Bangladesh: assessing the Vulnerability to Climate Change

the start of the ICZM Process

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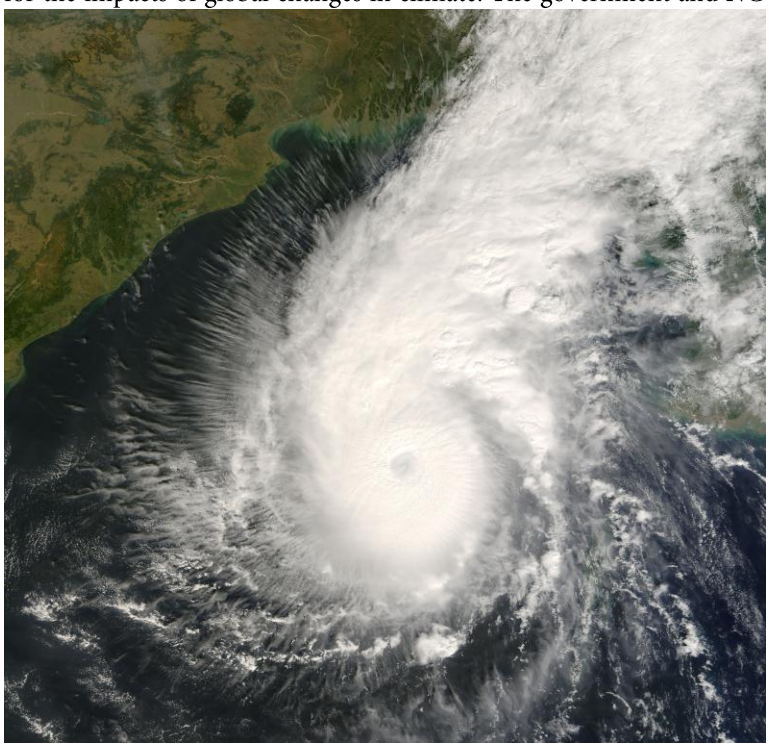
Contents

1. Introduction
2. Key Hazards and Risks
3. Coastal policies
4. Conclusions
5. References, PDF Reports and websites

Summary

Bangladesh is one the most vulnerable countries of the world to extreme weather events. The changing climate adds a new dimension to the risks that threaten the lives and livelihoods of coastal communities. Vulnerability assessments reveal that Bangladesh is critically vulnerable to impacts of climate change. The envisaged impacts are dealing with sea level rise, changing nature of cyclones and storm surges, and the occurrence of droughts,. This all will effect the population through increased risks of flooding, coastal and river bank erosion, salt water intrusion and expected decrease of agriculture production in absence of adaptive measures.

Bangladesh is developing its adaptation techniques sharing its knowledge with other vulnerable countries and planning for the impacts of global changes in climate. The government and NGOs are working together, setting a good example in analysing the vulnerabilities and finding solutions. Integrated planning of sustainable coastal management and adaptive measures is identified as one of the key areas to reduce Bangladesh's vulnerability. Important steps in integrated management were successfully taking, however much more needs to be done in the field of implementation of adaptive measures in a framework of local, national and international cooperation. The challenges are multi-sectoral, multi-dimensional and long term, the causes are global in nature.



Cyclone Sidr in the Bay of Bengal *:*
14th November 2007 - one of the strongest cyclones recorded in the Bay of Bengal; 3,447 death were officially declared. The Cyclone Preparedness Programme including the improved warning system, facilitated timely and massive evacuation to many new shelters. (photo: NASA)

1. Introduction

Bangladesh is one the most vulnerable countries in the world to climate change. It is highly sensitive due to its poor socio-economic development and limited capacity to deal with the impacts. Its geological situation and geographical location make the densely populated, flat coastal lands and islands, extremely vulnerable.

The most vulnerable part of the country is the coastal zone, housing over 35 million people, more than one fourth of the country's total population (CEGIS). Several studies indicate that the vulnerability of the coastal zone is critical due to the combined effects of climate change: sea level rise and increased cyclone frequency and intensity, to subsidence and changes of upstream river discharge and coastal embankments (see Box and World Bank, 2000).

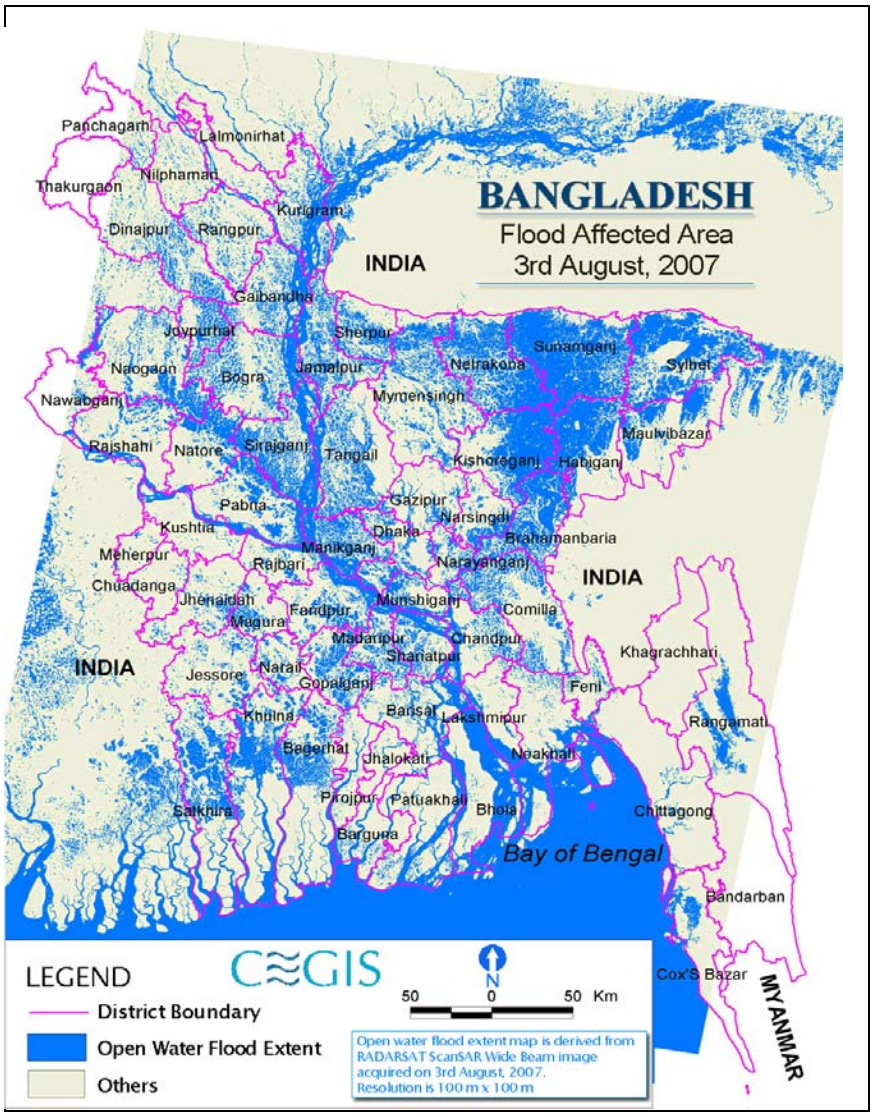


Figure 1: ***Flood situation map - Bangladesh:***
"Open water extent" area for a number of selected districts in Bangladesh, indicating the large areas susceptible for flooding. Derived from RADARSAT ScanSAR Wide beam image of 3rd August 2007.
(*source: CEGIS -* http://www.cegisbd.com/flood_situation.htm)

Box: **The Vulnerability Assessment (VA) to Climate Change - Bangladesh pilot study – BCAS/RA/Approtech, 1994:**

This study analysed the impacts of climate change in a comprehensive fashion and followed the IPCC (Intergovernmental Panel on Climate Change) -1991 Common Methodology on Vulnerability Assessment (VA) on impacts of climate change. This VA –Bangladesh, executed with the assistance of the Netherlands, demonstrated that climate change and sea level rise (SLR) will affect the whole of flat, low lying, deltaic Bangladesh not only the areas near the sea. Three of the many indicators analysed deal with the effects on the socio-economic system in Bangladesh, namely:

1. *Impact of inundation on the population*

This involves an assessment of how many people would be affected by an increase in flooding risk under changing climate conditions:
Today about 65% of the total Bangladesh population suffers annually from inundation of slight to moderate intensity. This proportion is very likely to increase under conditions of climate change and 1 m sea level rise (SLR). Assuming a "River-water-sharing-with-India" option adopted under BAU (a Business As Usual socio-economic development) scenario, 85% of the total population will be affected, of which 10% will be affected by severe floods e.g. when the water depth reaches 90-180 cm.
For the non-water-sharing option, the affected population will increase to 95%. Thus under the BAU/non-sharing option, without any adaptive measures, almost the entire country will face yearly inundations of varied intensity. About 15% of the total population will then be affected annually by severe floods in the 90 – 180 cm inundation depth range.

2. *Impacts of inundation on agriculture viz on Aman rice production:*

Effect of 1 m SLR on Aman rice production under BAU scenario with water-sharing option: a reduction of 12 % in the Aman rice production is envisaged. The effect of non-water-sharing option under BAU scenario and 1 m SLR will increase the reduction of rice production to 30%.

3. *Impacts of drought on population and agriculture:*

At present about 2/3 of the population live in areas that are prone to moderate to severe drought. The proportion of the total population living in the most severe drought-prone areas would increase from the present 4% , to 9% and 18% respectively under moderate to severe climate change scenarios.
The future availability of fresh water in the dry period of the year has major consequences for the Bangladesh food grain production. More water is needed for irrigation to compensate for changes in precipitation and evaporation. On the other hand les water will become available, due to lower river flows in the dry period and increased salt water intrusion enhanced by sea level rise. Under the severe climate change scenario, the overall rice production could be reduced by about 25% for all development scenarios considered.

The regional distribution (see Figure 2) of the possible impacts of climate change and sea level rise has two axes. Changes in sea level, river discharge and cyclone intensity have a N-S direction gradient. Temperature, evaporation and precipitation changes have a W-E gradient. Combining these effects the SW and NW-zones are the most vulnerable areas, while the NE-zone is least vulnerable.

The 1994 Vulnerability Assessment- Bangladesh' study identified several recommendations, like:

- Water availability: More balanced use of water between the two riparian countries India and Bangladesh (option water sharing), could work as important adaptive measures for Bangladesh;
- Integrated coastal zone management is considered as an effective adaptive response option and include preparing sustainable adaptive policies following the recommendations of the IPCC-1990 and the UN Framework Convention on Climate Change & UN Bio-Diversity Convention 1992, as well as those emanating from the World Coast Conference 1993;
- Effective no-regret measures to respond to the threat of climate change: improve agricultural practices and increase production, develop and apply desalinisation techniques, continue to plant protective mangrove belts and to create floating vegetable bed cultivation (see CCC III-3-3-8).

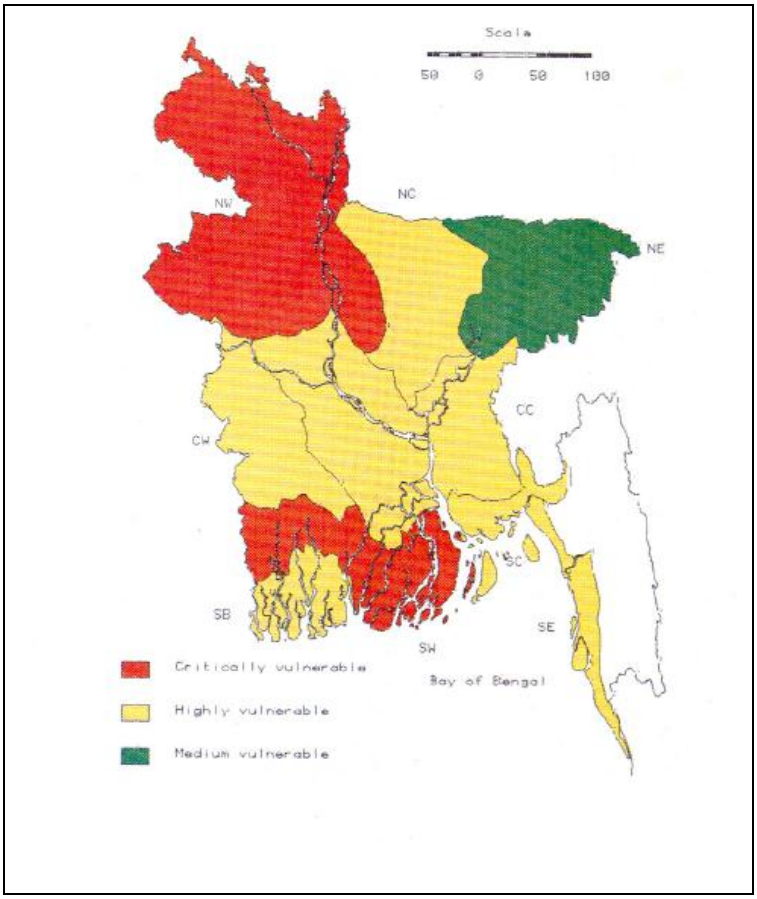


Figure 2: ***Overall vulnerability scores in Bangladesh for impacts of climate change****, including a 1 meter sea level rise: most of regions of Bangladesh are highly (yellow) and critically (red) vulnerable with increasing flooding risks in the coastal areas as well in the low lying river plains, droughts and salt water intrusion under Business-As-Usual socio-economic scenario (source: VA-Vulnerability Assessment Bangladesh, 1994).*

2. Key Hazards and Risks

This section highlights the most important key factors, which effect life, livelihood and investments on different sectors, ecosystems and communities.

Sea level rise

The South Asian Association for regional Cooperation - Meteorological Research Centre (SAARC-SMRC) carried out a study on recent relative sea level rise in the Bangladesh coast. The study used 22 years of historical tidal data from three coastal stations (Table 1). The study revealed that the rate of sea level rise during the last 22 years is several times higher than the mean rate of global sea level rise over 100 years. This is largely due to the effect of regional tectonic subsidence. Variation among the stations was found.

Table 1: Trend of relative sea level rise, observed in three tidal gauge stations (Source: SMRC-2003, Report No. 3)

Tidal Station	Region	Latitude (N)	Longitude (E)	Datum (m)	Trend (mm/year)
Hiron Point	Western	21^{O}48’	89^{O}28’	3.784	4.0
Char Changa	Central	22^{O}08’	91^{O}06’	4.996	6.0
Cox’s Bazar	Eastern	21^{O}26’	91^{O}59’	4.836	7.8

Salinity intrusion

The effect of saline water intrusion in the estuaries and into the groundwater will be enhanced by low river flows, sea level rise and subsidence. Pressure of the growing population and rising demand due to economic development will further reduce relative availability of fresh water in future. The adverse effects of saline water intrusion will be significant on coastal agriculture and the availability of freshwater for public and industrial sectors will fall.

Salt water from the Bay of Bengal is reported to have penetrated 100 km or more along the tributary channels in the dry season (IPCC, 2007). It is estimated that about 1.0 million ha of arable lands will be affected by varying degrees of soil salinity along the coastline of Bangladesh, adversely affecting crop production and livelihoods. Vast areas of croplands in the lower estuary of the coast remain fallow during the rabi (dry) season due to higher salinity.
Changes in the surface water salinity pattern due to 30 cm rise of sea level revealed that the present dry season saline front (= 2 deci Siemens/m conductivity) is expected to move 30 km to 50 km North, affecting most of coastal districts. With a 1 m rise of sea level, the saline water front will move further North and North-East, e.g. part of the greater Dhaka district and even the Meghna river valley may be affected by saline surface water intrusion, particularly during the dry season. The drinking water supply of major cities like Dhaka and Chittagong will then increasingly be affected by salinity intrusion.

Increased drought

Drought primarily affects agricultural crops reducing both vegetative growth and yield. It is caused by lack of rain and soil moisture.
The north-western part of the country normally has less vegetation and a soil moisture deficit. According to people of drought-affected areas, the intensity and longevity of drought is increasing over time. The western part of the country receives less rainfall averaging some 1400 mm as against the national average of about 2150 mm. Therefore, susceptibility and severity of drought in the western districts are much higher than elsewhere.
It is predicted that the intensity of droughts in this area will increase in the future, due to climate change. Similarly, the drought prone areas will suffer from water scarcity, temperature increase, increase in dust content in the air leading to economic deprivation and increased respiratory diseases.

Erratic behaviour of rainfall and temperature

Increase in temperature due to climate change is likely to result in increased demands for cooling in urban centres, housing and on transport.
In addition, Bangladesh's major crop is rice, which is vulnerable to increased temperature as rice crop yields fall with higher temperatures. Erratic weather patterns are likely to disturb and even disrupt part of the crop calendar. The rate at which climate change may affect these shifts may be faster than the rate at which technology and the farming communities' capacity to adapt to new and modified practices can occur.

Changing nature of cyclones and storm surges

The Bay of Bengal generates tropical cyclones that hit the coastal area of Bangladesh during pre-monsoon (April and May) and post-monsoon (October and November) seasons. One of the reasons why the Bangladesh coast is affected so often is the conical shape of the Bay of Bengal. Over the past 125 years more than 42 major cyclones hit the coast, of which 15 occurred during the past 25 years with wind speeds ranging from 140 to 225 km/hr. The frequency of monsoon depressions and cyclone formation in the Bay of Bengal has increased over the past decades affecting the coastal population the most. Fishing in the Bay of Bengal is one of the most important ways the poor make a living and this is currently hampered by the increased and frequent rough sea weather conditions.
It is difficult to attribute a single tropical cyclonic event to climate change directly, however, the nature and intensity of Sidr cyclone (2007) that battered the Bangladesh coast is consistent with the predictions of the Intergovernmental Panel on Climate Change (IPCC). Different models used by the IPCC revealed that future tropical cyclones (typhoons and hurricanes) are likely to become more intense, with higher peak wind speeds and heavier precipitation associated with an ongoing increase in tropical sea surface temperatures. The peak wind speed of Sidr reported to be 226 kilometres per hour, can be linked with observational evidence that intense tropical cyclone activity is related to increases in sea surface temperatures. Unfortunately, information on the extent of the area affected is limited. Pictorial representation from satellite data suggested that Sidr was the most extensive at 250,000 square kilometres, of all the cyclones to hit the Bangladesh coast in recent years. Sidr is an early message that Bangladesh is likely to face such severe cyclones more often.

Box : **Cyclone Sidr - 2007, one of the strongest cyclones**:

Cyclone Preparedness Program contributed to reduce number of casualties and damages.

Cyclone Sidr, (Super Cyclonic Storm, category 06B) was one of the strongest cyclones recorded in the Bay of Bengal, made landfall in Bangladesh on afternoon of 15th November 2007.
The storm caused large-scale evacuations and 3,447 deaths were officially blamed on the cyclone. The number of death was higher estimated by some NGOs.
Forecast heights of the storm surge, predicted by a numerical model, were communicated to the emergency response authorities in India and Bangladesh. Over 40,000 Red Crescent Bangladeshi volunteers were deployed to order residents in the 15 affected provinces into special cyclone and flood shelters. A total of 2 million people in the path of the cyclone evacuated to emergency shelters on 15th November.
The Cyclone Preparedness Program, including improved warning system, allowed to react adequately and timely reducing the number of victims and damages compared with earlier comparable strong cyclones of 1971 (500,000 deaths) and 1991 (140,000 death), while there are now more people are living in the coastal zone.

Frequency and intensity of flood

The combined effect of higher sea water levels, subsidence, siltation of estuary branches, higher riverbed levels and reduced sedimentation in flood-protected areas will impede drainage and gradually increase water logging problems. This effect will be particularly strong in the coastal zone where sea level rise will inundate coastal areas of Bangladesh. This will dislocate millions of people from their homes, occupation and livelihood.
It is predicted that around 10% of Bangladesh will be inundated with a 45 cm rise and over 21 % of the country will be inundated by a 1 metre sea level rise (IPCC, 2007). More recent estimates suggest that about 10-16% area will face additional flooding due to a 62 cm rise of sea level, which may result in over 35 million people having to migrate from coastal districts because of climate change. Sea level rise along with high winds would also allow saline water to overtop the existing coastal protection embankments and submerge coastal polders at varying degrees affecting crop yields and livelihood security (CEGIS). It is estimated that a 62 cm rise of sea level will cause severe drainage impedance in 25 polders in the southwest region and 13 polder embankments will be overtopped due to increased water levels in the peripheral rivers.
The world's largest natural mangrove forest - the Sundarbans (World Heritage Site) of Bangladesh may be lost all together with a 1m accelerated rise in sea level. This would not only affect the coastal ecosystem, but also marginalize many thousands of poor households who subsist on the Sundarbans.

The problem will be aggravated by the continuous development of infrastructure (e.g. roads) reducing further the limited natural drainage capacity in the delta. Increased periods of inundation may hamper agricultural productivity, and will threaten human health by increasing the potential for water borne disease.

Cyclone havoc and erosion, *about 85% of the total population of Bangladesh (more than 150 million inhabitants) lives in a rural environment, which is often very vulnerable to recurring hazards, particularly floods.* *(photo: BCAS)*

***Impacts of flooding**, clean water supply is one of the major problems during flooding; salt sea water not only affecting the drinking water availability but also the agriculture production depending on the duration, flood depths and season. (photo: BCAS)*

Disturbance of coastal morphological processes

This will become a significant problem with a warmer climate. Bangladesh's coastal morphological processes are extremely dynamic, partly because of tidal and seasonal variations in river flows and run off.

Simulations of expected changes in river run-off under influence of climate change (see Figure 3 and CCC III-3-2-6) revealed the extent to which loss of glaciers in the upper parts of the basins of the Ganges and Brahmaputra in the future will cause them to become mainly rain-fed. These changes will have serious impacts on salt water intrusion, agricultural production and nature development.

Climate change is expected to increase these variations, with two main (related) processes involved:

- Increased bank erosion and bed level changes of coastal rivers and estuaries. There will be a substantial increase of morphological activity with increased river flow, implying that riverbank erosion might substantially increase in the future;
- Disturbance of the balance between river sediment transport and deposition in rivers, flood plains and coastal areas. Disrupting the sedimentation balance might result in higher bed levels of rivers and coastal areas, which in turn may lead to higher water levels related to fixed landmarks.

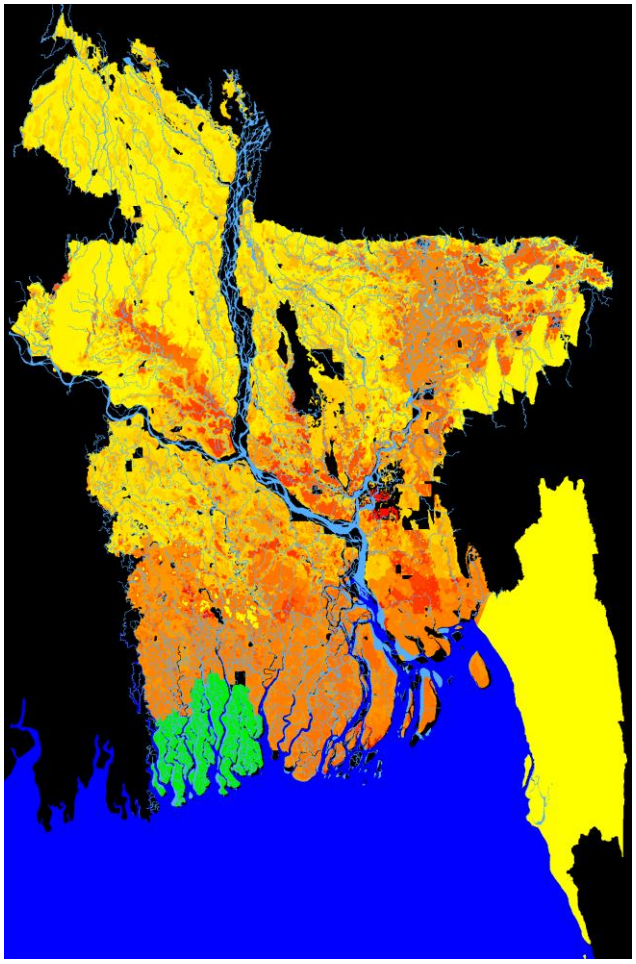


Figure 3: ***STREAM - Bangladesh****: river pattern and run-off simulation; the GIS based STREAM (Ganges/Brahmaputra/Meghna river basin model) produces outputs on future water availability and river run-offs affected by increased temperature, changes in rainfall according to IPCC scenarios and different river water-sharing scenarios. (source: STREAM 2001)*

The Sundarbans *forest covers 10,000 km² of which about 6,000 are in Bangladesh (dark blue green coastal area on the satellite image) and is the world largest single belt of tidal mangroves. It is an UNESCO world heritage site since 1997. About 150, 000 ha mangrove plantation was created in Bangladesh, since the 1960s, to increase the biodiversity, protection against storms and the livelihood of its inhabitants, and preventing land degradation. Large parts of the Sundarbans may be at loss under influence of a 1 m sea level rise. (photo: NASA Jesse Allen, 28-01-08)*

The mangrove ecosystem *provide multiple valuable subsistence uses for its human inhabitants, protection against cyclones and flooding, and represents a large range of high (natural) values. A variety of habitats is accommodating a rich wildlife. The mangrove vegetation helps to form new land. (photo: Tjark van Heuvel)*

3. Coastal policies

Balanced decision making in the coastal zone is facilitated by increasing knowledge of socio-economic and natural processes in coastal areas. One of the integrating tools applied in Bangladesh is GIS in combination with remote sensing. CEGIS (Center for Environmental and Geographic Information Services) has been developed with the assistance of the Netherlands (1996 – 2002). In 2002, the Government of Bangladesh established CEGIS as a national institution and a public trust. Since then CEGIS has been working as a self-financed not-for-profit government owned organisation (see CEGIS website).

Adapting to climate change

Integrated planning is identified as one of the key adaptations to reduce Bangladesh's vulnerability to climate change. This holds in particular for the coastal zone and fresh water resources (World Bank, 1999).
On the other hand, communities and peoples in Bangladesh are already actively adapting to climate variability. Bangladeshis are not sitting idle, they are building dams, changing agricultural practices and irrigating their soils to accommodate the effects of droughts. But despite their dynamic approach, the climate challenge is vast. Much remains to be done. Bangladesh needs to continue developing its adaptation techniques, share their knowledge with other vulnerable countries, and plan for future weather changes. It also needs to develop the use of clean energy.
It must also continue to develop a strong team, in order to raise attention for the plight of developing countries in relation to climate change and adaptation in international negotiations. The Government and NGOs are working together and setting a good example. However, continued efforts are needed to effectively prepare and implement adaptive measures, such as identified within the Coastal Development Strategy of Bangladesh. The challenges are multi-sectoral, multi-dimensional, long term and the causes are global in nature.

Afforestation

Realising the present situation and future consequences, the Government has taken a number of initiatives in the formulation of coastal policy, including integrated coastal management projects and zoning coastal land. The National Environment Policy (1992) declared the importance of sustainable use of coastal and marine resources and the protection of the coastal ecosystem. It has indicated that newly accreted lands will be transferred to the Department of Forest on a priority basis to stabilise them through afforestation and protect them from erosion. National Forest Policy realises the need for massive plantation and for the maintenance and preservation of the coastal areas reducing the velocity and intensity of cyclones and tidal surges. The National Land Use Policy supports both environment and forest policy and states that 25 % of the total land should be forested. The land use policy states that forest declared by the Ministry of Environment will remain as forestlands and create an effective buffer zone all along the coast. The Coastal Zone Policy also suggests maintenance of ecological balance and overall development through protection and improvement of the environment can be achieved as part of the protection of the country against natural disasters.
Coastal mangrove planting along the entire southern coastal frontier is an innovative measure, which begun during 1960-61 through an afforestation programme along the shore land of coastal districts. This initiative gained momentum from 1980-81 with the aid of development partners and afforestation programs, which extended over foreshore islands, embankments and along the open coasts. Since 1960-61 up to 1999-2000, more than 140,000 hectare of mangrove plantation have been created under a number of coastal afforestation projects.

Land zoning

The Integrated Coastal Zone Management Plan Project – ICZMP (see CCC II-1-3) identified more than 20 projects as part of the implementing phase, laid down in the adopted Bangladesh Coastal Development Strategy (CDS - 2006). Recently the Ministry of Land has taken up one project as suggested in the ICZMP namely the "Coastal Land Zoning Project". The objectives of this land zoning project are:

- To assign the land to its best possible uses, such as agriculture, livestock, forestry, shrimp culture, nature reserve, industrial development, etc;
- To prevent (further) land degradation and restore degraded lands;
- To preserve and protect ecosystems with high ecological and cultural value.

The project will also formulate rules and acts for different categories of use. Climate change has not been considered and therefore zoning will be static in nature. However, climate change requires that coastal land zoning should be part of a dynamic system of management to help adaptation to the changing condition of natural and physical systems.

4. Conclusions

Research and policies, relevant to integrated coastal zone management in Bangladesh, are indicating that the increase of extreme events (cyclones and storm surges) may be related to climate change. The executed studies on coastal area vulnerability reveal that Bangladesh is critical vulnerable to impacts of climate change. These studies provide directions for solutions and are important for the survival of small farmer's livelihoods throughout the coastal zone now and moreover in the future. Cyclones and tidal bores, water logging, impedance of drainage, various types of flooding, sand deposition and soil salinity are now a major hindrance to farming and production. These factors will most likely become more important as climate is changing. Strengthening of institutional capacity and mechanisms to support coastal communities in adapting to the impacts of climate change are still often missing although awareness on weather-related hazard and risk posed by extreme events has increased over time. Bangladesh has experienced several impacts of extreme weather perturbations and the costs in physical damage have been significant.
Key efforts promoting adaptive capacity to climate change, including understanding the variability in coastal processes, awareness of impacts and timing of adaptive interventions, are still limited in scope.
Gradual change such as salinity intrusion is not properly recognised. Furthermore policies, strategies and action plans are more based on historical climatic events rather than on future changes in the climatic system. Therefore related risks are not yet reflected in many policies and strategies, which contribute towards the governance of coastal development. The hesitancy to include findings from assessments of future climate risks on relevant sectors (e.g. water, agriculture, forestry etc) in coastal development strategies and programmes is a major constraint in the context of achieving and sustaining millennium development goals. The challenges are multi-sectoral, multi-dimensional and long term.

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