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H. S. Sen *Editor*

The Sundarbans: A Disaster-Prone Eco-Region

Increasing Livelihood Security

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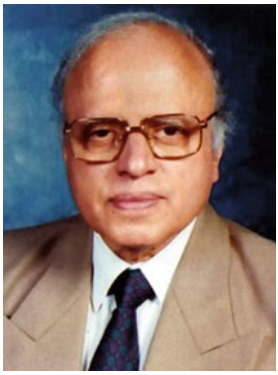
I dedicate the book in memory of my ***Mother, Arati Sen****, a teacher in mathematics, a great knowledge-seeker and human, infusing through her silent acts, forthrightness and motivation for higher studies not only in me but also the greater family members and beyond, particularly the women, that went a long way*

Foreword



Sundarbans is the largest delta in the world and shared between Bangladesh and India on the coast of the Bay of Bengal. It is adjacent to the border of India's Sundarbans World Heritage site inscribed by UNESCO in 1987. It contains the world's largest mangrove forest and is possibly one of the most biologically productive of all-natural ecoregion. It is located at the confluence between Ganges and Brahmaputra and supports a wide range of flora and fauna including several species threatened with extinction. The mangrove forest is divided as 66% under Bangladesh and 34% under India. The delta has 0.1% of the global population with high population density. It covers 133,010 ha area including 55% forest land and 45% wetlands in the form of tidal rivers, creeks, canals and estuaries.

Being highly populous, the contiguous area, spread over the two countries, with large number of soil- and water-related constraints, suffers seriously from the productivity in agriculture and aquaculture being the two major professions threatening the livelihood security of the inhabitants. The problems limiting the productivity and its sustainability, as well as damage to wealth and properties, tend to

become even more perilous because of climate change and frequent occurrence of storms and cyclones, which appear to become still more acute in time to come. The ecological balance of the area being essentially coastal is highly dynamic, sensitive and fragile in nature. The problems being transboundary in nature with several deteriorating factors, which are not only complementary in nature but also mutually dependent between the countries, affect the ecological balance and livelihood security of the populace. Although commendable progress in research has been made in individual countries, the validity of most may not be tenable spatio-temporally for the lack of a unified approach with both countries taken as a single unit. No attempt has been made so far in this direction with full regards to ecology and geopolitical sovereignty of both.

The book bearing the title *The Sundarbans: A Disaster-Prone Eco-Region – Increasing Livelihood Security* with Dr. H.S. Sen, having 26 years of experience of research and extension in Sundarbans, as the Editor, makes an attempt in the direction through threadbare discussion based on significant inputs on diversified areas received from experts in Bangladesh and India. I endorse such a publication and wish him every success in his endeavour for better planning by scientists and policy-makers of both countries.

Founder Chairman, Ex-Member of Parliament (Rajya Sabha), M. S. Swaminathan Research Foundation, Chidambaram, Tamil Nadu, India

M. S. Swaminathan

Preface

The Ganges delta, popularly known as Sundarbans, is one of the largest river deltas in the world. The rivers Ganges and Brahmaputra flow into the delta from the northwest and the north. The delta is distributed over major parts of Bangladesh and the southern part of West Bengal (India). At the extreme south, along the Bay of Bengal, the delta is roughly 360 km wide. Its total area is ca. one million hectares, roughly 55% of which is covered by forest, and it is distributed over both countries, with 60% in Bangladesh and 40% in India. With increasing population pressures, deteriorating hydrological conditions in the rivers and other anthropological factors, along with the trend of seawater rise vis-à-vis global warming, the majority of the area remains highly fragile and ecologically unsustainable. The productivity of agriculture and aquaculture, the principal sources of income for the majority of the population, is generally poor because of various constraints, which, along with ecological vulnerability, are responsible for the abject poverty and uncertain livelihood of the local inhabitants.

There is an urgent need to holistically assess the entire problem, which is essentially of a transboundary nature, so much so that the problems and solutions of the two countries are not only mutually dependent but also complementary; accordingly, this book attempts to devise a future roadmap for higher and sustainable productivity and improved livelihood status in this area. Obviously, any future steps for improvement should be of mutual benefit to both countries, more specifically the tide-dominated ecoregion. The latter acts as a sink for the entire river system, which originates thousands of miles upstream in India. Unfortunately, to date, no such attempt has been made in earnest, to the detriment of both countries. This being the crux of the issue, the present book addresses it by means of a multipronged approach.

The book encompasses analyses of various risk factors related to geohydrological, climatic, natural, biodiversity, socioeconomic and anthropological aspects of the Sundarbans ecoregion; further, it discusses strategies for disaster risk management and sustainability in natural resource management including agriculture, aquaculture and forestry for ecological sustenance, along with their impacts on

livelihood security, and, lastly, suggests future pathways for improved socioeconomy using interventions in both farm and non-farm sectors and in a transboundary mode cutting across political borders. The book includes several chapters authored by eminent scientists and practitioners specializing in the respective areas in both countries. A chronological review of societal transformation and related approaches to various livelihood patterns followed over the ages, with subsequent chapters on modern-age professional practices in agriculture, land and water management, sweet and brackish water aquaculture and mangrove ecosystem management, is presented – and all of these aspects, along with non-farm activities like transboundary ecotourism, together with their respective impacts on the economic growth of the inhabitants and the improvement of their livelihood, are discussed. The book places considerable emphasis on characterizing Sundarbans in terms of its dynamic behaviour, on the one hand, including the continual changes in several islands due to erosion and accretion in the riverbanks under changing surface-water hydrology in rivers and tide-fed estuaries, and on suggesting estuary management interventions in order to augment the freshwater supply, improve drainage and reduce bank erosion. On the other hand, the book highlights the challenges involved in combating future adversities in the ecoregion. Recent climate change-induced disasters, along with the relief measures undertaken and their impacts on biodiversity and livelihood, are discussed. In a departure from the common trend, the book includes an inventory of algal dynamics and examines their role as climate change proxies in a separate chapter. Further, it addresses the use of remote sensing satellites as a state-of-the-art technology for disaster management and monitoring ecological disturbances and landmass changes.

On the whole, I am forced to agree with what Dr. Uttam Kumar Mandal and his associates determine in their chapter in this book, namely, that conditions in Sundarbans are gradually becoming untenable due to climate change, the deteriorating hydrological balance of its rivers and streams, unscientific anthropological interventions, etc. Climate change appears to be irreversible, making the whole situation highly complex and adding to a host of previous constraints on the ecoregion's soils and waters, thereby further limiting the productivity of agriculture and aquaculture. Nevertheless, the question before us remains, whether it is technically possible to achieve 'improvements in farm productivity' by addressing these challenges. Alternatively, we may choose to content ourselves with 'subsistence farming' and nonetheless ensure the local inhabitants' livelihood security. The solution in this direction, though difficult, is not impossible if a holistic approach is pursued. In this regard, it is of utmost importance, as Prof. M.M.Q. Mirza and associates urge, to integrate the climate change policies of the two countries, and possibly Nepal also, all of which share the Ganges-Brahmaputra-Meghna (GBM)

basin, under the aegis of the South Asian Association for Regional Cooperation (SAARC), in order to address key concerns and vulnerabilities and discuss all related issues jointly. I strongly endorse the view that Bangladesh and India should work hand in hand to mitigate these miseries and find tangible solutions for improved and sustainable livelihood. The book seeks an answer in this direction.

West Bengal, India H. S. Sen

Acknowledgements

I began my engagement with Sundarbans in West Bengal, India, as a junior research worker at the Central Soil Salinity Research Institute (under the Indian Council of Agricultural Research, DARE, Government of India), Regional Research Station, Canning Town, West Bengal, India, in late 1971. The Research Station was regarded as the main centre for addressing the problem of coastal saline soils, which was affecting a number of Indian states, although our main focus remained with Sundarbans in order to characterize and suggest pathways to solve its (both then and now) massive and complex problems. In the absence of any scientific information, we started from scratch and, in the process, found ourselves working with various researchers and local inhabitants, including many working in agriculture and allied sectors in Sundarbans.

Amongst my colleagues in the academic world, I am deeply grateful to many, but will not venture to name them all, lest I leave out many important ones. Yet, I would be remiss in my duties if I did not pay my deepest respects to the late Dr. J.S.P. Yadav, a former director of the institute. Dr. Yadav was a true *doyen* in the field of agricultural science, and I drew my inspiration from him to always look ahead with a positive mindset. He was my mentor in every sphere of my academic activities. I am honoured to pay my heartfelt respects to him through this book. There were many amongst my contemporaries whose love and affection, and often criticism, constantly helped me to forge ahead. In this regard, I would like to above all recognize the silent yet subtle presence of my tried-and-true friend Dr. A.R. Bal, a plant physiologist who is now battling against a dreaded disease, and to express my heartfelt thanks for his constant and affectionate support.

During my long involvement with Sundarbans, spanning from 1971 to 2002, I encountered scores of people in the region's farming and non-farming sectors and was taken aback time and again by their at-times catastrophic economic and social conditions, living so close and yet so far from Kolkata, one of India's metropolises. During my initial stay, there were waterways, though primitive, connecting the major islands. During my first 15 years working in the region, these waterways disappeared, first slowly and then completely, due to a lack of management and

complete disregard for the local ecology, resulting in the unabated sedimentation of the rivers.

The inhabitants of Sundarbans have observed this and other developments and have often swallowed the bitter pill with little protest, leaving their fate to destiny and perhaps assuming that these changes were inevitable. Through this book, I wish to pay homage to the inhabitants of both countries in the farming and non-farming sectors in Sundarbans, who have been battling against all odds, silently but undaunted, for hundreds of years; their fighting spirit is a source of inspiration that moved me to serve them to the best of my abilities, in the hope that good sense will someday prevail with the authorities concerned, helping them find a lasting solution for livelihood security based on ecological approaches.

I am also deeply indebted to the contributing authors, one and all, for their untiring efforts to prepare the chapters despite their busy schedules. This would never have been possible without their belief in the purpose for which this joint venture, bringing together authors from Bangladesh and India, was conceived and put into practice. In the same breath, I greatly appreciate and wish to acknowledge the valued support I received from Dr. Dipankar Ghorai, SMS and Programme Coordinator (Acting), Krishi Vigyan Kendra, ICAR-CRIJAF, Budbud, Bardhaman, West Bengal, throughout the compilation and editing processes. I also wish to thank my late mother, a mathematics teacher, who was my spiritual guide. She constantly inspired me through her silent acts of morality and integrity and encouraged me to take up higher studies. In turn, the other woman who I have to thank for the accomplishments in my research career is my wife, Dr. Paramita Sen, a researcher turned physics teacher, who always gave me her candid support and encouragement, often sacrificing her own personal and academic interests in the process. Her unflagging reassurance has been, and continues to be, an invaluable source of support.

Similarly, I have enjoyed the support and patience of my son, a medical practitioner, and my daughter-in-law, another mathematics teacher, without which this endeavour would never have been a success. Not to mention my 2-year-old granddaughter, Arshi, who, buzzing around all the time, often had to do without a hug from, and some quality time with, her grandpa (who she calls dada). I am thankful to them all for bearing with me throughout the last 18 months and for exempting me from the major domestic chores during the preparation of this book.

H. S. Sen

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About the Editor

H. S. Sen is the former Director of the Central Research Institute for Jute & Allied Fibers (CRIJAF – a unit under the Indian Council of Agricultural Research under the Ministry of Agriculture, GoI), located at Barrackpore, West Bengal. He joined the research service after completing his MSc and PhD at the Indian Agricultural Research Institute, New Delhi, in 1971 and retired from regular service on superannuation on 31 January 2008.

During his career Dr. Sen was exclusively devoted to research, especially in the fields of water management and soil salinity related to coastal ecosystems during 1971–1976 and 1982–2002 at the Central Soil Salinity Research Institute, Regional Station Canning Town, which is located in the heart of the Sundarbans. His research on water management and soil salinity aspects on coastal Sundarbans covered a large number of areas on salt and water dynamics in soils, irrigation and drainage methods and applications, nutrient use efficiency under nitrogenous fertilizer use, and crop management under stressed environment. Between 1976 and 1982, he was involved in research in the field of water management under rice-oriented cropping systems at Central Rice Research Institute, Cuttack, Orissa. At CRIJAF, he was exclusively devoted to Research Management and Administration under the mandate "Productivity and Quality Improvement of Jute & Allied Fibers" with emphasis on Ecology and the Environment.

Lately, Dr. Sen has devoted his postretirement period to planning for future research strategies and livelihood securities in the tidal-dominated lower Ganges Delta

covering India and Bangladesh. He has also authored a book on this topic and a chapter in a book on a similar topic. Recently, he has also authored several papers on the drying up of the Ganges and its consequences on the deteriorating ecology in the lower delta in India and Bangladesh. In addition, he gives attention to climate change and its impact on water management, along with suggestions for possible remedies thereof for sustained productivity, as well as the role of climate change on oceanic hazards damaging coastal ecosystems at a global scale. He has published over 165 research papers, has guided 5 students for the PhD, and has been a post-graduate teacher at the University of Calcutta for 26 years. He also serves as a regular reviewer of leading journals. In 1999, Dr. Sen received a National Award on rainfed management in the Sundarbans.

Part I
Sundarbans – A Dynamic Ecosystem Meddling with Environment

Sundarbans in wilderness (Courtesy R. N. Mandal)

Chapter 1
The Sundarbans: A Flight into the Wilderness

H. S. Sen and Dipankar Ghorai

Abstract The Sundarbans is an agglomeration of about 200 islands, separated by some 400 interconnected tidal rivers, creeks and canals spanning across two neighbouring countries of India and Bangladesh. It is the habitat of world's largest contiguous mangrove forest and abode for the enigmatic Royal Bengal Tiger. The area, over time, has been continuously truncated in size and at present it is approximately three-fifths the size of what existed 200 years ago (about 16,700 km^2), the rest having been cleared and converted for agriculture and allied activities. Of the present expanse of 10,217 km^2, 4262 km^2 (41.7%) is in India. About half of the area in India (2320 km^2) is land mass. The rest 5955 km^2 (58.3%) is in Bangladesh. The eco-region has huge ecological significance in terms of the deluge of ecological services and functions for human welfare. But unbridled and naive anthropogenic avarice is taking a heavy toll of Sundarbans' resources in both the countries ripping people of the region off their precious livelihoods. There is a need for concerted efforts by all players transcending the international border for its ecological sustenance. A succinct overview of Sundarbans comprising of its structure, its historical progression, its ecological and economic value, its challenges and livelihood of people in it is chronicled in this introductory piece for the book.

Keywords Sundarbans · Livelihood · Community based tourism · Challenges · Recurvature of storm · Ecological value

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1.1 Introduction

> *To subdue Nature, to bend its forces to our will, has been the acknowledged purpose of Mankind since human life began, but the time has come for a revision of our conception of the benefits and responsibilities of holding dominion over all other created things*. (The Royal Bank of Canada Monthly Letter, Vol 41, No. 4 (May 1960))

History asseverates that evolution of *Homo habilis* to *Homo sapiens* has been a perpetual struggle of taming the untamed. First, it was struggle for existence, then it became necessity in order to colonize, and finally, to this present day, to an astounding avarice for exploitation – a tale of Nature accommodating Man changing to Man exterminating Nature. The consequences may be gravely disconcerting, at least the indications are so. All of World's pristine, and thus far virgin, ecosystems, or eco-regions, have been invaded to gain social and economic mileage mindlessly, altogether ignoring their enormous ecological values – as a result of which many of those are on the verge of extinction or endangered, to put mildly. It is time for Man to reinstate the wilderness of the wild, lest they may go into oblivion.

THE SUNDARBANS, spanning over two neighbouring countries of India and Bangladesh is one such example of endangered eco-region. Etymologically, Sundarbans means "Beautiful Forest". The name, SUNDARBANS, itself, conjures images of a mystic forest, predators and hostile environments. Populated by both animals and half-starved humans, Sundarbans is a place that has continued to be a perpetual battle ground of nature and man. Danda (2007) portrays Sundarbans as a microcosm for examining global dilemma for development, ecology, and competing values. The dilemma arises out of constructing built capital for welfare for the 4.5 million people living in the region thereby compromising ecology.

The Sundarbans eco-region is part of the world's largest delta, formed from the sediments brought down by three great rivers, the Ganges, Brahmaputra and Meghna. The eco-region is unique in the world and is *uniquely fragile, too*! The eco-region is unique by virtue of its most extensive mangrove forest in the world exposed to freshwater and seawater mix. Its uniqueness also pertains to being shelter to one of the most enthralling and endangered creatures in the world – the Royal Bengal Tiger and that the mangroves of Sundarbans acting as a natural buffer against the coastal erosion and seawater ingress into one of the most densely populated regions of the world. But the paragon of its uniqueness is, arguably, ascribed to the incalculable loss of human and built capital which would have otherwise happened had the Sundarbans mangrove not acted as a natural shield against the ever-increasing tropical cyclones and storms in the Bay of Bengal and Indian Ocean and arresting it from entering the mainland with their full throttle.

The Sundarbans is a conglomeration of about 200 islands, separated by some 400 interconnected tidal rivers, creeks and canals. The area, over time, has been continuously reduced and at present it is approximately three-fifths the size of what existed 200 years ago (about 16,700 km^2), the rest having been cleared and converted to agriculture (Hussain and Acharya 1994). Of the present expanse of 10,217 km^2, 4262 km^2 (41.7%) is in India. About half of the area in India (2320 km^2)

is land mass. The rest 5955 ha (58.3%) is in Bangladesh. The landscape is one of low-lying forested alluvial islands (56 in the Indian sector), mudbanks with sandy beaches, and dunes along the coast (Hussain and Acharya 1994). The forest swamp is extensively embanked and empoldered and is an essential buffer for inland areas against the ravages of frequent cyclones from the Bay of Bengal. The nutrient-rich waters also provide the most important nursery for shrimps and spawning grounds for crustaceans and fish along the whole coast of eastern India.

Sundarbans features, as per classification of WWF, two distinct eco-regions – '*Sundarbans freshwater swamp forest (IM 0162)*' and *'Sundarbans mangroves (IM 1406)'*. The Sundarbans Freshwater Swamp Forests eco-region is nearly extinct. Hundreds of years of habitation and exploitation by one of the world's densest human populations have exacted a heavy toll of this eco-region's habitat and biodiversity. Because, it sits in the vast, productive delta of the Ganges and Brahmaputra rivers and their annual alluvial deposits make the eco-region exceptionally productive. Therefore, most of the natural habitat has long been converted to agriculture, making it almost impossible to even surmise the original composition of the eco-region's biodiversity (https://www.worldwildlife.org/eco-regions/im0162). The Sundarbans Mangroves eco-region is the world's largest mangrove ecosystem. Named after the dominant mangrove species *Heritiera fomes*, locally known as Sundari, this is the only mangrove eco-region that harbors the Indo-Pacific region's largest predator, the Royal Bengal Tiger. Unlike in other habitats, here tigers live and swim among the mangrove islands, where they hunt scarce prey such as chital deer (*Cervus axis*), barking deer (*Muntiacus muntjak*), wild pig (*Sus scrofa*), and even macaques (*Macaca mulatta*). Quite frequently, the people who venture into these impregnable forests to gather honey, to fish, and to cut mangrove trees to make charcoal also fall victim to the tigers (https://www.worldwildlife.org/eco-regions/im1406).

The Bangladeshi and Indian parts of the Sundarbans, while in fact adjacent parts of the uninterrupted landscape, have been listed separately in the UNESCO World Heritage List as Sundarbans and Sundarbans National Park, respectively.

Over the centuries, Sundarbans had been, and is being, continually morphed to come to its present make up – physically as well as demographically. Physically through the unceasing accretion – erosion process of its river system and demographically through incessant in- and out-migration of people of diverse ethnicity, invasion of foreigners and colonial condign. Let us contemplate upon its history, briefly.

1.2 Sundarbans: A Brief History over Time

The history of Sundarbans can be traced back to the ages of Puranas. Mythologically, the Sagar island of Sundarbans was said to be the abode of Sage Kapila who incinerated 60,000 sons of King Sagar for some misdeed of theirs and it was Sagar's grandson, Bhagiratha, who placated Sage Kapila and brought the Ganges to earth to

revive his ancestors. Historically, several travellers as well as historians like, Satish Chandra Mitra, Kalidas Dutta have eloquently described Sundarbans in their accounts of Bengal Allusion to the famous coastal trading town of 'Chandraketugarh' can be found in the accounts of ancient Greek and Roman writers – dating back to the post-Gupta period, between fourth century BCE and sixth century AD (Mandal 2016).

1.2.1 The Muslim Time

The Muslim period (1204–1574) saw the rise of Sundarbans as a humanized colony. Following the Muslim invasion of Bengal in the twelfth century, from the early part of thirteenth century, Sundarbans witnessed infiltration of large number of Muslims rendering the area a Muslim dominated one. Unlike the native Hindus, whose primary occupation was fishery, the Muslims were agriculturists and following their suit the Hindus also took to agriculture as their primary livelihood with forest making way for agricultural land. Agriculture flourished also due to the fact that, unlike fishery produce, agricultural produce can be processed and stored for future use.

Joao de Barros, the acclaimed Portuguese historian, was the first to map the Sundarbans. Among the Muslim settlers, Khanja Ali was the most prominent, who along with his followers reclaimed large part of mangrove forest to build a sizable Muslim agricultural colony, although after his death the area relapsed into forests (Mandal 2016).

1.2.2 The Time of Baro-Bhuyans (The Twelve Zamindars)

Afterwards, Maharaja Pratapaditya, the most prominent among the Baro Bhuyans of Bengal, ruled the area from 1560 to 1611. He hired various tribal creeds to clear the forests for agricultural purposes. Maharaja Pratapaditya restored to various developmental activities like building of roads, forts, township and temples with an eye for holistic development of the area. Sadly, after his demise the forest crept back into place giving shelter to various miscreants and local dacoits.

With passage of time, the region saw mass scale plundering by the Arakan invaders along with Dutch and Portuguese traders. They continuously engaged themselves in human trafficking to far off places like Goa, Cochin, Ceylon and Batavia (now Jakarta in Indonesia) where they had established their colonies. This ensued rapid decline in population of the Sundarbans. Francois Bernier, the famous French traveller, has referred to these horrendous episodes of pillage and human trafficking in his book – "*Travel in the Mogul Empire*" (Bernier 1914).

1.2.3 The Colonial Times

Time went on. It was the colonial periods when Sundarbans started to revert back to its past glorified self. Britishers acquired the proprietary rights over the area from the Mougal Emperor during the later half of eighteenth century. Claude Russel, the then Collector-General of 24 Parganas started to make way for agriculture, again, by clearing the forests in 1770s. This was preceded by mapping of the area by the Surveyor-General in 1764.

During 1780s, Tillman Henckell, the then Magistrate of Jessore, established several government outposts in Sundarbans and set up number of salt manufacturing units along the coasts. Then began the land distribution among the *Talukdars* which was speeded up with the introduction of Permanent Settlement System in 1793. Rapidly lush mangrove made room for agricultural land and that was when anthropogenic doings, *or rather 'undoings'*, started to take toll on natural balance of the eco-region that continued several years afterwards and, with more apposite means of livelihood being available, people began to pour in, thereby shifting the natural equilibrium to irreversibility.

But, Nature retaliates – the fact was soon learnt by Viceroy Lord Canning in hard way. Viewing the multitude of promise for colonization in the Sundarbans, Canning started to build infrastructures, like roads, railway tracks; and even a port to support Calcutta port by the river Matla in the 1860s. But within 5 years of its completion, the entire port was annihilated in a super-cyclone and concomitant surge in Matla in 1867 (Mandal 2016).

Yet, the bigger damage was done. Sundarbans, by then, with its bountiful of resources and plethora of opportunities, caught the eye of many and with passage of time, during the late nineteenth century and early twentieth century, more influx of people of all creed and cast took place and more forest solemnly made way for their settlement.

1.2.4 The Time After Independence

The post-independence period encountered even greater in-migration into Sundarbans, especially in the aftermath of 1952 famine and subsequent liberation of Bangladesh in 1971. During this time the region also witnessed one of the most horrific political oppressions in human history, known as the Marichjhanpi massacre. Thousands of poor Bengali refugees, who came to India after Bangladesh Liberation War in 1971 and were relocated in prison like camps of Orissa and Madhya Pradesh, supported the Left Front in the state election as they promised to give them land in West Bengal if they won.

So, after the Left Front came to power in 1977, they came to West Bengal. A large portion among them settled in Marichjhanpi island of Sundarbans which was a deforested, but unpopulated island at that time. However, the left front was not

happy with the influx of refugees in Bengal anymore. In Marichjhanpi, after giving several warnings to the new settlers to leave, the police surrounded the island, cut its communication with outside world and destroyed the food stock, thus leaving people to die of starvation and diseases. On 31st of January, 1979, police opened fire on the settlers. Thousands were gunned down, forced to drown or beaten to death, women and children were assaulted and killed. The few, who were still alive, were driven out of the island and sent back to their old camps (Mandal 2016).

Thus, Sundarbans, although much impoverished, withstood the wrath of time and, finally better sense prevailing, it was recognized as a Ramsar site of ecological importance in May 21, 1992 seeing its huge ecological and positional importance.

Although much impoverished, the Sundarbans, in its rich ethnological backdrop, still envisages gargantuan value – ecological, economic, human and socio-cultural like all other coastal wetland and forests all over the world. Below is an annotation that delves into pricing this most exquisite biome.

1.3 Sundarbans: Valuing the Invaluable

Ever since the field of 'Ecological Economics' took flight in the 1940s, there had been deluge of works in this field to estimate the value of ecosystem services and functions globally. The economic value of natural capital and ecosystem services is accepted by mainstream environmental economics, but is emphasized as especially important in ecological economics. Ecological economics basically work on following methodologies,

- Allocation of resources
- Weak versus strong sustainability
- Energy accounting and balance
- Ecosystem services
- Cost shifting for externalities
- Ecological-economic modeling

A number of eminent ecological/environmental economists have evaluated various major ecosystems worldwide. Notable among these are Odum (1971), Westman (1977), Ehrlich and Mooney (1983), de Groot (1987), Costanza (1997), and many others. Ecological economists begin by estimating how to maintain a stable environment before assessing the cost in dollar terms (Costanza et al. 1998). Ecological economist Robert Costanza led an attempted valuation of the global ecosystem in 1997. Initially published in Nature, the article surmised the value of global ecosystem services to $33 trillion with a range from $16 trillion to $54 trillion (in 1997, total global GDP was $27 trillion) (Costanza et al. 1998). Half of the value went to nutrient cycling. The open oceans, continental shelves, and estuaries had the highest total value, and the highest per-hectare values went to estuaries, swamps/floodplains,

and seagrass/algae beds. The work was criticized in many corners, but the critics acknowledged the positive potential for economic valuation of the global ecosystem (El Serafy 1998; Opschoor 1998, https://en.wikipedia.org/wiki/Ecological_economics).

BUT!! And Yes, this is a capital 'but'. The question remains – *whether all the 'Externalities' or 'Avoided cost (AC)', as they prefer to call it, which is defined as 'services those allow society to avoid cost that would have been incurred in absence of these services' (de Groot et al. 2002), can be taken into account while valuing ecological services?*

Mangrove ecosystems are recognized as providers of untold ecological services – providing optimal breeding, feeding and nursery habitat for ecologically and economically important fish and shell fishes (Verma et al. 2017), habitats for resident and migratory birds, valuable source of fuel, fodder, timber and other natural products, protect freshwater resources from intrusion of saltwater, protect coastal lands from eroding winds and waves by stabilizing them (Prasetya 2006), etc. All these services have been assessed for their economic benefits by large number of researchers all over the world for different mangrove ecologies – many of them amounting to billions of US$ per year for these intrinsic values (Sathirathai and Barbier 2001; Rog et al. 2016). But, we surmise, the most important function of mangroves is protection of human and built capital, or the 'avoided cost' as defined earlier. For example, the post-independence period, once after 1947 and then after 1971, saw massive in-migration of people into Sundarbans and subsequent large-scale deforestation of mangroves paving way for their habitat. Then came the Great Cyclone Bhola in November 12, 1970 that ripped nearly 0.3 million people of their lives. Again the 1991 tropical cyclone accounted for some 0.14 million human lives. While the loss of built capital and the intrinsic resources were put to well over a billion US$ in 2004–05 prices (Hossain et al. 2008), question remains *can the loss of human capital be estimated*?

What presently is being done by the ecological economists, is to assess the following three chief value parameters while evaluating one ecology,

1. Ecological value
2. Socio-cultural value, and
3. Economic value

Economic value, again, is measured in terms of,

1. Direct market valuation,
2. Indirect market valuation,
3. Contingent valuation, and
4. Group valuation (de Groot et al. 2002)

We maintain that there should be one '*Anthropogenic value*' parameter in addition to the abovementioned. *Exempli gratia,* in Indian context, if somebody tries to assess the economic value of the Himalayan eco-region, it is beyond human

acumen to entwine all the 'externalities'. The Himalayas had shaped the past, is shaping the present, and will shape the livelihood of millions of Northern Indian population, its river systems, and its monsoon wind control. Therefore, it entails that for holistic ecological evaluation of the Himalayas, this '*Anthropogenic value*' have to be estimated, which is, unfortunately, beyond capabilities of man *simply because of the social capital of those billions of people, and is outside purview of monetary estimation*! Similarly, it is so in the present case – economic evaluation of Sundarbans. Apart from its huge ecological significance being the world's largest contiguous mangrove and habitat of the endangered Royal Bengal tiger, its positional advantage in unfathomable. The Sundarbans mangrove protects some of the world's most populated cities and towns, namely Kolkata, Dacca and others, from the ever-increasing wrath of tropical cyclones in the Indian ocean and Bay of Bengal by attenuating the storm surges and buffering wind thrust of the cyclones. Had it not been there, colossal loss of human and built capital would have occurred. While the cost of built capital is possible to estimate, the cost of human capital or '*Anthropogenic value*' is one '*externality'* of '*avoided cost*' that is beyond pricing. Therefore, we prefer the Sundarbans ecology be called, *ipso facto, 'INVALUABLE'*.

Although, there had been few attempts in the past to measure Sundarbans's ecological and economic value, it was essentially '*intrinsic'*, and not '*holistic'*. For academic interest, we prefer to put here few lines regarding the '*intrinsic value'* of this all important eco-region worked out by two workers (Verma et al. 2017; Shams Uddin 2011) to give the reader an idea of the stupendous ecological and economic value it would have gathered had the '*Anthropogenic value*' could have been estimated by some means. Since there is no such literature available about the intrinsic economic evaluation of Sundarbans eco-region as a whole transcending the international boundary, Indian part and Bangladesh part will be dealt separately.

Very recently, one study (Verma et al. 2017) has extensively tried to price the Sundarbans tiger reserve in the Indian part. As has been done in case of other mangrove ecologies (Viswanathan et al. 2011; Rog et al. 2016), Verma et al. (2017) evaluated for Sundarbans total of 25 ecological services and functions, namely, employment generation, agriculture, fishing, fuelwood, fodder/grazing, timber, non-wood forest produce (NWFP), gene-pool protection, carbon storage, carbon sequestration, water provisioning, water purification, soil conservation/sediment regulation, nutrient cycling/retention, biological control, moderation of extreme events, pollination, nursery function, habitat/refugia, cultural heritage, recreation, spiritual tourism, research and education, gas regulation and waste assimilation. As per their estimation he stock benefits accrued to US$ 10,089 million per year.

As for the Bangladesh part, Shams Uddin (2011) has similarly evaluated the same. He categorized the services into three broad categories, namely provisioning services (timber, fish, fuel wood, thatching materials, honey and wax, crab), cultural services, and regulatory services. Total economic benefits for these services, as per his estimates, stands at US$ 43 million per year.

These are the only two available studies that have tried to price the Sundarbans eco-region in the light of its ecological services and functions in the two

neighbouring countries. Notable point from these two studies is the large variation in the quantum of economic benefits derived. Although of the 10,000 km^2 area of the Sundarbans eco-region, Bangladesh accounts for some 3/5th, yet economic benefits derived for that part is abysmally low compared to Indian part (Shams Uddin 2011).

Other workers, who tried to value the mangrove ecologies over the world (Santhirathai and Barbier 2001; Hussain and Badola 2010, etc.), have used different metrics and valuing parameters resulting in wide variation in quantum values among their works. Hamel and Bryant (2015) and Boithias et al. (2016) categorized such uncertainties in assessment of ecological services. They maintain that varying number of services under consideration, selection of valuation metrics, stakeholders credibility and response, etc. are the root causes of the uncertainties in such kind of studies. From these, it can be surmised that *no single study should be adequately well-versed in deriving even the 'intrinsic value' of Sundarbans, leaving alone the 'Anthropogenic value'.*

Then, there are stiff challenges, both anthropogenic and climatic, those are gulping in the natural resource base of the ecosystem, thereby decreasing its intrinsic value, slowly yet steadily. Unless stringent measures are adopted to combat the human maleficence and to adapt to the climatic vagaries, the Sundarbans may not live to see another day in 100 years from now. Let's explore the challenges that the ecosystem is facing.

1.4 Challenges Typical of the Ecosystem

Coastal ecosystems are inimitable in view of their frailty as compared to terrestrial ecosystems, and yet in their indispensability in preserving the terrestrial ecosystems being the first line of defence against hazards of oceanic origin. More often than not, these are more precious in terms of their natural, built, human and social capitals over land ecosystems; and yet more often than not these are subjected to ill considerate, unbridled and indefatigable anthropogenic avarice for gaining *entrée* to these capitals. The human malfeasance over and above enhancement in climate change-induced degenerative – and often cataclysmic – marine influences in form of tropical and extratropical cyclones, tsunamis, hurricanes, etc. are only adding to the woes in so far as the stability of the coastal ecosystems – and their very existence as well – is concerned (Ghorai and Sen 2015; Sen and Ghorai 2017).

Global climate change will alter temperature and precipitation regimes, oceanic and atmospheric circulation, rate of rising sea level, and the frequency, intensity, timing and distribution of hurricanes and tropical storms (Ghorai and Sen 2015; Seneviratne et al. 2012), the magnitude of which and their subsequent impacts on coastal wetlands will vary temporally and spatially. The ecological effects of tropical storms and hurricanes indicate that storm frequency, intensity, and their variations can alter coastal wetland hydrology, geomorphology, biotic structure, energetics, and nutrient cycling (Mitchener et al. 1997). The more these storms eat out the coastal wetlands, the more will be the exposure, and hence the vulnerability, to