Chapter 8

Climate adaptation technologies in agriculture and water supply and sanitation practice in the coastal region of Bangladesh

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Abstract: The coastal zone of Bangladesh, covering 32% of the land area and home to 30% of the population, is one of the regions that is most vulnerable to climate change and sea-level rise. The fertile land of the Ganges–Brahmaputra delta provides a productive base for agriculture, and the coast offers a diversity of natural resources, such as marine fisheries and shrimps, forest, salt, and minerals. The high level of physical vulnerability is made worse by factors such as an increasing population density, poverty, and limited access to services, especially water supply and sanitation, energy, and health services. Examples of current adaptation technologies and practices in agriculture and the water supply and sanitation sectors are presented and relevant components of the National Adaptation Programme of Action (NAPA) discussed. Three potential barriers to the effective implementation of adaptation projects have been identified and need to be addressed: lack of awareness of the seriousness of the climate threat; lack of integration of the climate issue in the development of policies, plans, and programs in climate-sensitive sectors; and lack of adequate tools, knowledge, and methodologies for guidance and advice in decision-making.

INTRODUCTION

The countries on the coasts of the Indian Ocean and Bay of Bengal are highly vulnerable to climate change. The people of Bangladesh are reported to be among the most at risk worldwide from sea-level rise (World Bank 2007). Even at current rates of sea-level rise, more than one million people could be directly affected by sea-level rise in 2050 in the Ganges–Brahmaputra–Meghna delta (Ericson et al. 2006). As a result of saline intrusion in both soil and freshwater, millions of people may face serious challenges in accessing safe water for drinking and other domestic uses. Factors already affecting Bangladesh include variations in temperature and rainfall, increased intensity of floods and recurrent flooding, the frequent incidence of cyclone and storm surges, drought, and salinity intrusion. Climate change is one of the greatest challenges to the development process, and the adversity of

climate change impacts is greater when they combine with factors such as increasing density of population, poverty, and reduced access to services, especially water supply and sanitation, energy, and health services. A large proportion of the south Asian population lacks access to water services and more than 27% of the south Asian population are already without adequate food (Rahman et al. 2007a).

BACKGROUND AND CONTEXT

The coastal region of Bangladesh

The coastal zone of Bangladesh consists of 19 out of the nation's 64 districts. Twelve districts are classified as exposed coast and seven are defined as interior coast. The coastal zone covers 32% of the country in terms of land area and accommodates about 30% of the total population of the country (Islam 2004). The coast offers a diversity of natural resources, such as marine fisheries and shrimps, forest, salt, and minerals, and a location for high potential exploitation of both onshore and offshore natural gas. Export processing zones, harbors, airports, tourism complexes, and industrial units are located in this area. Some of the districts, including Chittagong, Cox's Bazar, and Patuakhali, have significant investment for tourism and associated business and trade.

Agriculture is the prime and economically most important sector of the country. The contribution of the broad agriculture sector to GDP was 20.29% in 2009–2010 (Ministry of Finance 2011), though this is down from around 26% in 1999–2000. There is a substantial indirect contribution to overall GDP, especially through the growth of the broad service sector including the wholesale and retail trade, hotel and restaurants, transport, and communication. In addition, the agriculture sector currently includes 43.6% of the total labor force in the country. The exact contribution of the agriculture sector from the coastal zone to GDP is not known, but it is reported that crop production, especially rice production per hectare, in the coastal zone has decreased slightly over the past several years. Total rice production (*Aus*, *Aman*, and *Boro*) over the nation increased to 28.9 million tons in 2008 from 27.3 million tons in 2007. Ten out of thirty-one agro-ecological zones are located in the coastal zone of Bangladesh (Islam 2004).

Bangladesh is well known as the land of the rivers (Box 8.1). Rivers, streams, and canals occupy about 7% of the country's surface. Surface water resources are dominated by the three major rivers: the Ganges, the Brahmaputra, and the Meghna. The Ganges–Brahmaputra–Meghna basins discharge about 43,000 m^3/s averaged over the year into the Bay of Bengal, draining over 1.65 million km^2 (Chowdhury and Bhuiya 2000). The country shares 57 trans-boundary rivers, 54 with India and 3 with Myanmar.

BOX 8.1 THE MEGADELTAS AND MEGACITIES OF ASIA

The large deltaic plains of the world are highly populated and subject to a range of natural and anthropogenic pressures. These low-lying areas are threatened from both land and sea, with the present-day impact of flooding, loss of sediment, erosion, subsidence, salinization, and storm surges aggravated by high population densities, poverty, and limited infrastructure and services. Climate change and sea-level rise will render an already precarious situation that much worse. According to Ericson et al. (2006), current rates of global sea-level rise, sediment trapping, flow diversion, and subsidence could, by 2050, result in more than one million people being affected in each of the three megadeltas (deltas with an area greater than 10,000 km^2), the Ganges–Brahmaputra–Meghna in Bangladesh, the Mekong in Vietnam, and the Nile in Egypt. Three quarters of the population affected worldwide by these trends live in Asian deltas or megadeltas (Ericson et al. 2006).

There are 11 megadeltas within Asia. The Intergovernmental Panel on Climate Change (Cruz et al. 2007) has concluded that Asian deltas are highly threatened by climate change and that responding to this threat will present important challenges. "The sustainability of megadeltas in Asia in a warmer climate will rest heavily on policies and programmes that promote integrated and co-ordinated development of the megadeltas and upstream areas, balanced use and development of megadeltas for conservation and production goals, and comprehensive protection against erosion from river flow anomalies and sea-water actions that combines structural with human and institutional capability building measures," according to Cruz et al. (2007).

Thirteen of the world's 20 largest cities are located in the coastal zone and seven of these are to be found in the Asian megadeltas. In 2005, Mumbai, Guangzhou, Shanghai, Ho Chi Minh City, and Kolkata were among the 10 most populated cities in the world (World Bank 2010). Based on case studies of climate risks and adaptation prospects for three Asia megacities, Bangkok, Ho Chi Minh City, and Manila, the World Bank (2010) concluded that, as climate change develops to 2050, the frequency of extreme events experienced in these cities will increase, as will the flood-prone area and the proportion of the population exposed to flooding. The costs of damage could range from 2% to 6% of the regional GDP, with damage to buildings an important component of the costs (land subsidence proved a major factor in the damage cost estimates). Impacts on the poor and vulnerable will be substantial, but even better-off communities would be affected. Three recommendations were advanced by the World

(*Continued*)

Bank study: (1) better management of urban environment and infrastructure; (2) climate-related risks as an integral part of city and regional planning; and (3) targeted, city-specific solutions, combining infrastructure investments, zoning, and ecosystem-based strategies. "Cutting edge approaches to urban adaptation are needed," the study concludes (World Bank 2010).

Mick Kelly

Nearly 1,000 billion m^3 of water enters into Bangladesh every year from these trans-boundary rivers but a very small portion of this total volume is available during the dry season, especially the month of February. Small, isolated wetlands, including ponds, lakes, *haors* (backswamps), and canals, serve the demand for water during the dry season. Access to improved drinking water source was 89% in 2008, while sanitation coverage was 63% in the same year (WHO/UNICEF n.d.). In 2004, access to safe water was 3% lower in the coastal region than at the national level, but sanitation coverage in the coastal region was 9% higher (Islam 2004).

Climate sensitivity, vulnerability, and impacts in the coastal zone

Over Bangladesh as a whole, the temperature is predicted to increase by 1.1°C in the monsoon season (May–September) and by 1.8°C in winter (December–February) by the year 2050 (World Bank 2000). These estimates are in good agreement with those used in Bangladesh's National Adaptation Plan of Action (Ministry of Environment and Forests 2005). Recently, temperatures have been generally increasing in the monsoon period of June–August, with maximum and minimum temperatures increasing at the rate of 0.05°C and 0.03°C a year, respectively (Rahman and Alam 2003). Average winter time (December–February) maximum and minimum temperatures show contrasting decreasing and increasing trends at a rate of –0.001°C and 0.016°C a year, respectively (Rahman and Alam 2003). The perception of local communities regarding temperature trends shows a similar picture in most of the regions of the country. That increased temperature, especially during the pre-monsoon period (March–May), is a major problem has emerged from various studies conducted in the coastal zone (Bangladesh Centre for Advanced Studies 2010).

It is predicted that rainfall levels on average could become greater and more irregular overcoming decades, though winter rainfall levels may decrease (Ministry of Environment and Forests 2005). Annual rainfall rose at about 4 mm a year over the period 1978–2008. The northwestern districts of the country usually face drought to some extent almost every year during the

March–May period, with severe drought occurring at least nine times since 1973. Some coastal districts also suffer from drought problems. Coastal flooding and water logging due to excessive rainfall is frequent. The recent floods in 1998, 2004, and 2007 affected most of the coastal districts. In future, increased snow melt from the Himalayan permafrost due to increasing temperature may force more water to flow through the Ganges, Meghna, and Brahmaputra river systems and their river networks resulting in additional flooding extending over the central flood plain of Bangladesh (Rahman et al. 2007b). Increased flooding due to climate change may affect large areas, with high potential for substantial casualties in coastal areas.

Temperature and rainfall variations are already affecting both rice and nonrice crops in the coastal zone. For example, erratic rainfall behavior (late onset, excessive rainfall over a short period, lack of rainfall in particular time of the season, etc.) is causing a reduction in agricultural yields (Bangladesh Bureau of Statistics 2010). Around a third of a million tons of rice (*Aus* and *Aman* variety) was damaged recently by excessive rainfall and flooding in Jessore, one of the major rice-producing coastal districts of the country (Bangladesh Bureau of Statistics 2010). Total production of *Aus* (local and high-yield variety) decreased from 3,606 tons in 2007 to 2,955 tons in 2008 in Satkhira, another vulnerable coastal district. A similar trend has been observed in the total production of other rice varieties (*Aman* and *Boro*) in Satkhira (Bangladesh Bureau of Statistics 2009).

According to the estimates used in developing the NAPA (Ministry of Environment and Forests 2005), Bangladesh could face a sea-level rise of 32 cm by the year 2050. Sea level at Hiron Point near Sundarban has been rising at 5.3 mm a year over the period 1977–2002 (Centre for Environment and Geographic Information Services 2006). Other stations along the Bangladesh coastline also show an increasing trend (SAARC Meteorological Research Centre 2003). In the future, low-lying coastal lands might be gradually inundated, affecting all agricultural activities, water supply and sanitation systems, and other infrastructure unless these are adequately protected. The primary physical effects of sea-level rise on the Bangladesh coast have been identified as the intrusion of saline water, drainage congestion, changes in coastal morphology as erosion rates and sediment flows alter, and amplification of the impact of extreme events such as storm surges (World Bank 2000).

Saline water intrusion represents one of the major physical effects of sea-level rise on the coast of Bangladesh. Saltwater is already intruding into fresh water and increasing the level of salinity in many coastal districts in the southern part of the country, including Patuakhali, Pirojpur, Satkhira, Bhola, Khulna, Feni, and Noakhali (Islam 2004). According to Rabbani et al. (2010), salinity intrusion is affecting about 0.83 million hectares of land, resulting in reduction in crop yields. The supply of clean water to the domestic, industrial, and agricultural sectors, and for business purposes, is also being affected.

It has been reported that at least 11 out of 19 coastal districts have a higher extent of severe malnutrition of children than that of the national average (Islam 2004). In addition, incidences of diarrhoea and dysentery are higher in coastal regions where salinization is affecting both water and soil. Saltwater will increasingly intrude through different channels (rivers, canals, etc.) as sea-level rise progresses. Higher sea level may occupy low-lying areas and push the saline water front further into the water channel and there could be upward pressure on the saline/freshwater interface in the groundwater aquifers. A higher level of storm surge would carry saline water further, reducing the quality of surface water. Any reduction in freshwater discharge or flow in rivers during the winter months would also increase saltwater intrusion. It is feared that, in the future, salinization could render the whole coast unsuitable for some rice varieties (i.e., *Boro*) and wheat production (Huq et al. 1999).

Drainage would be hampered by the combined effect of sea-level rise, subsidence, siltation, higher riverbed levels, and reduced sedimentation in areas that are flood-protected. Drainage congestion will result in increased waterlogging. Infrastructure development could also adversely affect the natural drainage capacity of the coastal zone. Morphological processes along the coast of Bangladesh are extremely dynamic. As climate change develops, there is concern that increased riverflow might heighten rates of bank erosion and disruption of the balance between sediment transport and deposition could lead to even greater rates of change in coastal morphology.

The geographical structure of the Bangladesh coast makes it particularly vulnerable to recurrent cyclones and storm surges, and this vulnerability would be exacerbated by sea-level rise. The coast of the country has been affected by at least two super cyclones (with winds greater than 220 km h^{-1}) and 19 very severe cyclones (119–220 km h^{-1}) over the past 40 years. Model results indicate an increase in precipitation intensity, and possibly wind intensity, in a warmer climate. Unnikrishnan et al. (2006) project no significant change in cyclone frequency in the Bay of Bengal, but large increases in the frequency of storm surges. Cyclones and storm surges affect most severely life, livelihoods, and coastal ecosystems. For example, in 2007, cyclone Sidr killed more than 3,000 people and affected the lives of about six million others (Rabbani et al. 2010). The storm damaged around 80% of the Sundarban area and destroyed crops over about 0.35 million hectares. In addition, embankments and roads, power supply networks, and sources of safe water, such as tube wells, ponds, and reservoirs, were seriously affected. Over 6,000 small ponds were contaminated with saline water. The problems of the local communities were aggravated when cyclone Aila hit the coast just one year after Sidr. At the time of writing, some coastal districts, notably Satkhira, Patuakhali, and Barguna, are still suffering from lack of safe water supply and proper sanitation practices.

Table 8.1 presents the assessment of the sectoral impacts of climate change and sea-level rise for Bangladesh developed by the NAPA team (Ministry of Environment and Forests 2005).

Table 8.1 Intensity of impacts on different sectors due to climate change

	Physical vulnerability							
		Sea-level rise			*Flood*			
Sectoral vulnerability	*Extreme temperature*	*Coastal inundation*	*Salinity intrusion*	*Drought*	*River flood*	*Flash flood*	*Cyclone and storm surges*	*Erosion and accretion*
Crop agriculture	+++	++	+++	+++	+	++	+++	
Fisheries	++	+	+	++	++	+	+	
Livestock	++	++	+++			+	+++	
Infrastructure	+	++			++	+	+	+++
Industries	++	+++	++		++	+	+	
Biodiversity	++	+++	+++		++		+	
Health	+++	+	+++		++		++	
Human settlement							+++	+++
Energy	++	+			+		+	

Note: +++ high, ++ moderate, + lower impact.

ADAPTATION IN AGRICULTURE AND WATER SUPPLY AND SANITATION

Governmental and nongovernmental organizations have introduced a number of adaptation technologies that are being practiced at the community level, not only in the coastal zone but also in other climate-prone areas in Bangladesh. Some of the current adaptation technologies in crop agriculture and water supply and sanitation are spontaneous in nature, but others are reactive (Rabbani 2010). Most of these available adaptation technologies in terms of both crops and water supply and sanitation are likely to address present climate variability. Communities may well, however, need improved technologies in every sector that needs to be resilient to the changes of climate discussed earlier. Examples of current adaptation technologies and practices in agriculture (particularly in rice production) and the water supply and sanitation sectors are presented here.

The Ministry of Agriculture and associated agencies of the Government of Bangladesh have introduced a number of crop varieties that are resilient to climate-induced hazards such as flooding and salinization (Table 8.2). Three rice varieties are grown in three different seasons: *Aus*, *Aman*, and *Boro* (Bangladesh Centre for Advanced Studies 2010). The season of *Boro* refers to the cultivation that takes place in the months of December–May. In the case of the varieties that are farmed during this season, the seeds are sown first and then transplanted, and the production has to be irrigated. The season of *Aus* starts in April and continues till August. In Bangladesh, these months are known for the monsoon and the crops grown at *Aus* are rain fed. These varieties are low yield and threatened by heavy monsoons. Agriculturally, June–December is known as the *Aman* season. This is the time when most natural climate-related hazards hit the country and harvests are often affected by natural calamities. Some varieties of *Aman* are scattered and raised, while others are transplanted. The yield of *Aman* is greater than those grown in *Aus* and lower than those grown in *Boro*.

The farmers in the coastal zone are using a number of stress-tolerant rice varieties to adapt to changing conditions (Figure 8.1). That some of the varieties are growing rapidly in popularity among farmers may be due to higher production and net profit. A recent study conducted in the coastal zone reveals that BR 47, which is a saline-tolerant variety, provides the highest production among all the varieties being practiced in different seasons in the study area (Bangladesh Centre for Advanced Studies 2010). Although this saline-tolerant variety takes 30–50 days more than any drought-tolerant variety to reach harvest, it gives 30%–40% more yield than the latter per unit (Table 8.2). Most of the farmers, however, in the study area still use traditional varieties of rice (Figure 8.1). Figure 8.2 spells out the case on the cost and net profit from the cultivation

Table 8.2 Climate-related stress-tolerant rice varieties in the coastal region and Bangladesh

Climate-related stress	*Climate-tolerant rice variety*	*Growing season*	*Growth duration (days)*	*Average yield (ton/ha)*
Flood (submergence)	BRRI dhan 51	*Aman*	142–154	4.0
	BRRI dhan 52	*Aman*	145–155	4.5
Salinity in soil, surface, and groundwater	BRRI dhan 40	*Aman*	145	4.5
	BRRI dhan 41	*Aman*	148	4.5
	BR 10	*Aman*	150	5.5
	BR 23	*Aman*	150	5.5
	BRRI dhan 27	*Aus*	115	4.0
	BR 47	*Boro*	152	6.0
Drought	BRRI dhan 42	*Aus*	100	3.5
	BRRI dhan 43	*Aus*	100	3.5
	BRRI dhan 33	*Aman*	118	4.5
	BRRI dhan 39	*Aman*	122	4.5

Sources: *Daily Star*, "Two salinity tolerant varieties of T-Aman paddy soon," July 18, 2010, http://www.thedailystar.net/; *Financial Express*, "BRRI releases 2 new stress-tolerant rice varieties," April 10, 2011, http://www.thefinancialexpress-bd.com/; Bangladesh Rice Research Institute (BRRI), "Achievement of BRRI-modern varieties," n.d., http://www.brri.gov.bd/; Huq, S. and Rabbani, G., "Adaptation technologies in agriculture: The economics of rice-farming technology in climate—Vulnerable areas of Bangladesh," in L. Christiansen et al. (eds.), *Technologies for Adaptation: Perspectives and Practical Experiences*, UNEP, Denmark, 2011; Mazumdar, M.L.H., "Adapting agriculture to climate change," *Daily Star*, January 1, 2011, http://www.thedailystar.net/; Salam, M.A. et al., *International Rice Research Newsletter*, 32(1), 42–3, 2011.

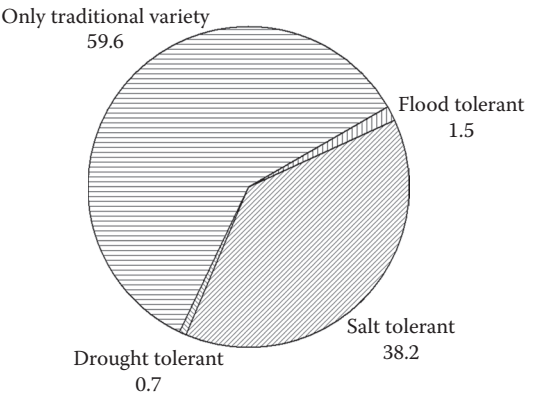

Figure 8.1 Number of households practicing different types of stress-resistant rice varieties in coastal areas (percentage of sample of 401 households).

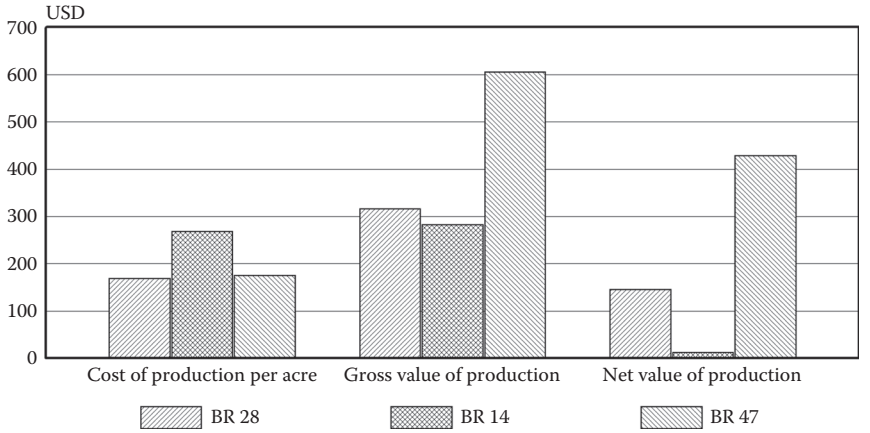

Figure 8.2 Estimates of cost and profit of traditional and salt-tolerant *Boro* variety (BR 47) in the coastal region.

of traditional and saline-tolerant BR 47. The salt-tolerant variety requires 20% less resources than the average cost of production for traditional varieties. And the net profit from the salt-tolerant variety is 81% greater than the average profit of the traditional varieties.

The *floating garden*, locally known as *baira* cultivation, is an adaptation technology in the agricultural sector that can easily be replicated in flood-prone areas. A floating garden is built using water hyacinth with some amount of soft soil or cow dung as a base on which vegetables are grown. Many villages in the coastal region in Bangladesh exposed to flood or inundation practice *baira* cultivation for basic or alternative income. Floating agriculture is being promoted by the governmental and nongovernmental organizations through training and cross visits (Ministry of Environment and Forests 2005). Communities that are facing climate-related hazards have long tried to generate additional income through alternative livelihoods, especially by women. Income diversification is an absolutely spontaneous adaptation practice that has been happening for many years. But, of late, the intensity of the practices has increased and diversified from a single crop (single vegetable) to multiple crops (various types of vegetables).

Safe water supply and proper sanitation practice is still a challenge for many communities in Bangladesh. Households and communities deploy a number of coping and adaptation technologies. For example, at the household level, one indigenous water treatment technology consists of three of four containers or pots, each covered by a clean cloth, arranged vertically and separately in a bamboo or wooden enclosure. All of the

containers, except the one at the base, have small leaks at the bottom to pass on the water. Some communities use pond sand filter technology, especially for the purpose of safe drinking water. Pond sand filter technologies are mainly provided by the governmental and nongovernmental organizations to ensure safe water for vulnerable communities. Many communities protect small isolated water bodies and ponds for domestic use. It is evident that a large number of households in Shyamnagar, Upazila subdistrict, under the district of Satkhira, still use pond water for drinking purposes. Many of these ponds on which poor communities depend on for domestic water needs and small-scale livelihoods (e.g., vegetable farming, home gardening) were submerged as Cyclone Aila hit in May 2009; most parts of Upazila (subdistrict) are already exposed to saline intrusion at different levels of concentration. Many communities are using water collected by rainwater harvesting technology. This practice is again increasing, especially in the water-scarce coastal areas of the country. A recent initiative taken by the Bangladesh Centre for Advanced Studies (BCAS) in association with the NGO Forum for Public Health with support from Swiss Agency for Development and Cooperation is working on an action research project to identify context-specific water supply and sanitation technology in five ecospecific areas of the country, including the coastal zone. A set of criteria (i.e., hydrologically feasible, locally repairable, locally acceptable, user-friendly, gender-friendly, locally affordable, seasonally durable, functionality during disaster, and sustainability) is being used to identify the context-specific WatSan technology to adapt with future changing conditions.

THE NATIONAL ADAPTATION PROGRAMME OF ACTION

The NAPA for Bangladesh was published in 2005 (Ministry of Environment and Forests 2005). It presents a set of adaptation measures that complement national goals, including poverty reduction, and the objectives of multilateral environmental agreements (MEAs) and that, if not implemented without delay, would increase vulnerability or increase adaptation costs at a later date. The priority actions or projects were developed on the basis of a series of consultative workshops and sectoral reports. The final workshop involved over 100 stakeholders from the government and civil sectors. The NAPA report concluded that, in the Bangladesh setting, logic and justice compel focused attention on the vulnerabilities and multiple stresses affecting the lives and livelihoods of the poor (Ministry of Environment and Forests 2005). In prioritizing adaptation needs and activities, poverty reduction and security of livelihoods, with a gender perspective, were

the most important criteria. The formal ranking order was based on the following main criteria:

1. Impact of climate change on the lives and livelihoods of the communities
2. Poverty reduction and sustainable income generation of communities
3. Enhancement of adaptive capacity in terms of skills and capabilities at community and national levels
4. Gender equality (as a cross-cutting criteria)
5. Enhancement of environmental sustainability
6. Complementarity and synergy with national and sectoral plans and programs and other MEAs.

The resulting list of priority activities or projects is summarized in Table 8.3. Details of selected projects that are particularly relevant to the themes of this chapter, agriculture and water supply and sanitation practice in the coastal zone, are as follow (see Ministry of Environment and Forests [2005] for additional information).

NAPA Project No. 1 concerns the reduction in climate change hazards through coastal afforestation. The justification for this action is that coastal forests play a vital role in stabilizing shorelines and providing protection against cyclones and other extreme events, as supported by recent experiences with tsunamis. The proposal is for a community-based afforestation program, based on deep-rooted, salt-tolerant species. Community participation will be a key element of the project; it is considered that the involvement of the local people, especially women, will enhance adaptive capacities and livelihoods in general. There will be synergy with the National Biodiversity Strategy and Action Plan, where afforestation is one of the critical working components.

The focus of Project No. 2 is the provision of drinking water to coastal communities to combat enhanced salinity due to sea-level rise. Given the threat to water supplies posed by climate change and sea-level rise, finding alternative sources of safe drinking water, such as rainwater harvesting and surface and groundwater treatment, is considered essential for the safety of the present and future generations.

The theme of Project No. 3 is capacity building, specifically, in integrating climate change in planning, designing of infrastructure, conflict management, and land-water zoning for water management institutions. It is observed in the NAPA document (Ministry of Environment and Forests 2005) that the National Water Management Plan (2001) is based on the current situation and does not take into account sustainability issues such as climate change, yet consideration of climate change issues and adaptive measures needs to be a regular part of the activities of water sector managers. There is a need for the knowledge of engineers and water sector managers to be more contextualized with climate change science and adaptation options.

Table 8.3 Projects advanced under the Bangladesh National Adaptation Programme of Action

No.	*Project*	*Type of project*
1	Reduction in climate change hazards through coastal afforestation with community participation	Intervention
2	Providing drinking water to coastal communities to combat enhanced salinity due to sea-level rise	Intervention
3	Capacity building for integrating climate change in planning, designing of infrastructure, conflict management, and land–water zoning for water management institutions	Capacity building
4	Climate change and adaptation information dissemination to vulnerable community for emergency preparedness measures and awareness raising on enhanced climatic disasters	Awareness/ capacity building
5	Construction of flood shelter and information and assistance center to cope with enhanced recurrent floods in major floodplains	Intervention
6	Mainstreaming adaptation to climate change into policies and programs in different sectors (focusing on disaster management, water, agriculture, health, and industry)	Capacity building
7	Inclusion of climate change issues in curriculum at secondary and tertiary educational institutions	
8	Enhancing resilience of urban infrastructure and industries to impacts of climate change	Capacity building
9	Development of eco-specific adaptive knowledge (including indigenous knowledge) on adaptation to climate variability to enhance adaptive capacity for future climate change	Intervention
10	Promotion of research on drought, flood and saline tolerant varieties of crops to facilitate adaptation in future	Research
11	Promoting adaptation to coastal crop agriculture to combat increased salinity	Intervention
12	Adaptation to agriculture systems in areas prone to enhanced flash flooding—North East and Central Region	Intervention
13	Adaptation to fisheries in areas prone to enhanced flooding in North East and Central Region through adaptive and diversified fish culture practices	Intervention
14	Promoting adaptation to coastal fisheries through culture of salt tolerant fish special in coastal areas of Bangladesh	Intervention
15	Exploring options for insurance to cope with enhanced climatic disasters	Research

Source: Ministry of Environment and Forests, *National Adaptation Programme of Action (NAPA): Final Report*, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, 2005, http://www.moef.gov.bd/.

Institutional and policy development is essential to assist water sector managers in the development of multiobjective projects involving all stakeholders. It is noted that conflict situations often arise in the water resources sector and that climate stress is likely to aggravate tension. Capacity for negotiating sustainable conflict management, particularly in the water sector, needs to be strengthened.

Project Nos. 10 and 11 respond to the threat of increased salinization in the coastal zone through research on drought, flood, and saline-tolerant varieties of crops and by promoting adaptation in coastal crop agriculture. It is accepted that crop agriculture needs new approaches and technologies to deal with salinization in the coastal area and that improved varieties of all types of crops must be developed to withstand potential climate impacts. Suggested adaptations include, for communities affected by tidal surge flooding, the use of wet bed, no-tillage methods for maize production after loss of the *Aman* rice crop, and before the next *Boro* rice crop; this would also help to meet fuel and fodder needs. Selected vegetables and fruits could be produced on raised beds to meet the day-to-day demands of affected households and, as well as providing for the household, this could also generate some income. Project No. 11 would motivate affected communities to adopt the technologies such as these.

The Bangladesh Climate Change Strategy Action Plan (Ministry of Environment and Forests 2009) also addresses both the agriculture and water supply and sanitation sectors. More than 50 projects recommended by the Action Plan in the areas of food security, social protection and health, comprehensive disaster management, infrastructure, research and knowledge management, mitigation and low carbon development, and capacity building and institutional strengthening are being implemented by different government institutions Many of these projects are related to agriculture and water supply and sanitation and some projects are working directly with climate-resistant crop varieties.

CONCLUSION

Climate change and sea-level rise pose a substantial threat to a developing nation such as Bangladesh. By virtue of their circumstances, though, the people of Bangladesh have a long history of responding to natural hazards and coping strategies exist at the household level and beyond that can provide a strong foundation for robust adaptation measures. Moreover, the Bangladesh NAPA provides an effective platform for longer-term adaptation planning, and its pro-poor ethos could be considered a model for other countries. In building on these foundations, difficulties will undoubtedly have to be faced. Resourcing is a critical issue. Beyond that, the NAPA report identifies three potential barriers to the effective implementation of

adaptation projects (Ministry of Environment and Forests 2005): (1) lack of awareness of both the seriousness of the climate threat and what actions can be taken in response; (2) lack of integration of climate change impacts in the development of policies, plans, and programmes in climate-sensitive sectors; and (3) lack of adequate tools, knowledge, and methodologies for guidance and advice in decision-making.

Ensuring that these deficits—in awareness, integration, and understanding—do not adversely affect the process of adaptation must be a high priority.

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