

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	Nagendrapur	4689	23069
	Nandakumarpur	5258	27070
	Radhakantapur	1769	8442
	Raidighi	5606	27240
Kakdwip	Bapuji	4672	22421
	Madhusudanpur	4230	20096
	Pratapaditya Nagar	7237	32932
	Rabindra	5479	26400
	Ramgopalpur	4224	18194
	Rishibankim Chandra	5954	26763
	Sri Sri Ramkrishna	6922	33847
	Swami Vivekananda	8420	38251
Sagar	Das Para Sumatinagar-I	4603	22793
	Das Para Sumatinagar-Ii	4280	20725
	Dhablat	6407	29439
	Ganga Sagar	6401	32470
	Ghoramara	1095	5193
	Muriganga-I	4434	20544
	Muriganga-Ii	4555	21279
	Ramkar Char	6159	30844
	Rudra Nagar	5782	28750
Namkhana	Budhakhali	6058	26815
	Fresherganj	5479	24554
	Haripur	5689	24626
	Moushuni	4014	19241
	Namkhana	7389	31913
	Narayanpur	5789	25550
	Shibrampur	7015	30131

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
Patharpratima	Achintyanagar	5619	25845
	Banashyamnagar	4000	19585
	Brajaballavpur	4796	23215
	Dakshin Gangadharpur	5300	27548
	Dakshin Roypur	3368	16089
	Digambarpur	5380	26930
	Durbachati	3922	18788
	G Plot	6356	28992
	Gopalnagar	3430	16700
	Herambagopalpur	4700	22352
	Laxmijanardanpur	4427	18900
	Pathar Pratima	6365	30807
	Ramganga	4308	20340
	Sridharnagar	3914	18616
	Srinarayanpur-Purnachandr	3756	17116
North 24 Parganas District			
Haroa	Gopalpur-I	5055	21692
	Gopalpur-Ii	3672	18173
	Kulti	6564	30732
Minakhan	Bamanpukur	5279	24033
	Chaital	5874	26358
	Champali	4432	17949
	Minakhan	6767	31249
	Mohanpur	5149	21658
Sandeshkhali-I	Boyermari-I	3881	16935
	Boyermari-Ii	4378	20069

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
	Hatgachhi	4638	20421
	Kalinagar	5509	23348
	Nazat-I	2216	10028
	Nazat-Ii	6210	27138
	Sarberia Agarhati	5697	26430
	Sehara Radhanagar	4815	20096
Sandeshkhali-Ii	Bermajur-I	2979	13136
	Bermajur-Ii	4360	19327
	Durgamandap	5642	24764
	Jeliakhali	5229	22623
	Khulna	4300	18010
	Korakati	5570	23606
	Monipur	5223	21200
	Sandeshkhali	4468	18310
Hasnabad	Amlani	5677	24245
	Barunhat Rameswarpur	5232	21533
	Bhowanipur-I	2668	11031
	Bhowanipur-Ii	3977	16881
	Hasnabad	4078	15756
	Patlikhanpur	5377	22033
Hingalganj	Bishpur	5485	21339
	Dulduli	6108	22676
	Gobindakati	4594	17032
	Hingalganj	4543	17121
	Jogeshganj	5761	21616
	Kalitala	4654	17584
	Rupamari	3680	15081
	Sahebkhali	4943	18489
	Sandeler Bill	6280	23607

Name of Upazila	Name of Union	Household no.	Population (Census 2011)
			3103822
Total			7172059

ANNEXURE 2: WHICH SEA LEVEL WILL SUNDARBANS LOCK IN?

The following maps show sea levels locked in by different amounts of carbon pollution, according to recent scientific research. If the world burns enough fossil fuels to heat the planet by 4°C it could drown much of Sundarbans, the Ganga tidal plain (West) in particular. If a rapid transition to a global clean energy economy is made to achieve the main goal of the Paris Agreement, limiting warming to 2°C, some parts of the Sundarbans (more of the forested than inhabited) will be saved.

Sea levels do not respond instantly to warming, once carbon pollution enters the atmosphere, it continues heating the planet for thousands of years. That is what scientists call locked-in or committed warming and sea level rise.

How long would it take for sea level rise? There is no certainty about the rate of sea level rise but recent research says that without cutting carbon pollution, the world could witness more than 6 feet (2 meters) this century, and reach 20 feet (6 meters) in the next.

The purpose of the maps is to provide a picture of post-2100 sea level rise threatened by different levels of carbon pollution, to inform public discourse and policy dialogues about the future of the Sundarbans. It is not meant as a planning tool.

At 1°C of global average warming since 1880

At 1.5°C of global average warming since 1880

At 2°C of global average warming since 1880

At 3°C of global average warming since 1880

At 4°C of global average warming since 1880

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