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DEVELOPMENT AND CLIMATE CHANGE IN BANGLADESH: FOCUS ON COASTAL FLOODING AND THE SUNDARBANS

by

Shardul Agrawala, Tomoko Ota, Ahsan Uddin Ahmed,
Joel Smith and Maarten van Aalst

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FOREWORD

This document is an output from the OECD Development and Climate Change project, an activity being jointly overseen by the Working Party on Global and Structural Policies (WPGSP) of the Environment Directorate, and the Network on Environment and Development Co-operation of the Development Co-operation Directorate. The overall objective of the project is to provide guidance on how to mainstream responses to climate change within economic development planning and assistance policies, with natural resource management as an overarching theme. Insights from the work are therefore expected to have implications for the development assistance community in OECD countries, and national and regional planners in developing countries.

This document has been authored by Shardul Agrawala and Tomoko Ota, drawing upon three primary consultant inputs that were commissioned for this country study: “Climate Change and Development in Bangladesh” by Ahsan Uddin Ahmed (Bangladesh Unnayan Parishad, Dhaka); “Analysis of GCM Scenarios and Ranking of Principal Climate Impacts and Vulnerabilities in Bangladesh” by Stratus Consulting, Boulder, USA (Joel Smith); and “Review of Development Plans, Strategies, Assistance Portfolios, and Select Projects Potentially Relevant to Climate Change in Bangladesh” by Maarten van Aalst of Utrecht University, The Netherlands.

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Further inquiries about either this document or ongoing work on sustainable development and climate change should be directed to Shardul Agrawala of the OECD Environment Directorate: shardul.agrawala@oecd.org, or Georg Caspary of the OECD Development Co-operation Directorate: georg.caspary@oecd.org.

TABLE OF CONTENTS

FOREWORD 3

EXECUTIVE SUMMARY 6

1. Introduction 9
2. Country background 9
3. Climate: baseline, scenarios, and key vulnerabilities 11
   3.1 Current climate 11
   3.2 Climate change and sea level rise projections 12
4. Key impacts and vulnerabilities 15
   4.1 Water resources 15
   4.2 Coastal resources 19
   4.3 Human health 20
   4.4 Agriculture 20
   4.5 Priority ranking of risks 21
5. Attention to climate concerns in donor activities 23
   5.1 Donor activities affected by climate risks 24
   5.2 Climate risk in selected donor strategies 28
   5.3 Attention to climate risks in selected development programs and projects 30
6. Attention to climate concerns in national planning 31
   6.1 Climate policies and national communications to international environmental agreements 31
   6.2 Interim poverty reduction strategy paper (I-PRSP) 32
   6.3 Other national policies of relevance to climate change 32
7. Climate change and coastal flooding 34
   7.1 Climate change impacts on coastal flooding 35
   7.2 Adaptation options available for management of coastal flooding 35
   7.3 Steps considered recently for the reduction of flood related vulnerability 37
8. Climate change and the Sundarbans 41
   8.1 Climate change impacts on the Sundarbans 43
   8.2 Adaptation options for the Sundarbans 45
   8.3 Measures undertaken to enhancing the flow regime in the Sundarbans 46
   8.4 Potential adaptation benefits from planned and ongoing activities 47
9. Concluding remarks 49

APPENDIX A: PREDICTIVE ERRORS FOR SCENGEN ANALYSIS FOR BANGLADESH 52

APPENDIX B: LIST OF PURPOSE CODES INCLUDED IN THE SELECTION OF CLIMATE-AFFECTED PROJECTS, ORGANIZED BY THE DAC SECTOR CODE. 53

APPENDIX C: REVIEW OF SELECTED DONOR STRATEGIES FOR BANGLADESH 54

APPENDIX D: REVIEW OF SELECTED DEVELOPMENT PROJECTS/PROGRAMMES 58

APPENDIX E: SOURCES FOR DOCUMENTATION 63

REFERENCES 66

Tables

Table 1. GCM estimates of temperature and precipitation changes ... 13
Table 2. Partial listing of cyclones along coastal Bangladesh and respective surge heights ... 14
Table 3. Change in rice yields in Asia under increments of temperature and CO2 level ... 20
Table 4. Percent change in Chittagong rice yields ... 21
Table 5. Priority ranking of climate change risks for Bangladesh ... 22
Table 6. Shares (by amount) of CRS activities for top-five donors in Bangladesh (1998-2000) ... 27
Table 7. Shares (by number) of CRS activities for top-five donors in Bangladesh (1998-2000) ... 27
Table 8. Climate change implications on select development projects in Bangladesh ... 30
Table 9. Key characteristics of the districts in the coastal zone of Bangladesh ... 34
Table 10. Projects identified in the draft NWMP that contribute to adaptation to coastal flooding ... 41

Figures

Figure 1. Map of Bangladesh ... 10
Figure 2. Development diamond for Bangladesh ... 11
Figure 3. Physiography of Bangladesh showing major floodplains ... 16
Figure 4. Historical flood extents in Bangladesh ... 17
Figure 5. Areal coverage of the 1998 flood ... 18
Figure 6. Development aid to Bangladesh (1998-2000) ... 23
Figure 7. Share of aid amounts in activities affected by climate risk in Bangladesh (1998-2000) ... 26
Figure 8. Share (by number) in activities affected by climate risk in Bangladesh (1998-2000) ... 26
Figure 9. Salinary ingress in the Sundarbans under 23 cm sea level rise ... 44

Boxes

Box 1. A brief description of MAGICC/SCENGEN ... 12
Box 2. The 1998 flood ... 17

EXECUTIVE SUMMARY

This report presents the integrated case study for Bangladesh carried out under an OECD project on Development and Climate Change. The report is structured around a three-tiered framework. First, recent climate trends and climate change scenarios for Bangladesh are assessed and key sectoral impacts are identified and ranked along multiple indicators to establish priorities for adaptation. Second, donor portfolios in Bangladesh are analyzed to examine the proportion of development assistance activities affected by climate risks. A desk analysis of donor strategies and project documents as well as national plans is conducted to assess the degree of attention to climate change concerns in development planning and assistance. Third, an in-depth analysis is conducted for coastal zones, particularly the coastal mangroves – the Sundarbans – which have been identified as particularly vulnerable to climate change.

Climate change poses significant risks for Bangladesh, yet the core elements of its vulnerability are primarily contextual. Between 30-70% of the country is normally flooded each year. The huge sediment loads brought by three Himalayan rivers, coupled with a negligible flow gradient add to drainage congestion problems and exacerbate the extent of flooding. The societal exposure to such risks is further enhanced by Bangladesh's very high population and population density. Many projected climate change impacts including sea level rise, higher temperatures (mean temperature increases of 1.4°C and 2.4°C are projected by 2050 and 2100 respectively), evapo-transpiration losses, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and increase in cyclone intensity would in fact reinforce many of these baseline stresses that already pose a serious impediment to the economic development of Bangladesh. A subjective ranking of key climate change impacts and vulnerabilities for Bangladesh identifies water and coastal resources as being of the highest priority in terms of certainty, urgency, and severity of impact, as well as the importance of the resources being affected.

Bangladesh receives around one billion dollars of Official Development Assistance (ODA) annually. Analysis of donor portfolios in Bangladesh using the OECD-World Bank Creditor Reporting System (CRS) database reveals that between 22-53% of development assistance (by aid amount) or 22-37% of donor projects (by number) are in sectors potentially affected by climatic risks. However, these numbers are only indicative at best, given that any classification based on sectors suffers from over-simplification – the reader is referred to the main report for a more nuanced interpretation. Donor country strategies and project documents generally lack explicit attention to climate change. Likewise, there is no national policy in place yet to comprehensively address climate change risks. At the same time however this report also reveals through a more in-depth analysis that despite this lack of explicit mention, a number of adaptations that climate change might necessitate are indeed already underway in Bangladesh, particularly since the mid-1990s, as part of regular development activity through several government-donor partnerships. A wide array of river dredging projects have been completed to reduce siltation and facilitate better drainage at times of flooding as well as to boost dry season flows to critical areas such as the Sundarbans. However there are remains an ongoing challenge with regard to their durability and sustainability. For example, measures such as dredging of waterways are not a one time response but require periodic repetition. Similarly flow regulators on coastal embankments require constant monitoring and maintenance for the lifetime of such structures. Monitoring and maintenance in turn requires continued government and donor interest as well as participation of the local population far beyond the original lifetime of the project.

There are also some examples of development policies and priorities in Bangladesh that might potentially conflict with climate change responses. In particular, policies to encourage tourism and build tourism infrastructure in vulnerable areas of the coastal zone, particularly the Khulna region, might need to take into account the projected impacts of climate change to reduce the risk of mal-adaptation.Meanwhile, plans to encourage ecotourism in the fragile Sundarbans might risk adding one more stress to a fragile ecosystem that will likely be critically impacted by sea level rise and salinity concerns.

The Bangladesh case study also highlights the importance of the trans-boundary dimension in addressing climate change adaptation. The effect of water diversion upstream on dry season flows and salinity levels in the Sundarbans was in fact comparable to (if not higher than) the impact that might be experienced several decades later as a result of climate change. Adaptation to climate change might therefore not just be local but might require cross-boundary institutional arrangements such as the Ganges Water sharing treaty to resolve the current problems of water diversion. Finally, climate change risks should also not distract from aggressively addressing other critical threats, including shrimp farming, illegal felling of trees, poaching of wildlife, and oil pollution from barge traffic, that might already critically threaten the fragile ecosystems such as the Sundarbans even before significant climate change impacts manifest themselves.

LIST OF ACCRONYMS

ADB	Asian Development Bank
BCAS	Bangladesh Centre for Advanced Studies
BMZ	Federal Ministry of Economic Cooperation and Development, Germany
BUET	Bangladesh University of Engineering and Technology
BWDB	Bangladesh Water Development Board
CERP	Coastal Embankment Rehabilitation Project
CRS	Creditor Reporting System of the OECD/World Bank
DFID	Department for International Development
DMB	Disaster Management Bureau
DOE	Department of Environment
DOF	Department of Forest
EDP	Estuary Development Program
FiFYP	Fifth Five Year Plan
GBM	Ganges-Brahmaputra-Meghna
GCM	General Circulation Model
GDA	Ganges Dependent Area
GDP	Gross Domestic Product
GEF	Global Environment Facility
GFDL	Geophysical Fluid Dynamics Laboratory
GOB	Government of Bangladesh
GRRP	Gorai River Restoration Project
GWST	Ganges Water Sharing Treaty
ICZM	Integrated Coastal Zone Management
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
IWM	Institute of Water Management
JICA	Japan International Cooperation Agency
KJDRP	Khulna-Jessore Drainage Rehabilitation Project
LGED	Local Government Engineering Department
MCS	Multi-purpose Cyclone Shelters
MES	Meghna Estuary Study
MOP	Ministry of Planning
MOWR	Ministry of Water Resources
MTP	Master Tourism Plan
NAPA	National Adaptation Plan of Action
NBSAP	National Biodiversity Strategy and Action Plan
NEMAP	National Environmental Management Action Plan
NFoP	National Forest Policy
NLUP	National Land Use Policy
NTP	National Tourism Policy
NWMP	National Water Management Plan
NWP	National Water Policy
OGDA	Options for Ganges Dependent Areas
PDO	Project Development Office
PRSP	Poverty Reduction Strategy Paper
SBCP	Sundarbans Biodiversity Conservation Project
SLR	Sea Level Rise
SPARRSO	Bangladesh Space Research and Remote Sensing Organization
SRDI	Soil Resources Development Institute
SRF	Sundarbans Reserve Forest
UN	United Nations
UNCBD	United Nations Convention on Biodiversity
UNCCD	United Nations Convention to combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
USAID	The US Agency for International Development
WARPO	Water Resources Planning Organization

1. Introduction

This report presents the integrated case study for Bangladesh for the OECD Development and Climate Change Project, an activity jointly overseen by the Working Party on Global and Structural Policies and the Network on Environment and Development Co-operation. The overall objective of the project is to provide guidance on how to mainstream responses to climate change within economic development planning and assistance policies, with natural resource management as an overarching theme. The Bangladesh case study was conducted in parallel with five other country case studies[1] in Africa, Latin America, and Asia and the Pacific.

Each case study is based upon a three-tiered framework for analysis (Agrawala and Berg 2002):

1. Review of climate trends and scenarios at the country level based upon an examination of results from seventeen recent general circulation models, as well as empirical observations and results published as part of national communications, country studies, and scientific literature. These projections are then used in conjunction with knowledge of socio-economic and sectoral variables to rank key sectoral and regional impacts on the basis of a number of parameters. The goal of this tier is to present a framework to establish priorities for adaptation.

2. Review of economic, environmental, and social plans and projects of both the government and international donors that bear upon the sectors and regions identified as being particularly vulnerable to climate change. The purpose of this analysis is to assess the degree of exposure of current development activities and projects to climate risks, as well as the degree of current attention by the government and donors to incorporating such risks in their planning. This section will review donor portfolios and projects, as well as development priorities of the Government of Bangladesh (GOB) to determine the degree of attention to potential risks posed by climate change on relevant sectors.

3. In-depth analyses at a thematic, sectoral, regional or project level on how to incorporate climate responses within economic development plans and projects, again with a particular focus on natural resource management. This report identifies two inter-linked issues for in-depth analysis: (i) coastal zones at enhanced risk of flooding as a result of climate change; and (ii) the vulnerability of the coastal mangroves – Sundarbans – to sea level rise and other climate change impacts. These analyses were conducted in-country, based on a review of past, ongoing, and planned activities that bear upon the capacity of these two systems to adapt to anticipated impacts of climate change. This was supplemented by interviews by a case study consultant with individuals from key government agencies, NGOs, as well as local stakeholders. In addition, a workshop on climate issues by the Bangladesh University of Engineering and Technology (BUET) and a national dialog on Water and Climate in preparation for the Third World Water Forum were taken as vehicles by a case study consultant to exchange ideas with participants and their views have been incorporated in the report.

2. Country background

Bangladesh is located between 20° to 26° North and 88° to 92° East. It is bordered on the west, north and east by India, on the south-east by Myanmar, and on the south by the Bay of Bengal (Figure 1). Most of the country is low-lying land comprising mainly the delta of the Ganges and Brahmaputra rivers. Floodplains occupy 80% of the country. Mean elevations range from less than 1 meter on tidal floodplains, 1 to 3 meters on the main river and estuarine floodplains, and up to 6 meters in the Sylhet basin in the north-east (Rashid 1991). Only in the extreme northwest are elevations greater than 30 meters above the

[1] Egypt, Tanzania, Uruguay, Fiji, and Nepal

mean sea level. The northeast and southeast portions of the country are hilly, with some tertiary hills over 1000 meters above mean sea level (Huq and Asaduzzaman 1999).

Figure 1. Map of Bangladesh

Bangladesh ranks low on just about all measures of economic development. This low level of development, combined with other factors such as its geography and climate, makes the country quite vulnerable to climate change. With a population of over 133 million people in a small area and a population density of more than 1,209 persons per km^2, and 75% of the population lives in rural areas, Bangladesh is a very densely populated country (World Bank, 2002). Higher population density increases vulnerability to climate change because more people are exposed to risk and opportunities for migration within a country are limited.

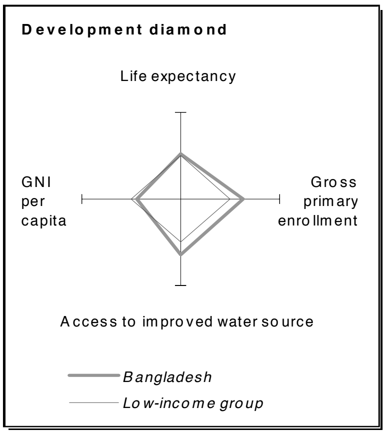
The per capita income in Bangladesh is US$370. This ranks below average South Asian per capita income and per capita income for low income countries (World Bank, 2002). With a Gini Index of 0.33[2], income distribution is somewhat unequal, although less so than in many other countries. More than one-third (36%) of the people in Bangladesh live in poverty; in rural areas, it is 40%. About one-quarter of the country's GDP comes from agriculture (World Bank, 2002), which makes the country's economy relatively sensitive to climate variability and change.

It is difficult to determine Bangladesh's potential to adapt to climate change, but several key statistics give some insight as to the state of its infrastructure and social and human capital. In 2000, the World Bank estimated that only 9.5% of Bangladesh's 207,500 km network of roads was paved, putting it well below the average for low income countries of 16.5% (World Bank 2002), suggesting that its physical infrastructure in general might be less developed than that of low income countries. In the same year, the World Bank reported Bangladesh had only 51 scientists and engineers per million people, a number comparable to that for low income countries in general. Similarly, gross secondary and tertiary school enrollment stood at 47.5% and 4.8%, respectively, in 2000. A relatively uneducated and illiterate public

2 The Gini coefficient is a number between zero and one that measures the degree of inequality in the distribution of income in a given society. The coefficient would register zero inequality for a society in which each member received exactly the same income and it would register a coefficient of one (maximum inequality) if one member got all the income and the rest got nothing.

will be less capable of adapting to climate change, and thus has higher vulnerability. Of that 4.8% in tertiary schools, however, nearly 50% were science and engineering students, a figure that compares favorably with much of the world. Figure 2 provides an indication of how Bangladesh compares to other low income countries in terms of four key indices of development.

Figure 2. Development diamond for Bangladesh



Source: World Bank 2002

3. Climate: baseline, scenarios, and key vulnerabilities

This section briefly reviews projections of temperature and precipitation change for Bangladesh from climate models, and then addresses the major risks from climate change that Bangladesh may face. The sectoral risk is presented in order of importance. This order is based on subjective judgments about the significance of climate change impacts (which is a function of severity and importance of the affected resource), timing of impacts (whether the impacts are likely to be significant or noticeable in first half of this century or not until the latter half), and certainty of impact (any uncertainties about the relationship with climate change or the nature of the climate change itself).

3.1 Current climate

Bangladesh has a humid, warm, tropical climate. Its climate is influenced primarily by monsoon and partly by pre-monsoon and post-monsoon circulations. The south-west monsoon originates over the Indian Ocean and carries warm, moist, and unstable air. The monsoon has its onset during the first week of June and ends in the first week of October, with some inter-annual variability in dates. Besides monsoon, the easterly trade winds are also active, providing warm and relatively drier circulation. In Bangladesh there are four prominent seasons, namely, winter (December to February), Pre-monsoon (March to May), Monsoon (June to early-October), Post-monsoon (late-October to November). The general characteristics of the seasons are as follows:

- Winter is relatively cooler and drier, with the average temperature ranging from a minimum of 7.2 to 12.8˚C to a maximum of 23.9 to 31.1˚C. The minimum occasionally falls below 5^{o}C in the north though frost is extremely rare. There is a south to north thermal gradient in winter mean temperature: generally the southern districts are 5^{o}C warmer than the northern districts.

- Pre-monsoon is hot with an average maximum of 36.7˚C, predominantly in the west for up to 10 days, very high rate of evaporation, and erratic but occasional heavy rainfall from March to June. In some places the temperature occasionally rises up to 40.6˚C or more. The peak of the maximum temperatures are observed in April, the beginning of pre-monsoon season. In pre-monsoon season the mean temperature gradient is oriented in southwest to northeast direction with the warmer zone in the southwest and the cooler zone in the northeast.
- Monsoon is both hot and humid, brings heavy torrential rainfall throughout the season. About four-fifths of the mean annual rainfall occurring during monsoon. The mean monsoon temperatures are higher in the western districts compared to that for the eastern districts. Warm conditions generally prevail throughout the season, although cooler days are also observed during and following heavy downpours.
- Post-monsoon is a short-living season characterised by withdrawal of rainfall and gradual lowering of night-time minimum temperature.

The mean annual rainfall is about 2300mm, but there exists a wide spatial and temporal distribution. Annual rainfall ranges from 1200mm in the extreme west to over 5000mm in the east and north-east (MPO, 1991).

3.2 Climate change and sea level rise projections

3.2.1 Temperature and precipitation

Changes in area averaged temperature and precipitation over Bangladesh were assessed based upon over a dozen recent GCMs using a new version of MAGICC/SCENGEN. MAGICC/SCENGEN is briefly described in Box 1. First results for Bangladesh for 17 GCMs developed since 1995 were examined. Next, 11 of 17 models which best simulate current climate over Bangladesh were selected. The models were run with the IPCC B2 SRES scenario (Nakicenovic and Swart 2000)[3].

Box 1. A brief description of MAGICC/SCENGEN

MAGICC/SCENGEN is a coupled gas-cycle/climate model (MAGICC) that drives a spatial climate-change scenario generator (SCENGEN). MAGICC is a Simple Climate Model that computes the mean global surface air temperature and sea-level rise for particular emissions scenarios for greenhouse gases and sulphur dioxide (Raoer et al., 1996). MAGICC has been the primary model used by IPCC to produce projections of future global-mean temperature and sea level rise (see Houghton et al., 2001). SCENGEN is a database that contains the results of a large number of GCM experiments. SCENGEN constructs a range of geographically-explicit climate change scenarios for the world by exploiting the results from MAGICC and a set of GCM experiments, and combining these with observed global and regional climate data sets. SCENGEN uses the scaling method of Santer et al. (1990) to produce spatial pattern of change from an extensive data base of atmosphere ocean GCM – AOGCM (atmosphere ocean general circulation models) data. Spatial patterns are "normalized" and expressed as changes per 1°C change in global-mean temperature. The greenhouse-gas and aerosol components are appropriately weighted, added, and scaled up to the actual global-mean temperature. The user can select from a number of different AOGCMs for the greenhouse-gas component. For the aerosol component there is currently only a single set of model results. This approach assumes that regional patterns of climate change will be consistent at varying levels of atmospheric greenhouse gas concentrations. The MAGICC component employs IPCC Third Assessment Report (TAR) science (Houghton et al., 2001). The SCENGEN component allows users to investigate only changes in the mean climate state in response to external forcing. It relies mainly on climate models run in the latter half of the 1990s.

Source: National Communications Support Program Workbook

3 The IPCC SRES B2 scenario assumes a world of moderate population growth and intermediate level of economic development and technological change. SCENGEN estimates a global mean temperature increase of 0.8 °C by 2030, 1.2 °C by 2050, and 2 °C by 2100 for the B2 scenario.

The spread in temperature and precipitation projections of these 11 CMs for various years in the future provides an estimate of the degree of agreement across various models for particular projections. More consistent projections across various models will tend to have lower scores for the standard deviation, relative to the value of the mean. The results of the MAGICC/SCENGEN analysis for Bangladesh are shown in Table 1.

Table 1. GCM estimates of temperature and precipitation changes

	Temperature change (°C) mean (standard deviation)			Precipitation change (%) mean (standard deviation)		
Year	**Annual**	**DJF**[4]	**JJA**[5]	**Annual**	**DJF**	**JJA**
Baseline average				*2278 mm*	*33.7 mm*	*1343.7 mm*
2030	1.0 (0.11)	1.1 (0.18)	0.8 (0.16)	+3.8 (2.30)	-1.2 (12.56)	+4.7 (3.17)
2050	1.4 (0.16)	1.6 (0.26)	1.1 (0.23)	+5.6 (3.33)	-1.7 (18.15)	+6.8 (4.58)
2100	2.4 (0.28)	2.7 (0.46)	1.9 (0.40)	+9.7 (5.80)	-3.0 (31.60)	+11.8 (7.97)

The climate models all estimate a steady increase in temperatures for Bangladesh, with little inter-model variance.[6] Somewhat more warming is estimated for winter than for summer. With regard to precipitation - whether there is an increase or decrease under climate change is a critical factor in estimating how climate change will affect Bangladesh, given the country's extreme vulnerability to water related disasters. The key is what happens during the monsoon. More than 80% of the 2,300 mm of annual precipitation that falls on Bangladesh comes during the monsoon period (Smith et al., 1998). Most of the climate models estimate that precipitation will increase during the summer monsoon because they estimate that air over land will warm more than air over oceans in the summer. This will deepen the low pressure system over land that happens anyway in the summer and will enhance the monsoon[7]. It is notable that the estimated increase in summer precipitation appears to be significant; it is larger than the standard deviation across models. This does not mean that increased monsoon is certain, but increases confidence that it is likely to happen. The climate models also tend to show small decreases in the winter months of December through February. The increase is not statistically significant, and winter precipitation is just over 1% of annual precipitation. However, with higher temperatures increasing evapotranspiration combined with a small decrease in precipitation, dry winter conditions, even drought, are likely to be made worse.

The Bangladesh Country Study for the U.S. Country Studies Program used an older version of the Geophysical Fluid Dynamics Laboratory (GFDL) transient model (Manabe et al., 1991) and projected that temperature would rise 1.3°C by 2030 (over mid-20th century levels) and 2.6°C by 2070. This is slightly higher than what is projected in Table 1 and may reflect lower climate sensitivity in more recent

4 December, January, and February – the winter months for Bangladesh

5 June, July, and August – the summer months for Bangladesh

6 Note that each GCM is scaled (i.e., regional changes are expressed relative to each model's estimate of mean global temperature change). Since the GCMs have different estimates of change in global mean temperature, this overstates inter-model agreement.

7 If, however, aerosols increase sufficiently, as a result of pollution and other causes, then it is possible they will exert a differential cooling effect over land. This is because pollution sources that are the source of the aerosols are found over land. Aerosols over land could therefore partially offset the warming over land, and it is possible that the air over land will warm less than air over oceans. This would weaken the low pressure system and the monsoon.

climate models. The core findings however are consistent with the analysis presented above: the report estimated that winter warming would be greater than summer warming. The study also estimated little change in winter precipitation and an increase in precipitation during the monsoon (Ahmed and Alam, 1999).

3.2.2 Change in frequency and intensity of cyclones

Bangladesh currently has extreme vulnerability to cyclones, both on account of its somewhat unique location and topography (that creates an inverted funnel effect), and because of the low (though growing) capacity of its society and institutions to cope with such extreme events. Cyclones originate in the deep Indian Ocean and track through the Bay of Bengal where the shallow waters contribute to huge tidal surges when cyclones make landfall. Existing literature records storm surges in the range of 1.5 to 9 meters, and some sources even cite particular cyclones as having resulted in surges almost 15 m in height. A partial listing of major cyclones and accompanying surge heights is given in Table 2. Given that over two-thirds of the country is less than 5 m above sea-level and densely populated, storm surges contribute to flooding and loss of life and livelihoods far beyond the coast. The intense precipitation that usually accompanies the cyclone only adds to the damage through inland and riverine flooding. A cyclone in 1970 resulted in close to 300,000 deaths, and another, in 1991 led to the loss of 138,000 lives, although in recent years greater success in disaster management has significantly reduced the lives lost (World Bank 2000). Nevertheless, the potential for economic and infrastructural damage remains very significant.

Table 2. Partial listing of cyclones along coastal Bangladesh and respective surge heights

Cyclone event	Season	Storm Surge Height* (in meter)
November 1876	Post-monsoon	3.0~10.0
May 1941	Pre-monsoon	4.0
May 1960	Pre-monsoon	3.2
October 1960 (First Event)	Post-monsoon	5.1
October 1960 (Second Event)	Post-monsoon	6.6
May 1961 (First Event)	Pre-monsoon	3.0
May 1961 (Second Event)	Pre-monsoon	6.0~8.0
May 1965	Pre-monsoon	7.6
December 1965	Post-monsoon/winter	8.8
October 1967	Post-monsoon	7.6
May 1970	Pre-monsoon	5.0
October 1970	Post-monsoon	4.7
November 1970	Post-monsoon	9.0
September 1971	Monsoon	5.0
December 1973	Post-monsoon/winter	4.5
August 1974	Monsoon	6.7
November 1975	Post-monsoon	3.1
May 1985	Pre-monsoon	4.3
November 1988	Post-monsoon	4.4
April 1991	Pre-monsoon	4.0~8.0

Note: * Surge height varies based on location. Modified from Ali, 2003.

Given this current vulnerability, a critical question is whether (and how) climate change might affect cyclone patterns and intensity in the Bay of Bengal. The IPCC Third Assessment notes that because of their relatively small spatial extent current climate models do not do a good job of resolving the influence of climate change on cyclones. Further, the historical record has large decadal variability, which makes any trend analysis based upon only a limited time-series data difficult to interpret conclusively. Nevertheless, based on emerging insights from some climate model experiments as well as the empirical record, the IPCC Third Assessment concludes: "*In conclusion, there is some evidence that regional frequencies of tropical cyclones may change but none that their locations will change. There is also evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%*" (IPCC 2001).

Even this tentative assessment has several major implications for Bangladesh. First, there is no reason to assume that cyclone tracks will shift under climate change – meaning that Bangladesh is likely to expect to continue to be hit with. The possibility of an increase in peak intensities may increase by 5-10% has potentially serious implications for a country already very vulnerable to storm surges driven by strong winds. A potential implication would be that future storm surges might be even higher than those observed currently. And a projected increase in 20-30% in the associated precipitation could only make the concerns even more serious given that Bangladesh is also prone to inland flooding because of its topography and lying as it does at the mouth of three major river systems.

3.2.3 Sea level rise

Another critical variable that determines the vulnerability of Bangladesh to climate change impacts is the magnitude of sea level rise. There is no specific regional scenario for net sea level rise, in part because the Ganges-Brahmaputra delta is still active and the morphology highly dynamic. Literature suggests that the coastal lands are receiving additional sediments due to tidal influence, while there are parts where land is subsiding due to tectonic activities (Huq et al. 1996). Since the landform is constituted by sediment decomposition, compaction of sediment may also play a role in defining net change in sea level along the coastal zone. A review of the literature and of expert opinion suggests that sediment loading may cancel out the effect of compaction and subsidence, so that net sea level rise may be assumed. The Bangladesh country study put the range at 30-100 cm by 2100, while the IPCC Third Assessment gives a global average range with slightly lower values of 9 to 88 cm. In any event the increases in mean sea level need to be viewed in conjunction with the discussion on cyclones in the preceding section. Higher mean sea levels are likely to compound the enhanced storm surges expected to result from cyclones with higher intensity. Even in non cyclone situations, higher mean sea levels are going to increase problems of coastal inundation and salinization in the low lying deltaic coast.

4. Key impacts and vulnerabilities

This section summarizes the potential impacts of climate change on key sectors in Bangladesh. Information is drawn from the Country Study (BCAS and DOE, undated), the World Bank study (World Bank 2000), Huq et al. (1999), and other sources where available. Sectors are listed in order of the subjective assessment of their relative vulnerability to climate change.

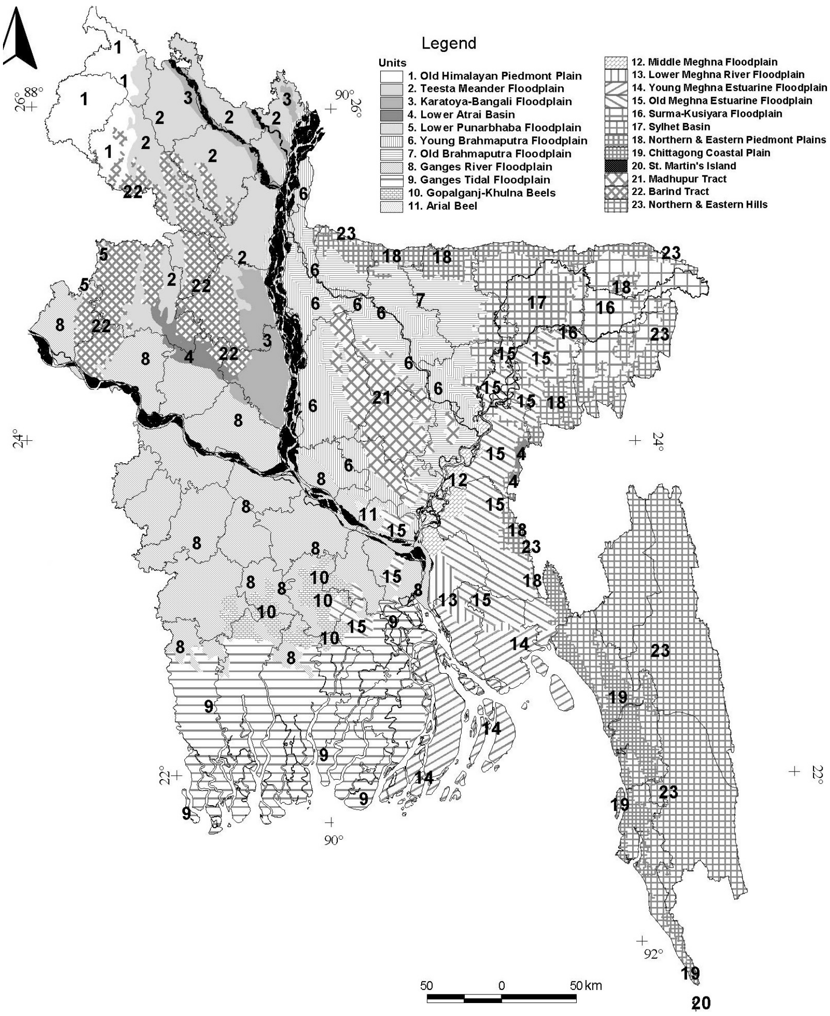
4.1 Water resources

Water related impacts of climate change will likely be the most critical for Bangladesh – largely related to coastal and riverine flooding, but also enhanced possibility of winter (dry season) drought in certain areas. The effects of increased flooding resulting from climate change will be the greatest problem faced by Bangladesh. Both *coastal* flooding (from sea and river water), and *inland* flooding (river/rain water) are expected to increase.

Flooding in Bangladesh is a regular feature and has numerous adverse effects, including loss of life through drowning, increased prevalence of disease, and destruction of property. This is because much of the Bangladesh is located on a floodplain of three major rivers and their numerous tributaries (Figure 3).

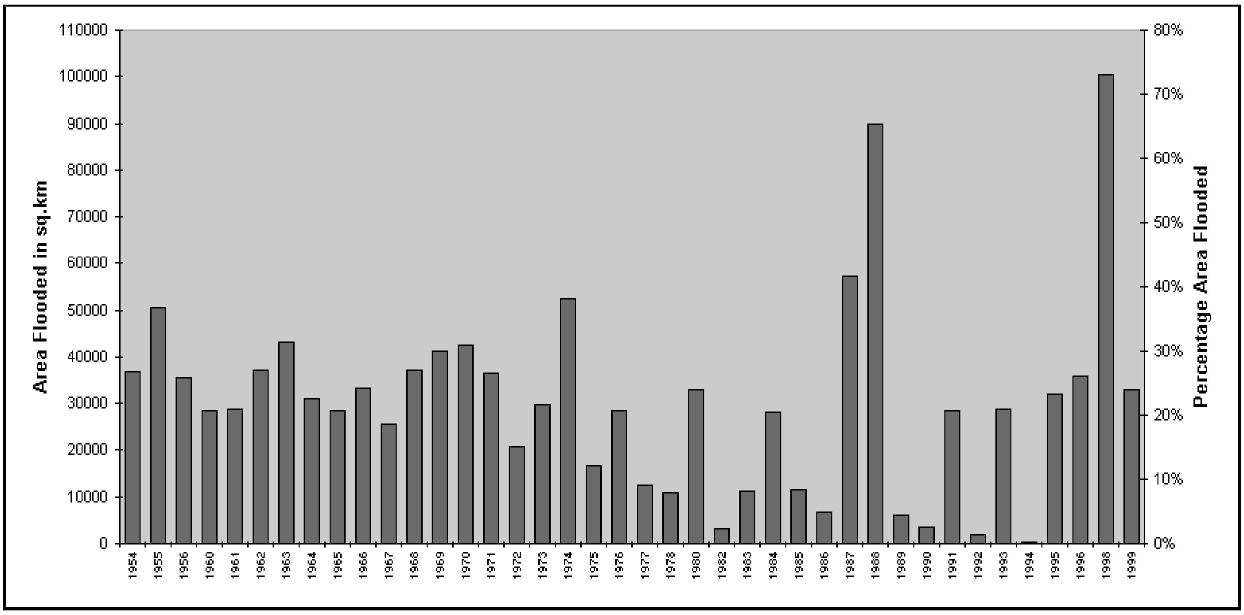
One-fifth of the country is flooded every year, and in extreme years, two-thirds of the country can be inundated (Mirza, 2002). This vulnerability to flooding is exacerbated by the fact that Bangladesh is also a low-lying deltaic nation exposed to storm surges from the Bay of Bengal.

Figure 3. Physiography of Bangladesh showing major floodplains



There has been a trend in recent decades of much higher inter-annual variation in area flooded. As shown in Figure 4, since the late 1970s flooding events have tended to cover significantly lower or significantly higher areas than what was observed in prior decades. This trend in extremes cannot be simply attributed to climate change. Rather several other factors are at play. First, better flood monitoring and control measures have probably contributed to significant reduction in areal coverage of moderate flooding events, which now cover much lower area.

Figure 4. Historical flood extents in Bangladesh



With regard to extremes at the upper end such as the 1988 and 1998 flooding events (Box 2), climatic variability (including events such as the El Nino Southern Oscillation) as well as long term climatic change could certainly be contributing factors. Looking into the future, climate change is likely to exacerbate flooding for a number of reasons, including the following:

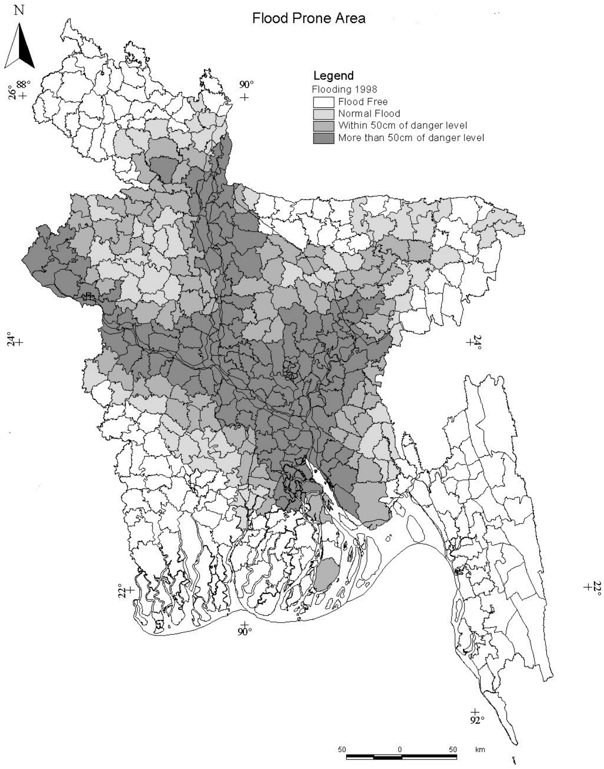
- *Increased glacier melt*. Higher temperatures will result in more glacial melt, increasing runoff from the neighboring Himalayas into the Ganges and Brahmaputra rivers. Given the altitude of the mountains and the enormous size of the glaciers, this problem will most likely continue over the century. The problem could be of even greater concern as there is evidence to show that temperatures in the Himalayas (where the glaciers are located) are rising at higher rates, thereby contributing to enhanced snow melt (see the Nepal case study).

- *Increased precipitation*. While this is not certain, the climate models tend to show increased precipitation, particularly during the monsoon season. This will contribute to increased runoff. For example, Mirza and Dixit (1997) found that a 2°C warming with a 10% increase in precipitation (close to the mean GCM projection for 2100 June-July- August) would increase runoff in the Ganges, Brahmaputra, and Meghna rivers by 19%, 13%, and 11%, respectively.

Box 2. The 1998 flood

The 1998 flood, one of the worst in recent memory, is an example of how vulnerable Bangladesh is to flooding. The flood was the result of three factors: 1) heavy rainfall and snowmelt in India and Nepal, 2) a 20% increase in rainfall in Bangladesh in its major rivers (the Ganges and Brahmaputra) and more than double rainfall in the Meghna, and 3) elevated tides in the Bay of Bengal from the monsoon. The third factor did not contribute to runoff, but the elevated tides blocked outflow of the swollen rivers into the Bay of Bengal. The flood inundated close to 100,000 km^2 of land (see Figure 5). More than 30 million Bangladeshis were displaced, with 20 million rendered homeless. Hundreds of people were killed directly by the floods, and several hundred thousand cases of diarrhea were confirmed.

Figure 5. Areal coverage of the 1998 flood



- *Sea level rise*. Sea level rise will result in coastal flooding both under ambient conditions (given the low elevations of the coast), and even more so in the event of storm surges. It will also indirectly cause riverine flooding by causing more backing up of the Ganges-Brahmaputra-Meghna rivers along the delta.

- *Increased intensity of cyclone winds and precipitation:* As discussed in Section 3.2.2, IPCC concludes that there is evidence of a 5-10% increase in intensity (wind-speed) that would contribute to enhanced storm surges and coastal flooding. IPCC also projects a 20-20% increase in intensity of associated precipitation that would contribute to (rain-water) flooding both in the coast and inland as the cyclone makes landfall. These estimates however are for tropical cyclones in general and are not location specific. Assuming a positive correlation between sea surface temperature and tropical cyclone intensity, Ali (1996) calculated the effect of a repeat of the 1991 cyclone with a 2°C increase (which causes a 10% increase in wind speed) and a 0.3 m sea level rise. He estimated that this would result in a 1.5 m higher storm surge that would inundate 20% more land than the storm surge from the 1991 cyclone.

On the other hand, it is also possible – though considerably more uncertain - that drought could increase under climate change. Drought is a recurring problem in Bangladesh: 19 occurred between 1960 and 1991. Drought is typically caused when the monsoon rains, which normally produce 80% of Bangladesh's annual precipitation, are significantly reduced. The southwest and northwest regions of the country are most vulnerable to drought. The estimates from the climate models do not yield a clear picture of how droughts will change. The estimated changes in precipitation are not significant. The models tend to show increased monsoon precipitation and annual precipitation, which could mean fewer droughts. But, a number of climate models estimate decreased annual precipitation, and the models tend to show reduced precipitation in the winter months. So the possibility of increased drought cannot be ruled out.

4.2 Coastal resources

This section addresses the risks from sea level rise to ecosystems as well as developed coastal resources. The certainty, timing, importance, and severity of impacts to the developed resources and ecosystems are about the same.

4.2.1 Ecosystems

One of the likely adverse impacts of climate change is the loss of the Sundarbans which are the coastal mangroves that straddle the coasts of western Bangladesh and neighboring India. The Sundarbans were formed by the deposition of materials from the Ganges, Brahmaputra, and Meghna rivers. If the Sundarbans are lost, the habitat for several valuable species would also be lost. A 45 cm sea level rise would inundate 75% of the Sundarbans, and 67 cm sea level rise could inundate all of the system. Extrapolating from this information, Smith et al. (1998) calculated that a 25 cm sea level rise would result in a 40% mangrove loss. It is not certain whether there will be many adverse effects on the Sundarbans with a sea level rise of a few tens of centimeters, although salinity could increase substantially in many areas. Even if barriers to migration such as physical structures could be moved, it is unlikely that inland migration would make up for losses of mangroves from inundation.

The impacts of climate change on the Sundarbans and the opportunities and challenges faced in mainstreaming adaptation responses to ameliorate some of these impacts are discussed in greater detail later in this report in Section 8.

4.2.2 Coastal infrastructure

A 1 m rise in sea level would inundate 18% of Bangladesh's total land, directly threatening 11% of the country's population with inundation (based on current population distribution). In addition, the backwater and increased river flow from sea level rise could affect 60% of the country's population (Karim and Rahman, 1995; Bijlsma, 1996). Nonetheless, such a rise in sea level is quite probable over many centuries (Church et al., 2001).

Inundation of such a large portion of the country could present major challenges in terms of loss of income and displaced populations. Huq et al. (1995) estimated that 11% of the country's population lives in the area threatened by a 1 m sea level rise. The area around Dhaka is quite dense, but there are also pockets of population density in the Khulna region, which is most vulnerable to sea level rise. More people would be at risk from flooding from coastal storms. In addition, the major port of Mongla would be at risk, as would one-eighth of the country's agricultural land and 8,000 km of roads (Huq et al., 1995).

At present, Bangladesh is too poor to be able to adapt to such a rise in sea level. The costs of protection would be substantial. Huq et al. (1995) estimate that 4,800 km of existing coastal defences would need upgrading and an additional 4,000 km of new defences would be needed. These protection measures would cost up to 1 billion US$ (Huq et al., 1995). The most vulnerable part of Bangladesh, the Khulna region, lies along the country's southwestern coast. With the exception of the hilly Chittagong area and the northwestern part of the country, most of the country is less than 10 m above sea level. In the long run, sea level rise could displace tens of millions of people. To resettle 13 million people, Debove (2003) estimates it would cost US$ 13 billion. However since this is a gradual and a long-run problem, it is less urgent than other risks that may become acute over coming decades rather than toward the end of the century.

4.3 Human health

The combination of higher temperatures and potential increases in summer precipitation could create the conditions for greater intensity or spread of many infectious diseases. However, risk in the human health sector is low relative to climate change induced risks in other sectors (such as water resources) mainly because of the higher uncertainty about many of the health outcomes. Increased risk to human health from increased flooding and cyclones seems most likely. Changes in infectious disease are less certain. The causes of outbreaks of infectious disease are quite complex and often do not have a simple relationship with increasing temperature or change in precipitation. It is not clear if the magnitude of the change in health risks resulting from climate change will be significant compared to current risks. It is also not clear if increased health risk will be apparent in the next few decades. On the whole climate change is expected to present increased risks to human health in Bangladesh, especially in light of the poor state of the country's public health infrastructure. Life expectancy is only 61 years, and 61% of children are malnourished (World Bank, 2002). Perhaps more illustrative of this point, though, is the US$12 per person per year that the Bangladeshi government expends on health, well below the US$21 spent in low income countries in general (World Bank, 2002).

4.4 Agriculture

With over 35% of Bangladeshis suffering from malnourishment (Lal et al., 2001), the threat of increased hunger from reduction in agricultural production would suggest the inclusion of agriculture as one of the major vulnerabilities facing the country. Yet the IPCC (Lal et al., 2001) and other studies (e.g., Karim et al., 1996) show crop yields *potentially increasing* at a few degrees Celsius increase in temperature (see Tables 2.3 and 2.4). Beyond that, particularly as the CO_2 fertilization saturates, yields could decrease. For example, Karim et al. (1996) estimated that rice yields would increase for about a 1.5°C increase combined with higher CO_2 levels.

Results reported by Karim et al. (undated) for Bangladesh's Country Study are consistent with Tables 3 and 4. They estimated that rice yields would decline under two GCM scenarios (GFDL and CCCM; the scenarios chapter did not give climate change estimates). They estimated increased yields for higher CO_2 alone (580 and 660 ppmv), higher CO_2 combined with a 2°C increase (but less of an increase than with no change in temperature), positive and negative changes in yields for a 580 ppmv of CO_2 combined with a 4°C increase, and mostly increased yields for a 660 ppmv of CO_2 combined with a 4°C increase. The marginal effect on yields of increasing temperatures (i.e., holding CO_2 constant) was negative. Reducing precipitation had a further negative effect on yields.

Table 3. Change in rice yields in Asia under increments of temperature and CO2 level

Model used and ambient CO_2 levels	Percent change in mean potential rice yield in Asia resulting from surface air temperature increment of			
	0°C	+1°C	+2°C	+4°C
ORYZA1 Model				
340 ppm	0.00	-7.25	-14.18	-31.00
1.5×CO_2	23.31	12.29	5.60	-15.66
2×CO_2	36.39	26.42	16.76	-6.99
SIMRIW Model				
340 ppm	0.00	-4.58	-9.81	-26.15
1.5×CO_2	12.99	7.81	1.89	-16.58
2×CO_2	23.92	18.23	11.74	-8.54
Source: Matthews et al., 1995, as reproduced in Lal et al., 2001.				

Table 4. Percent change in Chittagong rice yields

Scenario	Aus	Anan	Boro
2020: +0.7°C; 410 ppm CO_2	+3	+2	+4
2050: +1.5°C; 510 ppm CO_2	+9	+4	+11
Calculations are based on Karim et al., 1996.			

There are some causes for concern about agriculture in Bangladesh. Over the course of the 21st century and beyond, sea level rise will threaten hundreds of thousands if not more than a million hectares of agricultural land (Huq et al., 1995). For example, Islam et al. (undated) estimated that in eastern Bangladesh alone 14,000 tons of grain production would be lost to sea level rise in 2030 and 252,000 tons would be lost by 2075 (current agricultural production for the country is 30 million tons; WRI, 2001). Threatening the richest and most productive region of the country, sea level rise could have dramatic consequences for the Bangladeshi economy. A recent study estimates that a GDP decrease in the range of 28% to 57% could result from a 1m sea level rise (Debove, 2003).

Increased flooding from glacial melt, more intense monsoons, or more intense cyclones could also adversely affect agriculture in the near term by periodically inundating much agricultural land. Finally, Habibullah et al. (undated) estimated that several hundred thousand tons of grain production could be lost as a result of increased salinization from sea level rise.

4.5 Priority ranking of risks

The necessity of suitable responses to climate change not only relies on the degree of certainty associated with projections of various climate parameters (discussed in the previous section), but also in the significance of any resulting impacts from these changes on natural and social systems. Further, development planners often require a ranking of impacts, as opposed to a catalogue that is typical in many climate assessments, in order to make decisions with regard to how much they should invest in planning or mainstreaming particular response measures. Towards this goal, this section provides a subjective but reasonably transparent ranking of climate change impacts and vulnerabilities for particular sectors in Bangladesh.

Vulnerability is a subjective concept that includes three dimensions: exposure, sensitivity, and adaptive capacity of the affected system (Smit et al. 2001). The sensitivity and adaptive capacity of the affected system in particular depend on a range of socio-economic characteristics of the system. Several measures of social well-being such as income and income inequality, nutritional status, access to lifelines such as insurance and social security, and so on can affect baseline vulnerability to a range of climatic risks. Other factors meanwhile might be risk specific – for example proportion of rain-fed (as opposed to irrigated) agriculture might only be relevant for assessing vulnerability to drought. There are no universally accepted, objective means for "measuring" vulnerability. This section instead subjectively ranks biophysical vulnerability based on the following dimensions[8]:

- *Certainty of impact*. This factor uses available knowledge of climate change to assess the likelihood of impacts. Temperatures and sea levels are highly likely to rise and some impacts can be projected based on this. Changes in regional precipitation are less certain. This analysis uses the MAGICC/SCENGEN outputs to address relative certainty about changes in direction of mean precipitation. Changes in climate variability are uncertain. The Intergovernmental Panel on Climate Change (Houghton et al., 2001) concluded that higher maximum and minimum

8 A comprehensive vulnerability assessment would have necessitated collection/aggregation of a range of socio-economic variables at a sub-national scale, and was beyond the scope of this desk analysis.

temperatures are very likely, more intense precipitation is very likely over most areas, and that more intense droughts, increased cyclone wind speeds and precipitation are likely over some areas.

- *Timing*. When are impacts in a particular sector likely to become severe or critical? This factor subjectively ranks impacts in terms of whether they are likely to manifest themselves in the first or the second half of this century.

- *Severity of impact*. How large could climate change impacts be? Essentially this factor considers the sensitivity of a sector to climate change.

- *Importance of the sector*. Is the sector particularly critical in terms of its size of economy, cultural or other importance, or its potential to affect other sectors? This factor considers exposure of the sector to climate change, that is, how many people, property, or other valuable assets could be affected by climate change.

A score of high, medium, or low for each factor is then assigned for each assessed sector. In ranking the risks from climate change, the scoring for all four factors was considered, but the most weight was placed on the certainty of impact. Impacts that are most certain, most severe, and most likely to become severe in the first half of the 21st century are ranked the highest. The results of this analysis are summarized in Table 5[9].

Table 5. Priority ranking of climate change risks for Bangladesh

Resource/ranking	Certainty of impact	Timing of impact	Severity of impact[a]	Importance of resource
Water resources (flooding)	Medium-high	High	High	High
Coastal resources	High	Low	High	High
Human health	Low-medium	Medium	Medium-high	High
Agriculture	Medium	Low-medium	Low-medium	High

a. Note scoring is relative; significance is a function of severity of impact and importance of resource.

Water resources are ranked as the greatest concern because flooding is already an important issue for the country. Increased flooding would no doubt be significant. Since small changes in runoff can substantially increase flooding, it is expected that increased flooding will be noticeable in the next few decades. The combination of increased glacial melt, which is highly likely, and increased monsoon intensity, which appears likely, makes increased flooding also likely.

Bangladesh's coastal resources are ranked as next most vulnerable because the country exists mainly in a delta with most of its population and resources at low elevations and the Sundarbans are threatened by sea level rise. The Sundarbans are important because they are the largest mangrove system in the world and sea level rise could destroy or fundamentally change the entire ecosystem. Sea level is likely

9 This ranking is focussed primarily on biophysical risks and does not explicitly include a detailed analysis of socioeconomic and demographic factors that might mediate vulnerability, which was beyond the scope of this study.

to rise; indeed it is more certain than increased flooding. However, the full impacts of sea level rise may not be realized for many decades, thus yielding it second place in the risk ranking.

Since increases in flooding and sea level rise are quite likely, these two risks are “clustered” together. The remaining risks, while also potentially important, have much lower likelihoods of being realized as a result of climate change.

Human health is ranked below these other sectors because of the significant uncertainty about many impacts, although it is likely that climate change will present increased health risks to Bangladesh. In particular, increased flooding could threaten human health through drowning and spread of disease.

Finally, agriculture is last because a number of studies estimate increased yields with small amounts of warming, but decreased yields with larger levels of warming. With the mixture of beneficial and initially adverse impacts, agriculture is consequently ranked as having less vulnerability than the other sectors.

5. Attention to climate concerns in donor activities

Bangladesh receives over a billion dollars a year in donor aid, equivalent to about 2.5% of GNI. Figure 6 displays the distribution of this aid by development sector and by donor.

Figure 6. Development aid to Bangladesh (1998-2000)

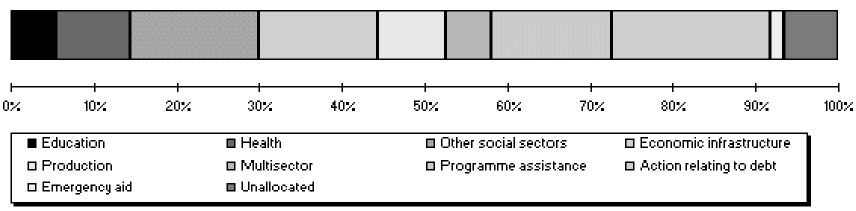
Bangladesh

Receipts	1998	1999	2000
Net ODA (USD million)	1 263	1 215	1 172
Bilateral share (gross ODA)	50%	48%	51%
Net ODA / GNI	2.8%	2.6%	2.4%
Net Private flows (USD million)	150	- 105	53

For reference	1998	1999	2000
Population (million)	125.6	127.7	129.8
GNI per capita (Atlas USD)	360	370	380

	Top Ten Donors of gross ODA (1999-2000 average)	(USD m)
1	IDA	385
2	JAPAN	354
3	AS. D B SPECIAL FUNDS	267
4	UNITED STATES	110
5	UNITED KINGDOM	104
6	EC	66
7	GERMANY	42
8	DENMARK	38
9	NETHERLANDS	34
10	CANADA	34

Bilateral ODA by Sector (1999-2000)



Sources: OECD, World Bank

The following sections highlight the possible extent of climate risks to development investments in Bangladesh, and examine to what extent current and future climate risks are factored in development strategies and plans, as well as individual development projects.[10] Given the large quantity of strategies and projects, this analysis is limited to a selection. This selection was made in three ways (i) a direct request to all OECD DAC members to submit documentation of relevant national and sectoral strategies, as well as individual projects (ii) a direct search for some of the most important documents (including for instance national development plan/PRSP, submissions to the various UN conventions, country and sector strategies from multilateral donors like the World Bank and UNDP, and some of the larger projects in climate-sensitive sectors), and (iii) a pragmatic search (by availability) for further documentation that would be of interest to the present analysis (mainly in development databases and on donors' external websites). Hence, the analysis is not comprehensive, and its conclusions are not necessarily valid for a wider array of development strategies and activities. Nevertheless, there is reason for some confidence that this limited set allows an identification of some common patterns and questions that might be relevant for development planning.

5.1 Donor activities affected by climate risks

This section explores the extent to which development activities in Bangladesh are affected by climate risks, which gives an indication of the importance of climate considerations in development planning. The extent to which climate risks affect development activities can be gauged by examining the sectoral composition of the total aid portfolio. Development activities in sectors such as water resources, infectious diseases, or agriculture could clearly be affected by current climate variability and weather extremes, and consequently also by changing climatic conditions. At the other end of the spectrum, development activities relating to education, gender equality, and governance reform are much less directly affected by climatic circumstances.

In principle, the sectoral selection should include all development activities that might be designed differently depending on whether or not climate risks are taken into account. In that sense, the label "affected by climate risks" has two dimensions. It includes projects that are at risk themselves, such as an investment that could be destroyed by flooding. But it also includes projects that affect the vulnerability of other natural or human systems. For instance, new roads might be fully weatherproof from an engineering standpoint (even for climatic conditions in the far future), but they might also trigger new settlements in high-risk areas, or it might have a negative effect on the resilience of the natural environment, thus exposing the area to increased climate risks. These considerations should be taken into account in project design and implementation. Hence, these projects are also affected by climate risks. A comprehensive evaluation of the extent to which development activities are affected by climate change would require detailed assessments of all relevant development projects as well as analysis of site specific climate change impacts, which was beyond the scope of this analysis. This study instead assesses activities affected by climate risks on the basis of CRS purpose codes (see Appendix B, which identifies "the specific area of the recipient's economic or social structure which the transfer is intended to foster")[11, 12].

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10 The phrase "climate risk" or "climate-related risk" is used here for all risks that are related to climatic circumstances, including weather phenomena and climate variability on various timescales. In the case of Bangladesh, these risks include the effects of seasonal climate anomalies (like a dry winter or heavy monsoon), extreme weather events, floods and droughts, as well as trends therein due to climate change, as well as sea level rise. "Current climate risks" refer to climate risks under current climatic conditions, and "future climate risks" to climate risks under future climatic conditions, including climate change.

11 Each activity can be assigned only one such code; projects spanning several sectors are listed under a multi-sector code, or in the sector corresponding to the largest component.

12 The OECD study "Aid Activities Targeting the Objectives of the Rio Conventions, 1998-2000" provides a similar, but much more extensive database analysis. It aimed to identify the commitments of ODA that targeted to objectives of the Rio Conventions. For this purpose, a selection was made of those projects in

Clearly, any classification that is based solely on sectors suffers from oversimplification. In reality, there is a wide spectrum of exposure to climate risks even within particular sectors. For instance, rain-fed agriculture projects might be much more vulnerable than projects in areas with reliable irrigation. At the same time, the irrigation systems themselves may also be at risk, further complicating the picture. Similarly, most education projects would hardly be affected by climatic circumstances, but school buildings in flood-prone areas might well be at risk. Without an in-depth examination of risks to individual projects, it is impossible to capture such differences. Hence, the sectoral classification only provides a rough first sense about the share of development activities that might be affected by climate risks.

To capture some of the uncertainty inherent in the sectoral classification, the share of development activities affected by climate change was calculated in two ways: a rather broad selection, and a more restrictive one. The first selection (high estimate) includes projects dealing with infectious diseases, water supply and sanitation, transport infrastructure, agriculture, forestry and fisheries, renewable energy and hydropower[13], tourism, urban and rural development, environmental protection, food security, and emergency assistance. The second selection (low estimate) excludes projects related to transport and storage. In many countries, these projects make up a relatively large share of the development portfolio, simply due to the large size of individual investments (contrary to investments in softer sectors such as environment, education and health). At the same time, infrastructure projects are usually designed on the basis of detailed engineering studies, which should include attention at least to current climate risks to the project.[14] Moreover, the second selection excludes food aid and emergency assistance projects. Except for disaster mitigation components (generally a very minor portion of emergency aid), these activities are generally responsive and planned at short notice. The treatment of risks is thus very different from well-planned projects intended to have long-term development benefits. Together, the first and the second selection give an indication of the range of the share of climate-affected development activities.

In addition, the share of emergency-related activities was calculated. This category includes emergency response and disaster mitigation projects, as well as flood control. The size of this selection gives an indication of the development efforts that are spent on dealing with natural hazards, including, often prominently, climate and weather related disasters.

The implications of this classification should not be overstated. If an activity falls in the "*climate-affected*" basket, which does not mean that it would always need to be redesigned in the light of climate change or even that one would be able to quantify the extent of current and future climate risks. Instead, the only implication is that climate risks could well be a factor to consider among many other factors to be taken into account in the design of development activities. In some cases, this factor could be marginal. In others, it may well be substantial. In any case, these activities would benefit from a consideration of these risks in their design phase. Hence, one would expect to see some attention being paid to them in project documents, and related sector strategies or parts of national development plans.

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the CRS database that targeted the Conventions as either their "principal objective", or "significant objective".

13 Traditional power plants are not included. Despite their long lifetime, these facilities are so localized (contrary to, e.g., roads and other transport infrastructure) that climate risks will generally be more limited. Due to the generally large investments involved in such plants, they could have a relatively large influence on the sample, not in proportion with the level of risk involved.

14 Note however, that they often lack attention to trends in climate records, and do not take into account indirect risks of infrastructure projects on the vulnerability of natural and human systems.

Figures 7 and 8 show the results of these selections, for the three years 1998, 1999, and 2000[15].

Figure 7. Share of aid amounts in activities affected by climate risk in Bangladesh (1998-2000)

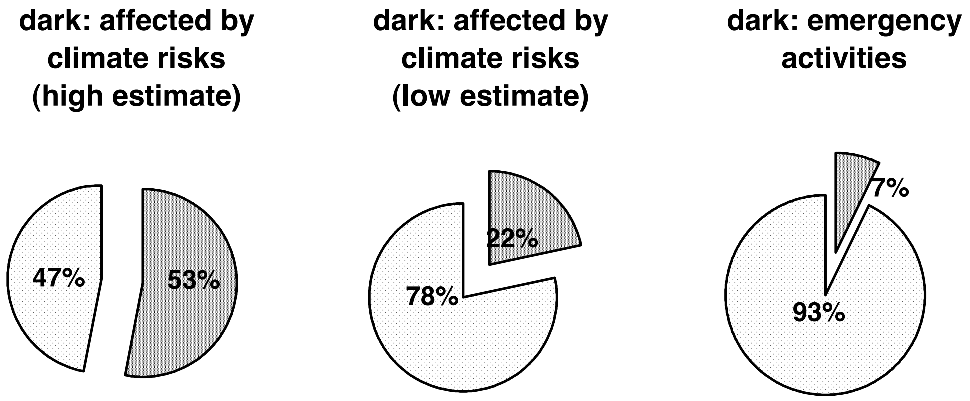
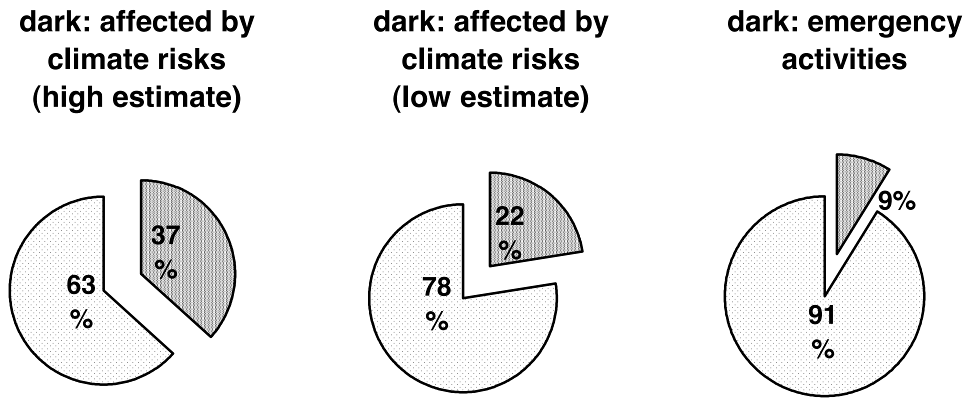


Figure 8. Share (by number) in activities affected by climate risk in Bangladesh (1998-2000)



15 The three-year sample is intended to even out year-to-year variability in donor commitments. At the time of writing, 2000 was the most recent year for which final CRS data were available. Note that coverage of the CRS is not yet complete: coverage ratios were 83% in 1998, 90% in 1999, and 95% in 2000. Coverage ratios of less than 100% mean that not all ODA/OA activities have been reported in the CRS. For example, data on technical co-operation are missing for Germany and Portugal (except since 1999), and partly missing for France and Japan. Some aid extending agencies of the United States prior to 1999 do not report their activities to the CRS. Greece, Luxembourg and New Zealand do not report to the CRS. Ireland has started to report in 2000. Data are complete on loans by the World Bank, the regional banks (the Inter-American Development Bank, the Asian Development Bank, and the African Development Bank) and the International Fund for Agricultural Development. For the Commission of the European Community, the data cover grant commitments by the European Development Fund, but are missing for grants financed from the Commission budget and loans by the European Investment Bank (EIB). For the United Nations, the data cover the United Nations Children's Fund (UNICEF) since 2000, and a significant proportion of aid activities of the United Nations Development Program (UNDP) for 1999. No data are yet available on aid extended through other United Nations agencies. Note also that total aid commitments in the CRS are not directly comparable to the total ODA figures, which exclude most loans.

In monetary terms, between about one-fifth and half of all development activities in Bangladesh could be affected by climate change. By number of projects, the shares are somewhat lower; between a one-fifth and half of the activities would be affected.[16] Bangladesh's extremely high exposure to natural hazards, particularly floods, is clearly reflected in the large share of emergency projects (about 7% of the amount and 9% of the number of development activities).

In addition to providing insight on the sensitivity of development activities in Bangladesh as a whole, the classification also gives a sense of the relative exposure of various donors. These results are listed in Tables 6 and 7 (again in the years 1998, 1999, and 2000).

Table 6. Shares (by amount) of CRS activities for top-five donors in Bangladesh (1998-2000)

All activities			**Affected activities** (high estimate)			**Affected activities** (low estimate)			**Emergency activities**		
Donor	Amount	%	Donor	Amount	%	Donor	Amount	%	Donor	Amount	%
Total	*5298*	*100%*	*Total*	*2806*	*100%*	*Total*	*1146*	*100%*	*Total*	*385*	*100%*
IDA	1698	32%	IDA	888	32%	AsDF	326	28%	IDA	200	52%
AS. D B	917	17%	AsDF	623	22%	UK	317	28%	AsDF	102	26%
UK	699	13%	UK	436	16%	Denmark	135	12%	UK	34	9%
Japan	671	13%	Denmark	239	9%	IDA	132	11%	Japan	22	6%
USA	341	6%	USA	203	7%	Japan	75	7%	Germany	10	3%

Table 7. Shares (by number) of CRS activities for top-five donors in Bangladesh (1998-2000)

All activities			**Affected activities** (high estimate)			**Affected activities** (low estimate)			**Emergency activities**		
Donor	Number	%	Donor	Number	%	Donor	Number	%	Donor	Number	%
Total	*1230*	*100%*	*Total*	*451*	*100%*	*Total*	*276*	*100%*	*Total*	*108*	*100%*
UK	257	21%	UK	126	28%	UK	77	28%	UK	37	34%
Norway	162	13%	Netherl.	54	12%	Netherl.	41	15%	Switzerl.	13	12%
Netherl.	116	9%	Denmark	37	8%	Denmark	20	7%	Norway	11	10%
Australia	74	6%	Australia	27	6%	Australia	20	7%	Netherl.	8	7%
Germany	72	6%	Norway	26	6%	Norway	16	6%	Germany	6	6%

Given the substantial share of development activities in Bangladesh that could be affected by climate risks, and the high costs of natural hazards, one would assume that these risks are reflected in development plans and a large share of development projects. The following sections examine the extent to which this is the case.

16 Note that the number of activities gives a less straightforward indication than the dollar amounts. First of all, activities are listed in the CRS in each year when a transfer of aid has occurred. Hence, when a donor disburses a particular project in three tranches, that project counts three times in the three-year sample. If the financing for a similar three-year project is transferred entirely in the first year, it only counts once. Secondly, the CRS contains a lot of non-activities, including items like "administrative costs of donors". Moreover, some bilateral donors list individual consultant assignments as separate development activities. In most cases, such transactions will fall outside of the "climate-affected" category. Hence, the share of climate-affected activities relative to the total number of activities (which is diluted by these non-items) is lower. On the other hand, the shares by total amount tend to be dominated by structural investments (which tend to be more costly than projects in sectors such as health, education, or environmental management).

5.2 Climate risk in selected donor strategies

As early as 1996, the World Bank's 2020 Long-run Perspective Study for Bangladesh (1996) raised the issue of climate change: "although the impacts of global warming are still far from precisely predictable, the prospect is sufficiently likely and alarming to warrant precautionary action at the national as well as at the international level." Particularly the potential economic impacts of sea-level rise (13% of GDP) gave rise to the conclusion that further work was needed: "The seriousness of the problem warrants strenuous research efforts to understand various aspects of the problem and devise remedies for future generations." It advocated a dual response – international diplomacy in support of global mitigation, and national planning for adaptation.

The World Bank responded to this by sponsoring the Bangladesh Climate Change and Sustainable Development study (2000), which analyzed the possible impacts of climate change, identified physical and institutional adaptation options, and reviewed a number of development projects (see below) and the National Water Management Plan. Its main aim was to mainstream adaptation in the regular development strategies and operations in Bangladesh.

Three years later (in 2003), it appears that the results have partly been embraced in some sectors (see Huq, 2002, and Rahman and Alam, 2003). When provided with suitably presented information, sectoral policy makers, planners, and managers have indeed mainstreamed climate change into their regular work. For instance, recommendations of the World Bank study have been incorporated in coastal zone management programs and adopted in the preparation of (cyclone) disaster preparedness plans and a new 25-year water sector plan (under development). In agriculture, the results were deemed relevant to research programs (particularly for drought and saline tolerant rice varieties), but not for agricultural extension. Stakeholders in public health showed interest in the issue, although they did not see any short-term implications for their day-to-day decisions.

While sectoral planners showed a fair degree of interest, the report was less successful in convincing high level policy makers and central ministries like Finance and Planning of the importance of taking climate change into account as an integral part of sustainable development planning (Huq, 2002). Surprisingly, this same lack of follow-up at higher levels is also reflected in the lack of attention to climate change in the World Bank's own Country Assistance Strategy, a high level policy document that was published in 2001 - a year after the Bank's study on Climate Change and Sustainable Development in Bangladesh. While ample attention is paid to natural hazards, the strategy only mentions climate change briefly, in the context of environmental problems, such as widespread resource depletion, ecological degradation, urban and industrial pollution - and natural disasters.

A similar pattern arises in most of the other donors' strategies for Bangladesh[17]: ample attention is paid to the risk of natural hazards, and many efforts are made to reduce Bangladesh's vulnerability to those risks, but climate change is not mentioned, or receives very little consideration. The European Commission has recently developed a climate change strategy for support to partner countries (European Commission 2003). The overall objective of this strategy is to assist partner countries in meeting challenges posed by climate change through mainstreaming climate concerns into EU development co-operation. The strategy consists of four strategic priorities: (i) raising the policy profile of climate change,

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17 Including UNDP/UNPF, DFID, CIDA, JICA Environment Profile. The ADB strategy lists climate change as a priority environmental theme in its policy matrix, but offers no further analysis of its crosscutting implications.

(ii) support for adaptation, (iii) support for mitigation, and (iv) capacity development, which are translated into a proposed action plan[18].

IFAD's Country Strategic Opportunities Paper also neglects climate change as a risk factor, but provides an interesting perspective on vulnerability to natural hazards and development strategies in Bangladesh. The paper finds a disconnection between "*micro success"* and *"macro stagnation*". It suggests that poverty reduction strategies in Bangladesh have been very successful in increasing resilience, demonstrated by impressive gains in the areas of food production, population control, health education, and in building up the institutional capacities of the poor. The way in which Bangladesh was able to manage the devastating 1998 floods is another example of this resilience, which is characterized by people's own efforts as well as government initiatives in safety net provisioning and rural infrastructure development. However, the paper contrasts this success from the perspective of the "*economics of resilience"* with the failure of the "*economics of graduation*". In other words while the loss of life and livelihoods from disasters have been considerably reduced, there remains a lack of real opportunities for the poor to embark on a path of progressive economic upliftment. The lack of such long-term opportunities for social upliftment is also likely to limit improvement in coping or adaptive capacity, and thereby constrain the success of efforts to reduce vulnerability to climate change.

Another perspective on climate change risks in Bangladesh is provided in a BMZ study on climate change and conflict (Brauch, 2002). Its case study on Bangladesh showed that this country has already been a primary victim of extreme weather events (cyclones, floods and droughts) that forced people to migrate. The increase in environmental stress due to climate change may further raise the conflict potential and might eventually lead to international tensions and regional instability: *"In Bangladesh the struggle for survival against the impacts of global environmental change has been real for decades. Without more intensive efforts to address the causes at their roots a major human catastrophe may be possible that will not only affect the neighboring states (India, Myanmar) but the OECD countries as well."* No attention to these trans-boundary risks however was reflected in any of the donor strategies.

18 This initiative however is too recent at the time of writing this report to assess its impact on in-country development co-operation policies of the EU.

Table 8. Climate change implications on select development projects in Bangladesh

(▓ = dark shading, ░ = light shading; ☹ / 😐 / ☺ = face symbols as printed)

	Coastal resources	Drainage congestion	Fresh water availability	Morphologic dynamics	Fresh water resources	Drainage congestion	Fresh water availability	Morphologic dynamics	Agriculture	Public health	Ecosystems/biodiversity
Small Scale Water Resources Development Sector Project (SSWRDSP)	▓	░ 😐	░ 😐	☹	▓	░ 😐	░ 😐	☹	▓		
Command-area Development Project (CADP)	▓ ☹	☹	☹	☹	▓	☹		☹	▓		
Khulna-Jessore Deainage Rehabilitation Project (KDRP)	▓	░ 😐	☹	░ 😐					▓		
Sundarbans Biodiversity Project (SBCP)	▓ ☹	☹	☹	☹							▓ ☹
Coastal Greenbelt Project (CGP)	▓		☹	░ 😐							
Forestry Sector Project (FSP)					▓		☹	☹			▓
Agricultural Research Management Project (ARMP)									▓ ☺		
Proposed Coastal Zone Development Program (CZDP)	▓ ☺	░ 😐	░ 😐	░ 😐	▓ ☺						
Forestry Resources Management Project (FRMP)			☹				☹				▓ ☹
Fourth Fisheries Project (FFP)		☹	☹				░ 😐				▓ 😐
1 Gorai River Restoration Project	▓ ☺	░ 😐	░ 😐		▓ ☺	░ 😐	░ 😐	░ 😐			
Third Inland Water Transport Project					▓	░ 😐		☹			
River Bank Protection Project (RBPP)					▓			░ 😐			
Water Sector Improvement Project (WSIP)					▓ ☺	░ 😐	☹	░ 😐	▓		
Sustainable Environment Management Program **	▓				▓					▓	▓
Third Water Supply and Sanitation Project **					▓					▓	
National Water Management Plan (NWMP)	▓ ☺	░ 😐	░ ☺	░ 😐	▓ ☺	░ 😐	░ ☺	░ 😐		▓	
	▓	░	░	░	▓	░	░	░		▓	

Key:		Characteristics of project:		Impact of climate change, in target sector of project. Depending on proposed activities in project, incorporation of adaptations can be relatively easy or difficult. This is indicated as follows:
	▓	Target sector in project	☹	Impact on target sector affecting success of project. No activities planned on issue. Adaptation possible only as additional activities.
	░	Target issue in Project: activities planned	░ 😐	Impact on target issue. No adaptations considered. However, as a target issue of project, adaptation can be part of activities, and project can help reduce vulnerability to climate change.
			░ ☺	Vulnerability to CC made explicit, adaptations is part of activities.
			▓ 😐	The project is vulnerable to climate change, however the proposed activities allow for adaptation. Opportunities to reduce vulnerability exist.
			▓ ☺	Proposed activities make project very promising to reduce vulnerability to climate change.

Source: World Bank 2000

5.3 Attention to climate risks in selected development programs and projects

The World Bank report *Bangladesh Climate Change and Sustainable Development* (2000) includes a review of sixteen development activities (mainly by the ADB and the World Bank, and also by the Netherlands and DFID) in the light of adaptation to climate change. This review considered two aspects: vulnerability of the projects themselves, as well as opportunities to reduce Bangladesh's vulnerability in a broader sense. The report's main finding was that most of the activities reviewed do not consider climate change impacts or adaptation to such impacts (see Table 8).

The current review, three years later, comes to a more nuanced conclusion. On the one hand it is true that little explicit attention is paid to climate change risks in most project documents[19], even for

[19] Note that this was a desk review; it could be that attention is not reflected in the documents, but still incorporated in the process of technical planning.

projects in sectors that are highly vulnerable, such as water management or coastal biodiversity (see Appendix B for an analysis of specific projects). However, at the same time – as discussed in greater detail in Sections 7 and 8 - many projects contribute directly or indirectly to a reduction in vulnerability, and most of them do take into account the natural hazards affecting Bangladesh. Only a few, such as the GEF/UNDP Coastal and Wetland Biodiversity Management at Cox's Bazar and Hakaluki Haor (2000-2007), note the potential effect of sea level rise. UNDP's Comprehensive Disaster Management Program (CDMP) lists climate change as a serious component of Bangladesh's vulnerability to natural hazards, to be integrated in the program's disaster risk reduction strategies. It is difficult to gauge the extent to which climate change considerations would have affected the design of the other projects.

At the same time, Huq (2002) and Rahman and Alam (2003) note that several ongoing development projects, such as the World Bank's coastal zone management project, and the GEF/ADB Biodiversity Conservation in the Sunderbans Reserve forest project, planned to incorporate considerations from the World Bank climate change study. However such developments, occurring during the project lifetime, are not reflected in the initial project documents.

One of the projects that was reviewed, the GEF/World Bank/DFID Aquatic Biodiversity Project, highlights the negative impacts of flood protection measures on inland open-water fisheries and biodiversity. Such findings re-emphasize the need to adopt cross-sectoral and comprehensive approaches to hazard risk management and sustainable development, particularly in the face of the increasing risks due to climate change.

6. Attention to climate concerns in national planning

Since its independence in 1971, Bangladesh has embarked upon a series of development plans, the latest being the Fifth Five Year Plan (FiFYP) that lays out development objectives and investments — both in public as well as private sectors — for the Plan period 1997-2002 (MOP, 1997). The major development objectives set out by the FiFYP include sustained economic growth, equity, poverty alleviation, human capability development, and sound environmental management. Bangladesh is also a signatory to a number of multilateral environmental agreements, and has a number of national level environmental and sectoral plans that intersect with responses that might be required to manage climate variability and long term climate change.

6.1 Climate policies and national communications to international environmental agreements

Although Bangladesh is significantly impacted by current climate variability, and is among the countries most vulnerable to climate change, there is no national policy in place yet to comprehensively address such risks. The need for a National Policy on Climate Change has been expressed time and again by the civil society of the country since early 1990s. In a recently held National Dialogue on Water and Climate Change, the formulation of a Climate Change Policy for the country was highly recommended. Work is currently underway to develop the National Adaptation Plan of Action (NAPA) for Bangladesh, although it is too early to assess whether the NAPA will lead to a comprehensive national policy that is endorsed and implemented by the government.

Bangladesh is a party to various international environmental conventions, including the UNFCCC, UNCCD, UNCBD and the RAMSAR Convention on Wetlands. Bangladesh submitted its first National Communications to the UNFCCC in late 2002. No copy was yet available for review. Bangladesh has also submitted two reports (in 2001 and 2002) to the UNCCD which do not discuss climate change. With regard to UNCBD, Bangladesh has not yet submitted a national biodiversity strategy and action plan (NBSAP). A report on alien species does not touch upon climate related issues. Bangladesh has also produced a National Planning Tool for the implementation of the Ramsar Convention on wetlands that draws linkages between Ramsar and biodiversity issues, but not with climate change concerns in the context of coastal wetlands. Similarly, the country's documentation for the World Summit on Sustainable Development only discusses climate change as a stand-alone air quality issue, rather than a cross-cutting concern affecting many aspects of sustainable development.

6.2 Interim poverty reduction strategy paper (I-PRSP)

Bangladesh's I-PRSP recognizes the direct links between poverty and vulnerability to natural hazards: "Given the risk and vulnerability to natural hazards that are likely to continue as a serious threat to national development efforts, macro level policies for disaster risk reduction, mitigation and management must be adopted in view of alleviating disaster-induced poverty". It notes that the incidence of disasters is likely to increase rather than decrease, particularly due to global climate change. The I-PRSP proposes a comprehensive and anticipatory approach to reduce Bangladesh's vulnerability: "… to reduce vulnerability to natural, environmental and human induced hazards through community empowerment and integration of sustainable risk management initiatives in all development programs and projects. This vision would be achieved by a multi-hazard and multi-agency approach to address vulnerability, risk assessment and mitigation that include prevention, preparedness, response and recovery. The vision considers a transition from a response and relief focus to vulnerability and risk reduction approach in disaster management."

In contrast to the strong emphasis on climate change in the discussion of Bangladesh's disaster trends, climate change is not mentioned in the context of planning vulnerability reduction measures (except for a proposal for further research on impacts). Outside of the section on natural hazards, the PRSP does not contain any references to climate change. Nevertheless, many of the proposed measures to reduce current vulnerability will also contribute to improved adaptation to climate change. For instance, the medium-term agenda for water management includes many items that will reduce climate vulnerability, including the formulation of national policies for water management, forestry, agriculture, fisheries and environment, but also regional and local level activities, ranging from engineering solutions and afforestation to community-level natural resources management arrangements. Some of these items would benefit from an explicit consideration of climate change. Similarly, in the context of agriculture policy, the PRSP proposes specific attention for improved agricultural technologies and practices in flood- and drought-prone areas, but does not mention climate change considerations, which would need to be taken into account in planning and implementation of such measures.

6.3 Other national policies of relevance to climate change

Bangladesh has put in place a number of sectoral policies and plans (particularly during the 1990s) that bear upon its ability to cope with current climate risks, and to some extent the additional risks posed by climate change. The following paragraphs discuss some of the most relevant policies.

The ***National Water Policy*** (NWP) announced in 1999 is the first comprehensive look at short, medium and long-term perspectives for water resources in Bangladesh. The NWP was followed by the ***National Water Management Plan*** (NWMP) in 2001 that looks at implementation and investment responses to address the critical priorities identified in the NWP. NWMP is currently being evaluated by a Parliamentary Committee. It is expected that the Plan will be accepted by the National Parliament in 2003 and its recommendations be endorsed by the National Water Council, the latter being the highest body to provide guidance to all water sector activities.

Given the criticality of climate change impacts on water resources (see Section 4.1), it is noteworthy that NWP does not explicitly mention this issue. NWMP however recognizes climate change as one of the factors determining future water supply and demand. The summary section on agriculture and water management states that "in undertaking these works the potential impacts of climate change and sea-level rise will be factored in". In relation to the coastal zone, the draft NWMP states, "…sea level rise due to global warming continued sedimentation of the rivers and flood plains and subsidence of the Ganges basin are all factors that will affect sea levels with respect to land levels. Each is difficult to predict with certainty, as reflected in the breadth of estimates of net sea level rise of 4.5~23 cm in 2025 and 6.5~44 cm by 2050". On coastal zones the NWMP further states "…the situation is further complicated by an observed trend of increased tidal amplitude associated with reduction of tidal flows due to empolderment in the South West Region. By 1995, the tidal range had increased to about 3.0 m from about 1.8 m in 1960. It is improbable that a new equilibrium has been reached, and the tidal range is expected to continue to increase. The combined effect of both sea level rise and increased tidal range will have a substantial impact over much of the coastal area. Furthermore, it has been estimated that the rise in sea level will result in backwater effects detectable as far inland as Faridpur and the *Haor* Basins of the North East". There is thus considerable internalization of climate change risks within this document which is expected to guide the implementation of the National Water Policy.

There are also a number of aspects of both NWP and NWMP that, while not mentioning climate change explicitly, do nevertheless bear upon adaptation to climate change. Some examples of priorities that are synergistic with adaptation responses to climate change include: (i) the recommendation in NWP to develop "early warning and flood-proofing systems to manage the (alternating cycles) of flood and drought" – as discussed in Section 4.1 flood risks and possibly drought risk are expected to increase under climate change; (ii) the NWP recommendation for "comprehensive development and management of the main rivers through a system of barrages", which the NWMP has followed up with a plan to construct a barrage on the Ganges to help sustain dry season flows and regulate monsoon flooding. This would not only be synergistic with adaptation of water resources, but may also contribute to reducing salinity concerns in the Sundarbans during the dry seasons and enhance their resilience under climate change and sea level rise; (iii) emphasis within the NWP on regional co-operation among co-riparian countries. This again is a good adaptation response: better co-ordination with India has the potential to partially offset the enhanced vulnerability of wet and dry season flows in Bangladesh under climate change.

Bangladesh's ***National Environmental Management Action Plan*** (NEMAP) which was published in 1995 does not explicitly discuss climate change. NEMAP however does add a cautionary note on the environmental damages that may result from structural flood control measures – which might highlight some conflicts with structural adaptation responses (such as the construction of barrages) highlighted under the NWP and NWMP, and other environmental consequences such as migration and breeding of fish-stock. Similar to NEMAP, the ***National Land Use Policy*** (NLUP) does not make direct reference to climate change. NLUP however aims to bring 25% of the land under forest cover and highlights mangrove plantations in *char* lands, and coastal green belts more generally as a priority. It also advocates conservation of existing forest lands, including the Sundarbans. These priorities of NLUP are also echoed the ***National Forest Policy*** (NFoP) that was initially formulated in 1979 and revised in 1994 – although the goal of NFoP is to bring 20% (as opposed to 25% in NLUP) of the total land under forest cover. Forest conservation priorities in NFoP and NLUP could help reduce some of the other stresses on ecosystems such as the Sundarbans, thereby increasing their resilience to the impacts of climate change. Further, policies such as the development of coastal green belts would be a good "no-regrets" adaptation response to reduce the vulnerability of the coastline to cyclones and storm surges, both under current conditions as well as under climate change. NFoP however also advocates Eco-tourism as a forestry related activity – within the context of the Sundarbans this has the potential to add to the stresses on the fragile ecosystem and could therefore lower its resilience. A similar concern comes up within the context of the ***National Tourism Policy*** (NTP) that was announced in 1992. NTP has developed a Master Tourism Plan (MTP) for the Sundarbans, and also highlights three coastal regions for tourism development, including Khulna which is the most vulnerable region in Bangladesh to sea level rise.

The following sections discuss in depth policy responses and challenges faced in mainstreaming them with regard to impacts of climate change on two critical systems: coastal flooding and the coastal mangrove forests of the Sundarbans.

7. Climate change and coastal flooding

Bangladesh has a 700 km long coastline that consists of a vast network of river systems draining the huge flow of the Ganges-Brahmaputra-Meghna river system. The river discharge on the Bangladesh coastline is heavily laden with sediments, both suspended and bed-load, giving rise to a highly dynamic estuary. The low topography gives rise to a strong backwater effect, and there is considerable seasonal variation in the interaction between the brackish and freshwater – with freshwater dominating during the monsoon and the saline front penetrating further inland during the dry season.

The coastal zone is home to 35 million people – over a quarter of the national population. The population density is 738/km^2. Current estimates project the coastal population to reach 40-50 million by 2050. Table 9 provides a listing of the administrative districts in the coastal zone along with their key characteristics.

Table 9. Key characteristics of the districts in the coastal zone of Bangladesh

No.	Name of District	Area Km^2	Population ('000)	Eligibility Criteria for Coastal Zone		
				Effect of Salinity	Tidal Fluctuation	Cyclone risk
1	Bagerhat	3,959	1,515,815	√	√	
2	Barguna	1,832	837,955	√	√	√
3	Barisal	2,791	2,330,960	√	√	
4	Bhola	3,403	1,676,600	√	√	√
5	Chandpur	1,704	2,210,162		√	
6	Chittagong	5,283	6,545,078	√	√	√
7	Cox's Bazar	2,492	1,757,321	√	√	√
8	Feni	928	1,196,219	√	√	√
9	Gopalganj	1,490	1,132,046	√	√	
10	Jessore	2,567	2,440,693	√	√	
11	Jhalokathi	758	696,055	√	√	
12	Khulna	4,395	2,334,285	√	√	
13	Laksmipur	1,458	1,479,371	√	√	√
14	Narail	990	689,021	√	√	
15	Noakhali	3,601	2,533,394	√	√	√
16	Patuakhali	3,205	1,444,340	√	√	√
17	Pirojpur	1,308	1,126,525	√	√	
18	Satkhira	3,858	1,843,194	√	√	
19	Shariatpur	1,181	1,057,181		√	
	Total	47,203	34,846,215			

Coastal lands are used for agriculture and livestock grazing throughout the year. Fishing is also a major activity in the coastal zones, while large scale industrial activity has been constrained by the limited availability of saline-free process water. The eastern coastal plains are also used for salt production, and a few coastal islands are used for drying of fish. Since the 1980s coastal lands have also been extensively brought under shrimp cultivation – primarily in response to the high salinity. Although the export oriented shrimp industry has given a boost to the national economy, it has encouraged farmers to artificially hold brackish water to boost shrimp production leading to adverse environmental and social effects, leading to government controls on such activity. Coastal zones are also offering potential for exploration of natural gas and other energy sources. Another emerging industry is tourism, with major plans underway to boost the infrastructure in coastal zones to promote both international and domestic tourism.

7.1 Climate change impacts on coastal flooding

The low lying costal zone in Bangladesh is located between the extensive drainage network of the Ganges-Brahmaputra-Meghna river system on one side, and tidal and cyclonic activity from the Bay of Bengal on the other. Since the 1960s a series of costal embankments has been constructed to protect low lying lands from tidal inundation and salinity penetration. Many of these lands have now become high productivity agricultural areas and are valued considerably more than lands outside the embankments. The same coastal embankments paradoxically also tend to block efficient drainage of freshwater on the other (land) side at times of excess rainfall and riverine flooding.

The situation is complicated further under climate change. As detailed in Section 4.1 several factors including enhanced glacier melt in the Himalayas, the possibility of enhanced monsoon precipitation, and the possibility of an increase in intensity of cyclones are likely to contribute to increased (freshwater) flood risk that could be further exacerbated in areas with coastal embankments. At the same time, sea level rise and potentially higher storm surges would result in over-topping of saline water behind the embankments. In other words, climate change could be a double whammy for coastal flooding, particularly in areas that are currently protected by embankments and therefore highly valued and home to productive economic activity. Outside the embankment areas, low lying lands will continue to be inundated in any case. But the magnitude and aerial coverage of inundation will likely be increased under climate change. Increased sea levels under climate change would also result in saline intrusion further upstream into the river system, which would increase the backwater effect. The whole process is likely to lead to enhanced sedimentation and gradually declining river gradients, increased drainage congestion and increased flood risks for coastal areas (Huq et al. 1996). Drainage congestion eventually increases the level of the floodplain, while the land inside the embankments remains unchanged. This in-turn increases the risk of overtopping of the crest height of the embankments, which would severely affect the productivity of more valuable land within the embankments. Coastal embankments themselves are virtually sitting on the floodplains of a delta, thereby not only interrupting the processes of delta formation, but also affecting the sedimentation process. Increased volume of water in the GBM river system during the monsoon that is projected under climate change would exert higher pressure on the erosion of vulnerable areas, which might increase coastal land erosion.

7.2 Adaptation options available for management of coastal flooding

Bangladesh is already vulnerable to coastal flooding, and this vulnerability will increase under climate change due to a combination of factors. Bangladesh already employs coastal embankment towards management of coastal flooding, particularly when it is caused by high tides and storm surges. However, inadequate drainage infrastructure along an embankment can be counter-productive, and could interact with several aspects of climate change to produce a cascade of adverse consequences that could in fact enhance the vulnerability of the coastal areas in Bangladesh.

A first order adaptation to climate change would therefore to build or maintain appropriate drainage infrastructure along coastal embankments. In fact flow regulators had already been incorporated in the design of existing embankments. However, in many cases the required number of regulators was not built as per design. In other cases, even if the regulators were built, they lacked proper maintenance and consequently failed to serve their intended purpose. The failure of regulators in polder[20] number 24, located in the western coastal region, caused saline flooding for over a decade. It caused severe damage to the agro-ecology within the embankment, and resulted in widespread dislocation of population. Therefore building of new drainage regulators along coastal embankments needs to be complemented by an assessment of the need for refurbishing existing regulators, followed by their periodic monitoring and

[20] A polder is a piece of land below sea level that is surrounded by a dyke.

maintenance. The participation of local communities would be critical for the effective monitoring and maintenance of coastal embankments and flow regulators. The National Water Policy (MOWR 1999) has given a clear mandate for the formation of associations of water users and water managers, and the participation of these local level organizations at all levels of planning and execution of projects, and more importantly, allowing them to take part in operations and maintenance activities.

While coastal embankments have flow regulators (albeit poorly maintained), the coastal roads network in Bangladesh generally lacks appropriate drainage infrastructure, a factor which is believed to have contributed to the flood of 2000 (Tutu 2001). Most of the newly built feeder roads along the coastal areas, building of which did not usually require rigorous planning and design and was done with local-level inputs, have completely ignored the necessity of having drainage infrastructure such as culverts, bridges and regulators. Construction of these drainage infrastructure offer a good adaptation option that would certainly reduce flood related vulnerability.

Another family of physical adaptation measures could revolve around enhancing the drainage and/or conveyance capacity of the coastal rivers. This could involve excavation/dredging of silting rivers to unclog their waterways. Controlled flooding to enhance sedimentation and thereby raise the floodplain further upstream is another adaptation measure that could enhance drainage by increasing the flow gradient. This measure has already been tested under the Khulna-Jessore Drainage Rehabilitation Project (EGIS 1998). Raising of the floodplain upstream helped drain the excess water, which in turn reduced flood vulnerability. Post project appraisals have concluded that this 'tidal basin'concept to be acceptable to the local population.

Another adaptation measure would involve the use of lifting pumps to take out excessive water from the flood affected areas may be considered as a physical adaptation. Since this involves high costs, it is considered only to save high value properties, infrastructure, urban centers and industrial zones. Pumps can also be used for the purpose of desalinization of high value agricultural lands. Repeated flushing of saline affected lands by freshwater and simultaneous disposal of excessive water can reduce soil salinity. Following the high intensity cyclonic event of 1991, Ganoshashthokendra (an NGO) tried such a measure to desalinize few hectares of land inside the embankment in Maheskhali Island (Haider, 1992). However, the cost of entire operation was high, thereby reducing its financial viability. The same NGO however also desalinized almost all the salinity affected tube wells after the 1991 cyclone. The operation was quickly completed and allowed people to have fresh potable water. Pumping option as an adaptation may, therefore, be considered to solve certain specific problems (such as salinization of potable water reservoirs) that are expected to occur under climate change.

Finally, the ongoing trend towards more effective disaster early warning and response in Bangladesh is also a viable adaptation strategy for flooding that might result from enhanced cyclone intensity that is projected under climate change. The directives given by the Standing Order on Disasters (DMB, 1999) in particular may be considered as elements of institutional adaptation. Continuous monitoring of the formation of cyclones in the Bay of Bengal involving satellite-based technology; monitoring the gradual development and track of imminent cyclone; issuance of cyclone warning well ahead of time for the people to take precautionary measures; evacuation from homesteads and relocation in multi-purpose cyclone shelters and concrete buildings — all may be considered as highly useful and proven adaptation strategies. Already such measures have allowed thousands of coastal people to successfully avoid loss of lives during two high intensity cyclonic events: one occurring in 1994 and the other in 1997 (Ahmed, 2000).

7.3 Steps considered recently for the reduction of flood related vulnerability

In response to the frequent problems associated with coastal flooding, both inside the embankments and outside, the Government of Bangladesh has undertaken measures to: (a) increase discharge capacity of the coastal rivers; and (b) deal with hindrances that do not allow passage of floodwaters from inside coastal embankments. A number of projects have already been completed and several more are currently underway. Some of these projects are described below. These projects are not explicitly designed to address vulnerability of climate change. They would only help achieve the objective of lowering present vulnerability, although lessons learnt from these projects would encourage the government and local communities to consider future similar adaptations to address climate change related additional vulnerability.

7.3.1 Khulna-Jessore Drainage Rehabilitation Project (KJDRP)

Funded by the Asian Development Bank, the KJDRP was implemented between 1995 and 2000 under the aegis of the Bangladesh Water Development Board (BWDB). The principal objective of the project was to achieve the national goal of poverty reduction by reducing drainage congestion of the rivers and channels in the coastal districts of Khulna and Jessore; increasing agricultural production; and creating on-farm employment. The project aimed at achieving a number of specific objectives: (i) to rehabilitate existing drainage infrastructure towards reducing drainage congestion and protecting the area from tidal and seasonal flooding; (ii) to provide support for the expansion of agricultural extension services in order to boost on-farm activities within the project area; and (iii) to facilitate improvement of culture fisheries management in various embankments in the project area.

KJDRP has been used as a test case for the implementation of a project through a participatory approach, a paradigm shift from the traditional top-down approach. The project activities involved the following:

- Dredging of rivers (a total of 30 kilometers have been dredged);
- Rehabilitation of over 550 kilometers of drainage channels;
- Creation/refurbishment of about 34 kilometers of coastal embankments;
- Building of 7 and rehabilitation of 19 hydraulic structures;
- Building of 20 outlet structures;
- Construction of 38 culverts and bridges (drainage infrastructure) along the road networks;
- Construction of a closure along one embankment; and
- Pilot testing of raising coastal land levels by means of controlled sedimentation ('tidal basin').

While KJRP – initiated in 1995 – certainly precedes the current discourse on "mainstreaming", it is interesting to note that the project links adaptation measures to coastal flooding directly with achieving the national development goal of poverty reduction. Also noteworthy is the use of a multi-pronged approach in which several adaptation measures were implemented in parallel. One of the interesting lessons learnt from the project is that, as an alternative solution to major regulators along the embankments, the local population favored a 'tidal river management' approach to remove coastal tidal inundation (EGIS, 1998). The environmental damages caused by decade-long saline water logging in polder number 24 have been adequately addressed as a result of KJDRP, which may be considered as an example of successful adaptation in dealing with coastal flooding (BWDB, 2000).

7.3.2 Coastal Embankment Rehabilitation Project

This project was jointly funded by the World Bank-IDA, the EC and the Government of Bangladesh at a total cost of US $80 million, and covering an 85000 hectare area along the south-eastern coast. The first phase project is already complete, and a second phase CERP-II is scheduled for completion in 2003. The overall objective of the project is to improve living conditions of the coastal population by taking a series of measures towards rehabilitation of coastal embankments. The measures of embankment rehabilitation include improved operation and maintenance of infrastructure; afforestation along embankments to facilitate land stabilization (creation of tree cover on the slope of embankments); and coastal (mudflat) afforestation.

Under the project that started in 1995-96, various engineering interventions for the rehabilitation have been made along 116 kilometers of embankment. Furthermore, protection works for embankment strengthening have been completed in 9.5 kilometers, while 40 drainage sluices have also been constructed to facilitate drainage from various embankments. The project authority claims that, over 1,500 hectares of foreshore areas have been brought under mangrove afforestation, while trees have been planted along the slope of embankments (BWDB, 1999; JPCOY *et al*., 2000). According to the project manager, the project has boosted agriculture production through prevention of saline intrusion and storm surges, enhanced use of HYV seeds which became more financially viable as a result of the enhanced security offered to agricultural lands, and improved drainage conditions in the polders (Rahman, undated). It is also estimated that 50% more lives could be saved for cyclonic surges with return periods of 10 years. However, the project had an initial emphasis primarily on structural responses and did not emphasize water resource management issues inside the polders, and saw the role of the government evolve from being a builder, to a partner working with NGOs and local communities for achieving the project objectives (Rahman, undated).

7.3.3 Noakhali Khal Re-excavation Protection Project

The objective of the project is to protect coastal lands in the target areas from saline water intrusion, provide drainage facility, reduce cyclone damages, and increase crop production. BWDB is the implementing agency on behalf of the government. The project commenced its activities in 1998-1999 and is likely to be completed in 2003. Under the project, the silted up Noakhali *Khal* (rivulet) has been re-excavated for a stretch of about 25 kilometers in the Thanas of Sudharam, Begumganj and Companiganj of Noakhali district. One flood protection closure and one regulator have also been constructed, which would provide autonomous adaptation towards reducing vulnerability to coastal flooding.

7.3.4 Meghna Estuary Study — Phases I and II (MES)

The long-term objective of MES is to understand estuarine processes, problems and opportunities so that the knowledge-base can be utilized for achieving the following: to improve the physical safety and social security of the people living in the coastal areas and on the islands in the estuary; to retain and increase the operational knowledge of the hydraulic and morphological processes in Meghna estuary; and to develop appropriate approaches and techniques for efficient land reclamation as well as effective river bank protection measures.

The recently completed study, under the joint management of WARPO and BWDB, performed a host of activities including: benchmark surveys on marine, land and socio-economic aspects; studies on hydrodynamics, estuarine morphology, environment, and socio-economy of the area; preparation of a 25 year (phased) Master Plan for the development of the Meghna estuary; preparation of 5 years (phased) land and water development plan with prioritization of projects; and preparation of small scale pilot schemes with complete design, implementation, monitoring and evaluation. A number of study reports along with the Master Plan have been published as outcomes of the study (MOWR, 2001a; MOWR, 2001b; MOWR, 2001c; MOWR, 2000).

On the basis of outputs of the study, the government promptly launched an *Estuary Development Program (EDP)* in July 2002, to be implemented by the Ministry of Water Resources. The general objective of the action program is to increase physical safety of the areas, thereby enhancing social security of the vulnerable people living in the estuarine areas. MES and EDP would certainly increase natural systems resilience to coastal hazards such as floods (tide and surge induced) and reduce vulnerability of both physical and socio-economic systems in the estuarine areas.

7.3.5 Other Polder Rehabilitation Projects

In addition to these major project activities, a number of polder rehabilitation projects have been undertaken with donor assistance along the coastal zone with a common objective to increase conveyance capacity of the coastal rivers and reduce drainage congestion. A partial listing of such projects is as follows:

- Bhulua River Re-excavation (1998-99 and 2001-02), cost US$ 2 million.
- Sureswar Pilot Project (1998-99 and 2003-04), cost US$10.5 million.
- Polder 64/IA, 64/IB, and 64/IC Rehabilitation (2001-02 and 2003-04), cost of US$6 million.
- Muhuri-Kahua FCD Project (2002-03 and 2005-06), cost US$43 million.
- Construction/rehabilitation of Polder 65 and 64B (2002-03 and 2003-04), cost US$1.8 million.
- Southwest FDR Project (2000-01 to 2001-02), cost US$16 million.
- Retired Embankment and Sluices in Polder 56/57 (2001-02 to 2002-03), cost US$2 million.
- Ramshil-Kafulabari FCD Project (1997-98 to 2002-03), cost US$5 million.
- Barabaishdia FCD Project in Polder 50/51 (1998-99 to 2002-03), cost US$4 million.

In order to enhance further protection from coastal flooding, the MOWR has undertaken a few other projects involving extension of a few identified polders. These projects include:

- Polder-69 extension (1998-99 to 2002-03), cost US$3 million.
- Kenduar Beel Polder 36/I Extension (1999-00 to 2001-02), cost US$0.4 million.
- Polder 59/2 Extension (1998-99 to 2002-03), cost of about US$2 million.

7.3.6 Protection of towns and transportation infrastructure

To protect important towns from tidal flooding, a number of projects have been undertaken by the MOWR. Two important projects in this category are the Bhola Town Protection Project, which has been implemented over a period of about 11 years starting from 1992-93 at a cost of about US$6 million, and the Chandpur Town Protection Project, which has been implemented since 1997 to protect Chandpur town from erosion at an estimated cost of about US$19 million. The project is expected to be completed by 2004. Another set of projects that are synergistic with adaptation to climate change involve the installation of adequate drainage infrastructure along the coastal road network a major means of adaptation towards facilitating flood drainage. The Local Government Engineering Department (LGED) has been very active in the coastal zone to implement a number of projects. Two major projects in this category are:

Flood Drainage Rehabilitation Project in Completed Rural Development Project: One of the major objectives of the project is to implant flood drainage infrastructure in rural roads which have been completed under the Rural Development Project-18 along the entire south-western region of the country. With the financial assistance from the Asian Development Bank (ADB), the project is now being implemented at a cost of about US$12 million. The project is likely to be completed in 2003.

Construction of Low Cost Bridge/Culvert in Rural Roads (Phase I & II): Beginning in 1995, a large number of small scale bridges and culverts, as required, have been constructed along rural roads under the project. Although the project has been designed to include the entire country, a good proportion of such drainage infrastructure has been built in the coastal areas.

7.3.7 Improving disaster relief

As discussed in earlier sections, Multi-purpose Cyclone Shelters (MCS) have contributed immensely towards enhancing local capacities to reduce death toll during an event of high intensity cyclonic storm surges. A total of over 2100 MCS have been built over the years, a large number of such infrastructure have been built particularly as a preparedness response of the big cyclone of 1991 (Ahmed, 2000; Haider, 1992). A number of government and non-government agencies, in coordination with the Disaster Management Bureau (DMB), have constructed these MCSs. In addition to these physical adaptation and capacity building, institutional adaptation in relation to provide coordination and management services during- and post-cyclone periods has been offered by DMB. SPARRSO and Bangladesh Meteorological Department are responsible for tracking the formation and progression of cyclones, and providing cyclone warnings. The Bangladesh Red Crescent Society has been playing a commendable role in organizing local communities, which may be regarded as a very successful social adaptation, to respond to cyclone warning and save human lives by temporarily taking refuge to the nearest MCS. It is to be noted here that, the adaptation package has so far been very successful. Considering that the coastal population is increasing, the total demand for such cyclone shelters cannot be met by the existing MCSs and new MCS must be built keeping the rate of population growth in perspective. Moreover, a mechanism must be developed to monitor the quality of the facilities. Many of the MCSs have been built in early 1970s, and therefore may require periodic maintenance.

7.3.8 Planned activities relevant to adaptation to coastal flooding

In addition to the above mentioned activities towards reducing coastal flood vulnerability, Bangladesh is contemplating to implement a number of activities in the coastal zone. Again, the general objective of each of these activities is not adaptation to climate change impacts. It may, however, be expected that these planned activities would be synergistic with adaptation to climate change. Table 10 lists projects identified in the draft National Water Management Plan (see Section 6.3), which are expected to contribute to the future adaptation to coastal floods under climate change.

Table 10. Projects identified in the draft NWMP that contribute to adaptation to coastal flooding

Project	Estimated cost (in million US$)
Cluster: Main Rivers	
Ganges Barrage and Ancillary Works	898
Ganges Dependent Area Regional Surface Water Distribution Networks	157
Main River Erosion Control at Selected Locations	380
Cluster: Towns and Rural Areas	
Large and Small Town Flood Protection	255
Cluster: Major Cities	
Khulna Bulk Water Supply and Distribution Systems	139
Chittagong Sanitation and Sewerage Systems	229
Khulna Sanitation and Sewerage Systems	987
Chittagong Flood Protection	15
Chittagong Storm water Drainage	212
Khulna Flood Protection	8
Khulna Stormwater Drainage	66
Cluster: Disaster Management	
Cyclone Shelters and Killas	175
Bari-level Cyclone Shelters	31
Flood Proofing in the Charlands and *Haor* Basin	46
National, regional and Key Feeder Roads – Flood Proofing	193
Cluster: Agriculture and Water Management	
Rationalization of Existing FCD Infrastructure	379
Land Reclamation, Coastal Protection and Afforestation	108

The *Integrated Coastal Zone Management* (ICZM) project in particular offers great potential for the identification and implementation of future measures that would contribute to the overall process of coastal zone adaptation. In addition to making provisions for adaptation to coastal flooding, ICZM could also facilitate the future management of the Sundarbans forest. The ICZM Project Development Office (PDO) is currently undertaking a climate change study with the purpose of providing policy guidelines for integrating climate change vulnerability issues in projects relating to the coastal zones of Bangladesh (PDO-ICZM, 2003). The ICZM project is also undertaking vulnerability mapping of the coastal zone. The development of such a knowledge base could facilitate better incorporation of climate risks in future projects in the coastal zone.

8. Climate change and the Sundarbans

Linked to the problem of coastal flooding is the potential impact of climate change on the Sundarbans which straddle south-western Bangladesh and the adjoining coast in the Indian state of West Bengal. With a total area of over 10,000 square kilometers, the Sundarbans constitute that world's largest contiguous mangrove ecosystem. The second largest is only about one-tenth in size. Roughly 60% of the Sundarbans fall in Bangladesh, located on the northern limits of the Bay of Bengal and the old Ganges delta.

The Sundarbans house one of the richest natural gene pools for fauna and flora in the world. The flora contains at least 69 species, with the *Sundari* (Heritiera Fomes) – which gives the forest its name – and the *Gewa* (Excoecaria Agallocha) being the dominant species that provide timber for paper and wood products. A total of 425 species of wildlife have been identified in the Sundarbans, including 42 species of mammals, 300 species of birds, 35 reptiles, and 8 amphibian species (Blower 1985; Rashid and Scott 1989). The most notable – the Royal Bengal Tiger – is endemic to the forest. In recognition of this richness in biodiversity, both the Indian and the Bangladesh Sundarbans were declared world heritage sites by UNESCO.

The Bangladesh Sundarbans Reserve Forest (SRF) also offers subsistence livelihood for about 3.5 million inhabitants within and around the forest boundary. The forest consists of numerous creeks and rivulets which play a crucial role in bringing a balance between saline and fresh water: the former being brought by semi-diurnal tides, and the latter through rivers and precipitation which helps continuously flush the salinity off the forest floor. Freshwater tends to dominate during the monsoon season while salinity levels are highest in the dry season that precedes the monsoons.

Traditional lifestyles were in fact reasonably well adapted to these unique characteristics of the Sundarbans. Human dwellings were built on raised platforms, and farmers cultivated salinity and flood tolerant rice during the monsoon in land protected by temporary dykes when the abundance of freshwater had greatly reduced salinity levels. The dykes were dismantled post-harvest, opening the land to tidal movements. Meanwhile fishing of salt tolerant varieties was the principal source of livelihood during the dry season when salinity levels were high (Firoze, undated).

These traditional lifestyles have been altered in recent decades on account of a number of factors. A high rate of population growth has led to the ecosystem supporting an ever-growing population. Poaching of wildlife and illegal felling of timber are among the most severe environmental threats. A number of species such as the Javan rhinoceros and the water buffalo have already disappeared (Siddiqui 1997). Industrial development in the region and opening up of access to trade has also imposed increased demands on forest resources, particularly timber. The growing barge traffic and lax environmental enforcement have also led to a number of oil spills which continue to adversely impact the ecosystem.

Recent decades have also seen two major infrastructural developments – one local and the other in neighboring India – that have caused a major change in the dynamics of the ecosystem, and consequently local livelihood patterns. The first ironically was intended as an adaptation to coastal flooding – a series of coastal embankments that were built by the Government of Bangladesh in the late 1960s. However, as discussed in Section 7.2, the flow regulators in these embankments were either not built according to design and/or not properly maintained thereafter, which over time led to drainage congestion and water logging starting in the early 1980s. The second development was the construction of the Farakka barrage upstream in the Indian state of West Bengal in 1974 that diverted water and reduced dry season flows and led to significantly enhanced salinity levels in the dry season.

The inundation and salinity changes interrupted the traditional livelihood practices discussed earlier. However, at the same time they offer an ideal opportunity for shrimp farming which exploded as an export oriented cash industry starting in the mid-1980s, boosting local incomes[21]. On the other hand however, shrimp farming encouraged farmers to artificially inundate lands with brackish water during periods of low salinity, causing severe damage to the forest cover. The depletion of forests in water logged shrimp areas also increased pressures in other parts of the Sundarbans for fuel wood and timber, enhancing the rate of forest depletion. The thin wire mesh that is used for shrimp collection meanwhile is also resulting in the capture of larvae of other species, which are then discarded, thus causing the depletion of the stock of other fish species (Firoze, undated).

Meanwhile high dry season salinity levels, in part the result of water diversion upstream in India, have also adversely impacted agriculture production, besides increasing the environmental stress on the forest cover. The south-western region of Bangladesh, including the Sundarbans forest areas have already witnessed how surface salinity penetrate with decreasing flow condition in the lower Ganges distributary systems. SRDI (1997) reports indicate that, following the drastic diversion of surface flow in the Ganges in 1975 there has been a gradual rise in salinity in the entire Ganges Dependent Area (GDA). As a consequence

[21] One village in the Begarhat district in fact came to be known as the “Kuwait of Bangladesh” on account of its new prosperity (Firoze, undated).

of saline penetration the 1 ppt isohaline line during the peak low flow season (March) has reached as far as Kamarkhali Ghat, a location which was free from surface salinity hazard in the pre-Farakka period. Around Khulna, a divisional town located some 146 km upstream from the Bay, the salinity has increased from 380 micro-mhos in the pre-Farakka period to about 29,000 micro-mhos in the post-Farakka period.

Salinity ingress also causes an increase in soil salinity, especially when farmers irrigate their lands with slightly saline surface water at the beginning of the low flow period. SRDI (1997) reported that, soil salinity levels south of Khulna and Bagerhat towns ranged between 8 to 15 dS/m during the low flow season. It is also reported that, several sub-districts (such as Kachua, Mollahat, and Fultali) south of the Sundarbans ─ known to be non-saline in the pre-Farakka period ─ have began to develop soil salinity during the low flow seasons of 1980s. The anticipated results of salinity ingress will be, at a minimum, of the same order for climate change induced low flow regime compared to similar effects shown by deliberate withdrawal of flows at Farakka barrage.

8.1 Climate change impacts on the Sundarbans

The potential impacts of climate change on the Sundarbans will only be superimposed on the baseline stresses discussed above that are already posing a critical threat to the ecosystem. Following from the scenarios outlined in Section 3, climate change is expected to have a significant effect on the flow regimes of the major rivers in Bangladesh, including the Ganges. Since the viability of the Sundarbans rests on the hydrology of the Ganges and its tributaries which supply the fresh water influx, climate change is expected to have significant impact on the Sundarbans. In addition to the altered hydrology, sea level rise will also have adverse impacts on the forest, directly through enhanced inundation and indirectly by enhancing saline intrusion in river systems.

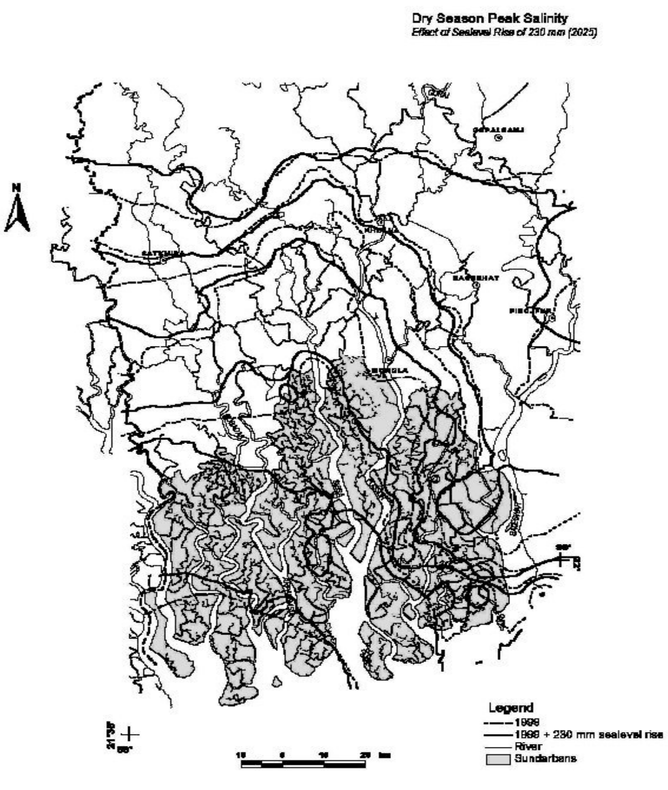
The climate change scenarios reviewed in Section 3.2 indicate that there is general agreement across climate models on increased precipitation during the monsoon season. Greater rainfall runoff would provide increased freshwater discharge in all the major distributaries of the Ganges supplying freshwater to the Sundarbans – the Gorai, the Modhumati and Bhairab system on the Bangladesh side and the Hoogly on the Indian side. Generally, increased flow regime in the distributaries of the Ganges would push the saline front outward towards the sea. Such a changed freshwater dominated hydrological condition during the monsoon in the absence of countervailing influences would help freshwater loving species such as the *Sundari*, especially in the mesohaline and polyhaline regions.

Simultaneously however, a rise in sea level would also occur under climate change which would cause increased backwater effect in the major distributaries of the Ganges and tend to push the saline front further inland. The final location of the saline front during the monsoon will therefore be the result of two opposing effects: enhanced freshwater flows and enhanced backwater effect, and is hard to predict precisely. The backwater effect would also reduce the discharge of freshwater flow from the northern reaches of the tributaries of the Ganges resulting in a relatively prolonged inundation of the forest land. Increased rainfall intensity – which is also anticipated in the region - would caused enhanced erosion upstream and result in increased availability of sediments, particularly along the Ganges and its distributaries. The latter effect in combination with prolonged flooding episodes would increase the rate of sedimentation/siltation in the back swamps and creeks inside the forest area. Such a change would be relatively more pronounced in the Bangladesh side of the forest and may slightly offset permanent inundation of the forest floor due to continued increase in sea level rise.

The effects of climate change on the Sundarbans would be considerably more critical during the dry season that extends from November to April. Climate models predict a decrease in precipitation during this period which might further reduce freshwater flows, which will encourage enhanced withdrawals upstream for irrigation. This reduction in freshwater inflows into the Sundarbans could be exacerbated by increased evapo-transpiration losses and water use on account of rising winter temperatures. Reduced freshwater flows coupled with sea-level rise would consequently further enhance the dry season salinity levels in the Sundarbans.

The reduction in freshwater flows would only deteriorate with time and the lowest water levels would be expected in March. As a response to reduced flow regime the salinity front would penetrate inland both inside the forest areas and in the entire south-western areas of the country. Similar ingress of salinity is also expected on the Indian side of the Sundarbans. The effect of sea level rise on salinity ingress is modelled here using the salinity model of the Institute of Water Management (IWM), Bangladesh. Considering about 23 cm of SLR, isohaline lines penetrate inland, as shown in Figure 9 Significant penetration has been indicated for the threshold salinity of 1 ppt or higher for the rivers supplying freshwater in the western and central parts of the Sundarbans: Betna, upper Bhairab and Kobadak.

Figure 9. Salinity ingress in the Sundarbans under 23 cm sea level rise



If an increased sea level rise of 44 cm is considered a relatively higher penetration is expected to occur along the western parts of the GDA for the isohaline limits of 1, 5 and 10 ppt. It must however be mentioned that the model offers results of low confidence due to its limitation of using a fixed salinity boundary along the downstream of rivers. The modelling results are indicative, and actual salinity ingress would be compounded but when model results are superimposed on the possibility of reduction of surface flows during the peak low flow period, one may have an understanding of the extent of salinity ingress along the rivers in the Sundarbans. As a consequence of salinity penetration in the Sundarbans, majority of the mesohaline areas will be transformed into polyhaline areas, while oligohaline areas would be reduced to only a small pocket along the lower-Baleswar river in the eastern part of the forest. Such a finding closely supports earlier studies (Ahmed *et al*., 1998).

High intensity cyclonic storm surge, induced by a general rise in sea surface temperature, is also likely to have compounding effect on salinity intrusion along the coastal areas of Bangladesh, including the Sundarbans. A simple frequency distribution of all observed cyclonic activities in the Bengal delta suggests that these events usually occur twice per annum: in late May and in early November (Haider *et al*., 1991). Cyclones are usually formed in a complex process where the sea surface water temperature is exceeded beyond the threshold value of $27^{o}C$. Since climate change will cause an increase in mean sea surface temperature, it may be expected that the excess heat energy will be dissipated in the form of increasing number of high intensity cyclones. Unfortunately, such high intensity cyclones are often associated with high storm surges. It may be argued that intensity of storm surges is likely to be increased under climate change scenarios, particularly in the later part of the 21^{st} century. Cyclonic storms would cause severe damages to the forest, its inhabitants and resources. A high intensity event in 1986 devastated the Sundarbans, drowned thousands of its magnificent animals including the threatened species, the Bengal Tiger. The wind associated with that particular cyclone also devastated vegetation of a large part of the forest. Influenced by climate change, high intensity storm surges would inundate high levees and back swamps that do not get submerged with saline water and thereby would be affected by salinity.

According to a number of studies available on the Sundarbans (Karim, 1994; Siddiqi, 1994), complex forest processes such as the natural regeneration of vegetation and forest succession also depend on salinity regime. Considering that the salinity regime inside the forest will significantly change as a consequence of climate change, it has been argued that increased salinity would have discernable adverse impacts on forest regeneration and succession (Ahmed *et al*., 1998). For example, the freshwater loving Sundari is projected to decline or disappear entirely under climate change. Areas with best quality standing timber predominated would be replaced by inferior quality tree or shrub species. Under such conditions vegetation canopy would become sparse and plant height would be reduced significantly. With such a dramatic series of anticipated changes in forest vegetation under climate change, the productivity of the forest would be severely constrained. Chaffey *et al*. (1985) demonstrated that, total merchantable wood volume per unit area of forest land decline with increasing soil and river salinity. Preliminary estimates suggested that, disappearance of oligohaline areas combined with decreasing mesohaline areas would result into over 50% loss of merchantable wood from the Sundarbans (Ahmed *et al*., 1998). Increase in salinity in the Indian side of the forest would have compounding effect to the existing poor productivity of the forest.

Since the composition of vegetation has profound effect on distribution of forest fauna, a change in forest succession would in turn affect the long-term sustainability of the ecosystem. Considering the timeframe of such changes and the land-use patterns inland, it is highly unlikely that forest species would have sufficient time or room to migrate inland in response to these changes.

8.2 Adaptation options for the Sundarbans

The most useful adaptation aiming at saving the Sundarbans from sea-level rise induced submergence would be to modify the threats of permanent inundation. Since most part of the projected sea level rise would occur from tectonic subsidence, it would not be quite possible to stop the processes involved. However, efforts must be made to figure out ways to enhance sedimentation on the forest floor, by means of guided sedimentation techniques. If such approaches appear to be technically feasible and economically viable at a pilot level, efforts must be made to undertake projects in order to save the forest. Controlled and guided sedimentation will have a balancing influence on subsidence process and could help delay permanent inundation of the forest floor.

The second most important adaptation strategy will be to reduce the threats of increasing salinity, particularly during the low flow period. This may involve a range of physical adaptations to offset salinity ingress, including: (a) increasing freshwater flows from upstream areas; (b) resuscitation of existing river networks towards improving flow regime along the forest; and (c) artificial enhancement of existing river networks to facilitate freshwater flow regime along the rivers supplying freshwater to the western parts of the forest.

For the sustenance of the forest in its natural state a previous study has recommended that about 240 cumec water should be allowed to flow through the Gorai river system, particularly during the critical dry period of April (Mirza, 1998). The actual amount of water flowing along the Gorai River in 1995-96 was about 52 cumec, which was far below that the recommended flow regime. The Gorai River is an important source of freshwater supply to the southwest region (SWR) of Bangladesh and is the only remaining major spill channel of the Ganges River flowing through the region where the Sundarbans is located at its southern most part. Dry season Gorai flows have been particularly affected by the building of the Farakka barrage on the Indian side. The most visible impact has been in the form of bringing morphological changes along the Gorai ─ since 1988, the river has been completely disconnected from the Ganges during every lean season. As a result only the base flow of the Gorai river system, contributed predominantly by seepage, was able to reach the Sundarbans during the dry season.

Following the signing of the Ganges Water Sharing Treaty (GWST) with India in 1996, the flow regime of the Ganges within Bangladesh has slightly improved. In order to increase the flow from its current level will require enhancing regional cooperation amongst coriparian countries to augment flow regime of the Ganges, and the creation of storage capacity within the Ganges basin on the Bangladesh side so that a sustained flow regime can be maintained in Gorai and other rivers throughout the lean season.

8.3 Measures undertaken to enhancing the flow regime in the Sundarbans

The implications of reduced dry season fresh water flows and salinity increase in the Sundarbans as a result of water diversion upstream have been severe enough for the GOB to take actions to ameliorate the situation, without giving any considerations to future implications of climate change on the Sundarbans forest. The steps taken in the past cannot, therefore, be considered as a planned adaptation to climate change, although they are certainly synergistic with climate change responses.

As a first step to enhance flow regime of the Ganges and its distributaries, Bangladesh and India negotiated the Ganges Water Sharing Treaty (GWST) in 1996. According to the GWST, Bangladesh would receive a maximum flow of 58,180 cusec (1,648 cumec) water in January, and a minimum of 32,623 cusec (924 cumec) water in April. Despite a few early hick ups towards implementation of the Treaty, flow regime in the Ganges improved significantly in the lower riparian Bangladesh compared to the pre-Treaty period.

Simultaneously, the GOB implemented a two-phase project to resuscitate Gorai and restore its flow conditions by dredging the mouth of the river. The project follows a pilot phase undertaken during1999-2001. The objective of the initial (feasibility) phase of the Gorai River Restoration Project (GRRP) was "to prevent environmental degradation in the SWR, specifically around Khulna, the coastal belt and in the Sundarbans, by undertaking restoration of the Gorai river and hence ensuring freshwater flow in the wet season and augmenting these flows during the dry season" (DHV-Haskoning and Associates, 2000). Pilot-scale dredging was carried out during 1998-1999 and 1999-2000. Based on the favorable findings of the initial phase, a number of engineering interventions have now been recommended:

- Flow divider
- Ganges/Gorai revetment

- River training works along the Gorai and restructuring of river training works
- Dredging of clay layers in the Gorai offtake
- Installation of bottom vanes.

The pilot study concluded by stating "it is probably opportune to implement such works in the future, when the firm need therefore has been established, or when suitable conditions prevail for their implementation" (DHV-Haskoning and Associates, 2000). The overall objective of GRRP-implementation project – undertaken by the Bangladesh Water Development Board (BWPD) was to implement the recommendations of GRRP study, and thereby ensure freshwater flows along the Gorai river system covering an area of about 16,100 km^2. The Feasibility Study for the GRRP identified significant ecological and environmental benefits from providing a minimum flow of 60 m^3/s, particularly by facilitating freshwater availability to the Sundarbans forest. The project envisaged other benefits arising from reduced salinisation, increased agriculture and other in-stream values such as aquatic biodiversity, freshwater fisheries and navigation. The Project was considered to be technically and economically justifiable. The GRRP was completed in January 2002 at a cost of about US$58 million. The engineering option which considered river training works in combination with occasional maintenance dredging has been found reliable and uncomplicated. The project activities provided for a significant recurrent cost saving over recurrent dredging options (PDO-ICZM, 2002a).

The BWDB is now undertaking a project, called Re-excavation of the Kobadak River, at a cost of about US$5 million. The river used to supply freshwater directly into the central part of the forest. In course of time it has lost its water conveyance capacity due to gradual sedimentation and human encroachment particularly during the dry season. The re-excavation project is aimed at resuscitation of the river and re-excavation is taking place in three major districts north of the Sundarbans. The re-excavation will continue till 2004 and it is expected to enhance freshwater flows along the river servicing the forest. Another river, the Betna, has also been considered for re-excavation by the BWDB. Betna is the only major river that used to provide with freshwater in the lean season to the western parts of the forest. The project began in 2001-2002 season and expected to be completed in 2003 at a cost of US$4 million. The project is expected to increase freshwater flow in the western parts of the Sundarbans and reduce surface salinity.

8.4 Potential adaptation benefits from planned and ongoing activities

In addition to the above mentioned projects and activities, a few others are currently underway or in the pipeline. The GOB has undertaken a major study for the entire GDA ─ called the Study on Options for the Ganges Dependent Areas (OGDA) ─ which identified a few options for environmental restoration of the Sundarbans forest. Although this was not a conscious effort to promote long-term adaptation to climate change, the study has now become an input to the recently undertaken National Water Management Plan (NWMP, 2001).

The objective of the OGDA study was to develop technically feasible and socially acceptable options for environmental restoration and enhancement of the entire GDA by utilizing the water obtained though the Ganges river following signing of the GWST. In spite of the fact that the study never meant to pay special attention to the improvement of freshwater flow regime and controlling salinity of the Sundarbans forest, its options provided apparent solutions to the core problems. The study developed a number of options for diversion and distribution of the Ganges flows, with a focus on supplying adequate freshwater in the lean season.

The study stated that, the dry season flows of the Ganges can be diverted into different parts of the GDA by pumping, through restoration/dredging old distributaries of the Ganges or by raising the Ganges command level with the help of a barrage (Halcrow and Associates, 2001). The study highlighted the potential and/or scope of these different options for augmentation of the flows in the internal rivers by diverting the Ganges waters in the following ways:

- *River restoration*, entailing quick dredging of Gorai and other distributary rivers of the Ganges. This option also called for a clear assessment of requirements for maintenance dredging and incorporation of some river training works.

- *Central pumping*, that would enable maintaining a flow regime in the distributary system of the Ganges river by lifting freshwater using pumps and releasing it into the existing and/or re-excavated river networks in the downstream. Such an option was regarded as technically feasible, but the study called for examining economic viability.

- *Barrage* option called for construction of a barrage on the Ganges to store freshwater enabling raised command levels in the lean season. This option appears promising, especially when combined with either of the previous two options.

The OGDA study recommended as many as seven choices by combining the above mentioned major options. The OGDA options have been incorporated into the recently formulated NWMP. The NWMP along with a 25 year implementation plan was currently placed before the Bangladesh National Parliament for discussion and approval.

The GOB is also undertaking an implementation project titled Integrated Coastal Zone Management Plan (ICZM). Instead of embarking on any specific project activity, the ICZM has got the official mandate to establish a process that would enable all the stakeholders in the coastal zone to implement their activities in a coordinated fashion towards improving the natural resources of the coastal zone and maximizing benefits for the poor people — those eking out a living based predominantly on natural resources. The major focus of the ICZM project is to help alleviate poverty. In doing so, the project aims to enhance livelihood opportunities of the poor, for which reducing vulnerability of the resource base to climatic variability and change must be considered as an important means. The terms of reference for the Project Development Office (PDO) for implementation of ICZM require the integration of adaptation responses to climate change. Although the detailed plan of various activities under the ICZM programme are not yet finalized, an interview with the team leader of the ICZM project revealed that integration of possible adaptation issues for the entire coastal zone including the Sundarbans might be considered under the Action Plan that is currently under preparation. ICZM-PDO has already expressed interest in undertaking a programme on climate change for the entire coastal region, focusing on enhancing adaptation activities to reduce adverse impacts of climate change on coastal resources and people's livelihood. Subject to endorsement by the Ministry of Water Resources, the activity would begin in later part of 2003. It is envisaged that, the project would integrate the activities recommended by the OGDA study and subsequently by the NWMP. This would certainly help increase freshwater flows along the distributaries of the Ganges which are the freshwater lifelines of the Sundarbans.

The ICZM project has conducted a number of stakeholder dialogue at the grassroots and identified the major elements of vulnerability of livelihood of the local poor. As identified by the local people, the most common elements of vulnerability along the coastal zone are linked heavily with bio-physical resources (PDO-ICZM, 2002b). In most cases, the identified bio-physical resources are found to be perturbed significantly by the current climatic variability. Under climate change regime several elements of vulnerability of the poor people would only get deteriorated.

There are however a number of measures available to offset some of these impacts. In addition to measures that reduce salinity (through enhanced freshwater flows), the forest resources in the Sundarbans themselves may be enhanced through species enrichment, increasing surveillance and management capabilities of institutions and personnel involved, and establishing a mangrove arboretum. The Sundarbans Biodiversity Conservation Project (SBCP) funded by the GEF and ADB is now being implemented by the Department of Forest (DOF) at a cost of about US$77.5 million. The main objective of the project is to develop a sustainable management and biodiversity conservation system for all resources of the Sundarbans Reserve Forest (SRF). SBCP was by no means intended to address adaptation to climate change for the forest and its resources. But the activities that would help achieve its specific objectives would also help achieving goals of conservation of the forest biota. For example activities under 'Field Forest Management' such as forest rehabilitation, enrichment plantation, assisted natural re-generation and conservation of aquatic species would contribute to the enrichment of forest biota making them more resilient to additional climatic stresses. Furthermore, wildlife management programme is expected to provide protection to the valuable threatened species and improvement of habitat for species such as tigers, deer, other mammal species, reptiles, birds, snakes, amphibians. The component of public awareness raising would enable enhanced voluntary surveillance by the communities living at the outer periphery of the forest and check poaching of threatened and endangered species. For example, it is expected that local community based organizations (CBO) and non-government organizations (NGO) would be involved to actively take part in in-situ conservation of rare and endemic marine turtles. Given the high vulnerability of the forest associated with climate change and sea level rise, it is most likely that the SBCP and its follow up projects would supplement adaptation activities towards conservation of the forest and its resources.

9. Concluding remarks

Bangladesh is critically vulnerable to climate induced hazards, but the core elements of its vulnerability are primarily contextual. It is probably the only country in the world with most of its territory lying on the deltaic flood-plain of three major rivers and their numerous tributaries. Between thirty to seventy per cent of the country is normally flooded each year. The huge sediment loads brought by these Himalayan Rivers, coupled with a negligible flow gradient add to drainage congestion problems and exacerbate the extent of flooding. The low coastal topography contributes to coastal inundation and saline intrusion inland. Bangladesh also lies in a very active cyclone corridor that transects the Bay of Bengal. The societal exposure to such risks is further enhanced by its very high population and population density, with close to 800 persons per square kilometer in vulnerable areas such as the coastal zones. Very low levels of development and high levels of poverty (between 33 and 40%) add to the social sensitivity to any external hazards. Meanwhile traditional adaptation via seasonal migration to less vulnerable areas within the Indian subcontinent was probably curtailed significantly half a century ago with the creation of a discrete geopolitical entity (East Pakistan), which subsequently became Bangladesh. The internationalization of the region probably also contributed to water sharing conflicts, most notably the building of the Farakka barrage in India that led to the diversion of dry season flows, which exacerbated salinity concerns in the Bangladesh Sundarbans.

Many projected climate change impacts including sea level rise, higher temperatures and evapo-transpiration losses, enhanced monsoon precipitation and run-off, potentially reduced dry season precipitation, and increase in cyclone intensity would in fact reinforce many of these baseline stresses that already pose a serious impediment to the economic development of Bangladesh. By the same token, many actions undertaken to address the baseline or contextual risks in Bangladesh are also synergistic with the so called adaptations that might be required as climate change impacts manifest themselves. There is therefore a need to clearly address whether climate change impacts are simply one more reason to lower contextual vulnerability via business as usual economic development activity, or whether adaptation to climate change might require suitable modifications in such projects or highlight the need for entirely new activities, and if so, what such activities might be. Thus far there has been no clear articulation on this important issue, despite the disproportionately high number (and somewhat duplicative nature) of conferences and donor funded projects on climate change that have taken place in Bangladesh over the past decade. New climate oriented projects in Bangladesh might therefore require a higher threshold of "value added" in the light of the considerable body of knowledge and past experience that has already been accumulated.

This report (like some others before it) indicates a general lack of explicit attention to "climate change" in many government plans and donor project documents in Bangladesh. At the same time however this report also reveals through a more in-depth analysis that despite this lack of explicit mention, a number of adaptations that climate change might necessitate are indeed already underway in Bangladesh through several government-donor partnerships. In particular, considerable progress has been made since the mid-1990s in implementing such projects. A wide array of river dredging projects have been completed to reduce siltation and facilitate better drainage at times of flooding as well as to boost dry season flows to critical areas such as the Sundarbans. The Ganges Water Sharing Treaty has been signed with India to boost dry season flows and reduce the threat of salinity, and more sophisticated cyclone early warning systems and protection shelters are being developed. All these measures are likely to contribute to reducing the vulnerability of Bangladesh to climate change impacts.

However, there are also some examples of development policies and priorities in Bangladesh that might potentially conflict with climate change responses. In particular, policies to encourage tourism and build tourism infrastructure in vulnerable areas of the coastal zone, particularly the Khulna region, might need to take into account the projected impacts of climate change to reduce the risk of mal-adaptation. On the other hand, plans to encourage ecotourism in the fragile Sundarbans might risk adding one more stress to a fragile ecosystem that will likely be critically impacted by sea level rise and salinity concerns.

With regard to structural adaptations such as coastal embankments and salinity reduction, even though it is true that many of these measures have already been integrated in development projects and policies in Bangladesh, there remains an ongoing challenge with regard to their durability and sustainability. For example, given the high influx of sediments from the Himalayan Rivers each year, measures such as dredging of waterways are not a one time response but require periodic repetition. Similarly flow regulators on coastal embankments require constant monitoring and maintenance for the lifetime of such structures – in fact it was the poor maintenance of such regulators in the original embankments established in the 1960s that cause widespread flooding when they became clogged by the 1980s. Monitoring and maintenance in turn requires continued government and donor interest as well as participation of the local population far beyond the original lifetime of the project. This point is echoed by the project director of the Coastal Embankment Rehabilitation Project who observed "The Operation and Maintenance (O&M) component appears to have been relegated. Political and institutional support from national to local level has been in favor of rehabilitation instead of preventative maintenance… The project's sustainability is apparently seriously deficient" (M.S. Rahman, 2002). Structural adaptations therefore need to be matched by efforts to facilitate financial and institutional adaptation – sustained interest on the part of the government and donors, and the participation of local populations to help monitor and maintain infrastructural projects.

The Bangladesh case study also highlights the importance of the trans-boundary dimension in addressing climate change adaptation. The effect of water diversion as a result of the Farakka barrage on dry season flows and salinity levels in the Sundarbans was in fact comparable (if not higher) than the impact that might be experienced several decades later as a result of climate change. Adaptation to climate change might therefore not just be local but might require cross-boundary institutional arrangements such as the Ganges Water sharing treaty to resolve the current problems of water diversion. Finally, climate change risks should also not distract from aggressively addressing other critical threats, including shrimp farming, illegal felling of trees, poaching of wildlife, and oil pollution from barge traffic, that might already critically threaten the fragile ecosystems such as the Sundarbans even before significant climate change impacts manifest themselves.

APPENDIX A: PREDICTIVE ERRORS FOR SCENGEN ANALYSIS FOR BANGLADESH

The table below shows the predictive error for annual precipitation levels for each SCENGEN model for each country. Each model is ranked by its error score, which was computed using the formula 100*[(MODEL MEAN BASELINE / OBSERVED) - 1.0]. Error scores closest to zero are optimal. The six models with the highest error scores from the estimation were dropped from the analysis.

Predictive errors for each SCENGEN model for Bangladesh

	Average error[22]	Minimum error	Maximum error
Models to be kept for estimation			
MRI_TR96	13%	8%	16%
CSI2TR96	22%	16%	32%
ECH4TR98	24%	9%	34%
CERFTR98	25%	4%	50%
CSM_TR98	26%	5%	48%
BMRCTR98	26%	17%	37%
HAD3TR00	26%	12%	38%
PCM_TR00	27%	12%	40%
CCSRTR96	36%	2%	94%
ECH3TR95	53%	30%	72%
IAP_TR97	62%	30%	118%
Models to be dropped from estimation			
GISSTR95	65%	30%	137%
GFDLTR90	67%	30%	134%
HAD2TR95	71%	26%	164%
LMD_TR98	73%	58%	94%
CCC1TR99	84%	11%	279%
W&M_TR95	92%	0%	227%

22 SCENGEN outputs data for 5×5 degree grids. To estimate for an entire country, a 10×10 degree area was used and the data output from the resulting four 5×5 grids were averaged. The maximum and minimum of these four 5×5 grids are also reported.

APPENDIX B: LIST OF PURPOSE CODES INCLUDED IN THE SELECTION OF CLIMATE-AFFECTED PROJECTS, ORGANIZED BY THE DAC SECTOR CODE.

DAC code	General sector name	Purpose codes that are included in the selection
110	Education	-
120	Health	12250 (infectious disease control)
130	Population	-
140	Water supply and Sanitation	14000 14010 14015 14020 (water supply and sanitation – large systems) 14030 (water supply and sanitation – small systems) 14040 (river development) 14050 (waste management/disposal) 14081 (education/training: water supply and sanitation)
150	Government & civil society	15010 (economic & development policy/planning)
160	Other social infrastructure and services	16330 (settlement) and 16340 (reconstruction relief)
210*	Transport and storage	All purpose codes
220	Communications	-
230	Energy	23030 (renewable energy) 23065 (hydro-electric power plants) [23067 (solar energy)] 23068 (wind power) 23069 (ocean power)
240	Banking and financial services	-
250	Business and other services	-
310	Agriculture, forestry, fishing	All purpose codes
320	Industry, mining, construction	-
330	Trade and tourism	33200 (tourism, general) 33210 (tourism policy and admin. management)
410	General environment protection	41000 (general environmental protection) 41010 (environmental policy and management) 41020 (biosphere protection) 41030 (biodiversity) 41040 (site preservation) 41050 (flood prevention/control)# 41081 (environmental education/training) 41082 (environmental research)
420	Women in development	-
430	Other multisector	43030 (urban development) 43040 (rural development)
510	Structural adjustment	-
520*	Food aid excluding relief aid	52000 (dev. food aid/food security assist.) 52010 (food security programmes/food aid)
530	Other general programme and commodity assistance	-
600	Action relating to debt	-
700*	Emergency relief	70000 (emergency assistance, general) #
710*	Relief food aid	71000 (emergency food aid, general) # 71010 (emergency food aid) #
720*	Non-food emergency and distress relief	72000 (other emergency and distress relief) # 72010 (emergency/distress relief) #
910	Administrative costs of donors	-
920	Support to NGOs	-
930	Unallocated/unspecified	-

* sector codes that are excluded in the second selection (low estimate).
\# purpose codes that are included in the emergency selection

APPENDIX C: REVIEW OF SELECTED DONOR STRATEGIES FOR BANGLADESH

C.1 World Bank

Bangladesh 2020: A long-run perspective study (1996)
Country Assistance Strategy (2001)

The Bangladesh 2020 Long-run perspective study (published as early as 1996) states that

"although the impacts of global warming are still far from precisely predictable, the prospect is sufficiently likely and alarming to warrant precautionary action at the national as well as at the international level. " A section on climate change discusses the potential economic impacts of sea-level rise (13% of GDP), and notes that "The seriousness of the problem warrants strenuous research efforts to understand various aspects of the problem and devise remedies for future generations." Already quite early in time, it advocated a dual response – international diplomacy in support of global mitigation, and national planning for adaptation. The World Bank responded to this challenge by preparing the Bangladesh Climate Change Study.

Given the work that was put into the Bangladesh Climate Change Study, and also given its outcomes, one would expect climate change concerns to be reflected prominently in the Bank's new Country Assistance Strategy (2001). Surprisingly however, not much attention is devoted to this topic. The strategy only mentions climate change risks in the context of environmental problems, together with widespread resource depletion, ecological degradation, urban and industrial pollution, and natural disasters. It notes that addressing these problems is essentially a governance issue – not a financial one. Without improved information, policy reform and public sector accountability, these problems are likely to get worse. The Country Assistance Strategy does address Bangladesh's vulnerability to natural disasters, albeit only at the end of the document: "Bangladesh's economy is also vulnerable to natural disasters of catastrophic proportions. In recognition of this, IDA must be prepared to consider additional assistance for post-disaster recovery through operations similar to those provided in the aftermath of the 1998 flood. This would be incremental to the investments for coastal embankments and riverbank protection that have been proposed to strengthen disaster mitigation capacity. IDA would support building the Government's capacity in managing these disasters and implementing a long-term flood control action plan." The implications of these risks for non-disaster-related sectors and projects are not discussed.

C.2 UNDP/UNPF

Second Cooperation Framework for Bangladesh (2001-2005)

The Framework recognizes the high susceptibility to natural disasters, which aggravates the consequences of unsustainable natural resources management. Disaster preparedness, management capacity, and mitigation remain national priorities, as is food security. In particular, environmental management and food security will be core elements of UNDP assistance in the coming years. Despite strong overlaps with these issues, climate change is not mentioned at all.

C.3 ADB

Country Strategy and Program Update 2003-2005 (2002)
Country Assistance Program Evaluation for Bangladesh (2003)

ADB's Country Strategy and Program Update lists climate change impacts as one of the priority environmental themes in a development coordination matrix. Elsewhere however, the topic is completely ignored, as is sea-level rise. Yet at the same time, current flood risks feature prominently, and many flood mitigation activities are planned and underway. Climate change not only poses an additional rationale for such activities, but there may also be opportunities to improve them by explicitly considering the shifting risks due to climate change, which are missed in this document. Droughts are not discussed at all.

The Country Assistance Program Evaluation for Bangladesh (2003) gives a similar picture. Several examples are given of the large influence of floods on Bangladesh's economic performance: "*output growth has fluctuated considerably over the years (not least because of the impact of flooding and other natural disasters*)". However, no attention is paid to droughts, or to increasing risks due to climate change and sea level rise.

C.4 IFAD

Country Strategic Opportunities Paper

IFAD's strategy paper finds a disconnect between "*micro success – macro stagnation*". It suggests that poverty reduction strategies in Bangladesh have been very successful in increasing resilience, demonstrated by impressive gains in the areas of food production, population control, health education, and in building up the institutional capacities of the poor. The way in which Bangladesh was able to cope with the devastating 1998 floods is another example of this resilience, which is characterized by people's own efforts as well as government initiatives in safety-net provisioning and rural infrastructure development. However, the paper contrasts this success from the perspective of the "economics of resilience" with the failure of the "economics of graduation". New poverty programmes tend to target the extremely poor, but the paper argues that particular attention should be paid to the moderately poor. This group, which makes up about 21% of all rural households, might well be *tomorrow's* poor. They include small and marginal producers living above the poverty line but within the boundary of vulnerability to crisis shocks. While this category does not receive much attention in poverty programmes, its entrepreneurial potential is much larger than that of the poorest groups, and could contribute to the "economics of graduation", a path of real growth. However, poverty programmes should ensure that these groups are not thrown back into poverty by crisis shocks, particularly natural hazards. Regarding the extremely poor, the paper finds another disconnect between current development programmes and the real needs of the country. Up to now, food security programmes have focused mainly on dry season food shortages. However, an additional challenge is to establish programmes dealing with seasonal poverty in the wet post-monsoon season.

While climate change is not explicitly addressed, IFAD's programmes in Bangladesh exhibit a high level of analytical work on poverty and vulnerability, and its programmes positively contribute to vulnerability reduction to both current and future climate hazards.

C.5 DFID

Country Strategy Paper (1998)

DFID's Country Strategy Paper (1998) explicitly lists the impact of current natural hazards on development, but neglects climate change and sea level rise. The 2001 Annual Plan and Performance Review acknowledges the macroeconomic impacts of the 1998 floods. While disaster management is not one of the priority areas of DFID's involvement in Bangladesh, there is support for disaster mitigation, and the agency also responded to appeals for aid after those floods. Climate change and sea-level rise are not mentioned.

C.6 CIDA

Bangladesh Programming Framework (1999)

CIDA's Bangladesh Programming Framework (1999) recognizes the high natural disaster risks to development operations and outcomes in Bangladesh, and the need for reinvestments in infrastructure and agriculture after the 1998 floods. It also notes the progress made in natural disaster risk reduction, and expects to continue support in this area. Climate change however, is not mentioned. A new Development Programming Framework is in preparation.

C.7 Government of Japan

Country Assistance Program Bangladesh (2000)

Japan's Country Assistance Program (2000) places that disaster control is one of the strategic priority areas of Japanese aid implementation to Bangladesh. This program notes that Japan will study cooperation in line with the National Water Management Plan (NWMP) of the Bangladeshi government and promote more effective and efficient aid for cyclone countermeasures including areas such as greater utilization of the information and communications networks.

JICA Country Program for Bangladesh (2000)

Disaster control is one of JICA's priority areas of cooperation to Bangladesh. JICA's cooperation to Bangladesh in the disaster control area is in line with the National Water Management Plan (NWMP) of the Bangladeshi government. In order to cope with flood and cyclone disasters that are repeated every year, JICA emphasizes disaster prevention in addition to disaster rehabilitation

Country profile on environment (1999)

This document provides a comprehensive overview of environmental problems in Bangladesh, ranging from sanitation to solid waste management to forestry issues. However, climate change is not discussed as an additional burden on Bangladesh's natural resources, and while flood risk is recognized as a major factor in the country's development and natural resource management, the potential flood risk increase due to climate change is neglected.

C.8 SIDA

Development cooperation with Bangladesh

This brief programme description notes that SIDA's aid focuses on education, health care, and development of rural areas. While climate-related risks (including current natural hazards) are crosscutting concerns in at least health and rural development, they are not mentioned at all in the document.

C.9 USAID

Bangladesh Annual Report 2002
Strategy for FY 2000-2010
Strategic Plan 2000-2005

The long-term Strategy for FY 2000-2010 notes that the US has in the past supported various climate-change related initiatives in Bangladesh (through the US country studies program, and by supporting the current development of a National Action Plan on climate change). Otherwise, climate change is categorized as an environmental issue, although the potentially serious economic implications are recognized. Climate change is not discussed in the context of sectoral programs or disaster management. A similar picture emerges from the Strategic Plan 2000-2005.

In 2002, USAID's program had a sizable disaster management and food security component, as well as programs in agribusiness, and open water and tropical forest resource management. All of these sectors could be vulnerable to climate change. Nevertheless, climate change is not mentioned in the 2002 annual report, except in an annex as a separate reporting requirement.

APPENDIX D: REVIEW OF SELECTED DEVELOPMENT PROJECTS/PROGRAMMES

Many donors, including the USA, the Netherlands, the UK, the ADB, and New Zealand have supported studies on climate change vulnerability and adaptation in Bangladesh, between 1989 and 1996. The most recent major study, which has reviewed most of the previous results, was supported by the World Bank.

D.1 World Bank: *Bangladesh Climate Change and Sustainable Development (2000)*

The World Bank report *Bangladesh Climate Change and Sustainable Development* (2000) aimed to mainstream adaptation in the regular development strategies and operations in Bangladesh. It reviewed possible climate change impacts in Bangladesh, but particularly focused on an overview of adaptation options for various sectors, including fairly specific suggestions for some of them. In addition, it includes a review of sixteen development activities (mainly by the ADB and the World Bank, and also by the Netherlands and DFID) in the light of adaptation to climate change. This review considered two aspects: vulnerability of the projects themselves, as well as opportunities to reduce Bangladesh's vulnerability in a broader sense. Its main finding was that most of the activities reviewed do not consider climate change impacts or adaptation to such impacts. In addition, it reviews the National Water Management Plan (NWMP), and offers specific suggestions to improve the NWMP.

D.2 CIDA/CARE Bangladesh Reducing Vulnerability to Environmental Change Project

CARE Bangladesh is conducting a project in Bangladesh's six coastal districts, working with 6000 rural households to improve resilience and reduce vulnerability to climate change. This project, which is just starting, is funded from the Canadian Climate Change Fund (CCCF). A detailed project document was not yet available for the current review, but the main objectives will to build local capacity to disseminate environmental change information and forecasts (including 600 farmer schools) and to extend proven grassroots techniques and measures to address climate change impacts.

D.3 GEF/ ADB Biodiversity Conservation in the Sunderbans Reserved Forest Project

The Sunderbans, a 3600 sq km cluster of coastal islands stretching from Bangladesh into India, are one of the world's largest remaining areas of mangroves. It has been recognized as an important Ramsar Wetland site, and UNESCO has declared it a World Heritage Site, mainly because of its exceptional biodiversity, with a wide range or flora and fauna, including the Bengal Tiger. Monsoon rains, flooding, delta formation, tidal influences, and plant colonization all make the Sunderbans a highly dynamic environment. The area has been a reserve since the 1870s, preventing permanent human occupation of the reserved forest. Nevertheless, the human population in the area, which is concentrated in the buffer zones around the three official wildlife sanctuaries, depends for a large part on the resources of the reserved forests, either directly of indirectly. In recent decades, a range of mostly human-caused problems, generated by population growth and expansion of human activities, threaten the sustainability of the ecosystems as a whole, and wildlife stocks in particular. Particular problems include over extraction of wood and other natural resources, habitat modifications due to dying trees and increased permanency of fishing camps within the reserved forests, potential species extinctions, poaching, lack of community participation in sustainable resource use programs, and lack of multisectoral management capacity.

A large project is underway to protect the rich biodiversity of the Sunderbans and enhance the rural livelihoods of the local population, through sustainable natural resource management. Activities include (i) improvements in the organization and management of the reserve; (ii) incorporation of biodiversity conservation considerations in fisheries and forestry, management of wildlife resources, and integrated conservation planning; (iii) increasing local support for biodiversity conservation by local communities through education, awareness activities, and ecotourism development, and (iv) establishment of biodiversity monitoring systems. The project is funded by a GEF grant (implemented through the World Bank) and the ADB, with co-financing from the Palli Karma-Sahayak Foundation, the Nordic Development Fund, the Netherlands, as well as the Bangladesh government, NGOs, and local beneficiaries.

The World Bank Climate Change study concluded that the Sunderbans are at high risk from climate change. While most of the proposed activities under the Biodiversity Conservation in the Sunderbans Reserved Forest Project will still pay off, the long-term viability of the reserve may require additional efforts. In response to the findings of the study, stakeholders involved in ecosystem conservation in the Sunderbans agreed to incorporate the results in the Biodiversity Conservation in the Sunderbans Reserved Forest Project (Huq, 2002, Rahman and Alam, 2003). Aside from strengthening existing efforts to better manage the reserve, the World Bank study also suggested that a minimum flow through the Ganges-Madhumati system is required to sustain the Sunderbans, with implications for the (already controversial) Ganges barrage, and the management of the Gorai river; issues which fall outside the scope of the GEF/World Bank/ADB project.

D.4 ADB Chittagong Hill Tracts Development Project

Report and Recommendation of the President (2000)

The Chittagong Hill Tracts area (inland hills) suffered a 20-year insurgency up to 1997, causing widespread poverty. This ADB project intends to relieve this poverty by improving local infrastructure (including small irrigation and flood control systems), community development funds, microfinance, and management support. Among the project risks, the document lists the fact that many of the roads to be constructed under the Project will pass through difficult terrain or will be subject to local flooding. The implication is that proper maintenance will be crucial. Climate change is not mentioned.

D.5 ADB Second Small-Scale Water Resources Development Sector Project

Report and Recommendation of the President (2001)

In accordance with Bangladesh's National Water Plan and Flood Action Plan (which was developed after the 1997/1998 floods), the project aims to improve the development of the water resources sector through participatory rehabilitation and management of small-scale water resources infrastructure, and will support policy work and sector reforms. It will assist stakeholders to form water management associations and to upgrade physical facilities including (i) flood management, (ii) drainage improvement, (iii) water conservation, and (iv) command area development. The project clearly notes the challenges of regular floods, droughts, as well as riverbank erosion, and drainage congestion due to the siltation of watercourses. However, it does not even mention the additional risks of climate change. Nevertheless, given that the project will certainly reduce Bangladesh's vulnerability to floods and droughts, and no project components critically depend upon the exact trends in water flows or local precipitation and temperature, it is unlikely that climate change considerations would have led to a very different project design.

D.6 ADB Second Aquaculture Development Project

Project Performance Audit Report (2002)

The report notes that Bangladesh's inland fisheries resources are among the richest in the world, due to the climate, water and soil conditions, particularly related to the annual flooding. However, fisheries have declined due to overfishing, and flood control and irrigation schemes. The project has addressed this decline in several ways. One was the opportunity for lending services to aquaculture farmers. This component did not meet its full objectives, due to a lack of appropriate extension services accompanying the loans, but also due to the severe flood in 1998 and recurring diseases, which both affected many aquaculture farms, causing difficulties in debt service and affected loan recovery. While the evaluation strongly recommends more attention for risk management with respect to shrimp diseases, the flood risk is taken for granted. No reference is made to climate change.

D.7 UNDP Empowerment of Coastal Fishing Communities for Livelihood Security (2000-2005)

The project has three main objectives: (i) empowerment of communities, (ii) enhancement of socio-economic capacity through savings, credits and income generation activities, and improved access to extension and social services, and (iv) improved capacity to cope with natural disasters. It also aims for sustainable conservation and management of coastal marine and estuarine fisheries resources and habitats. Hence, the project is likely to decrease the vulnerability of these communities and ecosystems to climate change. Nevertheless, the project description contains no reference to climate change as a risk to any of these project components.

D.8 GEF/UNDP Coastal and Wetland Biodiversity Management at Cox's Bazar and Hakaluki Haor (2000-2007)

The main objective of this project is to establish an innovative management system for Ecologically Critical Areas (ECAs), which will help conserve biodiversity. It focuses on a coastal area as well as inland wetlands. A section on global environmental benefits of the coastal area highlights the value of the Sunderbans, and notes the ongoing conversion to agricultural lands, shrimp culture, salt ponds and human settlements. In addition, it notes the effect of sea level rise and reduced fresh water supply on salinity in the coastal areas, making rice cultivation increasingly difficult. Native salt-resistant rice varieties should be conserved to become a source of genes for cultivated rice. Otherwise, no attention is paid to sea-level rise of climate change.

D.9 UNDP Support to Disaster Management (1996-2002)UNICEF/DFID/DENMARK

This disaster management project mainly focuses on soft measures to reduce the impact of disasters in Bangladesh. In particular, it aims to increase awareness of practical ways to reduce disaster risks and losses, to strengthen national capacity for disaster management (with emphasis on preparedness), to enhance the knowledge and skill of key personnel with disaster management responsibilities, to establish participatory local disaster action plans in the most disaster prone areas, to promote local–level risk reduction measures, and to improve the effectiveness of warnings and warning dissemination systems. All of these measures effectively contribute to a reduction of Bangladesh's vulnerability to climate change (even though this is no explicit goal of the project).

D.10 UNDP Comprehensive Disaster Management Programme (CDMP)

Just like its predecessor (the Support to Disaster Management Program), the CDMP also addresses the whole range of disaster management activities (risk reduction, response and recovery). It is executed by the Bangladesh Ministry of Disaster Management and Relief. According to the project document, effective mainstreaming of disaster risk reduction requires better information about the effects of climate variability, climate change and sea level rise, and in particular about the macro economic implications of increased floods, drought and cyclones. The project aims to establish "a systematic approach to prediction, monitoring, protection, evacuation, land use zoning, and information dissemination to build adaptive capacity, which in turn requires comprehensive and appropriate information produced and delivered at the right time, to the right people and agencies." The climate change component will collect and update existing knowledge, increase capacity to predict climate impacts (based upon a regional climate model), establish an institutional system to disseminate knowledge and mainstream risk reduction, and improve the capacity to implement adaptation measures at national and local levels.

D.11 IFAD Sunamganj Community-Based Resource Management Project

Appraisal Report (2001)

This project addresses poverty in the Sunamganj, a neglected and remote district characterized by frequent destructive flooding, which are listed as on of the prime causes of poverty. The project aims to address both poverty and vulnerability, among others by promoting labor-intensive infrastructure works, including erosion and flood control projects. The project design provides for community-based approach to floodplain ecosystem rehabilitation and erosion protection of villages through reforestation with indigenous swamp tree varieties. In these project elements, climate change mitigation and adaptation (as well as nature conservation) go hand in hand, even though neither of them is among the explicit objectives of the project. In fact, climate change is not mentioned at all. Natural hazard risk in general however, are fully taken into account, not just in terms of the project’s objectives, but also in the project risk analysis, which explicitly lists natural disasters as a risk to project outcomes in the field of rural infrastructure and the livelihood production program.

D.12 IFAD Income Diversification Project

Formulation Report (2003)

At the first page of its introduction, the project report notes the challenges of Bangladesh’s weather and climate, with high inter- and intra-annual variability, as well as cyclones. The project intends to address food insecurity and food production shortfalls by crop diversification and generation of other employment opportunities. It would take the homestead as its entry point, to target new opportunities to the wishes of the beneficiaries. Among others, agro-forestry would be promoted, because of the potential to use less productive lands, and to contribute to the supply of renewable raw materials, which would also supply income during the off-season (rainy season). The project would contain four main components: community development, agricultural development, credit facilities, and infrastructure improvement. The project is likely to contribute to vulnerability reduction, both directly and indirectly. Climate change however, is not discussed.

D.13 World Bank/GEF/DFID Aquatic Biodiversity Project

Project Information Document (1999)

The project notes that the fisheries sector accounts for 3% of total GDP, and 5% of the national workforce, which increases during the flood season. Fish supplies account for about 60% of animal protein intake in Bangladesh. However, per capita consumption of fish has substantially decreased since the 1970s, implying a significant loss of welfare. One of the reasons for a decline in inland open-water fisheries yields is the loss of biodiversity caused by, among others, flood control and road projects that interfere with natural breeding and life cycles of fish (the government is mitigating negative impact of flood control and road infrastructure on floodplain fisheries through a program of floodplain stocking and fish pass construction). The project aims to increase fish and shrimp production for domestic consumption and exports, consistent with sustainable resource management and with special emphasis on rural poverty alleviation, employment generation, improved capacity of local users to manage aquatic resources in a sustainable and equitable fashion, and conservation of aquatic biodiversity. One of the project components aim to improve inland open-water fisheries management through the development of sustainable, community-based institutions and supporting them in undertaking a program of adaptive management of their fisheries resources using technical measures such as stock enhancement of floodplain fisheries, restoration of fisheries habitats, establishment of fish sanctuaries, and construction of fish passes. Other elements aim to improve smallholder shrimp production, develop and apply an appropriate fisheries extension strategy, and prepare studies and strategic planning for the development and long-term sustainability of the fisheries sector. The (relatively brief) Project Information Document does not mention climate change, but it appears that the project will make the sector more resilient to environmental variability, and can help to balance the negative impacts of flood mitigation infrastructure with the needs for suitable fisheries environments and livelihoods.

D.14 ADBJamuna-Meghna River Erosion Mitigation Project

Summary Environmental Impact Assessment (2002)

The project aims to protect to vital irrigation systems, where riverbank erosion is threatening the embankments. Besides environmentally friendly structural measures, the project will also invest in riverbank erosion information management systems (including monitoring forecasting and warning), disaster preparedness and management support, social development support to vulnerable settlers in areas affected by riverbank erosion, and institutional capacity building. In this way, the project is highly likely to contribute to adaptation to current climate risks as well as climate change. The latter however, is not explicitly taken into account, and not mentioned anywhere in the document.

APPENDIX E: SOURCES FOR DOCUMENTATION

Statistics

CRS database, OECD/World Bank http://www.oecd.org/htm/M00005000/M00005347.htm

Government documents

PRSP www.worldbank.org/prsp, http://www.sdnbd.org/sdi/issues/poverty/BD-prsp/

National Water Management Plan www.warpo.org

UN Conventions

UN Convention on Climate Change (UNFCCC) www.unfccc.int

UN Convention to Combat Desertification (UNCCD) *www.unccd.int*

- First report (2001)
- Second national report (2002)

UN Convention on Biodiversity (UNCBD) *www.biodiv.org*

Ramsar Convention on Wetlands www.ramsar.org

- National planning tool for the implementation of the Ramsar Convention on Wetlands (and the approved format for National Reports to be submitted for the 8th RAMSAR Meeting of the Parties, Spain, 2002)

World Summit on Sustainable Development www.johannesburgsummit.org

- country profile
- national assessment (summary)

Donor agencies

ADB

- Country Strategy and Program Update 2003-2005 (2002)
- Country Assistance Program Evaluation for Bangladesh (2003)
- Chittagong Hill Tracts Development Project, Report and Recommendation of the President (2000)

- Second Small-scale water resources development sector project, Report and Recommendation of the President (2001)
- Second Aquaculture Development Project, Project Performance Audit Report (2002)
- Jamuna-Meghna River Erosion Mitigation Project, Summary Environmental Impact Assessment (2002)
- Sunderbans biodiversity protection project, Report and Recommendation of the President (1998)

DFID www.dfid.gov.uk

- Country Strategy Paper (1998)
- Annual Plan and Performance Review (2001)

CIDA http://www.acdi-cida.gc.ca

- Bangladesh Programming Framework (1999)
- Reducing Vulnerability to Environmental Change Project (2002)
- Canadian Climate Change Fund projects overview (2003)

GEF www.gefweb.org

- Biodiversity Conservation in the Sunderbans Reserved Forest, project description (1999)

IFAD www.ifad.org

- Country Strategic Opportunities Paper (n.d.)
- Sunamganj Community-Based Resource Management Project, Appraisal Report (2001)
- Income Diversification Project. Project Formulation Report (2003)
- Third Rural Infrastructure Project, Appraisal Report (1997)
- Smallholder Agricultural Improvement Project, Appraisal Report (1999)

JICA www.jica.go.jp

- Country profile on environment (1999)

UNDP www.undp.org

- UNDP/UNPF Second Cooperation Framework for Bangladesh (2001-2005) (2000)
- Empowerment of Coastal Fishing Communities for Livelihood Security (2000-2005)
- Coastal and Wetland Biodiversity Management at Cox's Bazar and Hakaluki Haor (2000-2007)
- Support to Disaster Management (1996-2002), Comprehensive Disaster Management Programme (CDMP), Programme Support Document (2002)

SIDA www.sida.se

- Development Cooperation with Bangladesh (2002)

UNEP *www.unep.org*

USAID *www.usaid.gov*

- USAID Bangladesh Annual Report

World Bank www.worldbank.org

- Bangladesh 2020: A long-run perspective study (1996)
- Country Assistance Strategy (2001)
- Bangladesh Climate Change and Sustainable Development (2000)
- Aquatic Biodiversity Program, Project Information Document (1999)

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