From our archives

Here are some reprints of selected articles which bear relevance to the overall theme of the supplement.

The global climate change phenomenon

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THE Earth is warming and climate is changing. Scientific evidence in favour of these developments is overwhelming and the consequences of climate change are unfolding. Even a few years ago, it could not be foreseen that climate change would be taking place as fast as it is now. Of course climate variability occurs over time, even during a day and spatially in the process of natural climatic evolution, i.e. without human interventions. But, the kind of climate change that we are now witnessing is mostly anthropogenic. It is due to the increasing global warming over a long time caused by increasing emissions of greenhouse gases as a result of human activities such as burning of fossil fuel, productive activities, transportation, marketing, land use, deforestation and various other activities.

Climate change manifests itself in natural disasters of various types. These include devastating floods, droughts, cyclones, and hurricanes. Both the number and the intensity of these natural disasters are now increasing around the world. In Artic and Antarctic regions, highlands and elsewhere ice is melting fast. The sea level is rising. Biodiversity is eroding widely. These disasters are causing widespread adverse impact on both natural and socio-economic systems.

After Bangladesh has been hit by two major floods and a devastating cyclone Sider in 2007, a question has often been asked: have these natural disasters been caused by climate change? Both the floods and the cyclone have occurred at times of the year when such disasters can naturally occur in Bangladesh. From a scientific point of view it cannot, therefore, be said for sure that these have been directly caused by climate change. But, it can be said with a high degree of confidence that these are related to the evolving climate change. This is because one calendar year saw three major natural disasters in Bangladesh, of which there is no known past record. Also, in various regions of the world intense precipitation, floods, cyclones, hurricanes and other natural disasters have recently been occurring in increasing numbers. At the same time, ice is melting fast everywhere at resides. Considering all these developments, it can be said that climate change is clearly accelerating. The manner and numbers in which these natural disasters are occurring around the world are in tune with the likely pattern predicted by the Intergovernmental Panel on Climate Change (IPCC). It is almost certain that in future devastating natural disasters will occur more frequently in various regions of the world and in various countries. Why, because the process of global warming is accelerating.

Introducing IPCC: I shall often use here the findings of the IPCC, particularly its Fourth Assessment Report (AR4) published in 2007. A brief introduction to the IPCC may, therefore, in order. The IPCC was awarded Nobel Peace Prize for 2007, jointly with former US Vice President Al-gore. It was established in 1987 within the framework of the United Nations as an intergovernmental body to review the science and implications of climate change to provide a basis for policies and actions to be designed and implemented to address the issues. It is jointly managed by UN World Meteorological Organization (WMO) and United Nations Environment Programme (UNEP) The First Assessment Report was published in 1990, the Second in 1995 and the Third in 2001.

An assessment is broadly divided into three broad aspects, each dealt with by what is known as a Working Group (WG). WG I deals with the science of climate change; WG II with climate change impacts, adaptation, and vulnerability; and WG III with mitigation of climate change. The outcome of the work of each WG is a major report, which includes a main report, a technical summary and a summary for policy-makers (SPM). A synthesis report is also prepared covering all the three WG reports. In addition, special reports are also prepared on certain key issues as deemed necessary.

These reports are prepared by experts drawn from all around the world but it is the governments which finally have to accept them. Once a report is finalized, a meeting of the representatives of the governments is convened. They review it in detail and introduce agreed changes or modifications before accepting it. Usually, the SPM is gone through sentence by sentence, even word by word before a negotiated document is finally approved. The experts provide necessary support at this stage. In fact, these reports are prepared on the basis of peer reviewed research findings from around the world; and drafts at various stages are reviewed by experts from around the world, who are not involved in preparing the reports as well as by governments of the member countries. The comments and suggestions coming through this process are duly taken into account as the report preparation proceeds.

Global climate changea brief on status

First of all let us consider some key findings of the IPCC AR4. One major conclusion in which there is a high degree of confidence is that global temperature will increase by 1.8oC to 4.0oC by the last decade of the 21st century compared to the last decade of the 20th century. This increase may even be up to 6.4oC. The concomitant sea-level rise during the same period is estimated at between 18 cm and 89 cm. Obviously, these figures are global averages. Different regions of the world may face different levels of warming and sea-level rise.

Indeed, the concentration of greenhouse gases in the atmosphere has now become so large that, even if further emission of greenhouse gases can be stopped today, global temperature and sea-level will continue to rise over the whole of this century, and even beyond. But, the reality is that emission of greenhouse gases continues to increase. The developed world, which is largely responsible for greenhouse gas emissions, is not taking steps to reduce greenhouse gases. In fact, they pursue the destructive path of increased emissions. Moreover, China, Brazil, India and several other developing countries are now emitting increasing quantities of greenhouse gases. The Kyoto Protocol adopted in 1997 called for reduction in the emission of greenhouse gases to the extent of 5% by 2012 compared to 1990. But, this global accord has been of no avail, particularly because the largest polluter, the USA, withdrew from the Protocol. A new process of coming to an agreement regarding reduction of greenhouse gas emissions has begun in an international conference in Bali, Indonesia, in December 2007. A roadmap for negotiations to reach an agreement to replace the Kyoto Protocol, which expires in 2012, by 2009 has been agreed. However, it remains to be seen how the approaches evolve and negotiations proceed.

It has been seen that, during 1970-2004, emission of greenhouse gases as a result of different human activities has increased by 70%. Most polluting is the energy sector (with an increase of 145% during this period), followed by transportation (120%), industry (65%), and land and forestry uses (40%).

It is crucial that reduction in the emission of greenhouse gases in a major way is begun without any further loss of time in order for the situation to become manageable towards the end of this century. If nothing or little is done up to then, the situation may go beyond control both in terms of required finances and technological possibilities.

It was concluded in the Third Assessment Report 2001 (WG II report)

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18th ANNIVERSARY OF The Daily Star

DHAKA WEDNESDAY FEBRUARY 25, 2009

Adaptation in water resources

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The increase of the annual mean surface air temperature has been evidenced in Bangladesh during the period of about 50 years. The warming of the sea surface temperature (SST) and rapid rise of Sea level (4-7.8 mm/year) in the Bangladesh coast of the Bay of Bengal have also been observed. The Fourth Assessment Report of IPCC has shown that the global mean surface air temperature scenarios will attain the values between 2.4 6.4o C by 2100, where the best estimate is 40C using A1F1 (the fossil intensive storyline with rapid growth) scenario of GHG emission. This was obtained from the climate simulation using a number of Global Circulation Models (GCMs). The projection for global sea level rise was estimated as 24-67 cm by 2100 based on the same GHG emission storyline.

According to IPCC the global sea level of Bangladesh is expected to rise by 67 mm by 2100 in the worst case. In Bangladesh, the current net sea level rise is 4-7.8 mm/year which accounts for the combined effect of global warming and geological subsidence of the tectonic plate. Subtracting the current rate of global sea level 1.8 mm / year due to warming from the total sea level, rise it is seen the contribution from subsidence is 2.2-6 mm /year. If we take the worst case the net sea level rise due to warming as well as geological subsidence will exceed 1m in the coming 100 years in the Bangladesh coast.

With the above climate change scenarios, Bangladesh will face severe consequences to its disasters, economy and environment. Most severe impacts will be experienced in the following sectors:

- Fresh water resources, Floods and droughts t
- Coastal zone and coastal resources
- Agriculture
- Forests and bio-diversity
- Fisheries
- Human health
- Socio-economic impact.

Table 1: Climate change projections for 2050 and 2100 as obtained from GCMs taking 1990 as the reference year.

Year	Parameter	DJF	MAM	JJA	SON	Annual
2050	Temp (C)	1.7	1.9	1.4	1.8	1.8
2100		3.6	3.5	2.6	3.1	3.3
2050	Rainfall (%)	10.5	15	11	7.5	10.4
2100		25	25.4	22.5	13	18.4

Note: DJF: December, January and February; MAM: March, April and May; JJA: June, July and August and SON: September, October and November

Vulnerability in fresh water resources, floods and drought

Floods: Bangladesh is a flood-prone country. Analysis of past floods suggests that about 26 percent of the country is subject to annual flooding and an additional 42 percent is at risk of floods with varied intensity. According to government sources, the 1998 flood inundated about 100,000 km2. In contrast, the 1987 flood had inundated about 57,000 km2 and the 1988 flood inundated 89,000 km2. The 1998 flood affected 68% of the country, and seriously impacted the livelihoods of 30 million people. Overall damage was estimated at two to three billion US dollars. The 1998 floods lasted for over 10 weeks. The 2004 flood affected about 57% of Bangladesh. It has been observed that the return period of severe floods is decreasing. For an increase of monsoon rainfall of 22.5% by 2100, the runoff is expected to increase by 40-50%. This will cause the increase of flood depth and inundation areas. The sea level rise causes delaying of the discharge of flood water due to the decrease of the sea ward gradient of water.

Due to prolonged discharge of floodwaters, the rate of sedimentation will increase. As a result, both the riverbed and the bed of the adjacent floodplains will rise leading to further drainage congestion, and possibly more intense flooding in the following years. Such a cyclic course of events would intensify flood problem in the already flood-prone areas of the country. Moreover, instead of fertile silt, if infertile sand or coarse sediments are deposited with flooding, it will severely reduce productivity of the topsoil.

Droughts: The source of water resources for Bangladesh is rainfall, water flowing along the rivers from upstream and ground water. Because of high increase of temperature the evaporation rate will be higher and the soil moisture will dry up rapidly and the surface water areas will shrink. Further it has been found that the river flow of the rivers is decreasing especially in the dry season. Thus the water demand for agriculture, industries and household purposes will increase. The demand for water will further increase due to population increase and increased economic development. The flow deficiency in the Ganges over Bangladesh in the dry period has caused the flow of the southern rivers to decrease; as a results these rivers are being silted up. Because of this, this vast area is facing severe salinity problem in the soil and both in surface and ground water.

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Adaptation

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Very severe droughts hit the country in 1951, 1961, 1975, 1979, 1981, 1982, 1984, and 1989. The drought years have low rainfall and high temperature. High temperature causes evaporation, further deteriorating the water balance situation. Past droughts have typically affected about 47 percent area of the country and 53 percent of the population. A geographical distribution of drought-prone areas under climate change scenarios shows that the western parts of the country will be at greater risk of droughts, during both the Kharif (January May) and pre-Kharif (June October) seasons. It is found that, under a moderate climate change scenario, Aus production would decline by 27 percent while Wheat production would be reduced by 61 percent. Under a severe climate change scenario (with 60 percent moisture stress), yield of Boro might be reduced by 55-62 percent. Moisture stress might force farmers to reduce the area for Boro cultivation. In case of severe droughts, forced by a change of temperature by +2oC with a decrease of rainfall by 10% the runoff in the Ganges, and Brahmaputra, and Meghna rivers would be reduced by 32, 25 and 17 percent respectively. This would limit surface irrigation potential in the drought-vulnerable areas, and challenge food self-sufficiency programs of the country.

Adaptations to Reduced Fresh Water Availability

Possibilities for physical adaptations to reduced fresh water availability refer to increasing surface water availability through additional inflows from upstream, construction of reservoirs by constr5ucting Barrages on the main rivers, increasing drainage capacity of infrastructure, and increase of storage of water in the area itself. One way of storage would be through rainwater harvesting excavation of ponds etc., which could be a promising alternative.

Institutional adaptation includes reducing water demand, and participatory management of the water use. For example: groundwater extraction, which is basically uncontrolled, could be better regulated and monitored; or farmers could be trained to increase water use efficiency through farm practices. Again, market concepts could be introduced (by having consumers to pay for water use, or allowing trading of water rights) which may help ensure that water goes to the most needed applications. Another important and promising institutional mechanism to increase the flexibility to adapt to climate changes is proper participatory arrangements for operation and maintenance of water resources infrastructure.

Adaptation to Drainage Congestions

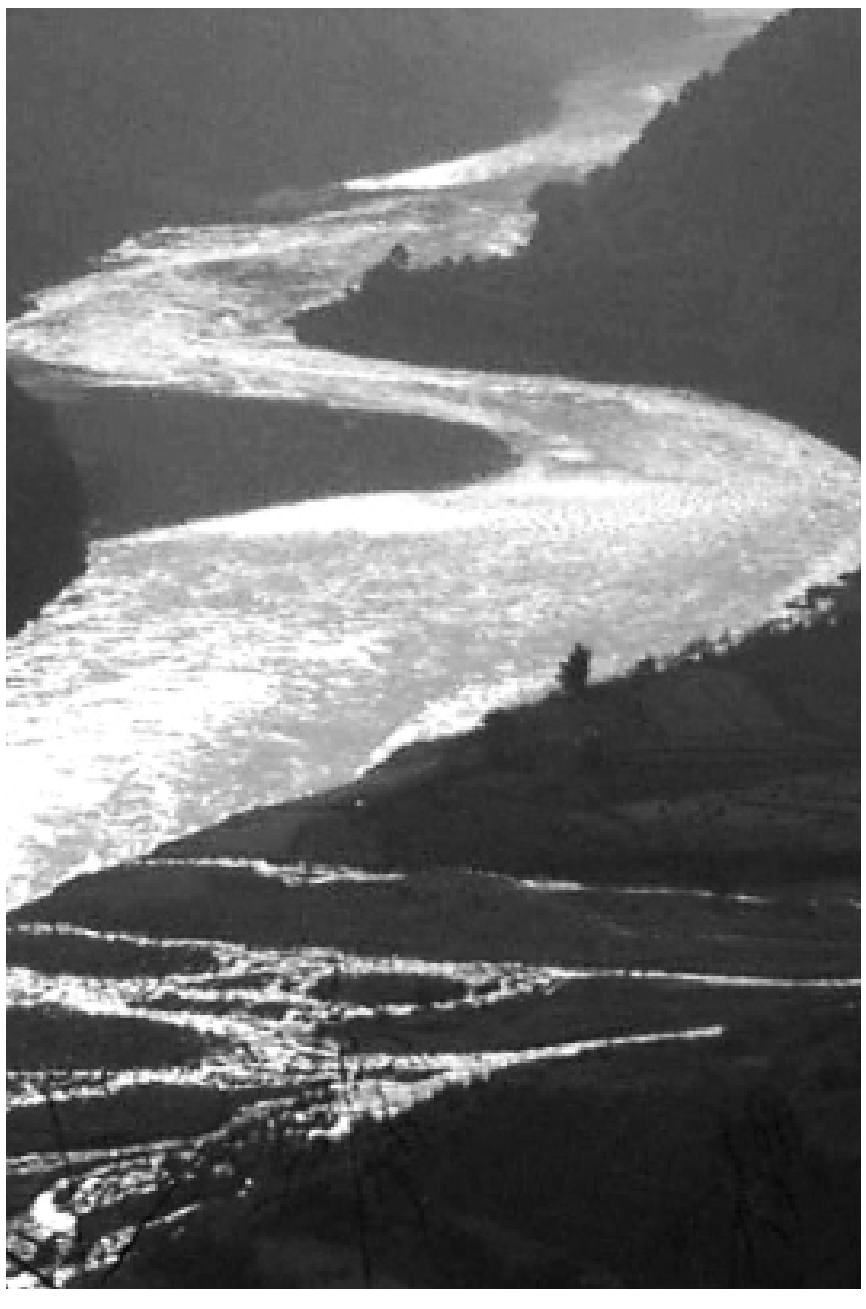
Physical adaptation to drainage congestion includes restoration of channels, flushing capacity enhancement, enhancement of drainage capacity of infrastructure in roads, controlled sedimentation and landfills, and pumped drainage. The institutional adaptation includes improved design criteria for openings in drainage blocking structures, and community involvement in the operation and maintenance of the water resources infrastructure.

Adaptations to Dynamic Morphological Changes

Physical adaptations to increased morphological dynamics (erosion & accretion) may include river training and bank protection, and dredging of navigation channels, which suffer from increased sedimentation. Institutional adaptation includes improved monitoring and forecasting of changes, relocation of victims of erosion, and navigation management and information dissemination. Monitoring and forecasting morphological changes become more and more important to prepare for anticipatory measures to protect the increasingly important infrastructure such as the Jamuna Bridge, Bhairab bridge, Meghna bridge etc. Knowledge and experience to analyze the morphological behavior of the rivers in Bangladesh are growing though still inadequate. An institutional and regulatory framework is necessary to relocate the victims in government-owned Khas lands, which may be supplemented by NGO-driven micro credit programs to facilitate income generation activities in those areas. Navigation would greatly benefit from proper and real time information about the navigability of rivers during the dry season and demarcation of navigation channels.

Adaptations to Increased Flooding

It includes full flood protection embankments, controlled flooding, elevated land as flood refuge, and increase in flood refuge areas. Full flood protection embankments are widely practiced in Bangladesh in areas, where full flood control is economically needed and justified. Although effective, their feasibility is medium because of the Operation & Maintenance requirements. Controlled flooding in combination with compartmentalization has been practiced under the FAP Project (FAP20), and deserves more attention. In terms of feasibility, controlled flooding scores low. Landfills (elevated land) and flood refuge areas focus directly on the affected people and assets rather than on limiting or managing the excess floodwater. In response to the need for increased dredging operations in Bangladesh, introduction of larger scale landfill or flood shelter operations could be considered. Most of the pucca schools and the elevated roadsides are considered now as flood refuge areas. These measures are quite effective and feasible. Besides, the people over the flood prone areas are advised to build houses by raising the lands or with high plinth height. This will save their houses and household properties. The tube wells for potable water are to be built by raising the base above the flood levels.



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Since, water is scares in the dry season, the multi-purpose water reservoirs may be constructed in the upstream as collaborative efforts among the SAARC member states as well as in the major rivers of Bangladesh like the Ganges and Brahmaputra, which will not be used only for flood moderation but also to produce electricity, provide irrigation water in the dry season, provide channel augmentation and cultivation of fishes. Such construction is feasible and would serve as long term adaptation measures in water sector over the region.

Improved flood warning and forecasting, setting limit to developments in high-risk areas, awareness brief up and evacuation of vulnerable people and valuables are some possible institutionally adaptation measures. The flood monitoring, warning and dissemination system should be improved. The bilateral relations between Bangladesh with India and Nepal are to be made more effective for exchange of data and information on the river conditions and rainfall amounts which are valuable inputs for flood warning. Flood warning should not only predict water levels in rivers, but should also give an estimate of inundation depth and duration of floods, which is much more useful to farmers. Improved forecasts need to be combined with proper dissemination mechanisms and techniques. Improved damage assessment techniques would then support efficient and effective relief measures. Involving local community in maintaining flood protection embankments should be a priority both as physical and institutional adaptation.

The flood victims should be properly rehabilitated to begin their economic activities as soon as the flood recedes. The agricultural adaptation is highly important for the food security. Sufficient seed beds are to be prepared in the highlands to meet up the emergency need, such as post-flood rehabilitation. After the flood is receded, the transplantation is to be performed as quickly as possible to replenish the loss. The damage to agricultural crop can be minimized by introducing flood resistant cultivars. The changing land use pattern may help overcome the crop loss. The farmers now grow winter rice more extensively using irrigation as the winter rice have lower risk compared to Aman rice. Again, the winter rice is engendered by more frequent severe flash floods in the eastern and north eastern zones of Bangladesh in the month of May. The winter rice may be saved from the flash floods by shifting the transplanting dates to middle of January from the middle of February. In that case, the rice would be harvested before the flash floods.

Vulnerability in coastal zone and coastal resources

The landmass of Bangladesh is connected to the Indian Ocean through a 710 km long coastline. The coastal region is marked by a vast network of river systems, and ever dynamic estuaries, interaction of huge quantities of fresh water that are discharged by the river systems with saline water and a saline waterfront penetrating inland from the sea. In addition to the coastal plains, there are a number of small islands that are subject to strong wind and tidal interactions throughout the year, and are inhabited by a large number of people. The coastal areas of Bangladesh are highly prone to cyclone-induced storm surges.

In the western coastal areas of Bangladesh, the Sundarbans, a large patch of naturally occurring mangrove forest is located. The Sundarbans stretches further west into the south-eastern part of the state of West Bengal in India. It occupies a total area of about one million hectares, about 62 percent of which is situated within Bangladesh.

The central region of the coastline is situated between the eastern and western coastal areas. Most of the combined flow of the GBM system is discharged through this low-lying area. The lower Meghna River is highly influenced by tidal interactions and consequential backwater effect. Heavy sediment inputs from the rivers result in a morphologically dynamic coastal zone. Cyclones and storm surges bring about the most catastrophic damages to the area.

The 1991 census recorded the size of the population of the coastal districts as approximately 24 million. The population density of the coastal districts is 959 inh/km2. compared to the national average of 861 inh/km2

Coastal resources highly vulnerable to climate change, include land and water resources, as well as the mangroves forests. More specifically there would be:

Changes in water levels and induced inundation and water logging;

Increased salinity in ground and surface water, and corresponding impacts on soil salinity and agriculture.

Increased coastal morphological dynamics (erosion and accretion).

Increased intensity of cyclones and storm surges.

Changes in water levels and induced inundation and water logging

Any rise in the sea level will propagate upstream into the river system. In Bangladesh, this backwater effect will be more pronounced because of the morphologically dynamic rivers, which will adapt their bed levels in a relatively short time period. This whole process will lead to decreased river gradients, increased flood risks and increased drainage congestion.

Since most of coastal plains are within 3 to 5 meters from the mean sea level, it was previously thought that a significant part of the coastal areas (as high as 18 percent of the country) would be completely inundated by rising seawaters. Such a speculative projection was made based on two major approximations; (a) the coastal plains are not protected and (b) the seawater front will follow the contour line. In reality, however, it is found that most of the plains in the coastal region are protected. Moreover, it is seen from the records that there is net gain of lands in coastal zone.

About 6000 km embankments have been constructed along the coastlines, banks of rivers and tidal estuaries to form polders. At present there are 108 polders and sub-polders in the greater Khulna, Barisal, Patuakhali, Noakhali and Chittagong districts in the coastal zone of Bangladesh. Several thousand drainage sluices are provided to remove accumulated rainfall run-off from the polders to the sea or adjacent rivers by gravity flow during low tide. Automatic flap gates are provided with the sluices to prevent saline water intrusion inside the polder during high tides.

Existing embankments provide protection against flooding from high tides but are not designed to prevent inundation by severe storm surges. In addition to protection of the regular inundations and saltwater intrusion, the embankments can reduce the tidal forces. This has an adverse effect on the drainage conditions (siltation due to reduced tidal volumes) and the ecosystems (water logging and stagnant waters). These negative effects have already been visible in parts of the coastal area such as Khulna, Barisal, Patuakhali and Noakhali regions.

Drainage congestion may become an even more serious threat than higher flood risks. Due to the siltation and poor maintenance of the drainage channel network in many parts of the coastal zone, drainage congestion is already a grave problem. The problem is expected to aggravate considerably.

Proper emphasis should be given to the fact that protection measures against inundation by embankments interrupt with the natural processes of land sedimentation and delta formation. This implies that subsidence and sea level rise will not be compensated by sedimentation and the risks of inundation and drainage congestion will be even greater in the future. These amplifying effects are particularly alarming and indicate that quite a different approach may be required to face the problems especially in the seaward parts of Bangladesh.

Unlike the densely populated seafront area, the Sundarbans is not protected and is heavily influenced by tidal effects. A rise in sea level will tend to inundate the mudflats of the forest and reduce the land area of the forest.

Increased salinity in ground and surface water: impacts on soil salinity and agriculture

The effect of saline water intrusion is highly seasonal in Bangladesh. Saline intrusion reaches its minimum during the monsoon (June October) when the GBM rivers discharge about 80 percent of the annual fresh water flow. In winter months the saline front begins to penetrate inland and the extent of affected areas rise sharply from 10 percent of the country in the monsoon to over 40 percent in winter. Climate change would further increase saline intrusion. Climate change-induced extreme weather events especially low flow conditions in winter will accentuate the saline intrusion in the coastal areas.

Increased coastal morphological dynamics (erosion and accretion)

The morphological dynamism of deltaic Bangladesh is manifested in the coastal zone. The coastal areas have been experiencing natural erosion and accretion. Although current literature suggests that coastal land is in the process of slow accretion at the approximate rate of 8 km2/year during the past 210 years (Allison, 1998, Martin and Hart, 1997), much of this may be attributed to cross dams that have been built to reclaim land from the shallow continental shelves. Nevertheless, due to climate change induced alterations in thermal energy at the ocean-terrestrial interface and the expected changes in the inflow of riverine sediments, the dynamics of coastal morphology appears to be highly uncertain. Furthermore, new embankments for reclaiming additional land would affect the morphological dynamics of the coast.

Cyclones and storm surges

From time immemorial, cyclones have been striking the delta causing extensive damages to the lives and properties of millions of people in the coastal districts of Bangladesh. In 1876, about 200,000 people were reportedly killed in Barisal by a cyclone. Another cyclone that hit in 1822 killed more than 70,000 people in Barisal and 95 percent population of the Hatiya Island. Considering the much lesser population during those times, the numbers of deaths give an indication of the severity of the cyclones. A cyclone in November 1970 hit the southern districts of Bangladesh forcing a 9 m high storm surge and killing approximately 300,000 people. The cyclone of 1991 caused loss of 138,000 lives. In more recent years, however, numbers of deaths caused by the cyclones with severe intensity have declined due to the growing successful institutional arrangements for disaster management and the fact that there are now over 2000 cyclone shelters spread along the coast which are being utilized during the cyclones. The most recent one is SIDR which was one of the most severe tropical cyclones which caused the losses of trees, crops, dueling houses and deaths of more than 3447 people. Climate change is expected to increase the intensity of cyclones and the penetration of storm surges further inland, causing higher damages.

ADAPTATION

Adaptations to Drainage Congestion

Physical adaptation requires mainly two steps: (i) bringing water from the land into the main drainage system; and (ii) drainage of water to the sea. Step (i) presently is done under gravity, mostly through regulators, which open during low tides. When higher water levels impede this process, pumping remains the main option. Step (ii) requires a well-maintained drainage network, and improvement of drainage system. Increasing the drainage capacity of existing infrastructure, maintaining the out fall channels of hydraulic structures and providing new drainage structures in the locations where sedimentation process is less. Increased river/channels flow by diverting the Ganges river flow in the existing 24 big and small rivers under the proposed Ganges Barrage Project will reduce the drainage congestion and river siltation problems in the south-western region of Bangladesh. Pumped drainage seems a last, but expensive resort especially when the outside water levels become too high for drainage under gravity.

Institutional measures include guidelines to incorporate climate change in long term planning. Establishing proper O&M arrangements for the maintenance of drainage channels and infrastructure could be an effective approach. Establishment of water management associations, support of local water management including involvement of local institutions and development of appropriate

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that both natural and human systems are affected by climate change. The AR4 (WG II) finds both the processes to be accelerating and intensifying.

It is further learnt from this report (AR4, WG II): Glaciers and ice are increasingly melting everywhere so that the concerned areas are faced with looming disasters. Due to melting of glaciers and ice, the mountains and the Arctic and Antarctic regions as well as oceans are facing structural changes, often extremely adverse to both natural and human systems. As a result of accelerated glacier and ice melt and increased precipitation, timing of run-offs and heights of water levels are changing; structure of water is changing as a result of warming of water in deltas and rivers; and with warming and sea-level rise accelerating, coastal areas are becoming increasingly disaster-prone and biodiversity is affected widely.

Problems are intensifying in various socio-economic sectors such as agriculture (crop, forestry, fishery, and livestock), industry, and human health and habitats. Essentially what is happening is that, due to climate change, life and living of human beings is adversely impacted and the process will intensify in future, particularly if the human behaviour in relation to economic, technological, and other aspects of life and living continue as usual.

It has also been stated clearly that developing countries will face high levels of risk as a result of climate change, i.e. these countries will suffer from the adverse impact of climate change the most. But, their capability to manage such consequences is extremely limited. How disastrous the consequences of climate change may be can be gauged from the following estimates provided in the report AR4, WG II): (a) Under business as usual scenario, if global warming rises by 1.0oC, another 1.2 billion in Asia and 0.25 billion people in Africa will face water shortages (about 1.0 billion suffer as of now). Also, the productivity of wheat may decline by up to 5% in India. (b) If the global warming rises by 2.0oC, productivity of rice in China may decline by 12%, about two million people in Asia will face storm surges and another 1.6 billion people in Asia and Africa will face water shortages. (c) If global warming increases further, the problems will further intensify.

It transpires that the countries which face the greatest risks from climate change are those which suffer from multiple stresses such as high population density, low economic development, limited human capability, institutional weaknesses and ineffectiveness, soil quality deterioration, socio-economic problems arising from the impact of globalization, and diseases of various kinds.

In the UK, Nicolas Stern prepared a review on climate change and its implications. He has emphasized that poor countries face the adverse consequences of climate change the most, the climate change management and socio-economic development must be pursued through an integrated process, and that the developed countries must provide resources to the developing countries as promised. It has also been proposed in the review that international community should come forward with financial assistance for collecting and improving data on the impact of climate change in different regions and for conducting research on achieving and maintaining improved agricultural productivity under conditions of droughts and increased precipitation.

If effective adaptation policies and programmes are implemented in a country or a region, it should be possible to minimize the adverse impact of climate change. For adopting steps to that end, certain guidelines emerge from AR4, WG II report, which include: (a) Adaptation to climate change and mitigation (i.e. reduction of greenhouse gas emissions) are both absolutely necessary. The process of reduction in the emission of greenhouse gases must be earnestly and adequately started without further loss of time so that by the end of the century it is possible to manage the process of global warming. (b) The climate change policy must be integrated with economic and social development policies to generate a process of sustainable development. The basic thrust, therefore, should be proper assessments of the problems in the context of both socio-economic development and climate change management and the utilization of the results in an integrated fashion.

AT THIS STAGE, ATTENTION MAY BE DRAWN TO FIVE MAJOR CONCLUSIONS

(a) On the basis of the findings of the IPCC (AR4 in particular), it can be emphasized that the world community must work together to start reducing greenhouse gas emissions adequately on one hand and promote adaptation policies and programmes to minimize the adverse consequences of climate change on the other.

(b) It is the developed countries which, having emitted greenhouse gases in huge quantities over the years, have caused the anthropogenic global warming. Therefore, the main responsibility for the climate change that is now occurring lies with the developed countries. Hence, they should come forward with adequate technical and financial resource transfer to the developing countries to help them formulate and implement appropriate adaptation policies and programmes. They must start reducing their own greenhouse gas emissions adequately.

(c) If climate change management and socio-economic development are not pursued in an integrated fashion, sustainable development cannot be achieved. Therefore, the international community should also provide adequate financial and technical assistance to developing countries towards achieving their socio-economic goals.

(d) The developing countries must formulate and pursue socio-economic development policies and programmes and climate change management in an integrated fashion with full determination and commitment. In these countries, of course, economic growth has to be equitably distributed with a view to reducing poverty and hunger at an accelerated rate.

(e) The local communities, which are climate change risk-prone, can also play a role in the management of climate change. For them to be able to do so, necessary education, training, and health services should be ensured at the local space so that the local people can acquire abilities to play appropriate roles in managing climate change impacts, while contributing to their own and national economic development.

BANGLADESH: Bangladesh suffers from multiple stresses. These include the ones enumerated earlier. One other major constraining factor is the location of the country at the bottom of the three mighty river systems: the Ganges, the Brahmaputra, and the Meghna. The country is very flood-prone given that it drains over 92% of the total water annually generated in the GBM region to the Bay of Bengal. On the other hand, increasing upstream abstraction causes acute water shortages in the country in the lean season (January-May).

Bangladesh is indeed one of the countries, which is set to suffer the most in the wake of climate change. Floods, droughts, tornadoes, storm surges, and cyclones are almost certain to occur more frequently and more intensely in future. Due to sea level rise, a significant area of the country in the coastal belt may be permanently inundated. River erosion will intensify and low-lying areas inside the country may not be available for any use at all. As a result, huge numbers of people will become climate refugees.

The relief and rehabilitation work following a natural disaster requires transfer of resources from the development budget in addition to other resources raise specifically for the purpose. This may have an adverse impact on development. Hence, the more frequent the disasters are the more difficult the prospects of development will be. The two floods and Sider of 2007 are indicative of what may come in future. In fact, the three 2007 natural disasters may constitute a loud wake up call for the country to take the climate change issues as seriously as they deserve and formulate policies and programmes to address them with total commitment.

According to IPCC (WG II report), the agricultural productivity in South Asia may decline by up to 30% by the middle of this century as a result of climate change. Even if Bangladesh suffers from only a 10% reduction in agricultural productivity coupled with a significant reduction in agricultural land through permanent inundation due to sea-level rise, river bank erosions, saline intrusion, and other uses, the country faces devastating food insecurity in 30 or 40 years time. During major floods, vector and water-borne diseases such as malaria, diarrhoea, skin diseases break out on a wide-scale. These health hazards often cripple, even kill people. As a result of accelerating glacier melt in the Himalaya, water flows in the eastern Himalayan rivers, particularly during the lean season, may increase over the next 10 or 20 years but will then start declining. Bangladesh which already faces severe water shortages during the lean season will face even greater shortages in the course of time, even if upstream abstraction remains equal. Indeed, there may be civil strife in the country as a result of shortages of agricultural land and increasingly declining water availability.

The drought-prone north-west Bangladesh will face intensifying economic problems (unemployment, declining agricultural productivity) as there may be more intense and longer droughts in future. The Sudarbans which contains World Heritage and Ramseur sites already faces decline due to freshwater problem. Moreover, Sider has destroyed virtually one-fourth of the Sundarbans. Biodiversity is declining fast. The Sundarbans is under severe threat of extinction as climate change intensifies in the coming decades.

Clearly, therefore, Bangladesh must focus on understanding, through properly designed and executed research activities, the nature of the problems arising from climate change and to devise adaptation policies and programmes to minimize the losses and damages. Indeed, adaptation is not a one-off activity. It is a process. Therefore, Bangladesh must increase its adaptive capacity and develop an integrated pathway for climate change management and socio-economic development. Obviously, Bangladesh is short of resources and climate change management is an area for which international assistance should be sought vigorously. Indeed, Bangladesh, while seeking to accelerate its economic development, should also try to do whatever it can in terms of using clean development technologies to reduce its greenhouse gas emission, although the total emission of the country is negligible. But, given that the developed countries which are responsible for climate change and, hence, for the sufferings of the people of Bangladesh in that context, equity and ethics would demand that they transfer necessary financial and technical resources to Bangladesh to enable the country to combat the consequences of climate change and pursue accelerated sustainable development.

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Adaptation

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design criteria for drainage infrastructure are other adaptation options that can be pursued.

Adaptation to Salinity Problem

Specific physical adaptations for the salinity problem should focus on increasing surface water flows from upstream, re-excavation of river networks, construction of cross dams/embankments to prevent saline water intrusion and increasing local storage of fresh water in the area.

Institutional adaptations for salinity include maintenance and operation of sluices and regulators, groundwater management, land use practice, extension services, and water saving techniques. The first two are management options. Improving maintenance and operation of sluices and other regulators to hold water in areas that are under increased stress from salinisation is high in priority. In Bangladesh, there still remains a tendency to consider water as a common property. Groundwater management and regulatory operations should therefore incorporate and make use of the difference between the dry and wet seasons in Bangladesh.

Providing incentives to change agricultural practices so that agricultural demand for fresh water goes down can influence land use practice. Therefore, a cohesive approach is necessary with an intensification of extension services to promote changes in land use and farm management techniques. For example, there could be a door-to-door service in providing access to, and information of weather extremity tolerant crops to the farmers and change of cropping pattern in the coastal zone.

Adaptation to Increased Morphological Dynamics

Physical adaptations to the threat of increased erosion would include provision of mangrove greenbelts, cross dams and/or river training works. Mangrove greenbelts in the foreshore areas and along the coastal embankments, and cross dams at the same time enhance accretion. River training works, e.g., through bank protection or strong-holds are confined to the estuarine river branches. All these measures are effective. Cross dams and river training works and their long-term maintenance are basically costly. The high effectiveness and feasibility of mangrove greenbelts are well acknowledged. GOB has undertaken social afforestation program to restore the ecological balance and to mitigate environmental hazards in the coastal areas. Presently this is found very effective and community participation in this program is very high.

Institutional adaptations would aim at protecting the wetlands & mangroves and land use arrangements (including land tenure laws) & policies. The value of growing mangrove greenbelts is closely related to the effectiveness, feasibility and sustainability of protecting mangroves in existing forest areas (through a combination of enforcement of existing legal provisions, and awareness raising among the coastal population). Protection of wetlands is assessed in a similar way, and wetlands can serve as a buffer against coastal storms and erosion. Another promising approach may be found through community-based adaptation where the community decides on how to share the limited common resources.

Although loss of land and the accretion of new lands are common phenomena in Bangladesh, at present, taking accreted land into culture for either forestry or agriculture falls under the jurisdiction of different ministries. The loss of land and relocation of displaced people needs to be addressed seriously. The mangrove belts could be managed in a much more flexible way. Reform of land tenure laws and policies, would give a sustainable adaptation base to climate change.

Adaptation to More Intense Natural Disasters in the Coastal Zones

It includes construction of new infrastructure such as cyclone shelters, coastal embankments and raised platforms, improved road communication networks, and improved technology of warning and signaling systems and mangrove greenbelts along the entire coastal zone. In addition to cyclone shelters for people, adequate provisions should be made for livestock, food grains and other perishable items. In the past, cyclone shelters for coastal cyclones have helped mitigate risks from cyclones. The size and adequacy of the shelters should be re-examined in the light of increased number of people at risk and the increased cyclone intensity as well. In recent years, over two thousand multipurpose cyclone shelters have been built in the coastal zones. Cyclone shelters are the safe heavens for the people during storm surges and for other period these are used as schools and health/community centers. For livestocks and other perishable items, raised platforms (Land fill above the flood levels) of adequate numbers should be built, that can also be used on a multipurpose basis as play grounds, village markets etc.

Embankments need to be maintained on a regular basis. Actual maintenance of the existing coastal embankments is insufficient. A sizeable proportion of the existing coastal embankments is in bad condition, and is already being breached. Therefore maintenance of embankments is very essential. Under CERP (Coastal Embankment Rehabilitation Project) BWDB recently completed the construction/renovations of about 700 km sea-facing embankments (mechanically compacted). These embankments are found very effective against erosion due to wave rush-up and rush-down. The embankments are maintained well with community participation. For its role in saving lives and property, this has been slotted as a high priority future incremental action. For quick evacuation of people and livestock to the shelters and other safe places from the vulnerable areas during storm surges, road networks need to be improved. In considerations of climate change situation, drainage networks and structures are to be improved and new ones need to be constructed to drain out rapidly the surge water from the polders. It has been found that mangroves and forest belts act as effective barriers against winds and storm surges and facilitate accretion. New mangroves and forests in the fore shore areas, sides of embankment and around the homestead areas should be build. Such activities in Bangladesh need to be streamlined by ensuring people's participation in maintaining and benefit sharing.

Institutional adaptations include improving monitoring, forecasting and warning systems and evacuation procedures, adapting appropriate land use & development policy, and maintaining existing and future coastal infrastructures (embankments, drainage structures, cyclone shelters etc.). These responses relate to an improved emergency preparedness for cyclones and storm surges etc., and could reduce risks to health and property.

Improvement of the monitoring and warning system of tropical cyclones and prediction of the associated storm surges would give more reliable advance warning about the landfall of cyclones. The research on these aspects should be strengthened. Dissemination system of the warning should be improved to alert the coastal residents about the severity of storms. The cyclone preparedness program may be further strengthened and the vulnerable people should be provided with appropriate training for self and community preparedness to face the disasters.

Besides, the forestry and fisheries sectors will suffer severe impacts due to future scarcity of water and reduction of surface and ground water and soil moisture. The high floods and storm surges will wash out the fish and shrimp ponds. The biodiversity will be seriously affected by high temperature, drought as well flood conditions, more stronger cyclones and higher storm surges. From the above discussions, it may be concluded that the impacts of climate change have already knocked at our door and we must wake up and resist these impacts with all of our resources and give our best efforts to this end. The climate change and future impacts should be studied thoroughly to save our valuable lands, environment and ecology and keep our country suitable for living.

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18th ANNIVERSARY OF The Daily Star

DHAKA WEDNESDAY FEBRUARY 25, 2009

Facing climate change

MOHAMMAD SHAHIDUL ISLAM

CAN you see in your mind's eye, our generations to come living in an over populated country where most of its coastal areas had been infringed by the sea, under boiling sunlight, gathering for food, water and shelter? Looking out a window upon a barren desert, a dry wasteland unfolds as a carpet to nowhere. Abandoned cities dot the horizon, as the ruins speak volumes to the once populated extravagance of a country which lived on wealth and opportunity. Our favorite crops would not grow anywhere in Bangladesh? Everything necessary for life would be drastically reduced. The vision just described is not one out of in the movie script, but one that is not only possible but probable. Truly the inevitable picture will be grimmer by the close effect of climate change. But this could even be the best of a worst situation expected in another 50 to 100 years.

Grim picture of climate change

The reality could be far worse, says Prof. Mohan Munasinghe one of the three Vice Chairs of the Intergovernmental Panel on Climate Change which won the 2007 Nobel Peace Prize. "If we do not adopt our development paths now, the effects of climate change would virtually be disastrous." Climate Change is all about the drastic changes in the global climate. It will affect countries like Bangladesh. Climate Change would be disastrous in all aspects of the lives of people, be it economic, social, cultural or religious. It would affect agriculture, health and industrial sectors.

Climate change would affect all developing countries including Bangladesh. The dry zone will become drier and the wet zones will get more rain. Extreme conditions are likely to be prevalent. Agriculture and water resources would be badly affected. The coastal areas will be severely threatened by the rising sea levels. Also diseases like malaria will be rampant. Agriculture, one of the key economic aspects that sustain the lives of the people, would be affected by global warming. The farming and climatic conditions in different regions in Bangladesh had been evolved in harmony and believes that despite the advances of technology climate is a very important factor in farming. In spite of the technological advances, weather and the climate are the key factors in agriculture.

Basically the hitherto established patterns of temperature and rainfall will be changed dramatically by global warming.

How would these changes in the established rainfall patterns and temperature affect farming? Increase in the temperature is more likely to affect directly and indirectly most of the crops such as rice, tea, rubber or potatoes, more than the pressure from the ever increasing population, poor facilities.

This is not all. The scenario is more serious since the change in rainfall patterns and the increase in the average temperature could reduce the harvest of the country's staple food, rice. High temperature injures the rice plant especially at the flowering stage

resulting in a lot of unfilled grains reducing the harvest.

Although it used to be a rare event to experience high temperature as 35 Celsius in the major rice growing of the regions in the past, such occurrences are frequent in both in the dry zone and the intermediate zone especially during the farming season from November to April.

The increase in the night time minimum temperature would affect potato cultivation even in the plain lands and hills where the crop is mainly cultivated. The increase in the night time

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Facing change

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minimum temperature would decrease the temperature difference between day and night.

Adopting development plans to face climate change

The warming of the Earth or global warming poses several other pressures upon lands available for the agriculture. The rising sea level is such a pressure which would gradually encroach lands for both agriculture and settlements in the coastal plains shrinking lands available for agriculture. Time is running short. Bangladesh needs to have devices to face climate change immediately.

We know, the richest countries of the world generated long-term climate crisis through decades of greenhouse gas emissions from fossil energy sources, chemical production and use, and industrialized agriculture. Yet the Intergovernmental Panel on Climate Change projects that the poorest countries will experience the worst impacts of climate change. They have the fewest resources to adapt systems to withstand rising sea level, floods and droughts, reduced water supply, and diminished food production.

Oxfam International has estimated that at least $60 billion a year will be needed to enable developing countries to adapt to the harmful effects of climate change. Oxfam has developed an Adaptation Financing Index, recommending that the USA, European Union, Japan, Canada, and Australia should contribute over 95 per cent of the finance needed for adaptation in developing countries.

The Index budgets a responsibility for adaptation aid according to each country's responsibility for causing climate change and its capability to assist. Donor countries should not count this investment in developing country adaptation as part of normal economic development aid to alleviate poverty. Oxfam allocates responsibility as follows:

- The USA should contribute over 40 per cent;
- The EU 30 per cent from the top five European generators of GHGs -- Germany, the UK, Italy, France, and Spain;
- Japan, Canada, Australia, and the Republic of Korea should contribute a further 20 per cent of the finance, with Japan providing over half of that.

A basic principle in adaptation planning is to integrate climate adaptation planning with the organisation's overall strategic planning, that is, adaptation to other environmental, economic, and social changes. This mainstreams climate risk as a normal aspect of risk assessment and planning. Climate risk is assessed for both standard projects and projects to prepare for climate change. This also means balancing adaptation and mitigation policies, strategies and investments, and particularly avoiding projects that increase GHG emissions. Bangladesh should be ready now to adopt all facilities given by the richest countries to face climate change.

A planning process for climate adaptation

The basic steps in a regional process to plan adaptation to the impacts of climate change include:

1. Develop an organisational structure for planning.
2. Assess system vulnerability, risk level, and capacity.
3. Assess likely climate impacts.
4. Develop strategic plan for adaptation.
5. Implement the plan.
6. Evaluate performance and changes in risk patterns.

Who needs to be involved in climate adaptation planning?

- Public agencies, business associations, major companies, and non-governmental organisations with responsibilities and interests in:
- Water and energy resources;
- Coastal, bay, and estuary regions;
- Biodiversity and habitat;
- Agriculture, fisheries, and food processing;
- Forestry;
- Human health care;
- Tourism;
- The built environment, infrastructure and planning;
- Natural disaster management.

The planning process in details

1. Develop an organisational structure for planning.
2. Identify the organisation that will act as home base for the adaptation process and recruit an initial set of stakeholder organisations from public and private sectors.
3. Determine the level of capacity for adaptation planning in the system and the means for capacity building.
4. Develop channels of communication and action to involve people and stakeholder organizations in the planning and action processes of adaptation.
5. Include a web site, speaker's bureau, and town meetings, involvement of schools and colleges, and media briefings.
6. Assess system vulnerability, risk level, and capacity.
7. Assess the capacity of natural systems to adapt to climate change.
8. Identify current stresses affecting the region and its natural resources. This baseline vulnerability assessment studies issues such as deforestation, water scarcity, air quality, soil degradation, loss of wetlands, and exhaustion of aquifers.
9. Assess the capacity of current human systems to adapt, such as economic sectors, the transportation, water, and energy infrastructure, county and city master plans, and building codes.
10. Assess likely climate impacts.
11. Identify and prioritise likely impacts of climate variability and change that will either amplify or lessen current stresses, or create new ones. This can be done at two levels;

a) Stakeholders identify climate impacts based upon their working experience and history of climate events and trends; and

b) Interdisciplinary teams of experts and stakeholders conduct a scenario planning process based upon regional application of climate change models.

12. Create alternative scenarios for best case, middle case, and worst case possibilities for all key variables.

Strategic plan for adaptation

1. Identify adaptation strategies that will address the likely impacts of climate change as well as the current stresses analysed in step 3.
2. Link these strategies with other important trends, like the transition to sustainable farming, energy and water efficiency, the implementation of renewable technologies, and sustainable land use master plans.
3. Prioritise adaptation strategies, projects, and plans according to the likelihood, intensity, and cost of climate impacts they address.
4. Determine an appropriate balance between the effort and budget devoted to climate adaptation and mitigation activities.
5. Choose policies, investment strategies, and action plans in each of the major areas of adaptation to climate change.
6. Identify the early no-regrets actions that will pay off, however climate change unfolds.
7. Look for interventions that will achieve both climate adaptation and greenhouse gas reductions.

Implementation of the plan

1. Assess the organisational structure and communication channels to assure clear responsibility for oversight and coordination of stakeholders.
2. Start with no regrets actions and steps responsive to climate impacts the system is already experiencing.
3. Evaluate performance and changes in risk patterns.
4. Set up an evaluation system with indicators of both the critical climate impacts and of your adaptation responses.
5. Modify and update plans, based upon the input from this monitoring and from scientific studies and scenarios.

It doesn't matter what final 'Roadmap'- "an historic breakthrough" has taken in the Bali climate conference, it is unambiguous that each country has to design and develop national plans to counter the climate change challenges, and that such a plan must principally involve each Ministry, authority and department. The crusade against climate change is no longer only an environmental affair, but is now principally an economic policy issue, and one that involves energy, infrastructure, industry, transport, construction, households, services, water supply, agriculture and last but not least, a major transformation in lifestyles.

Mohammad Shahidul Islam writes on Tourism Issues.

18th ANNIVERSARY OF The Daily Star

DHAKA WEDNESDAY FEBRUARY 25, 2009

Observed climatic variations

DR. D. A. QUADIR

GLOBAL warming and climate change is a well accepted phenomenon which has been extensively studied all over the world. According to the Fourth Assessment Report of Intergovernmental Panel on Climate Change (IPCC), the global mean temperature has increased by 0.740C during the past 100 years from 1906-2005. The linear warming trend over the last 50 years (0.130C per decade) is nearly twice that for the last 100 years. The causes of this warming are attributed mainly to the increase of enhanced anthropogenic emission of the greenhouse gases (GHGs). There are dozens of human-produced greenhouse gases, three of them get special attention: carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). Landuse change and deforestation processes also act as substantial contributor of the GHG to the atmosphere. The atmospheric GHGs absorb part of the long wave radiation emitted from the earth's surface in such a way that the global average energy of the earth-atmospheric system balances to keep more or less a constant temperature of around 150 C. Because of the anthropogenic increase of the GHGs mainly from the burning of fossil fuel in the era of the post-industrial revolution, the unique nature of the energy balance began to disrupt and the temperature started rising. The warming process has accelerated during the last few decades and the last 25 years from 1980 was found to be the warmest period of the past 100 years. According to estimation reference to 2004, it is seen that Bangladesh contributes to 0.24% of the global emission of CO2. The major share of GHG production goes to the industrialised countries. Though, Bangladesh has contributed the least for the global warming but the impacts are expected to be the worst. The following factors would aggravate the sufferings further: lack of awareness, extreme poverty, and high vulnerability to disaster, lack of technical knowledge to overcome the impacts, low economic growth and high population density.

The warming of the land-ocean and atmospheric system is not geographically uniform. Some areas are warming rapidly compared to others and some areas are found to have been cooling with a net effect of global warming. The differential pattern of the global, regional and sub-regional warming results in the variation and change in the atmospheric pressure fields, circulation patterns and thermodynamic characteristics causing the precipitation pattern to change. Thus, the atmospheric warming causes serious impacts on the environment, ecology, land-use pattern and socio-economic activities through the joint effect of warming and water balance. The sea-level rise is another impact of global warming which threatens the low lying islands and coastal zones to inundate. The climate change has enhanced in the global and regional scales the incidents of floods, droughts, severity of tropical cyclones, melting of ice, glaciers and snow packs, heat stress and cold waves, vector and water born diseases, lung and respiratory problems. The sectors like agriculture, water resources, forest and ecology and coastal zones are supposed to be highly vulnerable due to the climate change. The food security might be at stake due to failure of some crops because of the rise temperature to the critical stage.

Regional climate change

So far, the discussions were made on the general aspects of global climate change and vulnerability. Now, we cast our sight towards the regional status of climate change and its link with Bangladesh. We all know that Bangladesh is a disaster prone country. Floods, droughts, tropical cyclones and associated storm surges, river bank erosion and landslides are very common disasters having hydro-meteorological origin. Thus most of the territories of Bangladesh are situated in the low lying delta of the gigantic river systems, Ganges, Brahmaputra and Meghna (GBM). We know that the rivers Ganges and Brahmaputra originate in the Himalayan Mountains and traverse thousands of kilometers before entering Bangladesh.

The river Meghna originates from a number of streams entering to Bangladesh from the Khashi-Jaintia Hills. About 92% of the catchments of GBM lie in the upstream territories outside Bangladesh. These rivers carry huge amount of sediment laden water from the upstream hills and mountains along their channels and innumerable tributaries and distributaries and flush to the Bay of Bengal. Being situated in the monsoon region, the basins of these river systems get water mostly from the monsoon precipitation during June-September. The snow melt water and that deposited in the reservoirs in the Himalayas in the form of snow, glaciers and liquid water are the source of flow for the rivers in the dry seasons. From this consideration, Bangladesh is vulnerable to the impacts of climate change both inside and outside the country, especially in the water resources sector. Both Nepal and India reported rapid increase of temperature over the high mountains of the Himalayas, where the snow and glaciers are retreating. Most of the devastating floods of Bangladesh are caused due to excessive rain in the upstream. On the other hand the failure of monsoons along with possible interventions of river flows in the upstream might cause several ecological and environmental problems in Bangladesh. Thus, the climate change impacts should be treated as a national as well as regional problem. It is expected that a comprehensive adaptation plan may be developed with mutual collaboration among the neighbouring countries or under the SAARC umbrella for resolving the climate change impact and adaptation issues. Joint studies on regional level may be undertaken on the climate change issues. The SAARC Meteorological Research Centre (SMRC), which is

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situated at Dhaka may work as a regional platforms for this purpose. SMRC has already completed a number of climate change related studies for this region.

Observed climate change, impacts and adaptation in Bangladesh

Temperature: The climate change of Bangladesh has been analysed using the country average meteorological data of 57 years (1948-2004) by the author. The analysis shows that the minimum temperature of all months expect May shows warming with very strong increasing trends in the range 0.13-0.25oC per decade (ten years) for the months of February-March and November-December. The warming of the minimum temperature in the months of December-February has adverse impacts on wheat production in Bangladesh.

On the contrary, the maximum temperature from January-April shows cooling with no change in May, while rest of the

months show strong warming at the rate of 0.14-0.29 0C per decade except the month September which do not show much of trend. The cooling in maximum temperature in the winter may be related with the enhanced fog and precipitation activities over Bangladesh, which has serious negative impacts on the Ravi crops such as mustard and pulses through the fungal attack. It has been found that the maximum temperature of September, October and November has negative correlation with Aman rice yield. The correlation is quite strong for October. Thus, higher maximum temperature for these months will lower the yield of Aman rice. The annual minimum temperature shows stronger increase (0.09o C/decade) compared to the maximum temperature (0.05 o C per decade). In a warmer atmosphere, the consumption of water will go up. The evaporation rate will be higher for higher temperature, which will cause rapid drying of the soil and the reservoirs. Thus there are more chances of droughts in a warmer condition. Because of the rapid evaporation, the irrigation will need higher volume of water. In a warmer air temperature some diseases such as diarrhoea, malaria, dengue, heat stress and heart, lung and respiratory diseases are expected to increase.

The adaptation in the agriculture sector due to warming may be done through crop diversification and land-use change. Moreover, the heat resistant variety of wheat or other ravi crops may be developed using bio-technology.

Rainfall: The country average annual rainfall for 57 years (1948-2004) shows increasing trends of 45 mm/decade (2% with respect to the mean) with the seasonal distribution of 5.6 mm (7.1%) in winter (December-February), 21.4mm (5%) in pre-monsoon (March-May) and 21.2mm (1.3%) in monsoon (June-September). Post-monsoon (October-November) does not show much of changes. The pre-monsoon indicates relatively strong increasing trends compared to the monsoon in terms of the percent increase relative to the mean. The pre-monsoon flash floods in the northeast and southeast Bangladesh have become very common. Though the monsoon rainfall does not exhibit much of trends, the variability was found to increase in the recent decades. This means that frequency of the extreme rainfall is increasing which causes more frequent floods and droughts of severe nature. The historic floods of 1974, 1987, 1988, 1998, 2004 and 2007 may be mentioned as the evidences of frequent occurrence of floods. The floods of 1988 and 1998 were caused by the rainfall over the northern Bangladesh and associated territories of India in the north and west. The other floods were contributed by the combined rainfall over Bangladesh and upstream territories of the neighbouring countries. The floods cause damages to the agricultural crops, economy, infrastructures and causes sufferings to the livelihood of the people. Because of the scarcity of food and potable water during the floods, many diseases including diarrhea, respiratory problems, typhoid and skin diseases prevail among the flood victims.

The global sea surface temperature (SST) is increasing resulting in the volumetric expansion of the sea water. The melting of the polar ice and glaciers are being added causing further increase of the water volume. This is causing the sea level rise. According to IPCC (2007), though the global sea level rise is about 1.8 mm/year during 1961-2003 the rate was faster over 1993 to 2003, about 3.1 [2.4 to 3.8] mm per year. The sea level rise varies from basin to basin.

Some studies were conducted to understand the impact of variability of precipitation on Aman rice. It is found that the yield of Aman rice increases with the increase of rainfall up to certain level beyond which the yield decreases. The correlation of Aman yield with the rainfall of individual months show that excess rainfall in August lowers the yield while the rainfall of October increases the yield.

Surprisingly, the farmers of Bangladesh have adapted coping mechanism after 1988 and 1998 floods very efficiently by cultivating more and more bore rice during the subsequent winter. In some highly flood prone areas, the aman rice is cultivated as a bonus, while the boro rice is treated as the main crop. The October rainfall is crucial for good yield for aman rice. Thus if the weather prediction indicates low precipitation, supplementary irrigation is to be applied to the crop. Thus, weather services and agromet advisory are very important for adaptation to climate change. In the areas where water logging is a problem and the agriculture has suffered to a large extent, it is suggested that those areas are converted to shrimp and fish culture. For mitigating the floods, it is necessary to improve the drainage capacity of the rivers and canals and protect the socio-economically important zones by embankments. The embankments require timely maintenance. The houses are to be made on high platforms higher than the highest flood level. In the same way, the foods and seeds are to be protected in the raised stores, where water will not reach. The tube wells are to be built in the high raised platforms so that drinking water is not contaminated. The farmers should prepare seed beds in the high lands so that they are able to transplant just after the recession of the floods. The flood warning activities of Bangladesh have developed a lot in Flood Forecasting and Warning Centre (FFWC), which is to be further improved and the system of dissemination of the warning is to be strengthened. The Information Technology (IT) and mobile phone system may play important role in addition to the Radio and TV broadcasting. I am sure the internet has the access to the upazila level. The flood warning is available in the websites. Any responsible person dealing disaster management may download the up-to-date warning and extract the flood warning for their areas and then communicate to the Union Parishad by telephone. In this way high technology can play role. Not only that. The agriculture extension may have their website with weekly prescription for agricultural crop management incase of disasters or unusual weather conditions and in the process described above the information can reach the target groups.

Coastal zone and Sea-level rise: The global sea surface temperature (SST) is increasing resulting in the volumetric expansion of the sea water. The melting of the polar ice and glaciers are being added causing further increase of the water volume.

This is causing the sea level rise. According to IPCC (2007), though the global sea level rise is about 1.8 mm/year during 1961-2003 the rate was faster over 1993 to 2003, about 3.1 [2.4 to 3.8] mm per year. The sea level rise varies from basin to basin. In the Bangladesh coast the sea level rises at the rate of 4 mm/year at Hiron Point, 6 mm/year in Char Changa in the Meghna estuary and 7.8 mm/year in Cox's Bazar as observed during 1977-1998. This is to mention that the rate of sea level rise due to global warming is about 2 mm/year in Bangladesh coast which matches well with that of the global sea level rise. The residual 4-6 mm/year rise of sea level is associated with the subsidence of the tectonic plate in the Bangladesh coast. IPCC suggests the predicted sea level rise of about 24-67 cm by the end of the century. For Bangladesh coast if the subsidence is taken into account the sea level rise will be around 1 m or more in the worst case. This is very alarming to the land resources and ecosystem of the coastal zone. The coastal zone will suffer erosion and inundation, unless appropriate protective measures are taken. The world's largest mangrove forest is also threatened due to sea level rise and increase of salinity. The coral reef in the St. Martin Island might be bleached due to the increase of SST.

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What will happen to the 20 million people living and working in the rich economic zone? Either they will be pushed upland or they will learn how to live with water. The latter option does not sound practical though once, the poor snake charmers used to live on the boats. So, we have to innovate suitable measures for adaptation or to minimize the vulnerability by some other means and I think this is possible.

It may be noted that the rivers of Bangladesh carry huge amount of sediments from the upstream and 2.4 billion tons of sediment are flushed annually to the Bay of Bengal. The Bangladesh delta is in the process of continuous building. In spite of the sea level rise of about 2mm /year and 2-6 mm / year of geological subsidence, there is a net increase of lands in the coastal zone due to accretion. This means that the deposition is very active which is capable of balancing the present sea level rise. But the sea level rise is expected to be accelerated in the future. So we have to take necessary engineering measures and environmental conservation steps so that the accretion process may be accelerated. Earlier, cross dams in the Meghna estuary have shown very positive results in this regard. The new technology may be innovated for conserving the coastal land. For example, the newly accreted lands over the coastal zone may be brought under massive afforestation process to stabilise these accreted lands and enhance the deposition process. In fact, the afforestation of mangroves in the coastal zones started in the 1960s by Water Development Board, there after, realizing the positive impact of this afforestation, the Forest Department of Bangladesh conducted similar operations in phases in the eighties. This process should be continued not only over the coastal zone, but also extend all over the country where lands are unutilised.

The increased costal salinity and extension of the salinity front inward is another problem, which needs attention. The increased salinity has lowered the soil fertility where the agriculture is seriously affected. The saline resistant crops should be developed and introduced over these areas to keep the food production unaffected. Besides, it has been observed that the flow of the southern rivers has decreased to such an extent that many of the rivers almost dry up in the lean season. Because of the lack of flow of the fresh water, both surface and ground water pressure has decreased over the land; as a result the saline water is moving towards south to fill the gaps. Thus, as a solution, it may be suggested that portion of the water that is flowing through Ganges may be diverted to the southern rivers to save the vast area south of the Ganges. We may think of a sort of a multi-purpose Barrage to be constructed in the Ganges for rational utilization of the valuable water resources.

SST and tropical cyclone

The sea surface temperature over the Bay of Bengal is rising at the rate of 0.26 oC per decade as seen in the time series of SST anomaly from 1961-1988. It is known that the tropical cyclones are formed over the warm oceans with SST higher than 26.5oC. The major portion of the energy required for the formation of the tropical cyclone comes from the convergence of the moisture carrying the latent heat of evaporation through the mixed layer (boundary layer) of the atmosphere. The evaporation from the sea is higher if the SST is higher. Again for higher SST, the latent heat supply to the atmosphere due to evaporation is higher, which causes the tropical disturbances to intensify into strong tropical cyclones.

The time series of Cyclonic Storms (CS) with wind speed 62-88 km /hour and Severe Cyclonic Storm (SCS) with wind speed higher than 88 km/hour covering a period of 127 years from 1877 of the Bay of Bengal indicates both short and long term variability. Analysis of CS and SCS separately indicates the decrease of CS and almost simultaneous increase of SCS. This implies that more number of disturbances intensified from the stage of CS to SCS from around 1937 while the total frequency remained nearly trend free. Another study have shown that during the recent 3-4 decades, the frequency of severe cyclonic storms, during November has consistently increased and has nearly doubled to a value 2.3 from 1.3. The cause of such increase of SCS might have links with the increase of SST as well as surface air temperature. The studies of tropical cyclones using the numerical models strongly support this view. The wind stress on the water surface increases as the square of the wind speed. Thus the impact of enhanced SST on wind speed vis-à-vis on storm surge height would be quite large. If we look back to the past, it is seen that most of the very severe tropical cyclones of Bangladesh were formed in the last 4 decades. The most recent super cyclone (SIDR) which was formed on 9 November 2007as a low pressure area and made a rapid intensification into a severe cyclonic storm by 12 November 2007. Thus climate change has a role in the formation of more number of severe cyclonic storms. There is no way to get rid of these cyclones, but an effective early warning and signaling system can help mitigating the impacts through preparedness. As one of the important adaptation options to the tropical cyclones, the monitoring, warning and signaling system need to be improved. In addition, the man power development to appropriate skills is also necessary. As the physical adaptation, the coastal areas are to be protected from high storm surges by constructing suitable embankments. Sufficient number of cyclone shelters should be constructed as the poor people do not have the capacity to build houses tolerant to the storms. The people living and working in the vulnerable areas are to be made fully aware of the steps taken for the safety of their lives and belongings. They need to be educated on the signaling system and on the emergency safety measures though campaigns, TV and Radio programs and Special Training programs.

A few important remarks

The above discussions highlighted the status of climate change in Bangladesh that has already taken place during almost half a century or so, which shows that Bangladesh is one of the most vulnerable countries of the world for climate change impacts. Poverty adds a new dimension to the vulnerability. There is no doubt that food is the most essential item in a Bangladeshi's life. Because of the climate change, the food security is at stake. The repeated floods of 2007 and the wind action and storm surges associated with super cyclone CIDR; there was a big food loss, which has been reflected in the high market price. So to save the country and its people from the grave consequences and worst vulnerability, the country will have to have rapid socioeconomic and technological development, so that the country becomes capable to take the adaptation measures against any adverse environmental conditions. What has yet not been highlighted is that, for making the young people capable of innovating adaptation technology, it is necessary that the education systems at all levels have the curricula on science of climate change, environment and disaster. Though, Bangladesh is a country of meteorological and hydrological disasters and has a resourceful coastal zone, we never thought that we should explore our weather, climate, rivers and ocean for our survival and better living. The primary subjects that can deal the problems are Atmospheric Physics and Climatology, Water resources and Hydrology, Oceanography and Marine Science and Environmental Science and Disaster Management which are taught in the developed countries and many of the developing countries. For adapting the climate change impacts, the engineering, technology and other courses should incorporate climate change and impacts issues relevant to the respective fields of specialization. The appropriate economic and technological assistance are very much welcome from the donor countries who I think should come forward to assist Bangladesh considering its innocence in the role of global warming and climate change. Last but not the least; intensive studies are to be conducted on the various aspects of climate change, impacts and adaptations right now before it gets too late.

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