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**Natural and Traditional Defense Mechanisms to Reduce Climate Risks in Coastal Zones of Bangladesh**

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**Abstract**

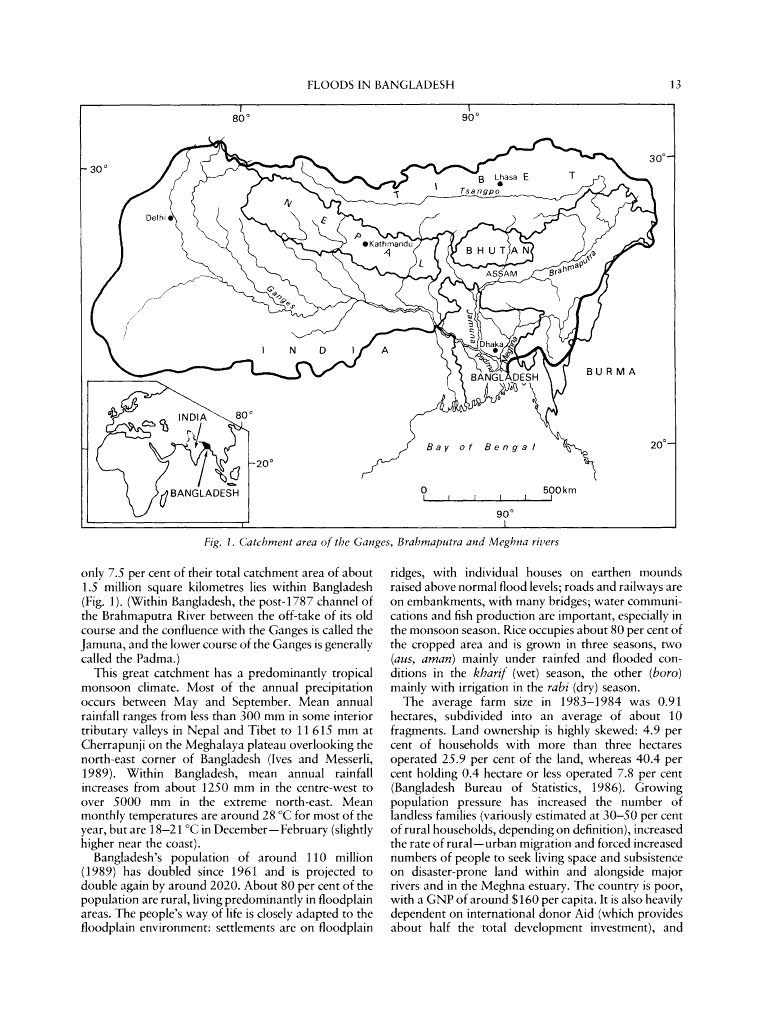
Substantially resourceful and densely populated coastal zones of Bangladesh have been experiencing frequent disasters *viz.* cyclones, tidal surges, floods, salinity intrusion and erosion etc. which cause large damage to lives and properties every year. Moreover, anthropogenic activities in the coastal zones are accentuating environmental degradation causing increased suffering to the people. Cyclones and tornadoes have been damaging infrastructures and crops every year and affecting the economy of the country. Some naturally adapted plants as well as landscapes usually reduce the speed of cyclones and tornadoes and thus, protect the coastal zones. However, human activities have destroyed many of the forests and landscapes and it is observed that at least 34 plant species of tropical forest are on the verge of extinction. Many animals e.g., cats, bear, porcupine, wild boars, pythons and anteater are in the process of being wiped out from the coastal areas. Among the marine and coastal species, red crabs, jelly-fish, sharks and dolphins are also rare but these were the major species prior to 1980s. Information also shows that the Sundarbans, Chokoria Sundarbans mangrove forests of Bangladesh are under a great threat of extinction due to illicit logging and agricultural expansion. This study revealed that, during the recent decades, massive plantations is being done, embankment and polderization are being constructed but many of those have been found to be impractical and ineffective. There is a need for integration of traditional adaptation practices and wisdoms with modern approaches. Available knowledge on practices has been documented for establishing a sustainable policy for management of coastal zones of Bangladesh. Through traditional practices for floodplain and scientific management of coastal ecosystem with mangroves and other plants following triple-tier mechanism and habitat, it is possible to reduce the effects of natural and climate change-induced disasters. Under such a management system, the entire coastal zone can be made more productive and sustainable.

**Keywords:** Coastal Zone, Mangroves, Excavation of fresh water reservoir, Triple-tier Mechanism

1. **Introduction**

In South Asia, Bangladesh is the most densely populated delta of the Ganges-Brahmaputra-Meghna (GBM) basin. Most of the country is the flood-plain of the GBM river systems with their tributaries and distributaries. The fertile alluvial flood-plain is characterized by gently undulated landscape with hills and hillocks in the north, east; a central undulated red soil terrace, the Madhupur Tract, and a huge coastal zone with highly fertile land, rivers, estuaries, mangroves, seashore and islands adjacent to the land-water interface of southern part of the country. The coastal zone comprising 19 administrative districts with a great diversity of natural resources including coastal fisheries, forests, salt, and minerals, as well as high potential for exploration of both onshore and offshore natural gas. It harbors ports, tourism facilities, and other development opportunities [1]. Although Bangladesh is most vulnerable to frequent disasters with floods, cyclones and droughts but historically, the people have adapted to these, making their homes and homesteads following disaster resilient traditional practices to protect them from floods, tornadoes and erosion etc.; climatic-season-based cropping, fish-farming and major transportation by boat, traditional flood plain management, and natural and artificial defense mechanism etc. However, over the last few decades, along with the increased frequencies of climate change disasters, increased urbanization, unplanned road construction, industrialization and population growth, many aspects of traditional life have been changing very fast.

Bangladesh is recognized globally as most vulnerable to Climate Change extremes. About 80% of the country is deltaic floodplain of the GBM and many rivers flowing from the central India, Himalayas, China, Assam, Lusai and Arakan-Burmese ranges; thecatchments of the GBM Rivers flowing to the Bay of Bengal through the estuaries (Fig. 1). Bangladesh is the most vulnerable country in the world to tropical cyclones and the sixth most vulnerable to floods [51]. More than 68 million people have been directly affected over the last eight years [52], and millions of lives and livelihoods are threatened by frequent weather-related disasters. Low-lying lands, coastline areas and floodplains of most part of the country are highly exposed to both disasters and sea level rise [50] especially in the coastal zones.



*Fig. 1 Catchments of the Ganges- Brahmaputra- Meghna Rivers flowing to the Bay of Bengal*

Above the coastal zone, one-third of the country is partially elevated plain-land, gets flooded temporarily but with the increased population this floodplain has gradually been occupied with expanded homes and townships. Another 44,000 km2 area consists of wet-bodies which remain wet in most of the period. However, after the 1960’s Green Revolution, these wetlands were also destroyed by earth-filling for agricultural expansion especially for HYV IRRI. Thus the natural systems including forests, wet-bodies and traditionally managed floodplains and coastal ecosystem have been destroyed and the country is facing serious climate change disasters and affecting millions every year [44].

**2.0 Methodology**

Considering the increasing frequencies of climate change disasters, this study was conducted to find out sustainable coping up methods, adaptation practices and the defense mechanisms to combat the disasters. During the study relevant information was collected from different scientific research and grey literature published either in peer reviewed journals or periodicals; news media, folklore and local cultures. Information has also been gathered through organizing workshops, seminars; also by attending different regional workshops and conferences, visiting research institutions and meteorological stations. More importantly, some information were collected directly from the stakeholders, rural and urban administrative bodies, farmers’ communities, Non-Government Organizations (NGOs), women and youth communities of the coastal region. Electronic media was also used to collect information. The impacts and vulnerabilities of natural and climate change effects in the coastal area were studied. For a cross-scale synthesis and policy recommendation, the traditional practices and coping up behaviors had been investigated; their efficacy was highlighted and compared with present practices to find out the misfits as well as to integrate the scientific basis of the traditional knowledge regarding natural and artificial defense mechanism which are being followed by the people of the most vulnerable region of the earth for thousands of years.

1. **Coastal Zone**

Coastal zone has many opportunities like, fertile land, fishing, mangrove forests, marine and terrestrial biodiversity, scenic beauty, ports, industries, tourism, marine resources, and minerals: Quartzes and Zircon, Uranium etc.; easy transportation and sailing facilities, and meeting point of flora and fauna of fresh and saline water and salt fields, etc. [3, 53]



*Fig. 2 Major river systems of the GBM estuaries*

The GBM estuaries in the south; the Karnaphuli, Halda and Sangu rivers and the shoreline of the Arakan ranges in the southeast have been providing a distinct feature of the whole coastal zone of Bangladesh (Fig. 2). It has a difficult coastline with many rivers and distributaries and complex ecology which is affected by natural hazards like cyclone, coastal flooding, tidal surges, erosion, salinity and other phenomenon. About 50 million people, nearly one-third of the total population of Bangladesh are living in the coastal zone [2, 3]. However, some phenomena often create disasters; make the lives hard and disrupt the whole coastal ecosystem. Among these, tropical cyclones and tornados, tidal surges and floods, erosion, heavy siltation, and pollution especially from the mega-cities and ports, shrimp hatchery and shrimp farms are the most prominent. Deforestation, over-fishing and overexploitation cutting of hills for unplanned construction, ship-breaking industries and tourism etc. have accelerated the damages of the ecosystem. More than 34 species of tropical rainforest plants, including *Podocarpus nerifolia* and *Enteda phaseoloids* etc. are facing extinction from the coastal hill forests of Chittagong ranges [4, 5, 6, 7]. Many animals e.g., cats, bear, porcupine, wild boars, pythons and anteater are in the process of being wiped out from the coastal areas. Among the marine and coastal species, Red crabs, jelly-fish, sharks, and dolphins are becoming rare but these were the major species before 1980 [4]. Coastal resource depletion leads to frequent conflict between users and also suffer from serious socio-economic and cultural problems, such as weakening of the social fabric, marginalization, unemployment and destruction of property by erosion. Moreover, unregulated removal of sand, gravel and pebble deposits from beaches and underwater coastal slopes have been creating threats to the coasts [8, 9, 4].

**3.1 Recent trend of Environmental changes and decline of resources:** Human pressure, misuse of resources, introduction of inappropriate technologies; industrial and agricultural expansion and pollution are the characteristics of recent changes in the coastal zone [55]. Vulnerabilities in the coastal zone are increasing with accentuations of natural hazards caused by environmental degradation, climate change and human activities as well as exploitation of mangroves [3, 56]. Bangladesh has already been affected by land erosion, salinity intrusion [59] and loss of biodiversity. The potential threats are going to be even stronger in future [57, 58]. Due to climate change effects, the incidences of tropical storms and tidal surges have been increased in the coastal belts of Bangladesh, India, Myanmar and Sri Lanka. The cyclones *viz.* Sidr- 2007, Nargis- 2008 and Aila-2009 are the typical examples which have caused significant damages to lives and properties of the coastal zones [66].

Withdrawal and diversion of upstream water from the major river systems in the dry monsoon has drastically reduced the freshwater flow. As a result, the salinity has been increased; salinity intrusion affects the coastal agriculture, natural fish-breeding centers and fresh water supply to the urban and rural areas of the coast. More than two hundred international rivers are carrying waters into Bangladesh from the neighboring countries. Withdrawal of water through upstream dams and embankments has been decreasing the dry season flow resulting in salinity intrusion which in-turn hampers agriculture in the coastal zone seriously [63]. Therefore, a regional consensus is needed for the share of common water flow.

Coastal population, including three million inhabitants of the 72 offshore islands are extremely vulnerable. About 18% households of the southwestern coastal zone are dependent on resources of the Sundarbans, *viz.* shrimp-fry, honey, Golpata, mollusks, shell, crabs and medicinal plants etc. Because of increasing rough weather in the Bay, about 0.5 million people, dependent primarily on fishing, are losing their works. Over 160,000 coastal fishermen and 185,000 shrimp-fry collectors involved in marine fisheries are threatened due to cyclonic disasters and tidal surges and reduced fish and aquatic resources [10]. According to a recent study of Soil Research Development Institute (SRDI), it is found that Sundarbans has lost 8.3% area (about 50,000 ha) of its northern front due to deforestation for shrimp culture during the period of 2000 to 2010. This destruction has been done by clear-felling of mangrove trees and creating un-noticed pockets [11]. As a result, the pockets have become low depression zones and more vulnerable to climate-induced cyclones and tidal surges.

**3.1.1 Effects of Global Warming:** According to IPCC-2007 (AR4)[12], average temperature has registered an increasing trend of about 1°C in May and 0.5°C in November during the 14 years period from 1985 to 1998 in Bangladesh The annual mean rainfall exhibits increasing trends in Bangladesh. Decadal rain anomalies are above long term averages since 1960s. Serious and recurring floods have taken place during 2002, 2003, and 2004. The intensity of cyclones originating from the Bay of Bengal has increased since 1970 which caused immense sufferings to lives and destruction of structures and natural resources [68, 69].

With the changing climate and withdrawal of water in the upstream, an acute water shortage has been impacted badly to rapid urbanization, intense agriculture and population growth. Salt water from the Bay of Bengal is reported to have penetrated more than 100 km in the inland along tributary channels during the dry season. The precipitation declines and droughts have resulted in drying up of wetlands and severe degradation of ecosystem services [12]. Sea level rise will tend to worsen coastal erosion. In some coastal areas, a 30-centimeter rise in sea level can result in 45 meters of landward retreat. Coastal erosion, cyclones, and storm surges will place coastal infrastructure—housing, industrial facilities, energy and sanitation systems, transportation and communication networks, tourist and cultural sites—increasingly at risk [78]. 40% of the productive land is projected to be lost in the southern region of Bangladesh for a 65 cm sea level rise by 2080s. About 20 million people of the coastal area have already been affected by salinity in drinking water. Rising sea levels and more intensive cyclones and storm surges could intensify the contamination of ground water and surface water causing more diarrhea outbreaks [79].

**3.1.2 Cyclones and Tidal Surges:** Owing to climate change effects the increased climate extremes of tropical cyclones along with tidal surges have affected the coastal zone seriously (Table 1)

Table-1 Tropical Cyclones Affected Coastal Zones

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Cyclones** | **Affected Regions** | **Wind Speed (km/hr)** | **Death** | **Damages (US $ in million)** |
| Bhola Cyclone-1970 | Bangladesh, India | 205 | 500,000 | 86.4 |
| Bangladesh Cylone-1991 | Bangladesh | 260 | 138,000 | 1,500 |
| Sidr-2007 | Bangladesh | 260 | 4,036 | 1,700 |
| Nargis-2008 | Myanmar, India, Sri Lanka, Bangladesh | 215 | 138,366 (126 in Bangladesh) | 10,000 |
| Aila-2009 | Bangladesh, India | 120 | 325 (26 in Bangladesh) | 552.6 |
| Mahasen-2013 | Bangladesh | 88 | 17 in Bangladesh | 200\* |

Source: [13, \*14]

**3.1.3 Floods**

About 45.5 million people are exposed to severe and moderate floods like river flood, flash flood and tidal flood. Floods of 1974, 1987, 1988 and 1998 caused death of 30,000, 1,657, 2,379 and 1,000 lives respectively and damaged crops and infrastructures [15]. Recurring floods during 2002, 2003, and 2004 caused huge damages of crops, structures and road transportation [44, 45]. In 2007, flood inundated 32,000 km² area twice in July-August and in September and 16 million people were affected in three million households of which 85 thousand houses were totally damaged and more than one million damaged partially.

**3.2.1 Effects of Environmental Change: Natural and Anthropogenic**

With the environmental change, agriculture has been suffering from uncertainty and having disasters from floods, droughts, salinity, cyclones and hailstorms and cropping is being hampered due to erratic precipitation pattern; and it has been predicted that rice and wheat production will reduce 8% and 32% respectively by 2050 [49] and fisheries are also expected to be impacted negatively .

Increased precipitation brings more water in the catchments which are beyond the drainage capacity, causes damage of infrastructure and drainage congestion in the urban areas due to faulty drainage and insufficient channels [54]. Salinity intrusion hampers irrigation, domestic use and drinking water. Trans-boundary withdrawal of water disrupts hydrological cycle and cause increased rainfall during the pre-monsoon, wet monsoon and post-monsoon in upper catchments and/or within Bangladesh leads to more floods and water-logging; causes more river bank and coastal erosion [60, 63, 64].

However, over the years, considerable investment has been made in disaster management especially for flood control works with the government and donors’ fund and expertise which have blocked traditional navigation routes, and roads and highways has further worsen the situation. Embankments and polderization and unplanned afforestation etc. have impacted negatively in the coastal zones. Poor maintenance and inadequate management of the polders have also contributed to internal drainage congestion and heavy external siltation. As a result, soil fertility and agriculture production in some areas are declining because of water logging and increased salinity inside the polders [65]. In 2008, Institute of Water Modeling (IWM) studied on “Impact of Sea level rise in coastal river of Bangladesh and assessed the change in the tidal characteristics of the surrounding rivers due to sea level rise and its impact on inundation area of the polder. Studies revealed that high water level at the surrounding rivers of polders increases in the range of 30-80 cm for sea level rise of 32 cm and 88 cm respectively and hampered the smooth drainage of the polders.

Prolonged water-logging affected cropping, thick wind-barriers increased the wind-speed and damaged the structures; uprooted trees damaged buildings, transmission lines, bridges and agricultural crops. However, increased awareness has significantly reduced the death tolls [4, 50].

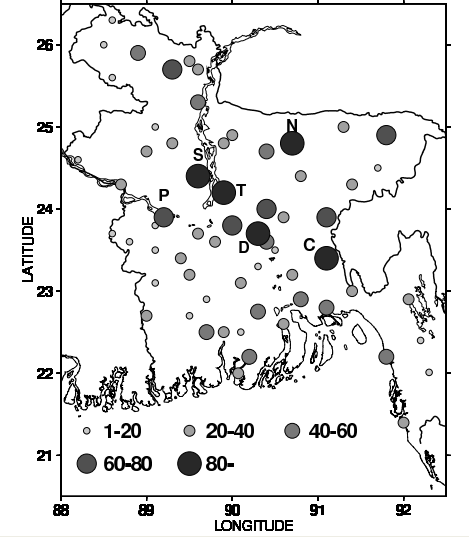
**3.3 Future Scenarios**

PRECIS (Providing REgional Climates for Impacts Studies) generated scenarios for Bangladesh and predicted that pre-monsoon rainfall will be reduced but wet monsoon and post-monsoon rainfall will be increased, from 2051 and onwards monsoon rainfall will follow higher increasing trend and annual average rainfall will follow an increasing trend. Regarding temperature, monthly average maximum temperature will increase in monsoon period and will decrease in other periods but minimum temperature will increase in all periods. However, annual maximum and minimum temperature will follow an increasing trend.

Impact on monsoon flooding will be severe and flood duration will be prolonged by significant number of days and inundation area and inundation depth will be increased [15]. The potential land loss estimated by IPCC is even worse*—*29,846 km² of land will be lost, making 14.8 million people landless by a sea level rise of 1 m. Land loss leads to loss of agricultural land, loss of homestead, loss of road and other communication infrastructure and above all loss of wide range of biodiversity. The great mangrove forest Sundarbans, the world heritage will be lost and the coastal region as well as the internal territory will be further impacted by the tropical cyclones [46, 47, 48].

**4.0 Traditional adaptation practices**

Since the Tropic of Cancer has passed through the center, Bangladesh is very prone to tornadoes due to wide-spread terrestrial wet-bodies all over the country; the coastal zone is more prone to tornadoes and cyclonic storms [63]. The coastal zones have excellent natural defense systems with Arakan hill ranges along Chittagong and Cox’s Bazar shoreline, strong windbreaks with hill forests in the eastern coast of the Bay of Bengal. Sea currents, web and tides and upstream fresh water flows play very important roles for enriching the coastal zones of Bangladesh [3]. The Sundarbans is the world’s largest Mangrove forests, the National Park of Bangladesh**,** has been declared as Tiger Reserve in 1973, UNESCO World Heritage Site (UNESCO-1987) and a Biosphere Reserve in 1989 is located in the GBM in Bangladesh and West Bengal (India) coast with an area 16,902 km2. Sundarbans' green cover has been standing firm against natural disasters for ages [61, 62]. The vegetation consists of 64 plant species (UNEP-WCMC-2008)and they have the capacity to withstand estuarine conditions and saline inundation on account of tidal effects, can face strong winds. Sundari (*Heritiera fomes*), Gewa (*Excoecaria agallocha*), Kankra (*Bruguiera gymnorrhiza*), Passur (*Xylocarpus mekongensis*, *Rhizophora* spp., Sundari (*Heritiera fomes*), Goran (*Ceriops decandra*) and Baen (*Avicennia alba*) etc., are important. The Sundarbans mangrove forests with triple tier natural protection mechanisms protect the inlands from cyclonic storms originated in the Bay of Bengal [3, 16] Most of the plant species have special physical and physiological adaptation to protect themselves as well as they prevent the mounting wind pressure of the cyclones, and storm surges. Viviparous germination, pneumatophore, stilt roots, buttresses, floating behavior of drupes and pods etc., are the unique natural adaptation features of many mangrove species [70]. Some trees e.g. Baen and Sundri are so strong that they can easily resist 11,100 psi load [17]. Tornado-prone zone areas (Fig. 3) have specially adapted growing bamboo clumps which are extremely strong with high elasticity and can easily disband the tornadoes. Therefore, every homestead has have bamboo clumps in the west and or north-west sides [18]. Bamboos also protect erosion with their strong anchorage-fibrous root system [67]; similarly many palms and nuts also break the wind speed and protect the habitats and the lives from disasters especially, the cyclones and erosion [19]. Local communities developed many adaptation techniques, innovations and knowledge to address climatic vulnerability. Rural people, farmers and other developed their location specific knowledge and practices of agriculture, natural resource management, human and animal health care. They know far more about their environment, livelihoods and how their society functions than those from the outside [76].



*Fig. 3 Geographical distribution of tornadoes in Bangladesh from 1990-2005*

Source: [20]

The inhabitants of the coastal zone used to adapt and manage the frequent storms and cyclones using their wisdoms usually building their homes on raised floor, low height and surrounded by highly protective windbreaks with coconut, areca nut and fishtail palm etc. (Fig 4).



*Fig.4 Homes with windbreaks of the coastal zone [21]*

Hill forests of the eastern and northern region and the central Sal forests are the natural defense system used to protect the human habitats from storms and tornadoes, erosion and land-sliding. Traditionally, the homes of the 1960’s or before, the people used to choose the multipurpose tree and shrubby plants those are specially established thinking to serve the specific purpose e.g. wind protection, erosion control and habitat restoration and of course for health conscious drinks and foods [18]. Maintaining their appropriate spacing, coconut, areca nut, dates, Palmyra palm, fish-tail palm, Cyperus, and Screw pine etc., are suitable for crop production, as well as, natural protection of the shelter home from the adverse condition. Palms can withstand 350 km/hour wind speed and their specially designed highly elastic leaves can break the wind speed. These plants altogether provide a triple-tier protection measure against tidal surges and strong winds [21, 71, 72].

The houses of the coastal zone are usually made on wooden platforms on raised earth excavating two or three ponds in each and every home. The flood plains were nicely conserved by digging deep ponds for multipurpose uses. Excavated earth used to meet the purpose of house building on raised landscape and the houses were designed to face the south (Fig 6, 7). Large ponds with an area above 1 acre are termed as Dighi; above 10 acres is Sagor and smaller ponds of area less than an acre are called as Pukur.

The houses of the coastal hilly areas of Chittagong and Chittagong Hill Tracts are traditionally designed with a central king post with suspended roof to protect from the earthquakes. Still in Chittagong and Cox,s Bazar, there are Khyangs, the Buddhist temples with traditional king posts..

There are other traditional practices e.g. rainwater harvesting and storage in large earthen vats for domestic usages, this practice is a very common one for the coastal island-dwellers [21].

Among the other traditional practices, people of the coastal zone used to do their marketing in the Haats and Bazars during the daytime using natural lights and to avoid the transportation problems at night.

**4.1 Traditional landscaping for homes in the floodplains:** Typically, rural homesteads follow a courtyard layout. The basic features are: a group of separate structures surround an open space which is defined as the courtyard. Each structure is essentially a one-roomed accommodating different function such as dwelling units for extended family members, kitchens and granaries. Toilets and outhouses such as cowsheds are located on the periphery of the homestead and where recycling of biomass takes place. The layout is introverted, that is, the buildings face away from the outside and are accessed through the courtyard. Entry into the compound from the outside is through gaps between structures. The homestead is extensively planted with trees along the boundary which strengthens the introverted layout. In flood-prone areas, an indigenous practice is to build homesteads on a raised mound, built with earth from the excavation of canals and ponds. Presently, because of resource constraints, it is not always possible for people to raise homesteads adequately above flood level. Planting design and selection of trees is the main aspect of landscaping. Land selection, preparation and homesteads are also part of landscaping. Homestead cropping maintains special adaptation procedure for raising creeper and climber crops on raised mound made with earth boulders to prevent water-logging in the wet monsoon. This is a scientific process to break the capillary system by the air-spaces among the earth-boulders [18, 24, 73].

Among the other traditional adaptation practices, the season-based cropping to maintain the flora and fauna of soils of dry and wet phases; floating agriculture and deepwater rice cultivation are also important [75]. People used to aware of getting the indication of storms and winds watching the mouth of the nests of the weaving birds [74].

**5.0 Cause of damages in the recent past**

Cyclone Gorki 1970**,** Bangladesh Cyclone 1991, Sidr 2007, Nargis 2008 Aila 2009 and Mohasen 2013 have caused significant damages of life and properties and resources. From the Table 1, it is clear that, Bangladesh has achieved great progress in awareness and minimized the death tool significantly but considering the overall property and resource loss, the proportionate loss is significantly higher in the recent years [76]. It has been observed that, unplanned afforestation, social forestry, shelterbelts, embankments and destruction of mangroves for ship-breaking and shrimp-culture; excavation of shallow ponds pisciculture etc. are the major causes of increased destruction of properties and resources in the recent years. Huge excavated shallow ponds get heated and create low pressure centres; thus increase the frequencies of local tornadoes and cyclones [21].

**5.1 Conventional methods and policies for reducing calamities:** Embankments, polderization, coastal afforestation and shelterbelts, construction of shelter-house are important activities. But in most cases these are constructed against the natural forces unscientifically and inefficiently. Embankment and polders have caused permanent water-logging in many parts of the coastal zones. Many coastal polders, constructed to protect agricultural land from saltwater inundation, were subsequently turned into large shrimp farms. Saltwater was allowed into the polders in order to raise shrimps. Driven by commercial interests, the land used for agriculture and mangroves was converted, often forcibly, to shrimp farming [25] leading to many land-use conflicts [26, 27], environmental pollution and social unrest [28, 4, 16].



*Figs. 8 and 9 Coastal erosion due to shrimp hatcheries in Cox’s Bazar and erosion control measure by sand jutex [21]*

Shrimp hatcheries pose a great threat to coast line. Cox’s Bazar, the world’s longest sea beach, is under threat of erosion due to disposal of effluents from the shrimp hatcheries (Fig. 8). Moreover, expansion of sea beach hotels, motels and recreation zone by cutting shoreline hills has destroyed a great part of the beach which needs immediate attention to prevent further destruction [3, 4, 16]. Recently, the government took action to protect the sea beach with sand in jutex bags (Fig. 9)

**Coastal green belt:**Dense forests can attenuate wave velocity [29]. To protect local, coastal and regional areas from storms, cyclones, tornadoes and tidal upsurges it is essential to reduce the wind speeds by planting appropriate tree species those can withstand the high speed wind and break the wind speeds. Naturally grown halophytic plants e.g. Sundri (*Heritiera minor*), Geoa (*Excoecaria agallocha*), Goran (*Ceriops* sp.), Kankra (*Bruguiera gymnorhiza*), Khamo (*Rhizophora mucronata*), Baen (*Avicennia officinalis*), Keora (*Sonneratia apetala*) and Kulsi (*Aegiceros majus*) etc. have the special adaptation for withstanding in the littoral zones with clayey alluvial soil, tides and strong salinity and winds. There are several palm species e.g. Golpata (*Nipa fruticans*), Hital (*Phoenix paludosa*), coconut (*Cocos nucifera*) and cane (*Calamus tenuis*) and some swamp elephant grasses (*Typha angustata* and *T*. *elephantiana*), *Alpinia allughas* and screw pine (*Pandanus facicularis*) etc. have the soil binding capacity and control erosion. They also reduce the speed of tidal upsurges. Moreover, they maintain a gradual hierarchy and reduce the speed of the strong winds. Most of the palms can withstand winds at a speed more than 250 km/hour. They can easily break strong wind-flow and reduce the speed [21].

In order to protect life better in coastal areas from cyclones and tidal surges, in 1966 the Forest Department began a mangrove plantation program outside the protective coastal embankments. The program was based on evidence that the Sundarbans natural mangrove forests provided effective protection from wind and waves for the western coastal areas and, thus, it was expected that the plantation of mangrove would give a worthwhile degree of protection to other coastal areas of the country open to the sea. The Coastal Afforestation Scheme had been operated from 1966 to 1974, and established 4,745 hectares of plantations; the project was extended to 1980, by which time another 29,700 hectares were raised. All these plantations were concentrated on the offshore islands and new accretions. The afforestation species were Keora (*Sonneretia apetala*), Baen (*Avicennia officinalis*), Kankra (*Bruguiera gymnorrhiza*), Golpata (*Nypa fruticans*) and Gewa (*Excoecaria agallocha*). Of late, the coastal green belt has been undergoing indiscriminate destruction and encroachment. Power-brokers with links to local politicians have taken the lead in clearing the forests. The administrative machinery does not stop the clearing. A program of participatory mangrove plantation involving nearby coastal communities, which has proved successful in other countries, could be a sustainable mechanism to protect mangrove forests. This mechanism is being actively considered within the Forest Department. However, still there lies problems with the selection of species, it has been studied that the species planted along the coastal embankment are not according to their habit and habitats, on many occasions the damage during the cyclones increased because inappropriate of choice of species [4].



*Fig. 10 Thick windbreaks in the coastal embankments [21]*

Thick shelterbelts on the embankments and along the roads and highways although protect the coastal zone but it causes adverse effect by increasing wind speed as per Pascal’s law and pass through the passages like river with high speed (Fig. 10). In both Sidr and Aila this effect increased the wind-speed of the cyclones and caused more damages in the interior region especially where shallow water-bodies for shrimp culture were made by removing mangrove forests [21].

**5.2 Wrong selection of species and methods of afforestation:** Massive plantation was done without caring their habit and habitats and disrespecting natural adaptation processes, millions of exotic trees especially the *Acacia* spp., Raintree (*Albizia saman*), Mahogany (*Swietenia macrophyla*), Royal Sirish *(Albizia richardiana)* and *Eucalyptus* spp. etc., were planted in the coastal embankments and in the homesteads replacing the indigenous species. Moreover, during the plantation, the optimum spacing was not followed and the safe distances were not maintained. As the trees are shallow-rooted and in the high water-table zone the root system could not develop for proper anchorage and thus during the cyclonic storms and tornadoes they were uprooted and damaged the structures and utilities and crops. The post-Sidr study showed that about 16.84 million woody and fruit trees were uprooted by Sidr. Haq *et.al.* 2012 [30] claimed that due to raising saplings in the earthen pots the taproot system could not develop which is found to be contradictory in field observations as it is solely an adaptive practice of habit and habitats of the plants [21]. So-called Sorjan planting system is not a new practice as the people traditionally excavated several ponds in every home for landscaping to make their homes and to grow trees on raised lands.

It was also reported that due to so-called development of land following Indonesian model ridges and furrows method, the coastal plantations were affected but it was also contradictory to traditional land management by excavating 3 or 4 deep ponds in each house for hundreds of years back (Figs. 5,6, 7) [21, ].

Plants absorb millions of liters of water everyday and about 95% of water transpirate to the atmosphere using 5% only [31, 32] and thus the plants keeps the atmosphere humid and maintain the hydrological cycle through transpiration and precipitation. Physiological studies revealed thatEucalyptus as a xerophytic plant has a low transpiration rate and control stomatal opening according to water availability [33, 34, 35, 36]. Similarly comparisons have been done among xerophytic *Acacia auriculuformis, A.* *magium* and native *Pterocarpus indicus* and observed that the stomatal size is almost half in case of *A. auriculuformis and A. magium* than that of *P indicus* [37]. Verma (1999) [31] also reported very low transpiration of *Acacia* sp. Thus it is proved that these exotic species provide less transpiration and impacts upon humidity and low precipitation in the region and thus huge Eucalyptus and Acacia spp. are causing dryness and changing the climate. Moreover, these exotic species do not provide food and shelter for birds and wild-lives and do not favor undergrowths.

**5.2.1 Destruction of mangrove forest:** Since 1980’s the mangroves of the South and South-western coast has been indiscriminately destroyed and the land was excavated for shrimp and fishery projects. These shallow large ponds holding saline water raise the local temperature and create pockets for low pressure depression and it is one of the major causes of huge damages of Sidr-2007 and Aila-2009.

The Sitakund mangrove forest has totally been destroyed for ship-breaking yard and caused havoc with pollutants destroying the coastal biodiversity. Due to availability of cheap laborers, ship-breaking industry is growing very fast in the coastal zone mainly concentrated in Sitakund, Baroawlia, Bhatiari and Kumira, just north of Chittagong city on the Bay of Bengal. Ship-breaking activities present both challenges and opportunities for coastal zone management. Meeting the increasing demand for raw materials such as steel it needs to be balanced with the negative impact this activity on coastal environment and the conditions of the workers. In Bangladesh, ships containing lead, cadmium, organo-tins, arsenic, zinc and chromium, oils, organophosphates, asbestos, materials are being cut up and handles manually, on open beaches, with no consideration given to safe and environment friendly waste management practices which can result in lung cancer, cancer of the skin, intestine, kidney, liver or bladder and damage blood vessels [38, 39, 4].

A ship-breaking activity is a threat to both the terrestrial and marine environment as well as to public health. It is like a mini version of a city that discharges every kind of pollutants a metropolis can generate like liquid, metal, gaseous and solid pollutants. Oil films on water reduce the exchange of oxygen and carbon dioxide across the air-sea interface which is harmful to aquatic life. It also causes damage to the bird population by coating their feathers with oil which causes buoyancy and insulation losses. Sometimes spilling may cause wide spread mortality amongst the population of fish, mammals, worms, crabs, mollusks and other water organisms. Furthermore, oil spilling may cause serious damage by reduction of light intensity, inhibiting the exchange of oxygen and carbon dioxide across the air-sea water interface, and by acute toxicity. As a result the growth and abundance of marine organisms especially plankton and fishes may seriously affected. Indiscriminate expansion of ship-breaking activities poses a real threat to the coastal inter-tidal zone and its habitat [38, 39, 4, 6].

Moreover, cutting of hill and hillocks for industrial establishment in Chittagong, is causing a great land area loss and exposure of the rocky strata. Some folded ranges in Cox’s Bazar are being cut for residential accommodation. The coast line of Cox’s Bazaar has been dug for shrimp-culture which will in the long run make the coastal belt vulnerable to sea current erosion. Hill-cutting may cause land-slides, faults during earth quake.

Unplanned development of resort area after cutting the hills and establishment of shrimp hatcheries along the coast threatens the beach with erosion, while waste from tourists and vendors are damaging the aquatic habitat. About 15 km of the Cox’s Bazar beach is at high risk of erosion, especially the shrimp hatcheries at Himchari and Kolatoli, and also motel and hotel zone, and the Diabetic Hospital areas of Kolatoli. A half of the Kolatoli village has already been lost to erosion due to unplanned discharges of water to the sea from 55 shrimp hatcheries [40]. Sea current has damaged 3.4 km of beach of the Old Marine Drive Road from Kolatoli to Himchari in Cox’s Bazar [4].

**6.0 Purview of Policy Challenges**

Despite increasing recognition of the need for Integrated Coastal Zone Management (ICZM) strategies, individual coastal policies in Bangladesh are still mainly formulated with narrow sector-oriented objectives in mind and are not part of an overall framework. Considering the following three reasons the Government of Bangladesh initiated the coastal zone policy in 2005: a) the coastal zone is lagging behind in socio-economic developments on many aspects; b) Poor initiatives to cope with different disasters and gradual deterioration of the environment; c) the coastal zone has the potential to contribute much to national development.

Under Coastal Zone Policy it included that “for a Strategic Planning and Program Development, a Coastal Development Strategy for poverty reduction, economic growth and social development will be formulated and implemented”.

The policy documents produced by the government did not consider proper participation of natural resource dependent occupational; groups and thus it recommends educating local people on climate change issues as an external matter. In the policy document, there is a priority area identified to conduct research on locally adapted crop varieties but it failed to respond to local farmers’ knowledge of crop varieties and there is no clear indication of farmers’ participation in the research activities. The most unfortunate thing is that policy documents are produced which involves lot of financial resources but are not implemented [76].

But the strategy should be a time and resource-bound specification with priority actions in coastal development; it will be about building a process to implement the policies, not preparing a classic master plan. Such a strategy makes critical choices, for example in relation to targeted regions, disadvantaged groups and issues. Focus is on implementation, including a set of indicators and corresponding monitoring arrangements to assess performance.

The strategy document should reflect the specific actions needed to achieve coastal development objectives. In particular, links should be made to the content and process of the National Strategy for Economic Growth and Poverty Reduction and the subsequent multi-year development plans and to other national policy and planning processes.

The strategy document is a component of the chain: policy ⇒ strategy ⇒ priority investment

Program [42].

Similarly, although many sectoral policies have clear implications for coastal development, in most cases they do not have specific sections on coastal areas and often fail to capture the distinctive combinations of vulnerabilities and opportunities that characterize the coast. The coast remains an area of institutional weakness [78]. Though several government agencies and NGOs are working in the coastal region, there are limited linkages between them and institutional fragmentation is common. Further, many of the government agencies responsible for coastal policies have hardly any presence at the local level. Insufficient coordination—compounded by a lack of institutional, financial, and human capacities for implementation and monitoring—impedes effective policy action. Consequently, sectoral development policies, the National Adaptation Programme of Action (NAPA), and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP) all suffer from inadequate execution and follow-up. Too often, policy efforts aim at formulating master plans rather than at creating flexible planning and implementation procedures that can be adapted to changing situations and priorities based on performance monitoring and continuous feedback from stakeholders [1]. Decision for policy making and implementation usually goes from top to bottom; due to this, various development disasters have been witnessed in Bangladesh. Therefore a bottom up approach involving grassroots voice, integration of local and indigenous knowledge should be incorporated to combat the climate change disasters [76].

Practice and experience developed over the years suggest that successful ICZM strategies should

be in accord with nationally accepted criteria for the development of the coastal zone, taking into account poverty alleviation and economic growth, environmental quality, empowerment of local communities and local participation in planning and implementation, disaster preparedness and mitigation, and international cooperation; stimulate and facilitate operational interactions among agencies needed to implement sector policies; create a national platform to facilitate implementation and monitor corresponding progress. Most importantly, the scientific values of the traditional knowledge should be evaluated and a comprehensive policy should be made through a science and policy makers’ dialogue.

The key to ICZM is to empower timely decision making at the appropriate levels, providing the flexibility to respond to evolving circumstances and cope with persistent uncertainties. When this has been achieved, the great range of opportunities offered by the coastal zone—including marine resources; the accretion of new land, oil and gas resources; the potential productivity of mangroves and other coastal ecosystems; and tourism and leisure activities—can be judiciously developed. However, there is inadequate information on pollution and sedimentation loads entering the Bay of Bengal, on coastal habitats and endangered species. This information is necessary in order to understand the functioning of the ecosystem and its reaction to stress over time [41].

After the initiation of the Coastal Zone Policy and ICZM, it has not contributed any significant improvement rather over all coastal zone ecosystems have been deteriorated a lot. The mangroves are diminishing, cyclones, floods and tidal surges are affecting repeatedly. The intensity of damages of properties has increased much. Moreover, both biodiversity and human life have been affected due to lack of scientific study and exclusion of traditional adaptation practices [76]. Bangladesh Resource Centre for Indigenous knowledge (BARCIK)[76] also studied on NAPA and BCCSAP and found that an amount of BDT 3.0 billion was allocated in 2008-2009 to deal with impacts and adaptation of climate change but nothing was spent during that period but later the government finalize the BCCSAP in the light of government’s Vision 2021 and perspective action plan and allocated BDT 7.0 billion to Climate Change Fund in 2009-2010 fiscal year. Report also pointed out that for every project, budget and project design cost has been proposed where more experts in the preparation of details project will also be included for donor hunting as loan or grant. The NAPA document has ignored the communities understanding, their experiences and observations, and the traditional and indigenous knowledge and practices. In every individual project documents, the writing teams have considered to involving several experts, infrastructural constructions, new project formulation but have not addressed how the existing similar projects could be incorporated and coordinated. That actually results in ‘action when the disaster starts’. Virtually a very little progress has been achieved to mitigate the long-term climate change impacts other than minimizing human death.

The major challenge to ICZM is to realize these potentials while mitigating or adapting to vulnerabilities through a process that enhances the livelihoods of the inhabitants and provides communities with avenues for input to, and support from, external institutions and of course traditional adaptation practices and the natural and traditional defense mechanisms.

For Bangladesh, the political institutional barrier is the largest obstacle to overcome, requiring awareness and capacity building at the highest political and policy levels. Increased funding would help, but must be channeled toward the most climate-vulnerable communities through appropriate structures to maintain accountability and transparency. A coherent, dynamic national action plan is needed to prioritize adaptation measures, regularly review implementation, and eventually revise and reprioritize policy actions. Such a plan should facilitate more comprehensive evaluation of adaptation options, providing a framework for assessing social and environmental as well as economic costs and benefits across all relevant sectors and stakeholders. Formulating this plan would force decision makers to think beyond the short-term, politically expedient horizons of three to five years. A shift to long-term planning will enable the long-term effects of climate change—with predicted rises in sea levels, possible increases in the frequency of major storms, and changes in rainfall patterns over the whole Ganges-Brahmaputra basin—to be taken into account.

For an effective ICZM, natural phenomenon of wind and water flow and the interaction with the adaptation procedures of biological systems must be respected. Protection of coastal lands, forests, shorelines, water-bodies and islands as well as land accretion such as charlands, sand dunes etc., and reduction of climate extremes especially the tropical cyclones and tidal surges, the laws of hydrodynamics and wind-forces and the interaction of biological adaptations especially of the trees must be respected and utilized for a sustainable coastal zone management.

**7.0 Conclusion**

The above synthesis indicates that, the traditional natural and artificial defense mechanisms are vital to protect the flood plains and the whole coastal zones. However, introduction of some impracticable and unsustainable practices have almost destroyed the long-term adapted cultures. The floodplains can easily be managed by landscaping and planting appropriate species for protection of the structures and lives from natural calamities like cyclones, tornadoes, floods and tidal surges. Hills and wet-bodies are also important natural protection measures and provide adaptation for diverse species. Since coastal zone of Bangladesh is very vulnerable to extreme events, there is no short-cut solution to protect the region from the vulnerability except natural and traditional defense mechanism. Conventionally, it was tried with many practices like polderization, embankments, dykes and improvement of roads and highways but these only are increasing the sufferings of people and increasing economic loss causing huge migration to the cities. In the name of grow more food, many wet-bodies were filled up with earth but lost the natural catchments for holding surface water and the people are almost dependent on ground water. Thus a great water crisis has been emerging, moreover, flood has become a frequent issue damaging huge crops and livelihoods every year. Massive plantation of some of the exotic and xerophytic trees are driving the country towards desertification and tree food and feed crisis thus losing biodiversity. The policy makers, as well as the researchers are required to think for better practices for an improved coastal zone management. Countries like India, Myanmar, Cambodia, Vietnam etc. where coastal zones are very vulnerable to climate change disasters need more interaction and integration of the traditional ways of adaptation. The natural and traditional adaptation practices should be evaluated scientifically through habitat research, in-depth analysis in the workshops and seminars involving stakeholders for a sustainable national and regional policy for coastal zone management.

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**9.0 References**

[1] D. Michel and A. Pandya, Coastal Zones and Climate Change; Stimson’s Regional Voices, ISBN: 978-0-9821935-5-6 (2010) www.stimson.org/programs/regional-voices.

[2] M.A. Miyan, Monsoon in Bangladesh; Changes and Adaptation: Asian Monsoon Years AMY-6 (2009), Kunming China November 30-December 01, 2009.

[3] M.A. Rahman, Coastal Zone Management of Bangladesh Presented in the International Geosphere-Biosphere Programme Synthesis Integration and Exploration: Global Environmental Change and Sustainable Development; Needs of Least Developed Countries (IGBP-LDCs) Synthesis Workshop (2010), Maputo Mozambique September 20-22, 2010 feppcar.org/122/**coastal**-**zone**-management-in-**bangladesh accessed on June 4, 2014.**

[4] M.A. Rahman, Study on the Changes of Coastal Zone: Chittagong to Cox’s Bazar along the Bay of Bengal; Global Summit on Coastal Seas, EMECS 9 (2011), August 28-31, 2011, Baltimore, Maryland, USA.

[5] Bangladesh National Herbarium, Red Data Book of Vascular Plants Bangladesh, Eds. M.S. Khan, M.M Rahman and M.A Ali., Bangladesh National Herbarium, (2001) ISBN 984-32-0128-0.

[6] M.K. Hossain and F.U. Ahmed, Nursery Manual of Endangered Tree Species; Arannyak Foundation, Banani, Dhaka 1213, (2008) ISBN 984-300-001966-0

[7] M.A. Miyan, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) (2012) Yeosu, Republic of Korea, May 23-29, 2012.

[8] A. Banica; J. Bastard, and M Kosiek, Integrated Coastal Zone Management (ICZM): a framework to tackle environmental issues? Danish Approach Centre for Environmental Studies, June 2003 Reprocenteret, Det Naturvidenskabelige Fakultet, Aarhus Universitet, (2003) ISBN: 87-7785-146-3

[9] E.C.F. Bird, **Environmental problems related to the coastal dynamics of humid tropical deltas;** Proceedings of the Jakarta workshop on coastal resources management, (1979) http://www.unu.edu/unupress/unupbooks/80130e/80130E04.htm#

[10] NPDM-2015, National Plan for Disaster Management 2010-2015 Disaster Management Bureau Disaster Management & Relief Division, Government of the Peoples Republic of Bangladesh; March (2010).

[11] The Daily Star, September 16, (2013), Sundarbans Shrinking http://www.thedailystar.net/beta2/news/sundarbans-shrinking/ accessed on 16th September 2013

[12] IPCC-2007, Oceans and Coastal Zones Climate Change: Working Group II: Impacts, Adaptation and Vulnerability (2007). http://www.ipcc.ch/publications\_and\_data/ar4/wg2/en/ch10s10-2-4-3.html

[13] M.A. Rahman, Vulnerability of the Bay of Bengal Enclosed Coastal Sea due to Socio‐Economic Conditions of the Megacity of Dhaka; Global Summit on Coastal Seas, EMECS 9, August 28-31, 2011, Baltimore Maryland, USA, Published in Indian Journal of Humanities, Vol. 01, Issue 04, (2011), ISSBN: 2248-9541Rarahman M.A., 2011

[14] AON Benfield, May 2013 Global Catastrophe Recap (2013) http://thoughtleadership.aonbenfield.com/Documents/20130604\_if\_may\_global\_recap.pdf

[15] Climate Change Cell, Impact Assessment of Climate Change and sea Level Rise on Monsoon Flooding (2009) http://www.climatechangecell.org.bd/publications/ResearchDocs/Monsoon\_Flooding.pdf accessed on 15the April 2013

[16] Miyan, M.A, Coastal Zone Management of Bangladesh, Fourth Session of the Joint WMO-IOC Technical Commission for Oceanography and Marine Meteorology (JCOMM-4) Yeosu, Republic of Korea, May 23-29, (2012)

[17] M.A. Sattar and D.K. Bhattacharjee, Physical and mechanical properties of Sundri (*Heritiera fomes*) and Baen (*Avicennia alba*). Bull. 10. (1987), Chittagong, Bangladesh: Government of the People's Republic of Bangladesh, Forest Research Institute, Timber Physics Series.

[18] M.A. Rahman, Model Rural Homestead Farming - A Real Example of Crop Diversification: *In* Plantation Crops and Organic Farming: Research Articles Series 1: Some Environment Related Problems and Their Solutions: January (2004). ISBN 984-32-1154-5

[19] M.A. Rahman, Case Study: The Brahmanbaria Tornado-2013 RCE Bulletin 23, May 22, (2013), http://www.ias.unu.edu/resource\_centre/RCE%20Greater%20Dhaka%20-%20Tornado%20in%20Brahmanbaria.pdf accessed on 16th June 2013

[20] Y. Yamane, T. Hayashi; A.M. Dewan, and F. Akter: Severe Local convective storms in Bangladesh: Part 1, Climatology, Atmos. Res. 2009 doi.: 10. 1016/j.atmosres.(2009).11.004 http://www.iawe.org/WRDRR\_Bangladesh/Preprints/S3Hayashi-Yamane.pdf

[21] M.A. Rahman, Workshop on Coastal Zone Management, Patuakhali University, (2012)

[22] AW Akonda, 'Bangladesh' in DA Scott ed, *A Directory of Asian Wetlands*, IUCN, Switzerland, (1989). http://www.banglapedia.org/HT/W\_0051.HTM accessed on 16th September 2013

[23] M Salar Khan *et. al.* ed, *Wetlands of Bangladesh,* Bangladesh Centre for Advanced Studies, Dhaka, (1994). http://www.banglapedia.org/HT/W\_0051.HTM accessed on 16th September 2013

[24] APDC, Handbook on Design and Construction of Housing for Flood-prone Rural Areas of Bangladesh ISBN: 984-32-2163-X (2005): Printed by Nymphea, 67/D, Panthapath, Dhaka-1209, Bangladesh; http://www.adpc.net/audmp/library/housinghandbook/handbook\_complete-b.pdf

[25] A.K.E. Haque, Sanitary and phyto-sanitary barriers to trade and its impact on the environment: the case of shrimp farming in Bangladesh*.* Dhaka, IUCN Bangladesh, Country Office, (2004) 63 pp.

[26] N. Karim: Options for Floods and Drought Preparedness in Bangladesh (2004). www.grif.umontreal.ca/pages/papers 2004/paper-karim N pdf, accessed in 11.10.2012

[27] A.K. Deb, Fake blue revolution: environmental and socio-economic impacts of shrimp culture in the coastal areas of Bangladesh. *Ocean & Coastal Management,* 41: (1998) 63–88.

[28] A. Firoze, The southwest coastal region: problems and potentials. Dhaka, *The DailyStar*, XIV, Issue 215 (2003).

[29] A. Mascarenhas, Extreme events, intrinsic landforms and humankind: post-tsunami scenario along Nagore-Velankanni Coast, Tamilnadu. *Current Science,* 90: (2006) 1195–1201.

[30] M.Z. Haq; M. Robbani; M. Ali; M.M. Hasan; M.J. Uddin; M. Begum; da Silva, X.Y. Pan, and JAT Karim, Damage and management of cyclone Sidr –affected homestead tree plantations: a case study from Patuakhali, Bangladesh; Received: 3 November 2011/Accepted: 11 July 2012; Springer Science+Business Media B.V. (2012)

[31] S.K. Verma, A Textbook of Plant Physiology and Biochemistry; S. Chand & Company Ltd Ramnagar, New Delhi-110 055 Third Edition 1999 ISBN 81-219-0627-X (1999) pp 85-102

[32] M.A. Rahman, Grey Water Use can Reduce Huge Water Crisis in Dhaka Megacity (2013a) - http://feppcar.org/280/grey-water-use-can-reduce-huge-water-crisis-in-dhaka-megacity/#more-280

[33] D. Kumar, *In* Eucalyptus Enduring Myths, Stunning Realities Abbasi SA, Ramesh N and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New Delhi, 110002, India ISBN W8171418929, (1984) pp 26-27

[34] Brown *et. al.*, *In* Eucalyptus Enduring Myths, Stunning Realities Abbasi SA., Ramesh, N. and Vinithan, S. 2004; Discovery Publishing House 4831/24, Ansari road, New Delhi, 110002, India ISBN W8171418929, (1976) pp 26-27

[35] Ackerson, *In* Eucalyptus Enduring Myths, Stunning Realities Abbasi, SA. Ramenh, N. and Vinithan, S. 2004; Discovery Publishing House 4831/24, Ansari road, New Delhi, 110002, India ISBN W8171418929, (1980) pp 26-27

[36] Singh *et.al.* 2004, *In* Eucalyptus Enduring Myths, Stunning Realities Abbasi SA, Ramenh N. and Vinithan S. 2004; Discovery Publishing House 4831/24, Ansari road, New Delhi, 110002, India ISBN W8171418929, (1990) pp 26-27

[37] M.S. Combalicer; D.K. Lee; S.Y. Woo; J.O. Hyun; Y.D. Park; Y.K. Lee; A. Edwin; E.A. Combalicer; and Jr. E.L. Tolentino, Physiological Characteristics of *Acacia auriculiformis A. Cunn.* ex Benth*., Acacia mangium* Willd*.* and *Pterocarpus indicus* Willd. in the La Mesa Watershed and Mt. Makiling, Philippines: Journal of Environmental Science and Management 14-28 (Special Issue 1- (2012) ISSN 0119-1144

[38] YPSA, Workers in Ship Breaking Industries: A base line survey of Chittagong, Bangladesh. Young Power in Social Action (YPSA), Chittagong. (2005).pp 79

[39] YPSA, Ship breaking in Bangladesh: Environmental Pollution (2010) http://www.shipbreakingbd.info/Environment.html

[40] The Daily Ajker Deshbidesh, October 16, (2008)

[41]. NOAA, Bay of Bengal large marine ecosystem, (2008) http://www.eoearth.org/view/article/150447/

[42] Coastal Zone Policy, Ministry of Water Resources; Government of the People’s Republic of Bangladesh (2005) http://www.warpo.gov.bd/pdf/czpo\_eng.pdf

[43] Islam, M.R. (edt.), 2004. Where lands meets the sea. A profile of coastal zone of Bangladesh. The University Press Limited, Dhaka, 2004. http://www.doe.gov.bd/publication\_images/8\_npa\_draft.pdf

[44] 2004 Flood Archive 2004 Global Register of Major Flood Events http://www.dartmouth.edu/~floods/Archives/2004sum.htm

[45] Farid Hossain 2002 Floods 2002, The Associated Press http://www.greatdreams.com/floods\_2002.htm

[46] Earth Justice ACJP 2009: The Role of Black Carbon in Endangering World Heritage Sites Threatened by Glacial Melt and Sea Level Rise,

[47] IPCC 2001b Coastal zones and marine ecosystems. *In* McCarthy, J.J., O.F. Canziani, N.A. Leary, D.J. Dokken and K.S. White (Eds.). Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, Cambridge

[48] OECD Report 2003 Development And Climate Change In Bangladesh: Focus On Coastal Flooding And The Sundarbans, http://www.oecd.org/env/cc/21055658.pdf

[49] Bhattacharya Sayan, Chattopadhyay Dhrubajyoti and Mukhopadhyay Aniruddh 2013:

Changing Dimensions of Food Security in a Globalized World: A Review of the Perspectives for Environment, Economy and Health International Research Journal of Environment Sciences, ISSN 2319-1414, Vol. 2(3), 67-73, March (2013)

[50] Forum 2009: Climate Change — The Anatomy of A Silent Crisis: — Case Study: Bangladesh A nation at the frontline of the climate change crisis, Human Impact Report Climate Change Global humanitarian Forum Geneva, http://www.ghf-ge.org/human-impact-report.pdf

[51] Government of Bangladesh. (2008): “Bangladesh climate change strategy and action plan.” Government of Bangladesh. http://www.foshol.org/IUCN\_BCCSAP\_2008/IUCN\_BCCSAP\_2008\_part2.pdf.

[52] CRED database, (2009).

[53] http://www.doe.gov.bd/publication\_images/17\_environment.pdf

[54] KK Biswas and Lars Emmelin 2010 Changing Climate; Bangladesh Facing the

Challenge of Severe Flood Problems; A Comparison of Flood Management between Bangladesh and the Netherlands http://www.bth.se/fou/cuppsats.nsf/all/4ac7b480ad562fb0c1257749005fc03e/$file/Thesis2010.pdf

[55] Alex de Sherbinin, David Carr, Susan Cassels, Leiwen Jiang Population and Environment

Annu Rev Environ Resour. 2007; 32: 345–373. doi: 10.1146/annurev.energy.32.041306.100243

[56] FAO (1998), Integrated coastal area management and agriculture, forestry and fisheries.

[57] Pender, J.S. 2008. What Is Climate Change? And How It Will Effect Bangladesh.

Briefing Paper (Final Draft). Dhaka, Bangladesh: Church of Bangladesh Social

Development Programme. https://www.kirkensnodhjelp.no/Documents/Kirkens%20N%C3%B8dhjelp/Publikasjoner/Temahefter/FINAL%20Draft%20WHAT%20IS%20CLIMATE%20CHANGE%20AND%20HOW%20IT%20MAY%20AFFECT%20BANGLADESH.pdf

[58]Wong, C.M., Williams, C.E., Pittock, J., Collier, U., and Schelle, P. 2007. World’s top 10 rivers at risk. WWF International. Gland, Switzerland

[59] Lubna Seal and Mohammed Abdul Baten 2012 Salinity Intrusion in Interior Coast: A New Challenge to Agriculture in South Central part of Bangladesh, January 2012 http://www.unnayan.org/reports/climate/Salinity\_Intrusion\_in\_Interior%20Coast-A\_New\_Challenge\_to\_Agriculture\_in\_South\_Central\_part\_of\_Bangladesh.pdf accessed on 9 July 2014

[60] CCC, 2009. Climate Change, Gender and Vulnerable Groups in Bangladesh. Climate

Change Cell, DoE, MoEF; Component 4b, CDMP, MoFDM. Month 2009, Dhaka.

[61] B.K. Chand, R. K. Trivedi, S. K. Dubey and M. M. Beg, 2012. Aquaculture in Changing Climate of Sundarban: Survey Report on Climate Change Vulnerabilities, Aquaculture Practices & Coping Measures in Sagar and Basanti Blocks of Indian Sundarban, West Bengal University of Animal & Fishery Sciences, Kolkata, India.http://www.nicra-icar.in/nicrarevised/images/Books/Aquaculture%20in%20Changing% 20Climate%20of%20Sundarban.pdf, accessed on 11 July 11, 2014

[62] The Sundarbans; http://whc.unesco.org/en/list/798

[63] Bangladesh: State Of The Environment 2001 http://www.moef.gov.bd/html/state\_of\_env/pdf/bangladesh\_disasters.pdf; accessed on 11 July 11, 2014

[64] M H Rahman 2004 Wetland and water pollution management in Bangladesh http://globalcommunitywebnet.com/gdufour/2004WorkHasiburrahman.htm

[65] Coastal Embankment Improvement Project Phase-I, Environmental Impact Assessment of Polder 35/3; May, 2013, Government of the People’s Republic of Bangladesh, Ministry of Water Resources, Bangladesh Water Development Board http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/08/28/000356161\_20130828151210/Rendered/INDEX/E41410v40CEIP0000PUBLIC00Box379813B.txt

[66] S. K. Dube: Recent Developments in Storm Surge Prediction in the North Indian Ocean http://nidm.gov.in/idmc2/PDF/Abstracts/Cyclone.pdf

[67] Guidelines on Erosion Control and Drainage of Railway Formation (Guideline No. GE: G-4) February- 2005 Geo-technical Engineering Directorate,

Research Designs and Standards Organisation Lucknow - 226011 http://www.vetiver.com/IND\_Indian%20railways.pdf

[68] Cruz RV, Harasawa H, Lal M, Wu S, Anokhin Y, Punsalmaa B, Honda Y, Jafari M, Li C, Huu N (2007) Asia. Climate change, 2007, impacts, adaptation and vulnerability. In: Parry ML,

Canziani OF, Palutikof JP et al (eds) Contribution of Working Group II to the Fourth

Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University

Press, Cambridge, pp 469–506

[69] Mannava V.K. Sivakumar and Robert Stefanski Climate Change in South Asia Chapter 2, *In* **Lal**, R., **Sivakumar**, M.V., **Faiz**, S.M.A., **Mustafizur Rahman**, A.H.M., **Islam**, K.R. (Eds.) 2011, Climate Change and Food Security in South Asia XXII, 600p.

[70] Conservation of Mangrove Forest Genetic Resources: A Training Manual

Edited by Sanjay V. Des~mukh and V. Balaji. @ CRSARD 1994 http://www.mssrf.org/csr/csr-pub/01-conservationofmangroveforestgenetic.pdf

[71] Morton, J.F. (1988) The Palmyra or Toddy Palm (Borassus flabellifer L.) Notes on Distribution, Propagation, and Products of*Borassus* Palms (Arecaceae). *Economic* Botany (1988) 42(3): 420-441 <http://www.fao.org/ag/aga/agap/frg/econf95/HTML/TODDY.HTM>

[72] MA Rahman 2009 Palmyra Palm: Symbol for Sustainability http://feppcar.org/59/palmyra-palm-symbol-for-sustainability/

[73] K. Iftekhar Ahmed 2006 The Rural Bangladeshi Courtyard BRAC University Journal, Vol. III, No. 1, 2006, pp. 9-15,

[74] Randy Peppler 2010 Fieldwork in Indian Country: A Conversational Experience

Draft Article Currently in Publication for July 2010 Weather and Society Watch http://www.sip.ucar.edu/wasis/boulder10/pdf/Peppler.pdf

[75] World Food Programme: Agricultural Production & National Food Balance http://www.foodsecurityatlas.org/bgd/country/availability/agricultural-production

[76] BARCIK Report 2013: National Adaotation Programme of Action (NAPA) and People’s Adaptation Plan; http://www.klima-und-gerechtigkeit.de/fileadmin/upload/Dialogforen/summary\_NAPA\_study.pdf

[77] Sayeeda Farhana 2011, Suitability of Pond Sand Filters as Safe Drinking Water Solution in Storm Surge Prone Areas of Bangladesh: A Case Study of Post-Aila Situation In Shyamnagar, Satkhira District, Khulna Masters Dissertation: Postgraduate Programs in Disaster Management (PPDM) BRAC University, Dhaka, Bangladesh http://dspace.bracu.ac.bd/bitstream/handle/10361/1822/sayeeda%20farhana.pdf?sequence=1

[78] World bank Report 2013: Warming Climate to Hit Bangladesh with Sea Level Rise, More Floods and Cyclones http://www.worldbank.org/en/news/press-release/2013/06/19/warming-climate-to-hit-bangladesh-hard-with-sea-level-rise-more-floods-and-cyclones

[79] Golam Rabbani, A. Atiq Rahman, and Nazria Islam 2010, Climate Change and Sea Level Rise: Issues and Challenges for Coastal Communities in the Indian Ocean Region Coastal Zones and Climate Change The Henry L. Stimson Center ISBN: 978-0-9821935-5-6