Feasible Solution of Protection and Adaptation Strategy for Coastal Zone of Bangladesh

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Abstract

The Bay of Bengal is the breeding ground for tropical cyclones and Bangladesh is the worst victim in terms of fatalities and economic losses incurred. Among the 508 cyclones that have originated in the Bay of Bengal in the last 100 years, 17 percent have hit Bangladesh, amounting to a severe cyclone almost once every three years. Of these, nearly fifty three percent have claimed more than five thousand lives. The high number of casualties is due to the fact that cyclones are always associated with storm surges. Storm surge height in excess of 6m is not uncommon in this region. The elevation of land is around 12 feet at 2.5km from the sea shore where it is around 22 feet at 100km inland from the sea shore in western and central regions of the country. Moreover there are many low lands, flood plains, rivers and channels within this 100km range. Thus the southern regions usually go under water during surge and face uncountable damage by destructive wind speed. Agricultural fields lose fertility due to erosion, sedimentation, sea-spray and saline water intrusion. Damage of crops and vegetations affects national food production and security. Loss of lives, livestock, damage of crops, contamination of water sources, destruction of house, transportation system, embankment and other development structures not only stop the flow of livelihood at a sudden, these infirm the long term social, health care, economic development and policy of the government. Every year, huge amount of budget needs to allocate for relief, medication, subsidy and post-disaster phase of socio-economic recovery, reconstruction and maintenance works in coastal area.

During the disaster, there is shortage of water supply and food apart from the loss of homestead, crop and livestock. Loss of the rural roads leads to a missing link for the supply of relief and rehabilitation facilities at the quickest possible time. This paper aims at a conceptual protection and adaptation strategy for the coastal population of Bangladesh at an affordable manner. The recommended strategy involves minimum intervention to the existing locality and thus a minimum of cost being involved with the maximum possible facilities to available at the end of the victims specially during and immediately after the disaster. The main theme of the adaptation strategy is the modification of the landscape to the smallest extent in order to facilitate the shelter for human being and livestock, storage of harvested crop, water supply, sanitation and the transportation network. Feasibility of the proposed theme has been analyzed from different direction applying scientific logics. Species of the salt tolerant crops have been mentioned targeting the food and job security. The paper proposes the minimum coastal zone that should be brought under the adaptation strategy at the initial pilot stage. The ecological balance of the affected locality is also considered in the adaptation strategy as well.

Key word: Cyclone, adaptation, landscape, wetland, mangrove, species, salt tolerant crop.

Introduction

The coastal zone of Bangladesh, an area covering 47,211 km² facing the Bay of Bengal or having proximity to the Bay, and the exclusive economic zone in the Bay (Islam, 2004), is generally perceived to be a zone of multiple vulnerabilities. Records of last 200 years show that at least 70 major cyclones hit the coastal belt of Bangladesh and during last 35 years nearly 900,000 people died due to catastrophic cyclones (Islam, 2004). The government of Bangladesh has already identified the zone as “vulnerable to adverse ecological process” (ERD, 2003). The opportunities and potentials of the zone have not received much attention, and also the disaster mitigation approaches are seen as curative measure rather than protective, which make questions for sustainable coastal belt planning and development.

To improve the overall situation, comprehensive long term disaster management is necessary. Cyclone shelter, embankment have insignificant role to mitigate the impacts of disaster. The best way is to introduce natural protective barriers with proper planning and design. In this paper the role of several components of nature in disaster mitigation has been described and a combined design and strategy have

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been mentioned. The design will be easy to implement in an affordable cost and people will get opportunities to involve in alternate income generating activities; improvement of overall production and health situation. In the initial stage this strategy can be experienced in a coastal island to evaluate its grade of sustainability.

Vulnerability of coastal area

Bangladesh is situated at the interface of two contrasting settings with the Bay of Bengal and the North Indian Ocean to the south and the Himalayas to the north. The geographical location, low and almost flat topography, very high population density, etc. have made this country one of the most vulnerable countries of the world to be affected by the impact of climate change. The funnel-shaped northern portion of the Bay of Bengal causes tidal bores when cyclones make landfall and thousands of people living in the coastal areas are affected. Of the 508 cyclones that have originated in the Bay of Bengal in the last 100 years, 17 percent have hit Bangladesh, amounting to a severe cyclone almost once every three years (GoB, 2008). From the statistical analysis of the recorded cyclones over the last 200 years, it has been found that number of occurrences of major cyclones has drastically increased in the recent decades. While the number of cyclones was 3 during the period of 1795-1845 and 1846-1896 respectively, the number increased to 13 during 1897-1947 and 51 during the period of 1848-1998.

The country has three distinct coastal regions, namely the western, central and eastern regions. The western zone is very flat and low and is crises-crossed by numerous rivers and channels. The central region is the most active one and continuous process of accretion and erosion is going on there. The eastern region is covered by hilly areas and it is more stable and has a long beach there. Some parts of western region have the capacity to stand against cyclone disaster where Sundarban, the largest mangrove forest exists. But the other parts of the coastal area have no significant protective barrier to dissipate the cyclone and tsunami energy. It is observed that the elevation of land is around 12 feet at 2.5km from the sea shore where it is around 22 feet at 100km inland from the sea shore in western and central regions of the country. Moreover there are many low lands, flood plains, rivers and channels within this 100km range. The elevation of those areas varies from 12 feet to 18 feet. In fact the major portion of land here is this type. As a result, in any types of moderate cyclone, the devastating impact expands more than this range. Bank erosion, saline water intrusion, and inundation in large scale are common matters in every cyclone disaster. The reality can also be found from the recent cyclone “AILA” hit Bangladesh at May 25, 2009. Maximum average wind speed was 110 km/h. The range of inland area affected by this disaster has been shown in Figure 1. It was reported that crops of about 323454 acre, 613778 households were fully or partially damaged and 3928238 peoples were affected in this cyclone (DMB, 2009). The wind speed of the previous cyclone landfall Bangladesh varied from 85 km/h to 260 km/h caused strong surge of height up to 7.8m. The Multi-purpose Cyclone Shelter project (MCSP) in Bangladesh (1993) modeled storm surge along the Bangladesh coast with the help of GIS. MCSP also prepared a table which shows surge height for cyclones of varying strength in Bangladesh (Table 1).

Table 1: Typical storm surge height for cyclones of varying strength in Bangladesh

Wind velocity (Km/h)	Storm surge height (m)	Wind velocity (Km/h)	Storm surge height (m)
85	1.5	195	4.8
115	2.5	225	6.0
135	3.0	235	6.5
165	3.5	260	7.8

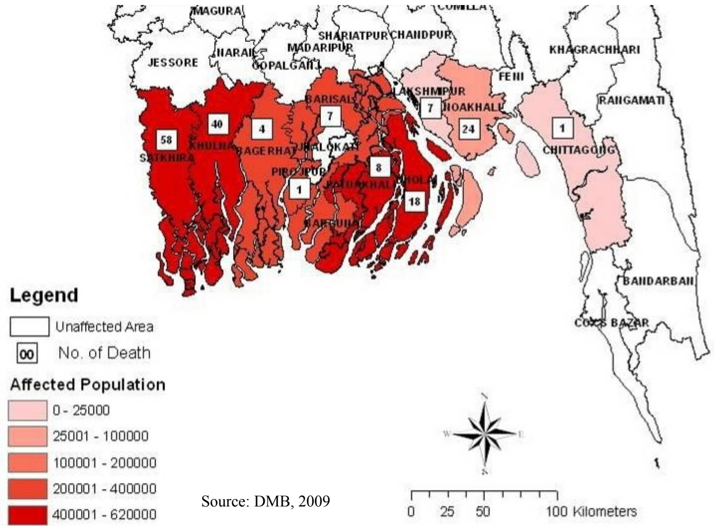


Figure 1: Range of inland area affected by cyclone "AILA"

Protection by improved coastal natural barrier

Cyclone and after cyclone situation analysis revels that for any types of moderate cyclone, the common occurrences are, i) destruction due to wind force and surge, ii) loss of lives, livestock and crop by tidal wave, iii) loss of soil fertility for spread of sea-spray, saline water intrusion and sedimentation, iv) water source contamination v) extensive environmental pollution, vi) spread of diseases and vii) unemployment and starvation. Embankment and cyclone shelter have very little protective capacity of these occurrences. But to resist the devastative impacts of cyclone it is necessary to develop natural protective barrier in a planned way changing coastal landscape considering all kind aspects as much as possible. In this context the following combined design of landscape from seashore to several kilometer inner lands may provide significant assistance to overcome almost all kinds of impacts of cyclone disaster and tsunami.

Zone of storm wave-sediment interaction

A range of seashore goes under water during high tide everyday and leaves it as bare land during ebb. If a 500-800 meter width of land area including the tidal area of interference can be kept as bare land it will act as "Zone of storm wave-sediment interaction". It can slow hurricanes, reduce their wave energy and protect the interior wetland. This land has the capacity to absorb incoming wave energy. It is the one side benefit and the other side is this extended bare land can be effectively used for the improvement of tourism industry in the country. The coastal people will get alternate source of employment facilities reducing the dependence on risky job of fishing in the ocean.

Wetland

Wetlands act as sponges to soak up excess water. Coastal marshes serve as storm surge protectors and help to reduce storm damage when hurricanes or tropical storms come ashore. Inland wetlands function like natural tubs, storing flood waters that over-flood riverbanks, surface areas and protecting adjacent and downstream property. According to EPA (2001), a one-acre wetland can typically store about three-acre feet of water, or one million gallons. An acre-foot is one acre of land, about three-quarters the size of a football field, covered one foot deep in water.

In the seaward side wetland, several water and salinity resistive plants and crops can be cultivated to yield more food production. But the main challenge is to identify the level of salinity and types of species, which can grow in that level and have high food or market value. Local name of some oryza species, Jamainaru, Lakshmikajal, Patnai Balam, Horkuch, Morichshail, Ashfal, Raniselute, Kajalshail, Pokkali, Nona Bokra and salt tolerant modern varieties (SMVs) IR29, BRRI dhan 29, BRRIdhan 40, BRRIdhan 41 etc. have high potential in saline environment (Laisa, et al, 2004).

The interior wetland has also some capacity to impart strength to the total protective system dissipating cyclone energy. Water enters into the interior low land during surge remain longer period getting no way to drain away. Proper management of this wetland may provide diverse benefit in normal time as well as in time of emergency. In normal season water and saline tolerant crops or mix cropping system can be exercised. New invented paddy, Swarna Sub1, BR11 Sub1, IR64 Sub1 and Sambamasuri Sub1 are highly recommended at this zone. The attractive features of these species are the sustainability in flood water or inundated condition more than 15days and short time period of harvest. In case of 12 months inundation this zone can be utilized for fish culture. After cyclone disaster, interior wetland can act as waterway of transport. It will make possible to send relief goods using waterway immediately after disaster to the affected groups.

Forest

Forests and tree roots provide a protective cover of vegetation that anchors soils, slows and soaks up water runoff. Deforestation worsens the impacts of hurricanes and other storms, increasing the likelihood of mudslides and flooding. Studies show that coastal forests like mangroves and cypress stands shield the coastlines by reducing wave height and energy. Areas buffered by mangroves were less damaged by the 2004 tsunami than areas without tree vegetation. Mangroves trap and stabilize sediment and reduce the risk of shoreline erosion because they dissipate surface wave energy. It is the attribute that makes mangroves a potential natural solution for particular coastal protection problems.

The fact that surface waves propagating within a mangrove forest are subject to substantial energy loss due to two main energy dissipation mechanisms: (1) multiple interactions of wave motion with mangrove trunks and roots; and (2) bottom friction. The resulting rate of wave energy attenuation depended strongly on the density of the mangrove forest, the diameter of the mangrove roots and trunks and on the spectral characteristics of the incident waves. Typically, wave energy is attenuated by a factor of 2 within 50 meters of the front of the mangrove forest. Hence, the wave heights are typically attenuated by a factor of square root 2 given that the wave energy is related to the square of the wave height (Braatz et al., 2007). The role of mangroves in reducing the sea-waves has been scientifically proved. For instance, a six-year-old mangrove forest of 1.5 km width will reduce 1 m high waves at the open sea and 0.05 m at the coast (Mazda et al., 1997). Energy dissipation is not only the main protective activity of forest against cyclone. Sea-spray enters and spread in the coastal area and inland with wind. Mangroves reduce the wind speed and capture sea-spray. It increases the turbulent flow of sea-spray, provides rough surface and easily capture the sediment and sea-spray.

But position, height, width, continuity and density of plants and trees are very important to consider for the reduction of wind speed, strength and direction. Plants with loosely dense and low height should be in the front position seaward side. The medium dense and moderate height plants should be in the middle position and finally most dense and tallest trees should be planned after the medium height mangrove row.

Stabilized elevated bank

An elevated land with sufficient stability is necessary to build up after the end of mangrove belt. Alignment, elevation, width, layer by layer compaction and slope should be designed properly. To impart more stability in affordable expanse, mat made of jute or scrap cloth can be used. In most vulnerable areas or where more protection is needed, concrete sea-wall with proper design need to be constructed.

The elevated bank creates wave reflections and promotes sediment transport offshore. It should be constructed along the whole coastline; if not, erosion will occur on the adjacent coastline. From the previous study it is found that only sea-wall, embankment or elevated land easily get eroded and damaged. But mangroves before sea-wall or embankment stabilize those structures and protect from wind speed and tidal wave.

Human habitat

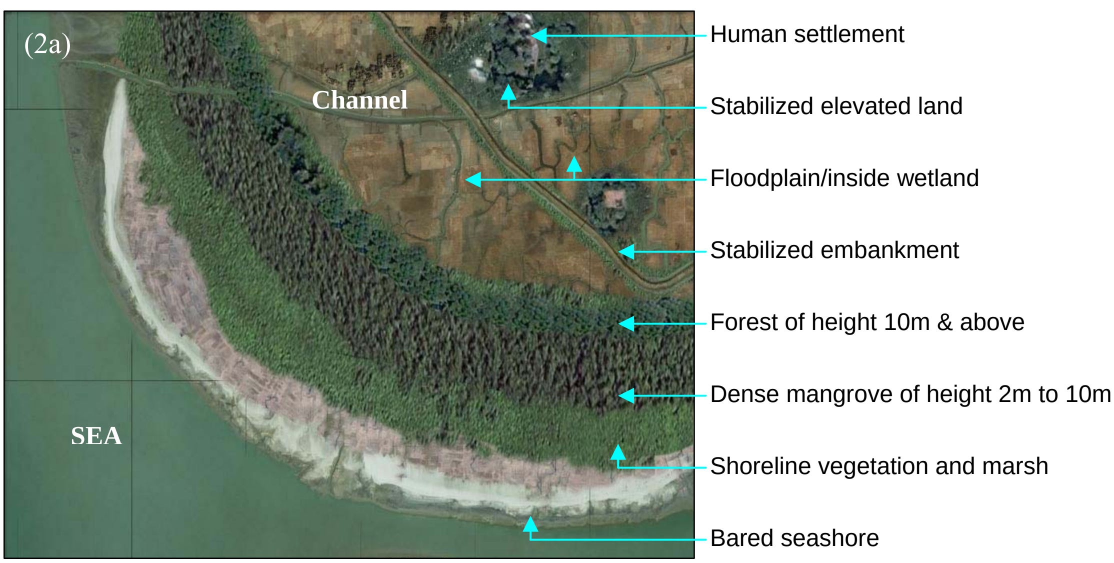
Human settlement in most of the coastal areas in Bangladesh is isolated and unprotected. Devastating wind force and surge easily attack the unsupported houses and other structures with full energy. For this, though the recent developed warning system providing decent role in evacuation but the resource damage is not decreasing substantially. To improve this conditions some specific areas should be taken under development plan. Housing and other structures should be built on elevated land which will remain beyond the normal flood level. This developed land should have stable slope and soil protective vegetations. Housing and other structures will be supported by tall and dense trees. People will live there in community based and there should have adequate facilities of potable water supply and sanitation.

Emergency response

It becomes the main task to shift people of vulnerable areas to cyclone shelter or other safe area before the landfall of cyclone. Most of the cases, the time available for evacuation are far less than the time required. If the time of approach of disaster is possible to extend, more life will be saved and large margin of resources can be restored from damage. There are some species like Sonneratia, Kandelia candel etc. can increase the arrival time of tsunami a lot and save lives and livestock by giving enough time to shift them to shelter. It was predicted with empirical evidence that Sonneratia and Kandelia candel forest of 1 m width can defer the time of Tsunami attack by 727 and 343 seconds respectively (Braatz et al., 2007).

Post disaster relief distribution activity and to reach adequate food, water and medication are very important to support the affected peoples. Damage of roads, embankment and other infrastructure make this very difficult. But if there are alternate provisions to transfer goods and emergency facilities to the affected areas, significant number of post disaster causalities and spread of diseases can be prevented.

Considering all kinds of aspects, affects of disaster, land characteristics, human behavior and action plan of Bangladesh government disaster management, an improved coastal design and strategy has been developed that is presented in figure 2a & 2b.



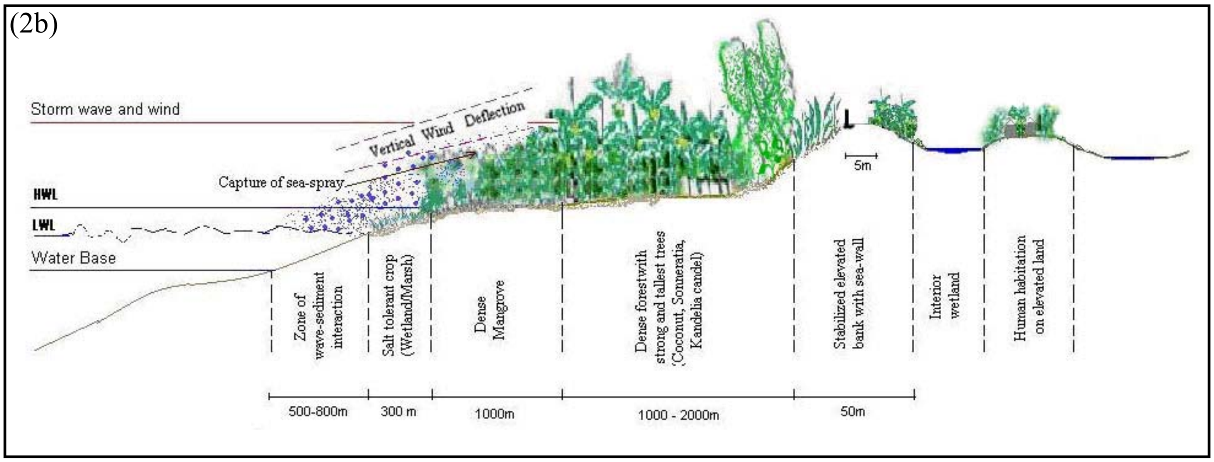


Figure 2: (a) Arial view of the proposed design of coastal area **(b)** Cross section of the proposed design of coastal area (including sea-wall)

Features of the proposed design

The main feature of the proposed design and strategy is to assure more involvement of natural barrier in a planned way. Other characteristics are as follows

- 500-800 m zone of wave sediment interaction
- At least 1km wide marsh and mangrove belt after previous zone
- Cultivation of Salt and water tolerant crops in seaward side before mangrove, which will act as marsh.
- Trees with loosely dense and low height in the front position seaward side, the medium dense and moderate height trees in the middle position and finally most dense and tallest trees will be planted after the medium height mangrove row.
- Build up 25m wide and 4m high elevated land with 5m wide crest. Proper compaction, slope stability, mangrove and vegetation before embankment must be assured. Construction of concrete sea-wall where necessary.
- Reforestation as long as possible in interior side from embankment.
- Preservation of low land and flood plain
- Fish culture or cultivation of submerged crops in floodplains and low lands
- Human settlement on stabilized elevated lands having proper communication system.

Implementation of the proposed design and strategy will provide benefits in four ways. All parts of the design have specific role in disaster mitigation, protection of lives and resources, improvement of living standard and preservation of coastal environment as a whole. These are separately described in table 2.

Except sundarban area, the proposed design can be implemented in almost all parts in coastal area since major development has not yet been done here and these areas remain in unprotected condition. To evaluate the effectiveness and sustainability of the proposed design, “Char Manica” (22°08′N and 90°41′E) can be a suitable area to implement it as a pilot project. The whole take should be performed on the basis of priority analysis. Some parts of the area need to bring under instance adaptation action in the first stage then the next stage should be completed as shown in figure 3.

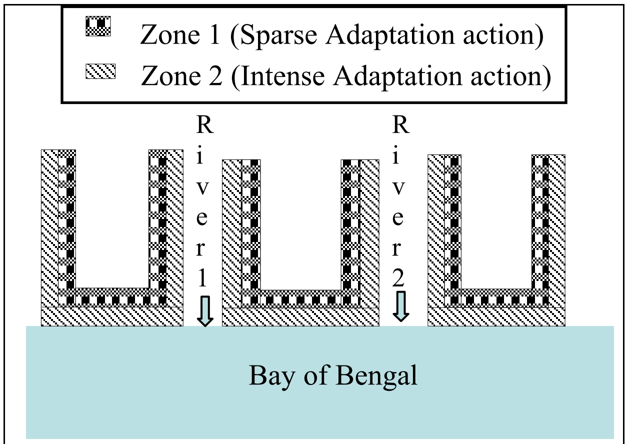


Figure 3: Priority of area under adaptation

Table 2: Beneficial role of different components of the proposed design and strategy in coastal area

Component	Beneficial role			
	Disaster mitigation	**Protection of lives and resources**	**Living standard and resource development**	**Preservation of environment**
Zone of storm wave-sediment interaction	Absorb tidal energy and protect sea-ward wetland	Reduce cyclonic power	Improvement of tourism, employment facilities	Coastal biodiversity conservation
Wetland/Marsh land	soak up excess water, increase of friction force	Surge height reduction	Cultivation of salt tolerant crops, food production, alternate income generation activity, less dependence on fishing in ocean	Absorption of polluted matter, improvement of coastal ecology
Forest/Mangrove	Reduction of wave energy, wind force, runoff, surge height, sea-spray, sediment transport, land erosion, increase of bank stability, tsunami approach time and change of wind direction	Decrease of sudden shock of disaster, death toll, loss of soil fertility, damage of house, embankment, infrastructures, crops and vegetations.	Collection of fruits, flowers and leaves with high medicinal, honey, wood and other materials. Improvement of tourism, employment facilities	Improvement of wildlife, ecosystem and coastal stability. Minimization of post disaster environmental pollution.
Elevated bank	Strong protective barrier to lessen impact of disaster	Act as protective land to facilitate transport and stay of lives temporarily	Serve as way of transport to carry products to growth center	Protection of interior lands and water bodies from contamination, salinity and sedimentation.
Interior mangrove and low land	soak up more water and impart more protection	Preservation and stabilization of land for human habitation.	Vegetation, crop cultivation and fish culture	Salinity reduction and ecological balance.
Protected human settlement	Act as island during flood and inundation	Protection of lives and livestock from tidal wave	Stable habitation, decrease of migration rate.	Minimization of pollution from causalities.

Feasibility

The proposed coastal landscape will not be difficult to implement if necessary steps are taken from local level to national level identifying it as priority issue. Some question may arise of availability of specific plant and mangrove species provide best performance. But those species are not rare in Bangladesh coastal region. Moreover, there is Sundarban, the largest mangrove forest in the world having 334 species of trees, shrubs and epyphites (BFD). According to BFD, 1,39,700 hectare forest land of Sundarban remains in Bangladesh section is declared as World Heritage Site. The main tree species in this forest are Sundri (Heritiera fomes), Gewa (Excoecaria agallocha), Keora (Sonneratia apetala), Baen (Avecennia officinalis), Dhundul (Xylocarpus granatum), Passur (Xylocarpus mekongensis) etc with 15cm and above diameter. Sundri is the most important tree in the Sundarban which is distributed over 73% of the reserve. Extent of Sundri is followed by Gewa, Baen, Passur, Keora etc . Mangrove afforestation along the entire southern coastal frontier is an innovation of foresters. The forest of central and northern districts covering an area of 1,20,000 is intermingled with the neighboring settlements and fragmented into smaller patches. Sal (Shorea robusta) is the main species in central and northern districts with other associates like Koroi (Albizzia procera), Azuli (Dillenia pentagyna), Sonalu (Cassia fistula), Bohera (Terminalia belerica), Haritaki (Terminalia chebula), Kanchan (Bauhinia acuminata), Jarul (Lagerstroemia speciosa), Jam (Syzygium spp) etc. Some non-mangrove species also available in Bangladesh like Hijlibadam (Anacardium occidentale), Neem (Azadirachta indica), Bash (Bambusa arundinacea), Latkon (Bixa orellina), Sondal (Cassia fistula), Bilati jhau (Casuarina equisetifolia), Narikel (Cocos nucifera), Jhal (Salvadora persica), Ritha (Sapindus emarginatus), Dumla/Poreshpipal (Thespesia populneoides Kostel), Nishinda (Vitex negundo) (WAFC) have multiple benefits for toughening coastal environments against the negative impacts of wind and water.

Casuarina is one species that is both tall and quite salt-tolerant and can be used on the landward side of the shelter behind the low-level protection afforded by shorter species. This species is very durable, and can survive in powerful storm surge. Rhizophora apiculata and Rhizophora mucronata are two species commonly used in mangrove restoration and afforestation. Their stilt roots provide extra support against strong winds and the wave action of tropical cyclones and tsunamis (Selvam et al., 2005).

Hurricane surges that are catastrophic (i.e., 7-20 feet) rapidly submerge marsh vegetation, but not forested wetland vegetation. Surge waves moving over marches get a rougher bottom than a smooth sediment. For the combined purposes of reducing wind speed, increasing salt deposition and reducing storm surge in coastal areas, however, wider shelters is advantageous. The “rough” surface created by the shelter belt increases the size of turbulent eddies and brings more small droplets and salt particles into contact with the vegetation, where they can be captured and prevented from travelling further inland.

Windbreaks substantially reduce wind speed on the windward side for a horizontal distance of 2–5 H, where H is the height of the barrier (Figure 3). U is wind speed in the lee of the shelter and U_o is the speed at the same location if there were no shelter. Windbreak height (H) is the most important factor determining the downwind extent of the sheltered region and usually is employed as the measure of its length. In shelterbelts with species of various heights used throughout the belt, the average height of the tallest species usually is taken to represent H. Since the coastal zone of Bangladesh is funnel shaped, the tracks of cyclone attacked before found to be passed nearly at right angle to the central coast line i.e. the incident of attack IA is nearly 90º. The proposed design is a combined landscaping with tallest trees having height 10m and above at the end of the belt. Analyzing the figure 4 it can be obviously said that implementation of the design will reduce the devastating wind speed significantly.

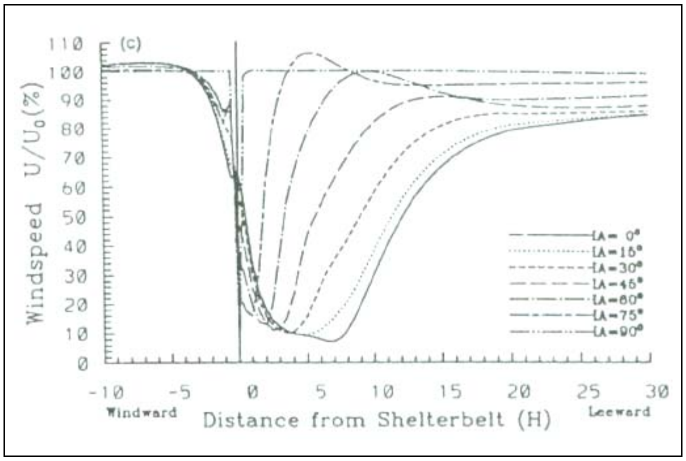


Figure 4: Percentage reductions in wind speed (U) upwind and downwind of a shelterbelt of width 1 H for various attach angles (IA) of the wind. (Source: Braatz et al., 2007)

The coastal region of Bangladesh is still unprotected and human habitation is not developed. Bare land, haphazard human settlement is the common characteristics of central southern coast. But the population is increasing day by day. So, it is the right time to take necessary steps for comprehensive research of selecting best options to meet all kinds of issues and integrated actions to develop a rigid protective coastal barrier.

Government Strategy and the proposed concept

The Government of Bangladesh (GoB) is committed to increase the resilience to coastal disaster; reduce the risks coastal disaster poses to national development; and rapidly develop the country. GoB has the Climate Change Action Plan which is a 10-year programme (2009-2018) to build the capacity and resilience of the country for meeting the challenge of climate change. The needs of the poor and vulnerable, including women and children, will be mainstreamed in all activities under the action plan. In the first five year period (2009-13), the programme will comprise six themes with sub programmes of each theme (MoEF, 2008). It is required to mention that the proposed design and strategy in this paper for coastal areas in Bangladesh directly or indirectly supports almost all the themes selected by GoB. More specifically the supported themes (T) and sub programs (P) are as follows-

- Food Security, Social Protection and Health (T1)
- Improvement of cyclone and storm surge warning (T2P2)
- Risk management against loss on income and property (T2P4)
- Repair and maintenance of existing coastal polders (T3P3)
- Adaptation against tropical cyclones and storm surges (T3P6)
- Preparatory studies for adaptation against sea level rise (T4P3)
- Monitoring of ecosystem and biodiversity changes and their impacts (T4P4)
- Afforestation and reforestation programme (T5P7)
- Revision of sectoral policies for climate resilience (T6P1)
- Strengthening human resource capacity (T6P3)
- Strengthening institutional capacity for climate change management (T6P4)

Conclusion

Coastal disaster management associated with food and life are the major concerns of coastal countries throughout the world. Every year GoB need to allocate a large amount of budget for cyclone disaster management, coastal development, repair and maintenance. Large number of cyclone shelter has already been made and warning system is modernized. These are contributing to minimize death toll a lot. But integrated management for preservation of land, embankment, infrastructure, water sources and overall environment from severe cyclone are not been seen yet. The dispatch of food, goods, medication and after disaster relief distribution system are still facing great difficulties for lack of proper planning and damage of routes. It is found that the overall damage and losses due cyclone Sidr was US$1674.9 Million. But if the Sidr effect could be minimized 20%, around 335 million dollar would be saved from instant losing and this could be used for more development works. The main feature of the proposed coastal design and strategy in this paper is to mitigate the affects of disaster by introduction of natural protection systems as much as possible and simultaneously, development of adaptation capacity of the local community with maximum utilization of existing environment. In one side, protective barrier will minimize the disaster effects; preserve the land fertility, potable water sources, infrastructures and resources. In other side, salt tolerant submerged crops, wetland and forest will give people more opportunities to yield more, improving living standard and adding additional in national income. Conservation of bio-diversity and ecosystem balance is also a crucial part of the proposed strategy.

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