CONCLUDING REMARKS

The south-western Sundarban region is a place where dense human population coexists with extensive and biologically productive mangrove ecosystem. The interplay of an estuarine system, tidal and wave action, monsoonal rainfall and loss of drainage through high siltation has formed a diverse geomorphology in this region. The mangroves provide the livelihood to millions of people residing here and support a high biodiversity. However, the mangrove ecosystem is threatened from ongoing climatic change and anthropogenic pressure, resulting in significant loss and degradation of the mangrove areas.

In this research work, the geomorphology, hydrology, climate, soil characteristics and the environment of two selected islands in the south-western Sundarban region are assessed. The selection of the two islands is done in a way so that they together can serve as a microcosm of the larger south-western Sundarban region. As a consequence of such a selection procedure, there is much contrast in the characteristics of the two islands. However, even through the contrasting features, certain common aspects are observed in the analysis of the various geo-environmental settings of the two islands, which reflect the ongoing changes in the geo-environmental settings of the broader south-western Sundarban region, and point to the potential state of the future environment of this region.

The geomorphology of the two islands exhibits a diverse set of features, including tidal flats, sea beach, salt marsh, mangrove swamps, saltpans, etc. Also, the different geomorphic settings have different mangrove characteristics. In the Patibania island, the westernmost zone along the seashore has undergone top soil removal due to the advancing sea. To the east of this zone, the vegetation is stunted and sparse with a low number of species, which is due to less nutrient transport, infrequent tidal inundation and less amount of siltation. Next to this zone, there is the saltpan zone with stunted growth of mangroves. The surrounding zone of the saltpan areas is full of saltmarsh and dwarf mangroves. This zone has high moisture content due to the presence of a network of creeks and canals. Next to this zone on the easternmost side of the island, the drainage is well-regulated by the Edward's creek. Consequently, a densely forested area of mangroves has developed here. In the Henry's island the top soil removal zone is present in the eastern part along the seashore, again due to the advancing sea. In the zone next to the top soil removal zone, vegetation is sparse due to lack of tidal inundation. Next to this zone, there is a moderately vegetated zone with high salt tolerant species of mangroves and salt marshes. Adjacent to this zone, there is a saltpan zone with sparse vegetation and barren surface. However, in the area surrounding the saltpan zone, restoration of mangrove habitats is

initiated.

Among the geomorphic features, the saltpans are accorded particular attention due to the unfavorable environment for mangrove growth found there. Saltpans form in the topographic depressions in the interior of the islands. The inter-granular space of the soil surface there gets reduced due to the high rate of siltation from stagnant tidal water in the depression. This diminishes the water infiltration rate in the soil from both lateral water flow (tidal water) and vertical water flow (rainfall). This enhances the surface water storage capacity, and eventually the accumulated water gets evaporated in the presence of extreme evaporative condition leaving the salt crystals on the soil surface. This process expands the saltpan area over time. Most of the freshwater influx in this region occurs through the monsoonal rainfall, which is often unable to balance the effect of the year-round evaporation. This further aids in the expansion of the saltpans.

The expansion of saltpans has negative implication for the future growth of mangroves as very few plant species can tolerate the very high level of salinity present in the saltpans. Most of the mangroves, though halophytic in nature, cannot tolerate that high salinity. So, steps are required to be taken to prevent further expansion of the saltpans, and then regenerate the degraded mangrove habitats in the saltpan regions. One of the most effective ways to achieve this is by preventing surface water storage in the saltpan regions. This is be realized by joining the depressions where the saltpans have formed with the drainage network in the islands. The micro-morphometry of the saltpans can be controlled by the development of high salt tolerant mangrove colonies in the saltpan regions if the freshwater and nutrient rich soil are added in the degraded mangrove systems during the tidal overflow. The topsoil may also be removed to decrease salinity.

The hydrology of the two islands is principally determined by tidal action. The amount of perennial freshwater inflow from the Hooghly estuarine system is relatively small, while the monsoonal rainfall, though considerable in amount, is seasonal. Evidences of both erosion in the seashore and accretion of sediment on the inland creeks are observed. Ironically, both of these erosion and accretion activities negatively affect the mangrove ecosystem. The erosion of the seashore regions remove the soil substrate on which the mangroves stand, while the sedimentation in the creek beds cause tidal drainage loss, reducing water inflow in the inner parts of the islands and consequently depriving the mangroves there of adequate water.

The drainage networks in the islands are augmented by constructing artificial ditches and

ridges in the interiors of the islands. Those ditches and ridges also serve as mangrove plantation zones. However, in many places, particularly in the saltpan regions, the constructed ditches and ridges become degraded due to lack of maintenance. During high tides, sediment rich tidal water enters these ditches and causes heavy siltation. Ditches need to be maintained properly, because they are easily silted during high tide when they get filled with sediment rich water. The empty ditches should be dredged to clear them of accumulated silts.

It is observed that the temperature in the south-western Sundarban region is following a positive trend, while the rainfall is exhibiting a negative trend. This indicates that the future climate in this region will be potentially warmer and drier. These are likely signs of the ongoing climate change. It is also observed that mangrove vegetation is adversely affected by the rise in temperature and the decline in rainfall. These observations together indicate further mangrove degradation due to climate change.

The frequency of cyclones and storm surges has also increased due to the ongoing climate change. The storm surges inundate significant portion of the islands. The wash process associated with the storm surge inundation causes nutrient loss from the soil, while also increasing the salinity in the saltpan areas of the islands. The rising sea level causes the removal of nutrient rich topsoil in the colony of frontal mangroves along the seashore, which adversely affects the mangrove habitat there.

Natural siltation process regulates the soil nutrients and creates condition for the peaty soil development and organic matter concentration under the floral cover. That is why the physical setting of the bank margin areas or the natural level banks and adjacent bank shores have dense forest mangroves. Mangrove density reduces as one moves towards the interior of the islands, as their the water intrusion and siltation diminish.

The local human population is very dense and principally depend on the mangroves for their livelihood. However, the environment has degraded due to the high population pressure. The anthropogenic influence cause stress and deterioration in the environment in two principal ways. Firstly, the mangrove habitats are cleared for the expansion of human activities, and secondly, the water needs are almost exclusively met through groundwater extraction, and the amount of groundwater extraction has reached unsustainable level causing deep falls in the groundwater table. It is observed that even the monsoonal rainfall is unable to compensate for the quantity of groundwater extracted throughout the year.

The problem of eutrophication is also worsened due to anthropogenic influence. Fertilizers

and other nutrients spread from the aquacultural plots and agricultural lands and get accumulated within the pan areas. This causes excess nutrient concentration and creates eutrophication. The resulting spread of algal mats reduces the water infiltration rate in the soil. Consequently, the growth of the mangrove is hampered and the natural restoration process of mangroves is also disturbed. This causes the vegetation dieback in the central parts of the islands where the pan areas are located.

Mangroves are invaluable for their biodiversity, as an efficient terrestrial carbon storage and the ecosystem services they provide. Significant loss of the Sundarban mangroves would endanger the livelihood of millions of poor people. So, it is imperative that proper strategies are developed and implemented for the preservation and restoration of mangroves in Sundarban. Towards this aim, artificial canals and mangrove plantation are already observed to have some positive impacts. For mangrove plantations, care should be exercised to choose the appropriate species based on the geomorphic settings, soil characteristics and particularly salinity in the site of the plantation.

The changing climatic and hydrological conditions cannot be controlled as they are natural processes. However, anthropogenic damages can be controlled by proper regulations and social and economic initiatives. It is in the interest of the local populace that the mangroves are preserved, because they are their source of livelihood. Further damages to the mangrove habitat due to expansion of human activities should be prohibited. Initiatives should be taken to reverse the damages of the unsustainable exploitation of groundwater. Surface water storage spaces should be developed for freshwater conservation. They would also aid in recharging groundwater levels.

Mangroves are by nature adaptive to changing environmental conditions. However, there is a limit to the stress they can withstand. The increasing trend of temperature, the decreasing trend of rainfall and over-exploitation of resources all point to the urgency of a sustainable development scheme in this region. Because human livelihood is intertwined with the mangrove ecology here, it is crucial for the success of any conservation strategy to incorporate the human angle in its setup. Adopting a sustainable development plan ensuring the preservation and restoration of the mangroves along with the betterment of the populace dependent on the mangrove ecosystem is the need of the hour.