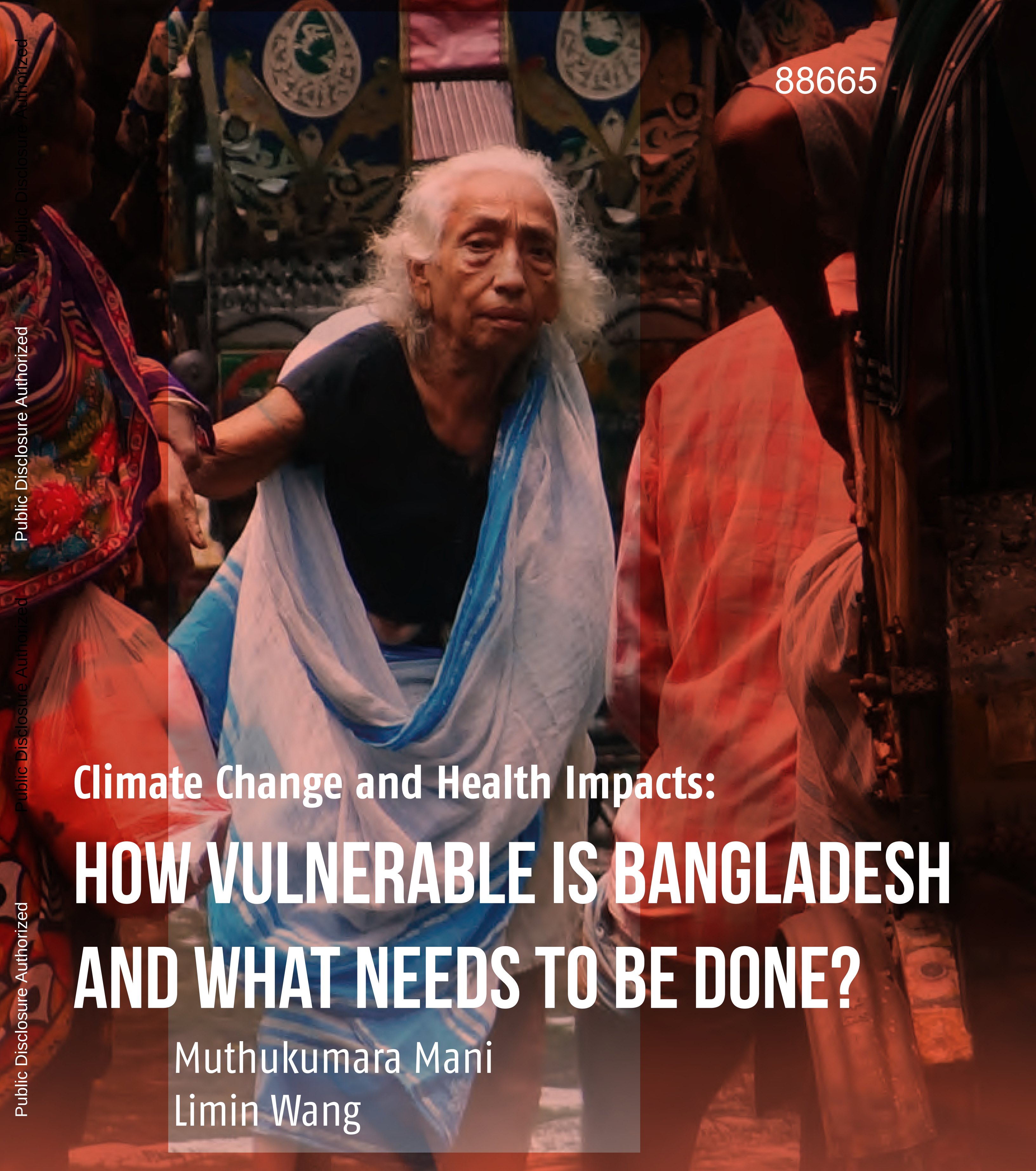

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Climate Change and Health Impacts:

HOW VULNERABLE IS BANGLADESH AND WHAT NEEDS TO BE DONE?

Muthukumara Mani
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Abbreviations

AIDS	Acquired immunodeficiency syndrome
ARI	Acute respiratory infection
BCCRF	Bangladesh Climate Change Resilience Fund
BDHS	Bangladesh Demographic and Health Survey
BINP	Bangladesh Integrated Nutrition Project
BMD	Bangladesh Meteorological Department
BWDB	Bangladesh Water Development Board
CBA	Cost-Benefit Analysis
CCHPU	Climate Change and Health Promotion Unit
CDC	Communicable Disease Control
CEA	Cost-Effectiveness Analysis
CPP	Cyclone Preparedness Program
DALY	Disability-adjusted life years
DGHS	Directorate General of Health Services
DHS	Demographic and Health Survey
DMB	Disaster Management Bureau
DMIN	Disaster Management Information Network
ENSO	El Nino-Southern Oscillation
ESD	Essential Service Delivery
FFWC	Flood Forecasting and Warning Centre
GBM	Ganges-Brahmaputra-Meghna
GDP	Gross domestic product
GIS	Geographic information system
HFA	Height for age
HFS	Health Facility Survey
HIV	Human immunodeficiency virus
ICDDR,B	International Center for Disease and Diarrhoeal Research, Bangladesh
IEDCR	Institute of Epidemiology, Disease Control, and Research
MDG	Millennium Development Goal
MIS	Management Information System
MoHFW	Ministry of Health and Family Welfare
NIPORT	National Institute of Population Research and Training
NNP	National Nutrition Project
PCDS	Priority communicable disease surveillance
SS	Sentinel surveillance
TRMM	Tropical Rainfall Measuring Mission
UHS	Urban Health Survey
USAID	U.S. Agency for International Development
VBD	Vector-Borne Disease
WFH	Weight For Height
WHO	World Health Organization

FOREWORD

Bangladesh is one of the countries that is most vulnerable to climate change. It is already facing enormous challenges due to extreme events such as droughts, land and coastal flooding, and other extreme weather events. Added to these challenges are demographic and socio-economic factors, such as rapid population growth and urbanization, poor health conditions, water scarcity and inadequate sanitary conditions. In this context, climate change is an additional stressor that is expected to increase the burden of diseases, resulting in increased morbidity and mortality.

The Government of Bangladesh has recognized the important challenge facing the country, and is taking a number of steps to address it. The 2008 Bangladesh Climate Change Strategy and Action Plan highlights the need for implementing surveillance systems for existing and new disease risks and ensuring health systems are prepared to meet future demands. Bangladesh became one of the first countries to establish a Climate Change and Health Promotion Unit (CCHPU) under the Ministry of Health and Family Welfare tasked to conduct research and evaluate and monitor programs related to health promotion and climate change. The Ministry of Environment has identified the need to conduct an in-depth nationwide study focusing on climate-sensitive diseases to fill in the important knowledge gap in the area of health in the context of climate change.

This study was jointly undertaken by the Climate Change and Health Promotion Unit of the Ministry of Health and Family Welfare, the International Centre for Diarrheal Disease Research, Bangladesh, and the World Bank.

This study had two broad objectives: (1) to assess national vulnerability and impact on major diseases of increased climate variability and extreme events in Bangladesh; and (2) to assess existing institutional and implementation capacity, financial resources at the local level, and existing public programs targeted at climate-sensitive diseases.

Three key messages emerge from this study:

- First, the health impacts of increased climate variability and extreme weather events are projected to be significant by 2050, but well-targeted development investments can mitigate the excess health burden attributable to climate change.

- Second, rapid urbanization and a growing urban slum population are quickly changing the population dynamics in Bangladesh, and this has implications for climate-induced health risks.

- Third, given the seasonality effects and the role of confounding factors, the allocation of public resources to deal with climate health risks in the future should be spatially targeted to reach locations that are likely to be at high climate and health risk to ensure cost-effectiveness.

Overall, climate change imposes a considerable additional burden on Bangladeshi society, and this burden falls disproportionately on the vulnerable poorer groups of population having lower adaptive capacity. It is my hope that this study contributes to a sound understanding of the health impacts of climate change in the context of Bangladesh and supports policymakers in their efforts to address these impacts.

This study would not have been possible without valuable inputs from the Government of Bangladesh, non-governmental organizations, and research and academic institutions in Bangladesh, and we are grateful for their contributions.

Johannes Zutt
World Bank Country Director, Bangladesh

ACKNOWLEDGMENTS

This study was undertaken jointly by the Climate Change and Health Promotion Unit of the Ministry of Health and Family Welfare, the International Centre for Diarrhoeal Disease Research, Bangladesh, and the World Bank. The study was led by Muthukumara Mani (task team leader and senior environmental economist), Disaster Risk Management and Climate Change Unit in the South Asia Sustainable Development Department (SASDC) under the guidance of Bernice K. Van Bronkhorst (sector manager, SASDC). The core team comprised Limin Wang, Shaphar Selim, Ahmed-Al Sabir, Sharif Hossain, Mohammad Shafiul Alam, and Wasif Ali Khan.

The team greatly appreciates guidance provided by Kabir Iqbal, coordinator of the Climate Change and Health Promotion Unit of the Ministry of Health and Family Welfare, and Peter Kim Streatfield, head of the Population Programme, ICDDR,B, at various stages and all the seminar participants in the World Bank Dhaka office and Washington, DC. John Henry Stein, sector director of the South Asia Sustainable Development Department, and Johannes Zutt, country director for Bangladesh, guided the overall effort.

In preparing the study, the team benefited greatly from detailed comments received from peer reviewers Kirk Hamilton, Anil Markandya, and Kanta Kumari Rigaud. The team would especially like to thank Jin Di, Hrishi Patel, Keith Miao, Mahmud Khan and Sushenjit Bandyopadhyay for their excellent guidance and assistance in data preparation and mapping work. The team was ably assisted by Angie Harney, Lilian MacArthur, and Marie Florence Elvie.

Finally, the team gratefully acknowledges the financial support provided by the Bangladesh Climate Change Resilience Fund (BCCRF), a multi-donor trust fund supported by the governments of the United Kingdom, Denmark, Sweden, Switzerland, Australia, the United States, and the European Union.

EXECUTIVE SUMMARY

Bangladesh is one of the most climate-vulnerable countries in the world. Climate variability and extreme weather events, such as inland and coastal floods, droughts, tropical cyclones, and storm surges, are projected to become more frequent and severe as average temperatures rise with climate change (MoEF 2008). Added to the climate risks are rapid but unplanned urbanization, with a growing slum population, inadequate access to safe drinking water and sanitary facilities, high levels of poverty and population density, and high prevalence of malnutrition and disease incidence among children. Without doubt, the adverse health consequences of increased climate risks are likely to worsen the situation if well-targeted and cost-effective health adaptation measures are not put in place now.

Over the past few decades, with support from donor agencies, Bangladesh has invested extensively in health and education, basic environmental services, and disaster risk reduction measures, all of which are central to improving health outcomes. However, one pertinent question is whether major investment decisions will be cost-effective and well-targeted, particularly in areas that are most vulnerable to health and climate risk in the coming decades.

The health impact of climate variability and extreme weather events is a major area highlighted in the 2008 Bangladesh Climate Change Strategy and Action Plan. This study was requested by the Government of Bangladesh and endorsed by the BCCRF Management Committee as a priority research project to inform the design and implementation of health adaptation policies and programs in Bangladesh in the next 10 to 15 years. The key objectives of this study are (1) to identify the temporal and spatial distribution of major water-borne and vector-borne diseases; (2) to assess the health impact of both climate variability and socio-environmental conditions and project the future health burden of climate variability; and (3) to identify cost-effective health adaptation interventions. The study benefitted greatly from the input provided by the BCCRF Development Partners, and it was finalized after due review and clearance from the BCCRF Management Committee.

Given that a significant amount of financial resources will be committed to the area of climate change adaptation and resilience in Bangladesh, CEA should be used routinely in allocating resources to programs and projects. The results of CEA should be disseminated widely among stakeholders as a means to improve transparency as well as to develop an evidence-based decision-making process for selecting of projects or programs and identifying new areas of policy interventions.

The methodology includes multilevel (hierarchical) modeling and econometric analysis using household survey data, correlation analysis of disease incidence and climate variables, vulnerability assessment using geographic targeting, and cost-effective analysis of possible adaptation interventions.

Organization of the report

This study consists of five chapters. Chapter 1 provides an overview of pathways between health and climate and the Bangladesh context in the area of climate change and health. Chapter 2 carries out an empirical analysis to estimate the impact of climate variability on the incidence of three major childhood illnesses (diarrhea, acute respiratory infection or ARI, and fever), controlling confounding factors. These childhood illnesses are major causes of under-five deaths, accounting for about a quarter of total child deaths in Bangladesh. Future vulnerability and health burdens associated with these illnesses are projected, and a simulation exercise is carried out to quantify how much investment in health adaptation interventions can mitigate the adverse impacts of climate on health.

Chapter 3 presents the seasonal and spatial patterns of vector-borne diseases (dengue fever, malaria, and kala-azar) and investigates the statistical links between climate conditions and cases of vector-borne disease in high-prevalence regions in Bangladesh. These three vector-borne diseases, although less significant as a share of total health burden, are predicted to become larger health concerns in the future as climate change affects the patterns of seasonality, temperature, and precipitation, which are likely to become more conducive to disease outbreaks.

Chapter 4 analyzes the evolution of population dynamics over the past decade and assesses vulnerability using geographic targeting to compare health adaptation capacity with disease incidence. Chapter 5 presents an illustration of cost-effectiveness analysis for ranking different health adaption interventions, including disaster and risk management investment, expansion of access to safe water and sanitation services, and investment in nutrition-focused programs. The final chapter presents conclusions and recommendations.

A summary of the key findings

Impact of climate variability on childhood diseases is significant and varies by season, but investment in traditional areas of development can mitigate to a great extent the excessive health burden attributable to climate change. The results from a combined data set that integrates data from geographically referenced national health surveys with data from local weather stations located across the country, spanning more than 30 years, confirm a significant impact of climate variability on the incidence of three childhood illnesses (diarrhea, fever, and ARI). The health impact of climate variability differs greatly between pre-monsoon and monsoon seasons. The estimated impact of an incremental change in climate variables (temperature, humidity, and rainfall) is relatively small, but the event of extreme precipitation has a large and statistically significant impact on disease incidence.

Lack of access to sanitation facilities, particularly in urban areas, is identified as a key confounding factor determining the incidence of childhood illnesses (fever and ARI). The health burden associated with these three childhood illnesses is projected to be about 14 million disability-adjusted life years (DALY), accounting for about 3.4 percent gross domestic product (GDP) by 2050. Policy simulations also suggest that excess health burden attributable to climate change can be mitigated completely through targeted investment in the traditional areas of development—namely, improving access to basic environmental services (water, sanitation, and electricity), female education, and child nutrition.

Strong seasonal patterns are identified between climate variability and vector-borne diseases (VBDs), but future efforts should focus on filling the evidence gap on cost-effectiveness of various control and management programs. Using monthly surveillance data in regions with a high incidence of VBDs, this study reveals strong patterns of seasonality for VBDs, but no clear trends over the past decade. The strong statistical correlation between short-term climate variability and VBD cases is also established. In the case of dengue fever and malaria, all climate variables (temperature, rainfall, and humidity), both current and lagged, have a strong correlation with the disease caseload. However, only temperature is significantly correlated with kala-azar cases.

Although VBDs are projected to increase with climate change in Bangladesh, as highlighted in the government's 2008 Climate Change Strategy and Action Plan, it is important to recognize that VBDs account for a significantly small proportion of total health burden, compared with water-borne diseases such as diarrhea or malnutrition. On average, about 1 and 0.9 percent of deaths are reported from malaria and dengue fever, respectively, compared with 10.7 percent from diarrhea (even higher when taking account of malnutrition). Priorities in the short term should therefore be placed on improving the collection of data on VBDs from both public and private health facilities to identify changes in seasonal patterns and the geographic distribution of VBDs to improve monitoring and surveillance. While Bangladesh historically has had a strong vector control program, data collection focusing on the impact and cost of a variety of VBD programs in Bangladesh is critical for identifying cost-effective interventions, ranging from community-based awareness initiatives and projects to improve access to rapid diagnostic devices and essential drugs.

Rapid urbanization and a growing urban slum population are quickly changing the population dynamics in Bangladesh, which has implications for climate-induced health risks. However, the initial spatial targeting assessment provides strong evidence of the poor geographic targeting of public resources. One of the key features of population dynamics in Bangladesh is the large rural-urban migration and the fast growth of urban slum areas where about a third of the urban population currently reside. The spatial assessment conducted in this study, which uses data from population censuses, provides strong evidence of poor targeting of public investment, with districts of high disease prevalence particularly lacking in access to health and basic environmental services.

The total population of Bangladesh is projected to increase by 64.6 million between 2010 and 2030, reaching about 217.9 million people in 2030, with three-fourths of that growth expected to occur in urban areas. Therefore, the health implications of population dynamics and rapid population growth in urban slums areas should be rigorously assessed. Policy makers need to recognize the full scale of the health threat that is posed by rapid but poorly planned urbanization in Bangladesh.

Cost-effectiveness analysis (CEA) should be fully implemented by both government units and donor agencies to inform the allocation and prioritization of public resources. Despite the significant investment in health over the past two decades in Bangladesh, evidence on the cost-effectiveness of different interventions is lacking. The CEA of different health adaptation interventions in Bangladesh, including investment in an early warning system and risk reduction measures, projects to improve access to safe drinking water and sanitation services, and nutrition-focused programs, is carried out using a variety of data sources. The CEA results suggest that nutrition programs are more cost-effective than the other interventions, although the findings should be interpreted with caution due to weakness in the data.

Given that a significant amount of financial resources, will be committed to the area of climate change adaptation and resilience in Bangladesh, CEA should be used routinely in allocating resources to programs and projects. The results of CEA should be disseminated widely among stakeholders as a means to improve transparency as well as to develop an evidence-based decision-making process for selecting of projects or programs and identifying new areas of policy interventions. Without concerted efforts to collect reliable data on the cost and impact of different projects and programs and to implement CEA with rigor and consistency, evidence-based policy making will remain simply an empty promise.

CHAPTER 1

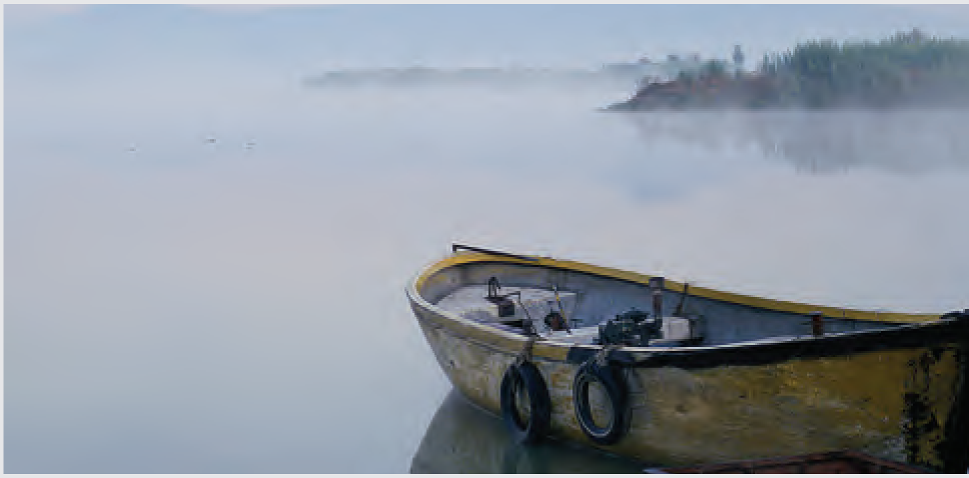
HEALTH AND CLIMATE CHANGE PATHWAYS ANDTHE BANGLADESH CONTEXT

It has been recognized for centuries that weather fluctuations and seasonal-to-interannual climate variability affect health outcomes. The geographic distribution of and seasonal variations in many infectious diseases are clear evidence of the links between climate and health. However, to understand the links between climate and health, it is important to distinguish between weather and climate variability and climate change (see box 1.1).

BOX 1.1 Weather and Climate Variability versus Climate Change

Weather and climate variability refers to the day-to-day change in meteorological parameters including temperature, precipitation, humidity, and winds. Extreme weather events are significant deviations of meteorological variables, such as floods caused by excessive rainfall, droughts, storm surges, and heat waves (extreme temperature).

Climate variability refers to short-term changes in the average meteorological conditions over a time scale, such as a month, a season, or a year. In contrast, climate change refers to changes in average metrological conditions and seasonal patterns over a much longer time horizon, often over 50 or 100 years. Recent studies show that climate change is projected to shift the mean value of temperature and precipitation, increase climate variability and the frequency and intensity of extreme weather events, and alter seasonal patterns (for example, delay the onset of the monsoon season or lengthen the hot season).



Most climate change studies so far have focused on the effect of rising temperatures on the intensity of El Nino-Southern Oscillation (ENSO) events (IPCC 2001.) The ENSO cycles influence interannual variability in temperature and rainfall and the likelihood of extreme weather events such as floods, storms, and droughts, which, in turn, have implications for local conditions. Therefore, the impact of global warming on local temperatures, precipitation, humidity, and seasonal patterns is likely to vary substantially across regions.

Most global climate models project that climate change will increase the frequency and severity of extreme weather events in the coming decades and consequently lead to more serious and adverse health consequences globally (Confalonieri et al. 2007; McMichael, Woodruff, and Hales 2006; WHO 2009; IPCC 2001). However, climate variability is not the only factor that will determine health outcomes. Many other factors, such as health system capacity, socio-economic conditions, and demographic characteristics, can have a larger effect on health, either independently or by modifying climate effects (WHO and PAHO 2010).

Pathways from Climate to Health

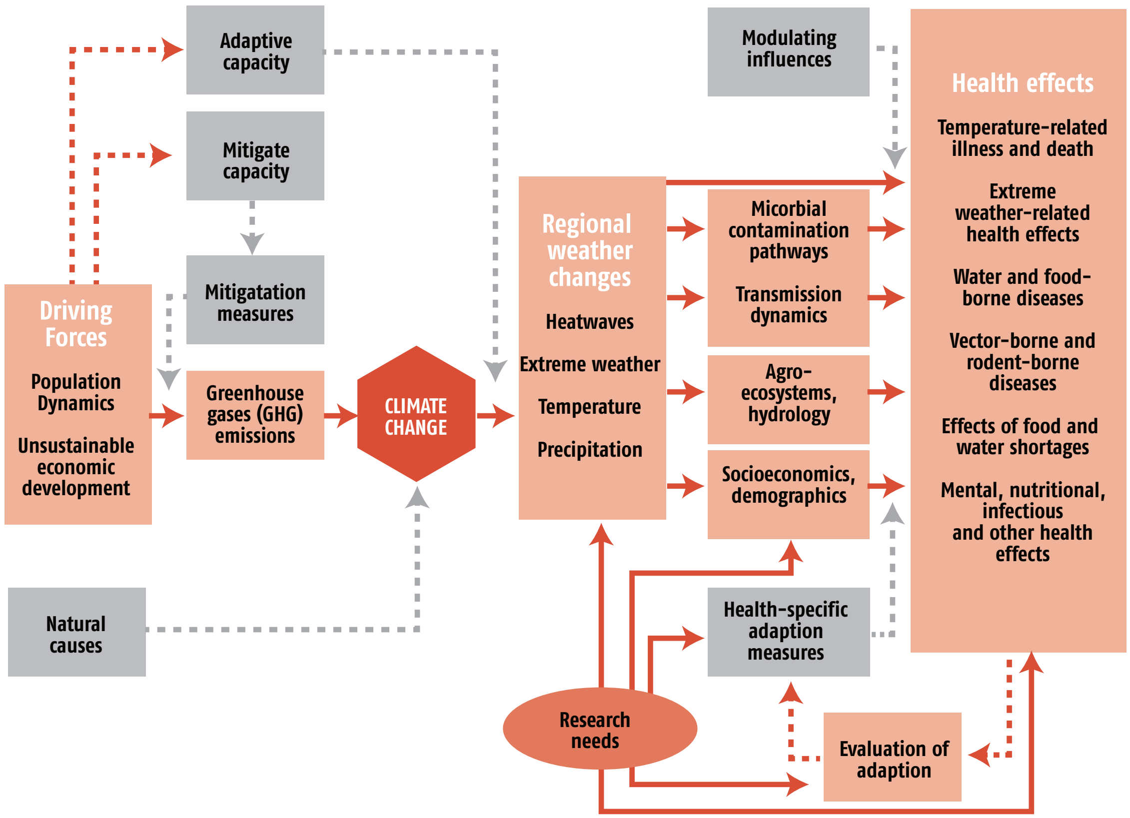
The complex pathways through which climate conditions affect population health are shown in figure 1.1. Climate conditions affect health outcomes both directly and indirectly. The direct impacts on health include outbreaks and spread of infectious diseases, thermal stress-related mortality from extreme high temperature, and mortality and morbidity from extreme weather events such as floods and storms.

Climate variability and extreme weather events also affect health indirectly through their effect on the replication and spread of microbes and vectors. For example, epidemiological evidence shows that vector-borne diseases such as dengue fever, malaria, and yellow fever are associated with warm and humid weather conditions; influenza becomes more prevalent during cooler seasons. In the tropics, diarrheal diseases typically peak during and after the monsoon season, and both flood and droughts are found to be linked to an increased risk of diarrhea.

Extreme weather events, such as droughts, floods, and cyclones, can contaminate drinking water, cause water shortages that result in poor hygienic conditions, and, in the event of natural disasters, cause outbreaks of disease among displaced populations in overcrowded shelters. During heat waves, excess mortality is greatest among the elderly and those with preexisting conditions. There is comprehensive literature (Hales, Edwards, and Kovatz 2003; Patz et al. 2010; Burke et al. 2001) on the links between climatic and weather conditions and various infectious diseases and health outcomes.

However, the impact of climate and weather variability on population health can be modified significantly by non-climatic factors. These include improving access of the population to basic environmental infrastructure, such as safe drinking water and sanitation facilities, and improving the capacity of institutions to adapt, such as better climate forecasting, disaster management, and health

FIGURE 1.1 Pathways from Climate Change to Health



Source: WHO 2003.

service provision. Further, locational characteristics such as population density and the geographic characteristics that determine local vulnerability to climate-related risk also play important roles. Over the long run, many unforeseeable social and environmental changes, human adaptation in response to climate-related risks, and advancement in vaccine and drugs can all modify the impact of climate change on health and the probability of disease outbreaks.

The Bangladesh Context

Climate conditions and climate change projections

Bangladesh is one of the most climate-vulnerable countries in the world, ranked sixth on the 2011 United Nations national disaster risk index. Climate variability and extreme weather events, such as inland and coastal floods, droughts, tropical cyclones, and storm surges, are projected to become more frequent and severe as the average temperature rises with climate change (World Bank 2010).

Bangladesh is located at the tail end of a delta formed by three major rivers—the Ganges, the Brahmaputra, and the Meghna—and two-thirds of the country is less than 5 meters above sea level.[1] The southwest summer monsoon is the major hydrologic driver in the Ganges-Brahmaputra-Meghna (GBM) basin, with more than 80 percent of annual precipitation occurring during this period. Its geographic location and the hydrologic impact of the GBM basin render it particularly vulnerable to a range of climate risks, including various types of flooding (inland monsoon flooding, tropical cyclones, and storm surges) and periodic droughts. Once every three to five years, up to two-thirds of Bangladesh is inundated by floods, resulting in loss of life, outbreaks of disease, and damage to infrastructure, housing, agriculture, and livelihoods (World Bank 2010).

Future changes in temperature and precipitation in Bangladesh have been projected based on 16 global circulation models for three emissions

1 Bangladesh is a subtropical country located between latitudes of 22°N and 27°N, with distinct seasonal climatic patterns. The winter season is from November to March, and the hot and humid summer season is from April to October. The incidence of rainstorms is highest during the hot season from March to May, and about 70 percent of total annual rainfall occurs during the monsoon season from May to September. Rainfall varies significantly across regions, with annual average rainfall reaching about 1,500 millimeters at Rajshahi, 2,150 millimeters at central Dhaka, rising to 2,900 millimeters in the southeast at Chittagong, and 4,200 millimeters in the northeast at Sylhet (U.K. Meteorological Office).

scenarios (Yu et al. 2010). Temperature is predicted to rise during all months and seasons relative to the historical data for 1980–99, with the median warming prediction of 1.55°C (degrees Celsius) by the 2050s. Annual and wet season precipitation is projected to increase, with a median increase in precipitation of 4 percent by the 2050s. The extent of land flooding is also projected to increase, given the existing flood protection infrastructure, with an average increase in flooded area of 3 percent in 2030 and 13 percent in 2050. The proportion of flooded area is projected to be highest during July through September, peaking in August. Sea-level rise is projected to be one of the most critical climate risks for Bangladesh due to its long coastline and high population density.

Major health issues

The 2008 Bangladesh Climate Change Strategy and Action Plan prepared by the government of Bangladesh highlighted the need to implement surveillance systems for existing and new disease risks and to ensure that health systems are prepared to meet future demands. According to the strategy document,

> *Climate change is likely to increase the incidence of water-borne and air-borne diseases. Bacteria, parasites, and disease vectors breed faster in warmer and wetter conditions and where there is poor drainage and sanitation. In view of this, it will be important to implement public health measures (immunization, improved drainage, sanitation, and hygiene) to reduce the spread of these diseases and to improve access to health services for those communities likely to be worst affected by climate change. Unless these steps are taken, the health of many of the poorest and most vulnerable people will deteriorate. Acute illness is known to be one of the main triggers driving people into extreme poverty and destitution in Bangladesh.*

Table 1.1 Estimated Total Deaths, by Cause, 2007–08

	WHO data, 2008 (ages 0–14)		DHS data, 2007 (ages 0–5)
Cause of death	**Number (thousands)**	**%**	**%**
All causes	221.7	100.0	100.0
Infectious and parasitic diseases	57.5	25.9	15.1
Diarrheal diseases	23.8	10.7	2.0
Malaria	2.3	1.0	–
Dengue	2.1	0.9	–
Respiratory infections	38.3	17.3	–
Lower respiratory infections	38.2	17.2	–
Upper respiratory infections	0.1	0.1	–
Otitis media	0.0	0.0	–
Pneumonia	–	–	22.0
Perinatal conditions	91.0	41.0	25.8
Prematurity and low birth weight	28.6	12.9	–
Birth asphyxia and birth trauma	30.3	13.7	–
Neonatal infections and other conditions	32.1	14.5	–
Nutritional deficiencies	4.5	2.0	0.4
Injuries and drowning	12.2	5.5	9.2

Source: WHO data for 2008 and 2007 DHS.
Note: – = not available.

Table 1.1 summarizes the leading causes of death among children (ages 0–14) based on the World Health Organization (WHO) data and verbal autopsies from the 2007 Bangladesh Demographic and Health Survey (DHS) for children ages 0–5. The large discrepancies in the causes of death (proportion of all deaths) from the two data sources are likely due to several factors, including differences in the data sources, population covered, ages covered, and definitions of diseases, illnesses, and infection.[2]

Table 1.2 presents the trends in key indicators of child health for the decade of the 2000s covering three childhood illnesses and two measures of child malnutrition.

Table 1.2 Child Health: Incidence of Illnesses and Malnutrition, 2000–11

% of children

Year	ARI	Diarrhea	Wasting	Stunting	Underweight
2000	18.3	6.1	10.3	44.7	47.7
2004	20.8	7.5	15.3	51.2	43.2
2007	13.1	9.8	17.4	43.4	41.1
2011	5.8	4.6	16.2	41.2	36.2

Sources: DHS, 1999–2000, 2004, 2007, and 2011.

2 The WHO estimates rely on vital statistics that are collected from primary health facilities, while the estimated proportions in the DHS data come from verbal autopsies, relying primarily on the recall of the child's caretaker in the households selected in the 2007 DHS. Only a few illnesses and diseases are defined in the verbal autopsy, whereas the vital statistics have much wider coverage, including illnesses, diseases, and conditions.

Childhood illnesses. Diarrhea, acute respiratory infection (ARI), and fever[3] are major causes of under-five deaths, accounting for about a quarter of total childhood deaths in Bangladesh. A range of climate variables, living conditions, and socio-economic factors can have an impact, directly and indirectly, on the incidence and geographic distribution of these childhood illnesses. Repeated common childhood infections can also result in child malnutrition because they reduce the child's ability to absorb nutrients during or even beyond the period of sickness.

Child malnutrition. The rates of child malnutrition in Bangladesh are among the highest in the world. About half of preschool-age children, equivalent to more than 9.5 million children, are stunted, and more than 36 percent are classified as underweight.[4] Recurring natural disasters exacerbate malnutrition by wiping out crops, homes, safe water sources, and livelihoods. Recent evidence from a large number of countries highlights the two-way causal relationship between malnutrition and the frequency of childhood illnesses.[5] Children with poor nutritional status face far greater risk of mortality and severe illness due to common childhood infections, such as pneumonia, diarrhea, malaria, human immunodeficiency virus (HIV), acquired immunodeficiency syndrome (AIDS), and measles, suggesting that the health burden associated with childhood illnesses and malnutrition can be even higher with higher climate risk.

Vector-borne diseases. Dengue fever, malaria, and kala-azar, although less significant as a share of total health burden (accounting for about 2 percent of total deaths each year), are projected to become more prevalent in the coming decades in Bangladesh. This is due to fact that climate change is projected to affect the patterns of seasonality—in particular, prolonging the monsoon season and raising temperatures, which will affect the abundance and spread of many disease vectors. The number of malaria cases reported increased from 1,556 in 1971 to 51,773 in 2011. Table 1.3 summarizes the major vector and water-borne diseases for the total population in Bangladesh.

Dengue fever was an unfamiliar disease in Bangladesh until its outbreak in the summer of 2000 in three major cities—Dhaka, Chittagong, and Khulna—with the highest caseload recorded at 6,132 in 2002. During the period of 2000–11, a total of 23,518 cases and 239 deaths from dengue fever were reported in Bangladesh. No deaths from kala-azar were reported, although it is considered an important vector-borne disease in Bangladesh. Despite the recent attention paid to vector-borne diseases in the public health discussions of climate change, water-borne diseases, in particular diarrhea, are a more important health concern with regard to the total number of deaths in the population (see table 1.3).

Mortality and emerging health issues associated with natural disasters. In Bangladesh, natural disasters such as flooding, cyclones, and storm surges have been a major source of health threats to the population, in terms of lives lost, injuries, and disease outbreaks. Bangladesh has a long history of natural disasters. According to data collected by the European Detailed Mortality Database, between

Table 1.3 Major Infectious Diseases: Number of Cases and Deaths, by Cause, 2000–11

	Malaria		Dengue		Kala-azar	Diarrhea	
Year	Cases	Deaths	Cases	Deaths	Cases	Cases (thousands)	Deaths
2000	54,223	478	5,551	93	7,640	1,556	475
2001	54,216	490	2,430	44	4,283	1,866	521
2002	62,269	588	6,132	58	8,110	2,599	1,022
2003	54,654	577	486	10	6,113	2,287	1,282
2004	58,894	535	3,934	13	5,920	2,246	1,170
2005	48,121	501	1,048	4	6,892	2,152	929
2006	32,857	307	2,200	11	9,379	1,962	239
2007	59,857	228	466	0	4,932	2,335	537
2008	84,690	154	1,153	0	4,824	2,295	393
2009	63,873	47	474	0	4,301	2,619	360
2010	55,873	37	409	0	2,810	2,427	345
2011	51,773	36	1,362	6	2,534	2,268	70

Source: Ministry of Health.
Note: There were no reported deaths caused by kala-azar.

3 Fever is a symptom of many childhood illnesses. It was not recorded in the DHS during the two-week survey period, and it is not classified by the WHO as a cause of death.

4 Three of the most commonly used measures of child nutritional status are underweight, stunting, and wasting. Stunting (height for age) refers to shortness, reflecting growth achieved pre- and postnatal, that is, long-term and cumulative effects of inadequate nutrition and poor health status. Wasting (weight for height) is a measure of an acute or short-term effect of an occurrence of illness, such as a bout of diarrhea that causes loss of body fluids and the consequent reduction in calorie intake. Underweight (weight for age) is a good indicator for children under 24 months, but it does not take height into account.

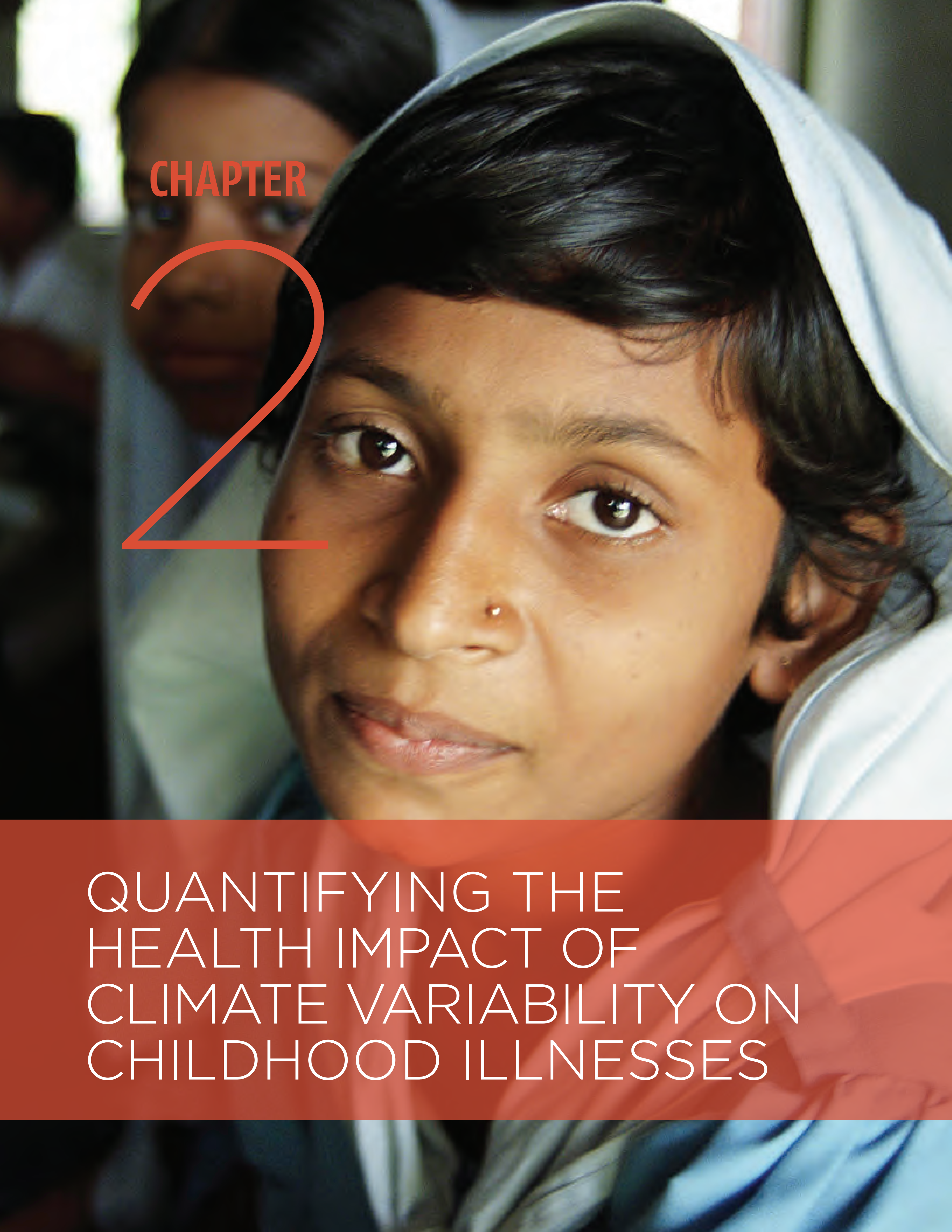
5 Based on a UNICEF report (UNICEF 2013) a child who is severely underweight (weight for height) is 9.5 times more likely to die of diarrhea than a child who is not, and the risk of death of a stunted child is 4.6 times higher. Moreover, malnutrition is also a consequence of infections and repeated episodes of illness.

1980 and 2010, Bangladesh experienced 234 natural disasters, causing more than US$17 billion in total damage. The total number of people killed as a result of natural disasters between 1980 and 2010 was about 191,836; on average, 6,188 people are killed each year.

Many outbreaks of water-borne diseases have been recorded during and after major floods. While complete records of disease cases in the aftermath of major natural disasters are not available, officials from risk management and disaster management units have reported evidence of outbreaks of various infectious diseases as a result of overcrowding in temporary shelters with inadequate drinking water and poor sanitation. The displaced population is particularly exposed to the risks of infectious diseases when humans and livestock share shelters.

In the coastal regions, the contamination of drinking water by salinity as a result of storm surges caused by cyclones, rising sea levels, cyclone and storm surges, and upstream withdrawal of freshwater has been identified as the main cause of emerging health problems. The rising incidence of several health conditions and diseases, including hypertension, premature delivery due to pre-eclampsia, ARI, and skin diseases has also been recorded among populations living in the coastal regions (Khan et al. 2011).

The following two chapters analyze the statistical links between climate variability and health. Chapter 2 quantifies the impact of climate variability on the incidence of three childhood illnesses using nationally representative health surveys that collect childhood diseases among children under the age of five. Chapter 3 focuses on the statistical correlation between climate conditions and vector-borne diseases using aggregate disease records collected by the Ministry of Health covering the entire population.



CHAPTER 2

QUANTIFYING THE HEALTH IMPACT OF CLIMATE VARIABILITY ON CHILDHOOD ILLNESSES

This chapter aims to quantify the impact of climatic variability on the incidence of childhood illnesses—diarrhea, acute respiratory infection (ARI), and fever—while controlling non-climatic confounding factors. While climate conditions such as weather fluctuations and seasonal and interannual climate variability influence many infectious diseases, disease incidence can be modified by many non-climatic factors. These include drinking water sources, sanitation facilities, sewerage system infrastructure, the capacity of public health services (such as disease surveillance, control, and treatment systems), human adaptation responses to health risks and climate variability, and population migration. In the context of Bangladesh, these non-climatic factors are particularly important in urban areas, where population density is high and the slum population is rapidly increasing as a result of massive rural-urban migration over the past decade.

Quantifying the health impact of both climate and non-climatic factors provides valuable information for the formulation of public policies in two areas. First, knowledge of the relative importance of different health determinants can inform the design of measures to maximize the health benefits of interventions. Second, the statistical links between climate variability and disease incidence provide critical parameters for projecting future health burdens attributable to climate change. While these projections are subject to large uncertainties due to the complex pathways from climate conditions to health, they provide some benchmark estimates that help policy makers to plan health adaptations in a medium- to long-term time frame.

The following analysis is conducted at the national level using information from the geographically referenced national health surveys and local weather stations located across the country and spanning more than 30 years. This study is based on uniquely rich data sources—combining health, a wide range of socio-environmental information, and local climate conditions—and large in spatial and temporal scale. It attempts to address limitations in current research in the area of health and climate links by controlling confounding factors and taking account of seasonality effects.[6]

Key Data Sources

Quantifying the impact of climate variability on disease incidence or health in general remains a formidable empirical challenge because of data requirements and the complex pathways from climate conditions to health. The analyses are extremely data intensive, requiring local information on a sufficiently large spatial and temporal scale (taking account of seasonality) and covering health, local climate conditions, the features of ecosystem and topography, as well as a wide range of socio-economic conditions.[7] The complete list of data sources in this study is summarized in appendixes A, B, and C. In the following analysis, the extensive weather station data are matched to the primary sampling units or clusters (villages in rural areas and neighborhoods in urban areas) of the two nationally representative health surveys using geographic information system (GIS) information.

Weather data

The Bangladesh Meteorological Department has been collecting monthly weather data since 1970 in 35 weather stations located across the country. The five weather variables (rainfall, average temperature, maximum temperature, minimum temperature, and relative humidity) have been collected daily,[8] but only monthly data are made publicly available. Figure 2.1 summarizes monthly average weather variables constructed from the 35 weather stations from 1970 to 2010 for six regions.

The monthly climate variables provide important climate features for Bangladesh. While there is little spatial variation in temperature (maximum, minimum, and average) and humidity, monthly rainfall varies substantially across regions, in particular during the monsoon season of May to September. The average monthly temperature starts to rise in April, reaches the peak (around 30°C) in May, and starts to fall in September. The maximum temperature during the hot season can vary between 30°C and 35°C. The humidity level starts to rise in April, reaching the peak in June and continuing through September.

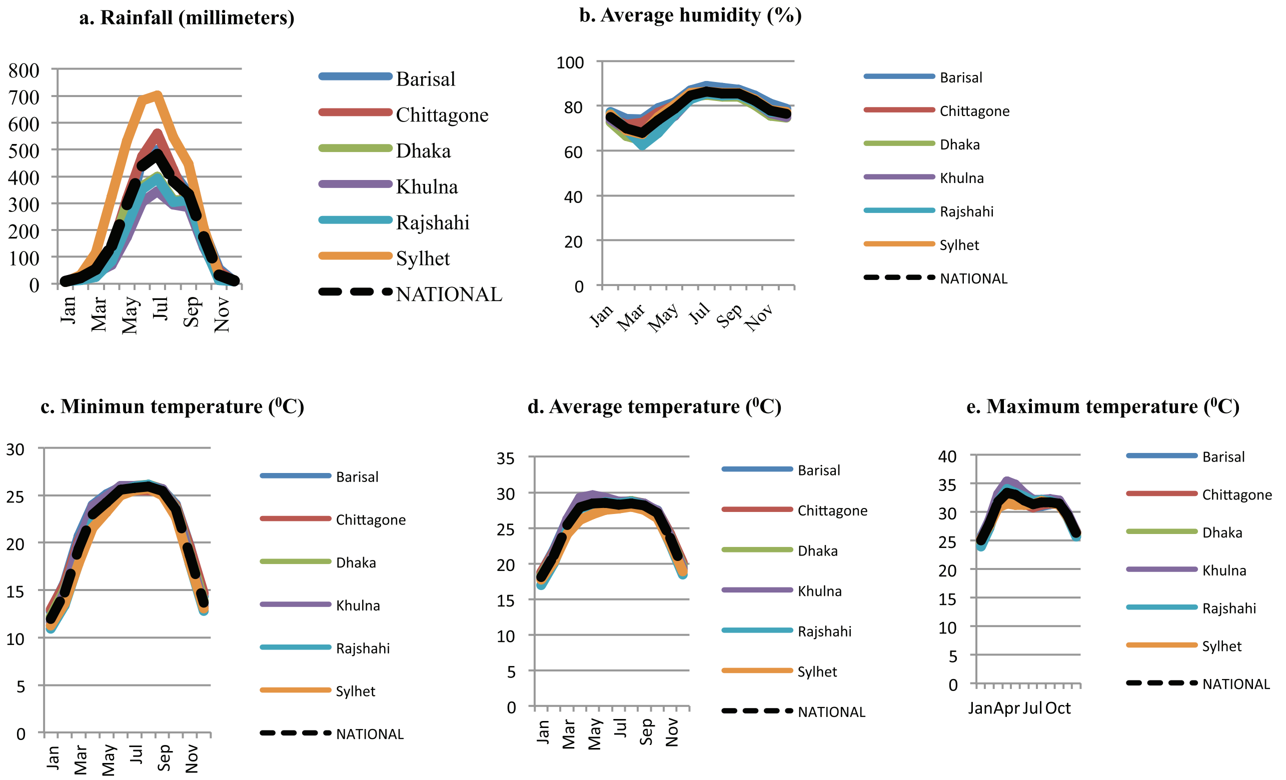
Both incremental changes in average climate variables and climate variability—in particular, extreme weather events—affect disease outcomes. In the following analysis of the statistical links between climate conditions and

6 A few studies have been carried out to analyze the statistical links between climate variables and infectious diseases in Bangladesh, focusing on diarrhea, cholera, kala-azar, and malaria. These are district case studies, covering the drought-prone district of Rajshahi, the flood-prone district of Manikganj, the salinity-affected district of Satkhira, and the malaria-epidemic region of Chittagong Hill Tracts (Matsuda et al. 2008; Pascual and Dobson 2005; Islam and Uyeda 2007; Hashizume et al. 2007) examine the association between climate variability and diarrhea cases in Dhaka City. While these studies provide useful information on the statistical association between climate variables and disease incidence, they are of local scale and do not control important confounding factors, such as household drinking water, sanitation facilities, and socio-economic conditions, that are important determinants of disease incidence (with the exception of Hashizume et al. 2007). Del Ninno and Lundberg (2005) use an indirect measure of extreme weather events—the household flood index—to estimate the impact of floods on the nutrition of under-five children in Bangladesh.

7 Many leading researchers in the field of public health and climate change (Burke et al. 2001; Patz et al. 2010; McMichael, Woodruff, and Hales 2006; Hales, Edwards, and Kovats 2003; Gage et al. 2008; Rogers and Randolph 2006) have called for concerted efforts to improve the collection of data on health, local socio-economic conditions, and environmental infrastructure by integrating GIS and remote-sensing data on a wide variety of environmental parameters that are known to affect local disease risks (for example, forest coverage and soil conditions).

8 The completeness of these observations for the five variables varies across the 35 weather stations.

FIGURE 2.1 Average Monthly Weather Variables, by Region and Month, 1970–2011



Note: The monthly averages are constructed using monthly data from 1970 to 2011 collected from 35 weather stations located across the six regions.

the incidence of disease, both the level and variability of climate variables are matched to the GIS-referenced national health surveys.

Excessive precipitation (floods) or extreme low rainfall (droughts) is conventionally defined as when rainfall at a given location and month is bigger (smaller) than 1 (or 2) standard deviation from the long-term average. The location and monthly long-term average climate conditions are established using the monthly weather station data from 1970 to 2010. The extreme temperature is similarly defined—the extreme hot (cold) month is defined as when the temperature is higher (lower) than 1 (or 2) standard deviation from the long-term mean at a specific month and location.

The Bangladesh national health surveys

The Bangladesh nationally representative Demographic and Health Survey (DHS) is used in the analysis. The survey's sample framework covers the entire population residing in private dwelling units in the country based on the enumeration areas created in the 2001 census.[9] Map 2.1 displays the locations of primary sampling units or clusters (villages in rural areas and neighborhoods in urban areas).

The 2004 and 2007 DHS, the fifth and sixth waves of health surveys that have been conducted since 1993, are chosen for analyzing the links between health and climate. The choice of these two surveys is driven by the survey months and the availability of GIS information in the surveys. The survey months are from January to May in the 2004 DHS and from March to August in the 2007 DHS, presenting the opportunity to analyze the effect of climate variability for

9 Bangladesh is divided into six administrative divisions; each division is divided into zilas, and each zila is divided into upazilas. Each urban area in the upazila is divided into wards, and each ward is divided into mahallas; each rural area in the upazila is divided into union parishads, and each union parishad is divided into mouzas. The urban areas are stratified into three groups: (1) standard metropolitan areas, (2) municipalities, and (3) other urban areas.

Map 2.1 DHS Survey Locations, 2004 and 2007

a. 2004 DHS clusters

b. 2007 DHS clusters

pre-monsoon and monsoon seasons separately. Table 2.2 presents the sample distribution for the 2004 and 2007 DHS by survey month and by region.

The 2004 and 2007 DHS collected GIS information for each primary sampling unit. The GIS data provide the critical link for spatially matching disease incidence as well as socio-economic information collected in the DHS with the weather station data at a relatively high resolution.

In addition to detailed information on childhood diseases, the DHS collects information on household-level access to a wide range of basic services, such as drinking water sources, sanitation facilities, and electricity, as well as socioeconomic conditions. The key household-level variables are summarized in tables 2.2 and 2.3. It is notable that there is little variation in water or the availability of electricity over the time period. There is, however, some variation in sanitation and education, but one would expect much more improvement over the period.

Table 2.2 Household Distribution in 2004 and 2007 DHS, by Region and Survey Month

Survey year and month	Barisal	Chittagong	Dhaka	Khulna	Rajshahi	Sylhet	Total
2004 DHS							
January	304	490	546	–	–	521	1,861
February	314	27	1	258	261	367	1,228
March	134	352	155	374	321	56	1,392
April	–	498	403	203	314	–	1,418
May	–	136	426	31	416	–	1,009
Total	**752**	**1,503**	**1,531**	**866**	**1,312**	**944**	**6,008**
2007 DHS							
March	207	133	–	–	–	139	479
April	455	421	34	–	–	591	1,501
May	129	586	139	104	102	388	1,448
June	–	135	379	257	355	–	1,126
July	–	–	356	353	497	–	1,206
August	–	–	377	–	13	–	390
Total	**791**	**1,275**	**1,285**	**714**	**967**	**1,118**	**6,150**

Note: – = no households surveyed.

Table 2.3 Summary of Key Variables in 2004 and 2007 DHS

Variable	2004 DHS	2007 DHS
Sample size	6,908	6,150
Water sources (%)		
Piped water = 1	7.32	6.03
Tube well = 2	84.52	80.36
All other = 9	8.16	13.61
Sanitation		
Septic tank = 11	11	24.36
Slab latrine = 21	15	0.00
Pit latrine = 22	33	16.73
Open latrine = 23	27.51	31.33
All other = 99	13.52	27.58
Has electricity	41.06	42.33
Has TV	24.57	28.39
Religion		
Islam = 1	91.26	91.19
Hindu = 2	8.26	8.06
Other = 99	0.48	0.62
Location		
Urban = 1	30.01	34.26
Rural = 2	69.99	65.74
Sex head of household		
Male	93.01	90.86
Mother's education		
No education = 0	36.78	27.25
Primary = 1	31.09	31.33
Secondary = 2	26.45	34.05
Higher = 3	5.67	7.37

Quantifying the Health Impact of Climate Variability

The analytical model

The links between the incidence of childhood illnesses and climate variability are analyzed here using the multilevel (hierarchical) modeling approach. The statistical presentation of this model is summarized in box 2.1. This modeling approach has several analytical advantages over the existing biological and statistical modeling approaches that are widely used in epidemiology to study the links between climate and health. First, it allows the incorporation of both climate variables and a range of individual, household, and community-level covariates, that is, confounding factors. Therefore, the estimated impact of climate variability can be interpreted as a causal effect as opposed to a statistical correlation between climate and disease incidence.

Second, the multilevel model can be extended to test various health adaptation policy variables. For example, what is the differential effect of extreme rainfall on disease incidence between households with sanitary toilets and those with open latrines, holding all other factors constant? This interactive effect can be tested by incorporating in the model an interactive term (for example, extreme precipitation event * toilet types). Another example is identifying the synergy effect of integrated health interventions—whether the combination of improving both drinking water sources and sanitary facilities (for example, access to water * access to sanitation) is more effective in reducing disease incidence than the sum of two separate interventions (improving drinking water sources and sanitation facilities).

Seasonality of disease incidence

In the DHS, cases of diarrhea, ARI, and fever are collected for children under the age of five. The information is recorded based on the mother's response to the question asking whether her children had experienced episodes of any of the three illnesses during the period two weeks preceding the survey date. Diarrhea is not defined medically, and answers to this question are left to the mother's perception and diagnostics. This means that reporting biases may arise as mothers with more education are more likely to recognize the symptoms associated with diarrhea than mothers with less or no education. A child is recorded to have experienced ARI if the mother reported any one of three symptoms, including short but rapid breathing, difficulty breathing, or labored respiration.[10]

The DHS does not collect information on malaria or dengue fever, which are major vector-borne diseases in Bangladesh. However, fever can be a major manifestation of malaria, which is more prevalent after the end of the rainy season, as well as a symptom of a wide range of acute infections that can occur through all seasons in Bangladesh.[11] It is estimated that the proportion of malaria among all fever cases in Bangladesh, on average, is about 12 percent (ICDDR,B 2007).

Table 2.4 summarizes the incidence of illness by month and season estimated from the 2004 and 2007 DHS. During the pre-monsoon season, ARI is more prevalent among young children, with an incidence of 14 percent compared to 10 percent during the monsoon season. The incidence of fever is higher in the monsoon season than during the pre-monsoon season. Based on the two health surveys, the incidence

10 The combined symptoms that are associated with ARI are similar to pneumonia or bronchiolitis. In the diagnosis guidance of the World Health Organization (WHO), the symptoms of ARI include convulsions, shrunken eyes, high respiratory counts, noisy breathing, and high body temperature.

11 Fever can be a common symptom of many non-life-threatening illnesses, including both vector- and water-borne diseases such as ARI and diarrhea, and of life-threatening illnesses, including cerebral malaria, meningitis, septicemia, and typhoid. Its causes can be associated with local endemic and epidemic diseases that may or may not be seasonal.

BOX 2.1 The Model

The probability of event (Y)— a child who lives in household h located in village i experiences an episode of illness at survey month t — is assumed to follow the logistic distribution:

$$(B2.1.1) \quad P_{hi} = E(Y = 1 \mid X_i) = \frac{1}{1 + e^{?? + ??X_i}}.$$

The odds ratio defined as $\frac{P_{hi}}{1 - P_{hi}}$ is commonly used in the medical field and epidemiology. The logistic regression model, which is the log transformation of equation B2.1.1, has a linear relationship between the odds ratio and X_i, the covariates. The specification of the logistic regression model is as follows:

$$(B2.1.2) \; \text{Log}\left(\frac{P_{hi}}{1 - P_{hi}}\right) = \alpha + \beta_1 \text{Climate}_i + \beta_2 \text{SE}_{hi} + \beta_3 \text{Village}_i + \beta_4 V_i + u_{hi}.$$

Where, Climate_i is the vector of climate variables (both level and variability) in village_i, SE_{hi} is the vector of individual- and household-level variables (for instance, age, gender, birth order, drinking water source, type of sanitation facilities, and other key socio-economic characteristics such as mother's education level or religion). Village_i is a vector of village-level variables, such as the proportion of households with access to safe water and sanitation, access to health facilities, presence of a village drug store or village medical personnel, and presence of a health outreach program. V_i is the unobservable village-specific random effect, which is likely correlated with Village_i, and u_{hi} is the residual following i.i.d. distribution and is not correlated with the included explanatory variables.

The model specification incorporates both the level of precipitation and extreme rainfall events. Excessive rainfall can have different health consequences depending on the season and topography as well as household and community environmental infrastructure (for example, drinking water sources, sanitation facilities, waste discharge, and sewerage systems).

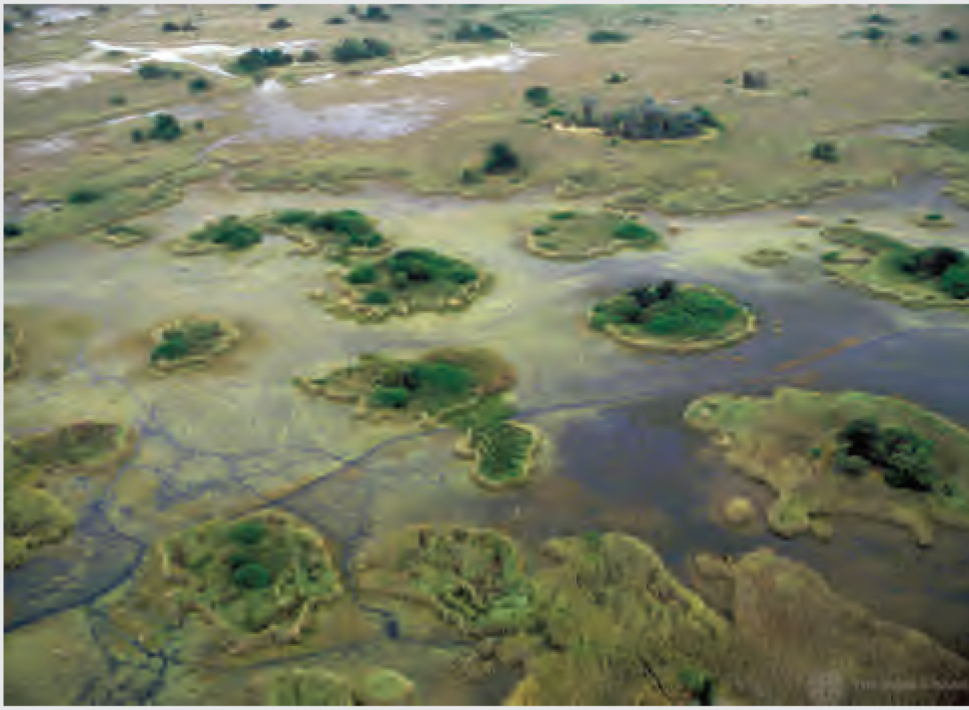


Table 2.4 Disease Incidence, by Survey Month and Season, 2004 and 2007

Survey year and month	Fever	Diarrhea	ARI
2004 DHS			
January	27.18	7.50	17.39
February	35.2	6.64	15.30
March	39.36	6.69	20.63
Cold season: January–February	29.89	7.21	16.68
April	44.98	7.26	19.53
May	41.29	6.22	15.06
Pre-monsoon: March–May	41.97	6.76	18.61
Total	**37.19**	**6.94**	**17.85**
2007 DHS			
March	43.60	6.02	17.10
April	34.22	10.00	16.20
May	31.43	9.91	11.59
Pre-monsoon: March–May	34.06	9.43	13.98
June	33.22	7.48	9.65
July	41.19	9.38	12.14
August	39.84	12.24	11.35
Monsoon: June–August	37.68	9.07	10.98
Total	**36.07**	**9.23**	**12.32**

of diarrheal illness appears constant through all seasons. However, using the hospital data for both children and adults, Teshima et al. (2007) find two peak seasons for diarrhea in Bangladesh: the pre-monsoon (March and April) and the end of the monsoon season.

A direct comparison of disease incidence by month and season using the 2004 and 2007 DHS is complicated by the fact that the primary sampling unit locations changed between 2004 and 2007 (map 2.1). For example, the average disease incidence for the same survey months (March–May) is markedly different in the 2004 and 2007 surveys. This indicates that the location effect is particularly important in estimating disease incidence. Therefore, for disease monitoring purposes, the national disease surveillance system should be considered a more reliable source of data than the national health surveys.

The impact of climate on disease incidence

The regression results using the multilevel model confirm that climate variability is strongly linked with the incidence of childhood illnesses and that the impact of climate varies by season. Table 2.5 summarizes the estimated impact of climate variables on the odds ratio of fever, diarrhea, and ARI among children under the age of five, controlling for confounding factors at multiple levels: child, household, and community. The full regression results from the complete model specification are presented in tables D.1, D.2, and D.3 in appendix D.

Effect of temperature and humidity. During the pre-monsoon season (January–April), results from the 2004 DHS show that high temperature and humidity levels increase the incidence of fever and ARI. A 1° increase in average temperature increases the odds ratio of fever by about 21 percent and ARI by 14 percent, respectively, controlling for household socio-environmental factors; a one-unit increase in humidity increases the incidence by 4 and 6 percent, respectively. No statistically significant effect is found for diarrhea during the pre-monsoon season, although Hashizume et al. (2007) confirm a positive association between the number of cases and temperature, using weekly diarrheal cases collected in Dhaka hospitals from January 1996 to December 2002.

The effect of temperature and humidity levels during the monsoon season of May to August (2007 DHS survey) is, however, markedly different from that of the pre-monsoon season. Higher temperature is associated with a lower incidence of ARI, but higher humidity has no significant effect. The differential impact of climate conditions on disease incidence across seasons may be due to the distinct seasonal patterns of climate variables in Bangladesh.

During the pre-monsoon season when the average temperature in Bangladesh is in the range of 15–28°C before peaking at 30°C in May, an increase in temperature is likely to foster the development and spread of a wide range of pathogens and parasites, causing more illnesses such as fever and ARI among young children. The temperature reaches above 30°C during the monsoon season, possibly approaching the limit of physiological tolerance for pathogens, as an increase in temperature can destroy many types of pathogens, reducing the disease incidence. The nonlinear relationship between temperature and the survival of a wide range of pathogens has also been documented in epidemiological studies for other countries (Patz et al. 2010).

The effect of extreme heat (temperature) on health is also investigated in the analysis. An extreme hot (cold) event is defined as when the temperature is higher (lower) than 1 (or 2) standard deviations from the long-term mean at a specific month and location. However, unlike precipitation, extreme heat events were very rare in the months and locations surveyed in 2003 and 2004; therefore, it is not possible to use the model to test the effect of extreme heat events on disease incidence.

Table 2.5 Impact of Climate Variables on Disease Incidence, 2004 and 2007 DHS

	Pre-monsoon season			Monsoon season		
Climate variable	**Fever**	**Diarrhea**	**ARI**	**Fever**	**Diarrhea**	**ARI**
Temperature at survey month	1.21***	0.87	1.14*	0.92	0.88	0.51*
Relative humidity at survey month	1.04*	1.04	1.06*	1.01	1.01	0.97
Rainfall at survey month						
Rainfall level (log form)	0.81*	1.39	0.76	1.32	0.95	0.78
Extreme rainfall event (dummy variable; base case = normal rainfall)						
Heavy rainfall event	1.82*	1.23	1.47	0.67*	0.74	1.03
Low rainfall event	0.96	1.27	0.89	1.44	0.95	0.96
Rainfall-one month lag						
Rainfall level (log form)	0.84***	1.04	0.87	1.27*	1.25	1.02
Extreme rainfall event (dummy variable; base case = normal rainfall)						
Heavy rainfall event	1.18	1.09	1.28	0.72	0.56*	1.08
Low rainfall event	No	No	No	0.96	0.85	0.89
Non-climatic covariates (included)						
Child age and gender	Yes	Yes	Yes	Yes	Yes	Yes
Household socio-economic factors (water sources, sanitation, mother's education, religion)	Yes	Yes	Yes	Yes	Yes	Yes
Community factors (clinic, health program)	Yes	Yes	Yes	Yes	Yes	Yes

Note: The estimates of all non-climatic covariates are presented in appendix B.
*** $p<0.001$; * $p<0.05$.

Effect of precipitation. The effect of precipitation on disease incidence is more complex, and a distinction should be made between excessive rainfall (floods) events and an incremental increase in precipitation. The results from the DHS data show that an incremental increase in the level of precipitation during the pre-monsoon season, both at the survey month and with a one-month lag, decreases the incidence of fever, but has no effect on diarrhea or ARI, everything else being the same (the full results include socio-economic variables and household access to basic services and are reported in the appendix D, tables D.1, D.2, and D.3). This finding can possibly be explained by the fact that higher rainfall during dry seasons makes groundwater more plentiful, improving the quantity of drinking water available from safe sources[12] as well as the hygienic environment overall.

Compared to the incremental change in precipitation, excessive rainfall events have a much larger effect on the incidence of fever. Relative to normal rainfall conditions, excessive rainfall events increase the odds ratio of fever by 82 percent during the pre-monsoon season, but reduce it by 33 percent during the monsoon season, controlling for all other variables. What explains the nonlinear relationship between rainfall and fever incidence across seasons? Some studies show that, in tropical and subtropical regions, high precipitation may cause the outbreak of diarrhea, whereas excessive rainfall may reduce vector-borne diseases by flushing larvae from their habitat in pooled water, reducing the vector population (McMichael, Woodruff, and Hales 2006), or improving water quality through the dilution of pathogens in an environment where water quality is poor.[13]

The nonlinear health impact of precipitation may be attributable to seasonal patterns in precipitation in Bangladesh. As shown in figure 2.2, the average monthly rainfall normally peaks in June and continues through July and August. Therefore, a heavy rainfall event during the monsoon season may generate a positive health benefit by reducing the vector population and diluting the contamination of pathogens in groundwater sources (as reflected in the estimated negative impact of heavy rainfall events on the odds ratio of fever, 33 percent).

12 Using DHS data from 25 countries in Africa, Bandyopadhyay, Wang, and Kanji (2011) find that high rainfall during the survey period in the dry season reduces the prevalence of diarrheal disease by around 3 percentage points.

13 For example, 51 percent of water-borne disease outbreaks were preceded by precipitation events above the 80th percentile of the monthly average for the particular weather station using a database of all reported outbreaks of water-borne disease in the United States from 1948 to 1994.

Caveats on data limitations. While national health surveys are valuable for analyzing the links between climate and health, the lack of integrated climate information collected at the survey locations limits their usefulness. The reliance on matching 35 weather stations to the survey location can result in large imprecision in the measurement of local climate conditions and, consequently, in the estimated impact of climate variability on the incidence of diseases.

Rainfall is widely regarded to be the most challenging meteorological parameter to measure due to its spatial and temporal variability. Along the spatial dimension, rainfall can vary over short distances and interact with local climate and topography. The availability of low-cost modern rain gauges and advances in remote-sensing precipitation products that estimate global and high-resolution precipitation open up the possibility to carry out more local-level validation studies to explore the best options for collecting rainfall data for research in the area of climate change and health.[14] Islam and Uyeda (2007) validate precipitation data by comparing rainfall data collected from satellite-based Tropical Rainfall Measuring Mission (TRMM) and from the rain gauge network from 1998 to 2002 in Bangladesh. They conclude that TRMM is useful for estimating the average values of rainfall in Bangladesh, but that satellite data overestimated the rainfall during the pre-monsoon period and in dry regions and underestimated it during the monsoon period and in wet regions.

The review of existing literature on health and climate change—in particular, the links between climate variability and infectious disease, malnutrition, and other climate-sensitive diseases—shows that this important area is still in its infancy. Leading researchers and experts have called for future analytical efforts focusing on empirical studies that use a wide range of analytical methods and data to assess the consistency of the climate-disease relationship in different societal contexts and across a variety of temporal and spatial scales. The analysis presented here takes an important first step in this direction.

In the context of Bangladesh, future studies should seek to use disease data collected from the national surveillance system and other sources of climate data, including both weather stations and remote-sensing precipitation data, to supplement studies using national health surveys. In particular, these studies should investigate the impact of extreme precipitation on infectious diseases by season. Research efforts should focus particularly on flood-prone areas where population density is high, as credible evidence is needed to assist policy makers in designing health adaptation programs.

14 In particular, the spatial resolution of satellite-based products may have become less a concern, with several precipitation products (including RFE, ARC, and CMORPH) achieving high spatial resolution of 0.1 x 0.1 (degree), covering an area of about 11 square kilometers). Such a level of resolution is likely adequate for measuring village-level precipitation in many rural areas.

Impact of household environmental conditions on health

The estimation of the health impact of household environmental services focuses on drinking water sources and sanitation facilities, as well as their interactive effect with an extreme precipitation event (defined as the dummy variable in the model). The drinking water sources and sanitation facilities are markedly different in urban and rural households; therefore, a separate analysis is carried out for urban and rural areas (the full estimation results are presented in appendix D, tables D.1, D.2, and D.3). The estimated impact of household environmental conditions on health is summarized in table 2.6.

Poor sanitation facilities are identified as a key determinant of disease incidence in urban but not in rural areas. During the pre-monsoon season in urban areas, a child living in a household with unsanitary toilet facilities (slab, pit, or open latrine) is two times as likely as a child living in a household with access to a flush toilet (septic sink) to experience an episode of ARI and nearly three times as likely if living in a household with no toilet, holding all other factors constant.

During the monsoon season, unsanitary toilet facilities significantly increases the incidence of fever. Given that fever is a symptom of many infectious diseases, this finding suggests that households with poor sanitary facilities are likely to be located in areas with unsanitary living environments, which are conducive to the development and spread of a wide range of pathogens and disease vectors.

The results are consistent with findings of the World Bank Water and Sanitation Program (WSP 2011), which are based on the 2007 DHS. That study found that inadequate sanitation is responsible for economic losses of about US$4.22 billion, equivalent to 6.3 percent of the country's gross domestic product (GDP) each year.

Contrary to findings in other studies, no statistically significant effect of drinking water sources on disease incidence is established in these two national surveys. The estimated impact of drinking water sources shows that a

Table 2.6 Impact of Water and Sanitation Facilities on Disease Incidence, Odds Ratio, 2004 and 2007

Survey and variable	Number of households	Fever	Diarrhea	ARI
Pre-monsoon season, 2004 DHS				
Urban				
Access to water sources				
Relative to piped water	473			
Tube well and other	1,598	1.072	0.525	1.165
Sanitation facility				
Relative to septic sink	555			
Slab latrine	435	1.34	0.807	1.933**
Pit latrine	465	1.241	0.76	1.924*
Open latrine	483	1.202	1.15	1.859*
No toilet	133	1.251	0.771	2.943**
Rural				
Access to water sources				
Relative to tube well	4,574			
Surface and other	254	1.058	0.862	1.435
Sanitation facility				
Relative to septic or slab	824			
Pit latrine	1,790	1.011	0.882	0.774
Open latrine	1,415	1.159	1.179	0.902
No toilet	800	1.09	1.241	0.761
Monsoon season, 2007 DHS				
Urban				
Access to water sources				
Relative to piped water	350			
Tube well	1,535	1.268		0.968
Surface and other	222	1.853		1.384
Sanitation facility				
Relative to flush or septic sink	649			
Flush to pit	345	1.834***		1.42
Pit latrine	311	1.802**		1.562
Open latrine	425	1.284		0.943
No toilet	377	1.654*		1.477
Rural				
Access to water sources				
Relative to tube water	3,435			
Surface and other	608	0.832	0.937	1.124
Sanitation facility				
Relative to flush or septic sink	504			
Pit latrine	718	0.787	0.782	0.643*
Open latrine	1,502	0.8	0.675	0.767
No toilet	1,319	0.788	1.004	0.676

*** $p<0.001$; ** $p<0.01$; * $p<0.05$.

child living in a household using surface water is more likely to contract diseases, such as fever and ARI, although the estimates are not statistically significant.[15] The lack of variation in drinking water sources is likely the underlying reason for the lack of statistical significance. In 2004 about 77 percent of urban households and 72 percent of rural households had a tube well. In 2007, about 95 percent of urban households had piped water, and 85 percent of rural households had a tube well.

The impact of water contamination is investigated by incorporating lagged precipitation variables in the model. In general, surface water is quickly contaminated in the event of heavy rainfall in areas where sewerage systems and sanitation services are poorly constructed, but it can take a much longer time to observe the impact of groundwater contamination after heavy rainfall. This suggests that the time period for observing the occurrence of disease outbreaks varies by season and depends on the quality of local water supply and sewerage infrastructure. The regression results with lagged climate variables, however, do not show a statistically significant effect of extreme rainfall on the incidence of the three childhood illnesses.

Summary of Results

While these results are broadly consistent with evidence from the existing epidemiological studies that focus on the impact of climate change on disease transmission and incidence, new findings emerge from this analysis:

- First, the impact of climate variability on disease incidence varies sharply between pre-monsoon and monsoon seasons. The estimated impact of an incremental change of a climate variable (temperature, humidity, and rainfall) is relatively small, but the impact of extreme precipitation on disease incidence is large and statistically significant. The impact of extreme precipitation on disease incidence varies by season.
- Second, as expected, household environmental conditions are identified as an important determinant of the incidence of childhood diseases, although the interactive effect of extreme precipitation with drinking water sources or sanitation facilities is not statistically significant. The estimation results show that unsanitary toilet facilities are a key factor determining the incidence of fever and ARI, but only in urban areas.
- Third, on average the incidence of childhood illnesses estimated from the national surveys varies by survey month and is strongly influenced by survey location. Therefore, using disease surveillance data to estimate disease incidence at disaggregate levels may be more reliable than using national health surveys.
- Finally, the findings provide useful information on the links between health- and climate-related conditions, but they should be interpreted with caution. The pathways from climate conditions to health are complex, and non-climatic factors and human adaptation responses to climate variability are often important underlying determinants of disease dynamics and population health. These factors are difficult to account for in some cases due to data deficiency and limitations in the existing analytical approaches.

The most effective means to improve our understanding of the links between health and climate change may include (a) improving the collection and use of ecological and environmental data using remote-sensing technologies and meteorological conditions from satellites at higher levels of resolution and (b) building a base of data for sufficiently long periods of time and across regions. The analysis in this section takes a first step in this direction in the context of Bangladesh.

Projecting Future Health Burden

The statistical relationship between climate variation and disease incidence estimated in the previous section provides critical parameters for projecting future health burden in the context of climate change. It is important to acknowledge that the health impact of climate change and variability remains highly uncertain, and extrapolating future health impacts of climate variability based on estimated statistical relationships at the local level can be highly imprecise (National Research Council 2001). However, projections are useful for understanding the potential economic and social implications of disease burden. In this section, future disease burden is projected under several assumptions (see box 2.2).

The climate projection is taken from the global circulation models adopted in World Bank (2009) which studies climate adaptation in Bangladesh. The vast majority of climate change predictions relevant to Bangladesh have been made using regional climate models. These models project that the rate of warming in South Asia will be significantly faster than that seen in the twentieth century and more rapid than the global mean rate of warming. During December, January, and February, warming is expected to be at its greatest and to be associated with a decrease in precipitation, while the consensus of regional models is that summer rainfall will increase.

Extreme weather events are projected to become more frequent in South Asia, including heat waves and excessive rainfall. Tropical cyclone intensity is also expected to rise by 10–20 percent and sea surface temperature is expected to increase by 2–4°C. Glacial and sea-ice melt and the expansion of the oceans due to higher mean temperature suggest that sea-level rise is certain (the minimum rise of about 40 centimeters by the end of the century is projected based on the most conservative climate change estimates; Map 2.2 presents the projected spatial distribution of disease incidence, temperature, and floods by 2050.

15 The interactive effect of extreme rainfall and household environmental services (drinking water sources and sanitation facilities) is also investigated. The regression results show no statistically significant interaction effect on health. This finding is at odds with widely held perceptions that the impact of extreme precipitation on disease incidence depends on the household's source of drinking water and type of sanitation facilities.

BOX 2.2 Key Assumptions for Projecting Disease Burden by 2050

First, the projection of future temperature and precipitation is based on 16 global circulation models from the fourth report of the Intergovernmental Panel on Climate Change (Yu et al. 2010), which predicted temperature rises during all months and seasons. The median warming prediction for Bangladesh across the models by the 2050s is 1.55°C. The projected monthly precipitation assumes that both annual and monsoon season precipitation increases, but that precipitation during the post-monsoon dry season does not rise. A median increase in precipitation of 4 percent by the 2050s compared with the baseline of 1980 for Bangladesh is assumed.

Second, the level of public investment in water and sanitation in the coming four decades is assumed to be sufficient to improve access to safer drinking water and sanitation services taking account of population growth. It is assumed that by 2050 all households currently without safe water sources will be connected to piped water and that households currently using open latrines will be provided with sanitation facilities that connect to a septic tank.

Map 2.2 Spatial Distributions of Disease Incidence, Temperature, and Floods by 2050

a. Disease incidence b. Temperature c. Floods

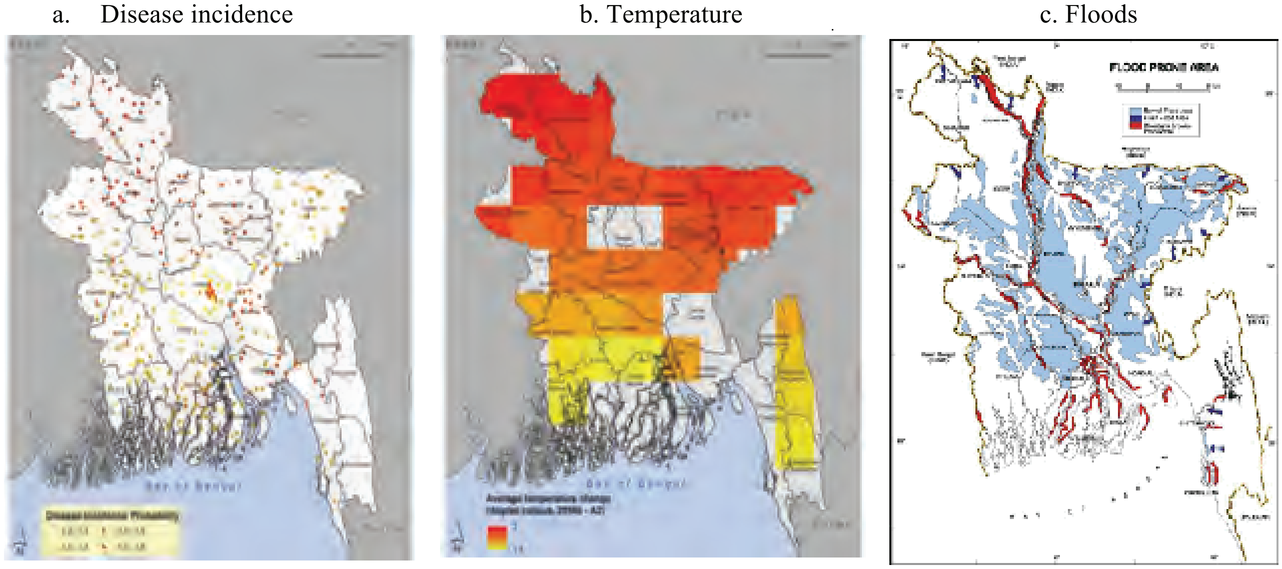


Table 2.7 summarizes the projection results by 2050. Under the scenario of a rise in average temperature of 2°C and increased frequency of excessive rainfall events across all regions (from 30 to 40 percent) in Bangladesh, the incidence of ARI and fever is projected to increase, but the incidence of diarrhea is projected to remain unchanged. The future health burden of these three childhood illnesses is projected to be about 14 million disability-adjusted life years (DALY), accounting for about 3.4 percent of GDP by 2050, based on the United Nations population projections for Bangladesh for 2050.[16]

This projection should also be regarded as the lower-bound estimate for at least two reasons. First, it covers only three childhood illnesses. Many studies in Bangladesh show that other diseases in adults, including hypertension due to water salinity caused by coastal flooding, malnutrition due to both increased food insecurity and high disease incidence (the two-way causation between nutrition and childhood illnesses, and mental disorders, have already become more prevalent in recent years and could be attributed to climate change).

Second, in the coming decades, the population—in particular, in urban and coastal areas—is likely to be more exposed to a variety of health risks of much bigger magnitude as the frequency of extreme weather events rises.

Table 2.7 Projected Health Burden by 2050

	Estimation from DHS data		Projection
Indicator	**2004**	**2007**	**2050**
Climate variable			
Average temperature (survey months)	23.5	27.8	29.0
Probability of flooding (%)	22.6	30.6	40.0
Disease incidence			
ARI			
Incidence (%)	18.7	12.3	23.0
Cases (thousands)	9,009	5,734	14,220
Diarrhea			
Incidence (%)	7.0	9.2	7.3
Cases (thousands)	3,376	4,296	4,529
Fever			
Incidence (%)	39.2	36.1	46.3
Cases (thousands)	18,916	16,787	28,605
Population ages 0–14 (thousands)	48,222	46,541	61,833

Note: The average temperature refers to the survey months. Flooding is defined as monthly rainfall above 1 standard deviation for a particular location and month.

How Much Climate Impact Can Be Mitigated through Development?

The projection in the previous section shows that temperature warming and more frequent extreme weather events, including both inland and coastal flooding, will increase the health burden under the assumption of maintaining the status quo, meaning that no additional targeted health adaptation interventions take place. As discussed in chapter 1, the impact of climate and weather variability on population health can be significantly modified by non-climatic factors, such as access to safe drinking water and sanitation facilities, access to basic health care services, health information, and better hygiene. Promoting development can be the best option for addressing climate change–related health issues. This begs the question of how much the projected excess health burden (as a result of climate change, holding all factors constant) can be averted through investment in key areas that are known to have a significant impact on health.

This section illustrates the impact of development investment on mitigating the excess health burden associated with climate change in the context of child health measured by both disease incidence and nutritional status. The impact of household environmental conditions on child health is estimated using the Bangladesh 2011 DHS (see appendix D, table D.4). The results are consistent with evidence compiled from many low-income countries by the World Health Organization (WHO 2003, 2009; WHO and PAHO 2010), indicating that children's health (both disease incidence and nutritional status) is influenced by a range of household-level factors, such as living conditions, access to safe water, sanitary toilet facilities, access to electricity, and maternal and child-care practices (such as hygiene practices).

Table 2.8 presents the results of a simulation exercise illustrating how much of the excess health burden, in terms of the incidence of childhood illnesses and premature deaths, that is attributable to the effects of climate change (warming and increased frequency of extreme weather events) can be averted by investing in basic infrastructure

16 The calculation of DALY for children under the age of five is the sum of morbidity and mortality from three illnesses. Morbidity is estimated from the projected disease cases for 2050, assuming that the average length per episode is four days, a DALY disability severity weight of 0.11 and a DALY age weight of 0.31, taken from WHO guidelines (Murray and Lopez 1997). Mortality is calculated based on total disease cases for 2050, which are estimated based on the conditional probability of mortality for each illness and discounted years of life lost per child, based on WHO guidelines.

Table 2.8 Simulation of the Health Impact of Climate Change (Warming and Flooding) by 2030 under Two Scenarios: Current versus Higher Levels of Investment

		Scenario 2: Additional investment to promote development			
Impact	**Scenario 1: Current level of investment**	**Infrastructure**	**Education**	**Nutrition**	**All three combined**
Incidence of illness (base line: 0.42 in 2011)	0.432–0.474	0.395	0.396	0.400	0.371
Averted deaths in children ages 0–14 (thousands)	464	−224	−215	−160	−605

Note: The incidence of childhood illness is projected based on regression estimation using the 2011 DHS, assuming that (a) average temperature increases by 1.5°C and (b) the probability of flooding increases from the current level of 0.225 to 0.35 by 2030 across the whole country. The population between the ages of 0 and 14 was 51 million in 2011(based on WHO figures) and is projected to be 66 million in 2020, and 61.8 million in 2030, based on U.S. projections. Overall development investment achieves (a) universal access to safe drinking water (that is, tube well in rural areas and piped water in urban areas), sanitary toilet facilities, and household access to electricity; (b) secondary female education attainment; and (c) elimination of child stunting in 2030.

(drinking water sources, sanitation, and electricity access), female education, and improving children's nutrition.

Table 2.8 presents the simulated impact on the incidence of childhood illnesses and premature deaths averted under two scenarios by 2030. The first one is the case where total investment is only sufficient to keep up with population growth, which means that the current levels of access to basic services, female education, and child nutrition status remain the same in 2030. The projected child deaths attributable to climate change would be around 464,000 in 2030.

The second scenario assumes that additional investments are made to achieve the following targets: (1) universal access to basic environmental services; (2) secondary female education attainment; and (3) elimination of child stunting by 2030. These targets are set in reference to both the current level estimated from 2011 DHS and the Millennium Development Goal (MDG) targets set for 2015 (see box E.1 in appendix E). In this scenario, about 605,000 child deaths would be averted. This is more than the total deaths that are projected to occur as a result of climate change, which indicates that targeting social investment in areas that are particularly important to child health could mitigate completely the excess child deaths attributable to climate change. The message is clear: while climate change is indeed an important issue and can affect health both directly and indirectly, focusing resources on traditional areas of development, such as improving access to safe drinking water, sanitation, electricity, female education, and child nutrition, is the best option for mitigating the adverse health impacts of increased climate risks.

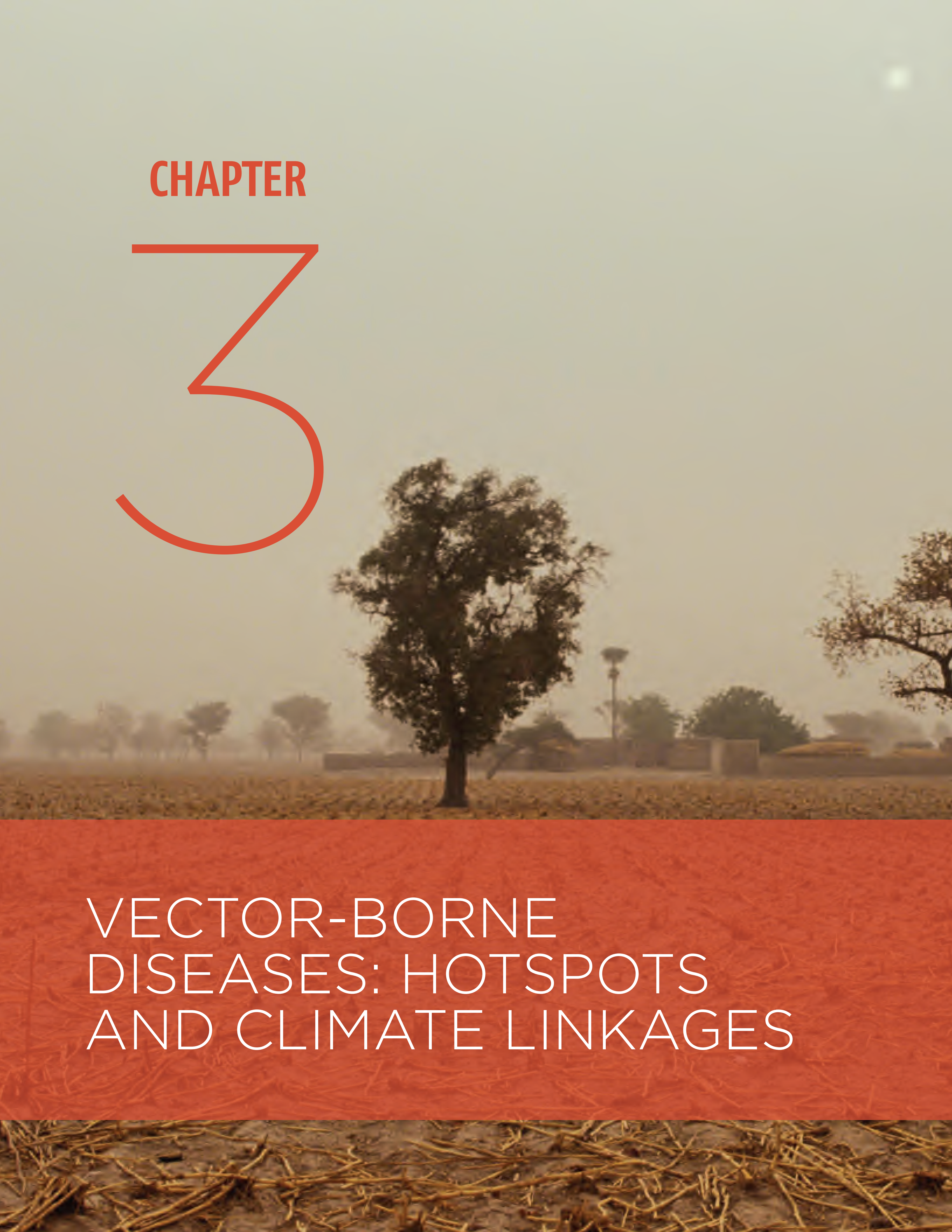
Key Messages

- Given that resource limitations (for example, medical personnel and drug availability) have always been one of the key constraints in Bangladesh, findings from this chapter—that the impact of climate variability on the incidence of childhood illnesses varies sharply between pre-monsoon and monsoon seasons—suggest that policy makers should focus on selectively targeting the implementation of disease control programs, both temporally (focusing on peak seasons) and spatially to reach the most vulnerable locations in terms of climate and health risks.

- The identification of vulnerable locations should be based on a comprehensive spatial database, which covers climate-sensitive diseases (incidence and outbreaks) and their seasonal patterns, patterns of extreme climatic events (such as heavy rainfall or prolonged periods of drought), and local environmental infrastructure (drinking water sources, sanitation, sewerage system, and waste management). The spatial database should be at a disaggregate level, such as unions in rural areas or slum and non-slum areas in urban areas.

- The disease data collected from the national surveillance system and the climate data collected from various sources, including both weather station and remote-sensing precipitation equipment, should supplement the national health surveys. Research efforts should focus particularly on flood-prone areas with high population density to provide location- and context-specific information for improving the implementation of disease management programs in these locations.

- While the adverse health consequences of climate change have gained recognition in recent years, it is important not to lose sight of the importance of socio-environmental conditions for health. A simple message is that focusing resources on traditional areas of development, such as improving access to safe drinking water, sanitation facilities, electricity, female education, and child nutrition and improving resilience and risk management capacity, can be the best health adaptation option in the face of increased climate risk.



CHAPTER

3

VECTOR-BORNE DISEASES: HOTSPOTS AND CLIMATE LINKAGES

Epidemiological studies across the world show that climate variability has a direct influence on the replication and movement of microbes and vectors of many vector-borne diseases (VBDs). The temporal and spatial changes in temperature, precipitation, and humidity affect the biology and ecology of vectors and intermediate hosts and, consequently, the risk of vector-borne disease transmission among the exposed population. Socioeconomic and environmental conditions—in particular, rapid urbanization and population migration—are also identified as important determinants of the spread and outbreak of VBDs.

The Bangladesh government, in the 2008 Climate Change Strategy and Action Plan, highlighted the importance of addressing the emerging public health risks associated with three VBDs: malaria, dengue fever, and kala-azar (see box 3.1). However, studies that focus on the links between climate conditions and the incidence of VBDs in Bangladesh are extremely limited, with the exception of malaria. This scarcity of empirical studies in the area of VBDs is largely a result of poor data sharing and underuse of VBD information and weather station data that are readily available in Bangladesh.

This chapter provides some evidence on the links between climate conditions and these three VBDs using several data sources that are available in Bangladesh. Section 3.1 summarizes the epidemiology of VBDs. Section 3.2 reviews existing data sources on key disease data in Bangladesh. Section 3.3 analyzes the temporal and spatial distribution of the three VBDs using the most recently available data in high-prevalence regions. Section 3.4 presents a statistical analysis of the correlation between climate variables and the incidence of VBDs.

BOX 3.1 Major VBDs in Bangladesh

Malaria is one the most common vector-borne diseases in tropical regions, and pathogens are protozoan that are transmitted to humans by the Anopheles mosquito. Anopheles mosquitos tend to prefer a temperature range from 24°C to 27°C. If the overall temperature rises, their habitat may be reduced, and the breeding period may be shifted and prolonged, leading to a possible change in malaria distribution in Bangladesh.

Dengue fever is transmitted by Aedes aegypti, a type of mosquito that feeds primarily on humans and thrives especially in urban environments where still water and plant containers are abundant. The intensity of dengue vectors is determined mainly by the availability of breeding sites such as water containers. Based on studies in some areas of Bangkok, the abundance of vectors is largely independent of rainfall.

Kala-azar is caused by the female sand fly Phlebotomus argentipes on the Indian subcontinent, including Bangladesh. The disease is lethal if left untreated and affects approximately 500,000 new patients annually worldwide, with 60 percent of new cases on the Indian subcontinent. Climate adaptation measures (for example, building more embankments in response to sea-level rise) may be conducive to the spread of visceral leishmaniasis vectors, increasing the number of cases of kala-azar. Kala-azar cases in Bangladesh are found to cluster near flood control embankments.

The Epidemiology of Vector-Borne Diseases

Malaria, dengue fever, and kala-azar are all transmitted between human hosts by vectors.[17] The effect of climate variability on the incidence and caseload of VBDs is mediated through its impact on each component of the transmission cycle of different pathogens. The transmission components include pathogen (viral, bacterial, and parasites), vector (mosquito), non-biological vehicle (water, soil), non-human reservoir (mice, rodent), and human host.

Many studies show that climate variables such as temperature, precipitation, and humidity affect the life cycle of many disease pathogens and vectors and, consequently, the outbreak and incidence of disease.[18] Changes in temperature are therefore likely to have the biggest impact on the transmission of vector-borne diseases. Transmission occurs at two ranges of temperature: 14–18°C at the lower end and 35–40°C at the upper end.[19] An increase in temperature in the lower range has a significant and nonlinear impact on the extrinsic incubation period and consequently on the transmission of disease (Watts et al. 1987). A rise in temperature above 34°C generally has a negative impact on the survival of vectors and parasites (Rueda et al. 1990), reducing transmission risks. However, at around 30–32°C, vector capacity can increase substantially as result of a reduction in the extrinsic incubation period.[20] Reeves et al. (1994) find that extremely high temperatures can actually increase mosquito mortality, which decreases the transmission of arboviral disease (related to dengue fever).

Several studies have shown that rainfall is positively associated with dengue incidence. Rainfall could facilitate the spread and transmission of vector-borne diseases by expanding breeding sites. Heavy rainfall contributes to inland water bodies and flooding almost every year in Bangladesh, creating a suitable environment for the vector.

Humidity is another critical climatic factor that can influence the survival and transmission of VBD pathogens and vectors. Most studies that include the humidity variable show a consistent pattern of rising humidity being positively associated with disease incidence, suggesting that a high level of humidity is conducive to the replication and survival of many pathogens and viruses. Humidity is found to be one of the most critical determinants of dengue fever (Hales, Edwards, and Kovatz 2003).

While these climate variables are correlated with a high incidence of VBDs, the seasonal patterns of infectious diseases are one major pathway through which climate change can have a potentially drastic effect on the dynamics and outbreaks of disease (Pascual and Dobson 2005). For example, long-term climate change affects seasonal patterns, altering the timing of the onset of the monsoon season or lengthening the hot season, all of which can affect the key components of the transmission cycle. A longer monsoon season may affect the reproduction rate of pathogens and increase the coverage of still water to facilitate the geographic spread of mosquitos and, consequently, the spread of VBD risk.

However, the impact of climate variability on the incidence of many vector-borne and water-borne diseases can be significantly modified by local environmental conditions and human adaptation responses. For example, in a tropical region such as Bangladesh, drought can lead to an increase in dengue fever because more people may store water in open containers in areas where access to piped water is limited, thus increasing the number of breeding sites for mosquitos. Another striking example of the importance of non-climatic factors on VBDs is the sharp difference in dengue fever cases along the United States and Mexico border, with about 5,033 cases reported on the Mexico side, compared with only 100 cases on the United States side between 1980 and 1996; given the identical climatic conditions, the difference is attributable almost entirely to socio-environmental factors.

Key Data Sources and Issues for VBDs

Three main institutions in Bangladesh are directly involved in the collection of data on major water- and vector-borne diseases. These include (1) the Directorate General of Health Services (DGHS) under the Ministry of Health and Family Welfare (MoHFW); (2) the Institute of Epidemiology, Disease Control, and Research (IEDCR); and (3) the International Center for Disease and Diarrhoeal Research, Bangladesh (ICDDR,B).

The DGHS is responsible for the Management Information System (MIS) of the health system, which records a wide range of diseases collected from health facilities across the country.

17 In epidemiology, infectious diseases are broadly classified as anthroponoses if the natural reservoir of the pathogen is human and zoonoses if it is animal. Direct transmission is defined as when the pathogen is transmitted directly between human hosts or between animals through physical contact or droplet exposure, while indirect transmission is defined as when the pathogen is transmitted between human hosts by either a physical vehicle (water) or a biological vector (mosquito).

18 For example, Hales, Edwards, and Kovats (2003) show that warm ambient temperature and high humidity increase the probability of transmission by shortening the time for mosquitos to become infectious, resulting in higher vector-borne incidence.

19 Jetten and Focks (2006) find that warming temperature increases the incidence of dengue fever up to a threshold and that, when passing the threshold, rising temperature reduces the incidence of many vector-borne diseases. For regions where cases of dengue are already present, the impact of an increase in average temperature is substantial—the aggregate epidemic risk is increased by an average of 31–47 percent for a 1°C increase in mean temperature (Patz et al. 1996).

20 The relationship between temperature and the survival of a wide range of pathogens is complex and nonlinear (Patz et al. 2010). Extreme temperatures (too high and too low) are destructive to the survival of pathogens because their physiological tolerance has a limit. But a gradual increase in temperature in the spectrum of moderate temperatures is likely to increase the survival and spread of pathogens and viruses.

The IEDCR also collects information on water- and vector-borne diseases through disease surveillance and disease outbreak investigations. ICDDR,B has also developed a surveillance system for diarrheal disease and vector-borne infections (malaria) over the past decade. In addition, the incidence of water- and vector-borne diseases among children under the age of five is collected through nationally representative Demographic and Health Surveys (DHSs) at regular intervals of every three years by the National Institute of Population Research and Training (NIPORT). Table 3.1 summarizes the data sources for these three VBDs.

As part of the capacity assessment, focus group interviews were conducted to identify major data issues and ascertain the quality of data from different agencies in charge of collecting health data in Bangladesh. Poor data quality and inadequate institutional capacity, ranging from the primary data sources (the health facility level) to the final centralized data system (health MIS) were identified as the key problems by all agencies.

The inaccuracy of disease data result largely from lack of computer facilities and designated staff for data collection and database management at the facility level, in particular hospitals. The responsibility for collecting and recording disease data rests on doctors and nurses who are already overloaded with health service delivery. The information collected on VBDs is often not based on laboratory tests due to lack of diagnostic devices. Also, the data are not collected using a standardized health format; for this reason, the data reported to the health MIS is likely to be incomplete and inconsistent across regions and over time.

Another important data deficiency is the omission of disease cases reported from private health practitioners where a large proportion of VBD patients are treated. It is estimated that more than half of total annual cases of disease not recorded in the health MIS because cases are treated in private sector health facilities .

Table 3.1 Key Data Sources for VBDs

Indicator	Dengue	Malaria	Kala-azar
Source	Disease Control Room of Directorate General of Health Services (DGHS)	National Malaria Control Program (NMCP) of DGHS	Malaria and Parasitic Disease Control Unit (M&PDC) of DGHS
Period and frequency	Monthly from 2000 to 2011	Monthly from 2007 to 2011; yearly 2000 to present	Yearly from 1994 to 2007; monthly from 2008 to 2011
Level	District	District	Yearly data at district level; monthly data at upazila (subdistrict) level
Comments	Cases were confirmed by different government and private hospitals of Bangladesh	Cases were confirmed by different government hospitals (mostly upazila health complex) and nongovernment organizations	Cases were confirmed by different government hospitals (mostly upazila health complex)

The MoHFW has taken some initiatives to improve the health MIS to ensure the delivery of timely and reliable disease information. These include regular and timely publication of health bulletins, modernization of the data collection and storage system in a central department, and creation of an assessment report using Health Metric Network assessment tools. The key findings from the focus group interviews suggest that efforts to improve the quality of health data should target lower-tier facilities, such as subdistrict-level hospitals and clinics where the regulator's collection of disease data is taking place, and include private health facilities. Data should be verified using multiple data sources to check consistency and reliability before they are published in the health MIS.

The Temporal and Spatial Distribution of VBDs

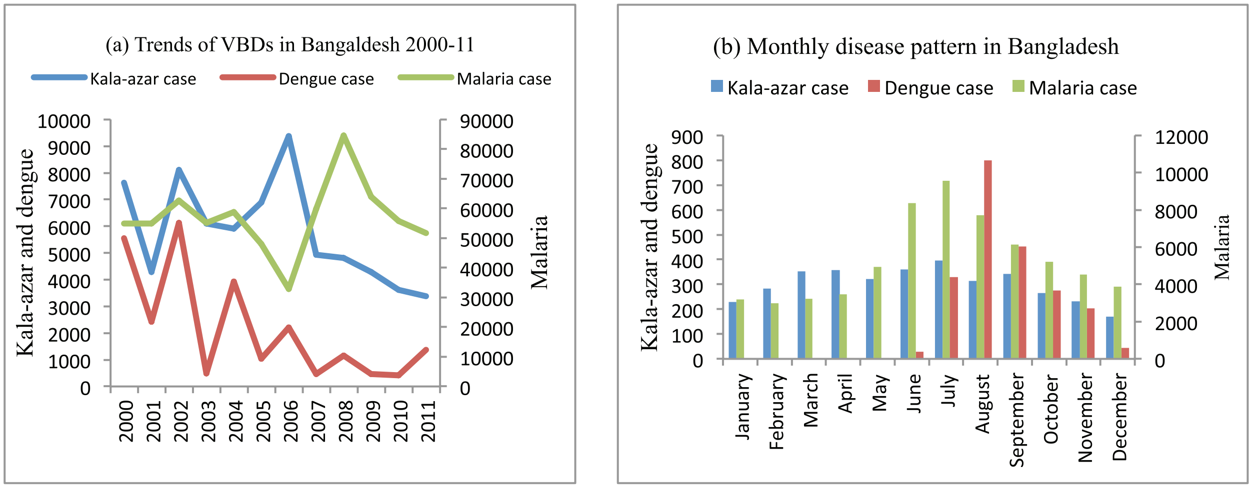
Temporal and seasonal trends

Figure 3.1, panel a, presents the trends of three VBDs from 2000 to 2011 and their seasonal patterns based on monthly VBD cases collected from the government disease surveillance system managed by the DGHS. The caseloads for all three VBDs vary erratically from year to year, with no clear trends of increase or decrease observed for this period.

For dengue fever, a total of 23,518 cases and 239 deaths were reported during the period of 2000–11. The highest caseload was recorded in 2002 (6,132), followed by 2000 (3,964), and the lowest caseload was in 2010 (409). In the case of kala-azar, a total of 104,313 cases were recorded from the 36 districts during 1994–2011. A declining trend of cases is seen from 2004 to 2011. The number of malaria cases remained stable between 2000 and 2005 but spiked in 2008. However, due to inconsistent data collection across locations and over time, caution should be taken in reaching any conclusions regarding the trends of VBDs using these data sources.

Figure 3.1, panel b, presents the seasonal patterns of three VBDs using the average monthly number of disease cases constructed for the period 2000–11. A clear seasonality pattern is evident for dengue fever and malaria, but not for kala-azar. The dengue fever season starts in July, peaks in August (accounting for 37.5 percent of total annual cases on average), and declines in October (20.5 percent). In the Dhaka area where more than 98 percent of cases are reported, no cases were found from January through April during 2000–11. An outbreak of dengue fever and dengue hemorrhagic occurred in Dhaka in 2000, with more than 5,551 hospitalized cases and 93 reported deaths between July and December.

FIGURE 3.1 Trends and Monthly Disease Patterns of VBDs, 2000–11



While malaria cases are recorded throughout the year, the malaria season starts in June (accounting for about 13.2 percent of annual total cases), peaks in July (15.1 percent), and declines from September onward (accounting for about 12.2 percent in September). The seasonal pattern of kala-azar disease is less obvious, with the caseload rising gradually from March and declining from October onward.

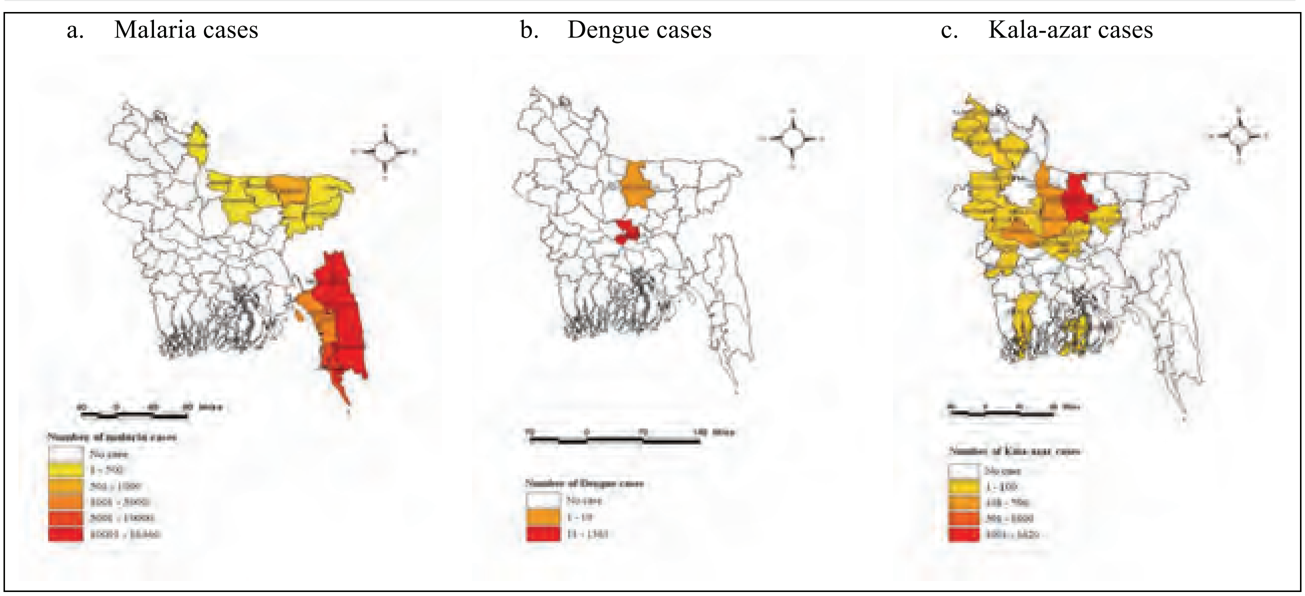
Disease hotspots

In general, the infectious disease hotspots are likely to change over time, depending on local climate conditions, geographic shift of seasonal patterns, local environmental conditions, and population movement. Map 3.1 presents the spatial distribution of dengue fever, kala-azar, and malaria using the most recently available data of 2011.

The cases of dengue fever were reported primarily in two cities, Dhaka and Khulna. Using geographic information system (GIS) technology, Ali et al. (2005) showed that dengue clusters are less identifiable in areas farther away from major hospitals, suggesting that proximity to hospitals determines whether cases of dengue are diagnosed.

In Bangladesh, 45 out of 64 districts are recorded to have kala-azar cases. Mymensingh is the most endemic region, accounting for about 48.5 percent of total cases, followed by Pabna (11.4 percent) and Tangail (9.4 percent) (Rahman et al. 2008). Five upazilas in the Mymensingh District have the highest number of kala-azar cases. At the aggregate level, about 5,000 new cases of kala-azar are

Map 3.1 Geographic Distribution of Vector-Borne Diseases in 2011



reported every year, although officially recorded cases are likely an underestimation due to lack of access to diagnostic devices and an inadequate public health surveillance system in many parts of the high-endemic areas.

The map of malaria shows that the majority of malaria cases occurred in 13 districts close to the areas bordering India and Myanmar, accounting for 98 percent of the reported cases of malaria identified in Bangladesh. These 13 districts are difficult to reach due to the hilly terrain and lack of surveillance and information systems. Therefore, substantial underreporting of malaria cases in this region by the Ministry of Health is highly plausible. Bandarban, Khagrachari, and Rangamati, collectively known as the Chittagong Hill Tracts districts, recorded the highest incidence of malaria in Bangladesh. Rangamati District has the highest number of cases of malaria throughout the year, followed by the districts of Bandarban and Khagrachari. Moulvibazar District, situated in the northeast part of the country, is also classified as a high-malaria-risk area, with malaria cases rising significantly from June to August in 2011 to reach the level of Chittagong District.

Statistical Correlation between Climate Conditions and VBDs

In this section, the statistical correlation between climate variables and VBD cases is analyzed using the monthly disease cases collected from the health surveillance system managed by DGHP and validated by ICDDR,B. The Spearman rank correlation coefficient is used to assess the strength of correlation. Both current and lagged climate variables are used in the correlation analysis to allow for the long incubation period of many of the vectors.[21]

Dengue fever

The analysis focuses on Dhaka District, where most (about 92 percent) of the total number of dengue cases were recorded during the period 2000–11. The results presented in table 3.2 show a strong correlation between lagged climate variables (rainfall, temperature, and humidity) and dengue cases. Monthly rainfall (both current rainfall and rainfall lagged up to three months) is positively correlated with dengue cases, with the highest correlation observed in two-month lagged rainfall (0.73). The average temperature (lags of up to three months) is also significantly correlated with dengue cases, as is humidity level. These results provide important evidence on the links between climate variability and dengue fever in Bangladesh.[22]

The findings of stronger correlation between lagged climate variables (lags of up to two to three months) and the cases of dengue fever are particularly useful. They suggest that closer monitoring of climate conditions (rainfall, temperature, and humidity) in June and July (one or two months preceding August, the expected peak month for dengue fever) can provide some prediction of the caseload of dengue fever in August and thereby help in preparedness. For example, preventive and case control measures should be put in place in high-risk locations such as Dhaka when abnormal climate (for example, higher rainfall and hotter weather than long-term means) is observed one or two months preceding the peak month of August.

Malaria

The statistical analysis is based on monthly data collected by ICDDR,B from three hilly districts (Khagrachhari, Rangamati, and Bandarban) and one coastal district (Cox's Bazar) from 2007 to 2011. Table 3.3 presents the results, which show that high rainfall is positively correlated with malaria cases in Rangamati and Khagrachhari, while in Bandarban the positive association is strongest with one-month lagged rainfall. High humidity is also positively correlated with malaria cases. In all the four districts, high temperature increases the number of malaria cases with a one- to two-month lagged effect, and the correlation between climate variables and malaria cases becomes stronger as the location of the district is farther away from the coastal area, with the correlation in Cox's Bazar (an inland district) being the weakest.

Table 3.2 Spearman Rank Correlation of Dengue Cases and Climatic Factors

Factor	Lag 0	Lag 1	Lag 2	Lag 3
Total rainfall	0.39	0.64	**0.73**	0.54
Average minimum temperature	0.43	0.66	**0.67**	0.55
Average maximum temperature	0.05*	0.26	0.44	**0.58**
Average humidity	0.60	**0.74**	0.65	0.33

* Statistically not significant. Highest correlations are marked as bold.

21 For example, research shows that the dengue vector, Aedes mosquito, takes 7 to 45 days to become an adult from an egg.

22 Other studies have found similar results in the other settings. In Rio de Janeiro, Brazil, dengue incidence was significantly correlated with a 0-month time lag for minimum and maximum temperature and a 1-month time lag for accumulated rainfall. Minimum relative humidity and total rainfall at a 2-month time lag and minimum and maximum temperature at a one-month time lag were correlated with dengue incidence in Guangzhou, China. In Guadeloupe, French West Indies, dengue incidence was most positively correlated with three climatic factors: relative humidity with a 7-week lag, minimum temperature at a 5-week lag, and mean temperature at an 11-week lag. In Barbados, the strongest correlation was found between dengue incidence with vapor pressure at a 6-week lag, precipitation at a 7-week lag, minimum temperature at a 12-week lag, and maximum temperature at a 16-week lag. In Kaohsuing City in Taiwan, China, amount of rainfall, relative humidity, and minimum and maximum temperature were positively correlated at a 2-month lag with dengue incidence for 1995–2000 and at a 3-month lag for 2001–08. For 1992–2001, dengue incidence in Jakarta, Indonesia, was correlated with a 2-month lag of rainfall and 1-month lag of temperature.

Table 3.3 Spearman Correlation between Malaria Cases and Climate Conditions

District and climatic factors	Lag 0	Lag 1	Lag 2	Lag 3
Khagrachhari District				
Total rainfall	**0.73**	0.63	0.36	0.04*
Average minimum temperature	**0.7**	0.66	0.48	0.16*
Average maximum temperature	0.15*	0.38	**0.57**	0.57
Average humidity	**0.65**	0.38	0.01*	−0.41*
Rangamati District				
Total rainfall	**0.7**	0.66	0.49	0.08*
Average minimum temperature	0.71	**0.72**	0.53	0.19*
Average maximum temperature	0.20*	0.5	**0.6**	0.53
Average humidity	**0.7**	0.39	0.02*	−0.37*
Bandarban District				
Total rainfall	0.59	**0.66**	0.46	0.16*
Average minimum temperature	0.66	**0.8**	0.72	0.43
Average maximum temperature	0.34	0.57	**0.62**	0.48
Average humidity	**0.76**	0.67	0.45	0.15*
Cox's Bazar District				
Total rainfall	0.39	**0.44**	0.24*	0.02*
Average minimum temperature	0.29	0.43	**0.5**	0.35
Average maximum temperature	−0.08*	0.21*	0.57	**0.68**
Average humidity	**0.44**	0.38	0.22	−0.07*

*Statistically not significant. Highest correlations are marked as bold.

Table 3.4 Spearman Rank Correlations of Kala-azar Cases and Climatic Factors

Factor	Lag 0	Lag 1	Lag 2	Lag 3
Total rainfall	**0.26**	0.25	0.05	−0.10
Average minimum temperature	**0.34***	0.17	−0.15	−0.20
Average maximum temperature	**0.34***	0.14	0.01	−0.11
Average humidity	**0.14**	0.11	−0.04	−0.14

*Statistically significant. Highest correlations are marked as bold.

Kala-azar

Table 3.4 presents the Spearman correlation analysis for kala-azar. The correlation between kala-azar cases and climate variables is much weaker than that for dengue fever and malaria. The Spearman rank correlation coefficients are statistically significant only for temperature (minimum and maximum). Unlike the results for dengue fever and malaria, no lagged climate variables are correlated with kala-azar cases.

Another noteworthy finding is that the correlation changes from positive to negative after two- or three-month lags, although the lagged correlation is statistically insignificant. For example, the correlation between the current monthly average temperature and kala-azar cases is 0.34, but it changes to −0.15 for temperature with a two-month lag and to −0.2 with a three-month lag. The results show a strong positive correlation between temperature and number of cases. Average humidity is also positively correlated with kala-azar cases, but weaker than temperature and rainfall variables.

While we did not find a significant correlation between climate variables and kala-azar, some research has been conducted in this area in Bangladesh. Using data collected in the highly endemic district of Mymensingh from 2000 to 2004, Alam (2005) investigated the links between the abundance of the kala-azar vector and environmental factors, focusing on soil conditions (temperature, moisture, pH level, and organic composition) and housing structure. The results show that organic composition is significantly correlated with the abundance of vector species and that houses with mud walls are twice as likely to have vector species than houses with walls made of tin.

In another study, using active surveillance data from 2006 to 2009 collected jointly by ICDDR,B and the University of Tsukuba in Trishal upazila of the Mymensingh District, establishes a statistically significant correlation between the kala-azar caseload and household location as well as a gender effect on the incidence of kala-azar disease (in general, males have a higher risk of contracting kala-azar than females).

Summary of Results

The findings presented here shed light on the seasonal patterns of three VBDs and their sensitivity to climate variables. The results confirm a strong correlation between short-term climate variability and VBD cases in high-prevalence regions of Bangladesh. In the case of dengue fever and malaria, all climate variables (temperature, rainfall, and humidity), both current and lagged, have a strong correlation with disease caseload. For kala-azar, only temperature is significantly correlated with the number of cases. Soil conditions and housing structure were also found to be correlated with the abundance of the kala-azar vector in the high-incidence district of Mymensingh.

However, the correlation analysis does not control for local socio-economic and environmental conditions and therefore has limitations for projecting future VBD burden or mapping the geographic distribution of VBDs in Bangladesh.[23] The findings suggest that the implementation of VBD control programs should target resources (diagnostic equipment and medical staff) not only in high-risk locations but also in seasons with high caseloads.

Interdisciplinary approach should be promoted for research on VBDs and climate links. For example, the epidemiological research that is based on laboratory or field experiments and mathematical modeling of the dynamics of infectious disease epidemics can be combined with the dose-response between the exposure of pathogens and the disease incidence to assess the health impact of future climatic risk factors. This approach has been used by the U.S. Environmental Protection Agency to develop controls for key water-borne disease agents and by the World Health Organization, which conducted a global assessment of the health impact of climate change (Campbell-Lendrum, Corvalan, and Pruss-Ustun 2010).

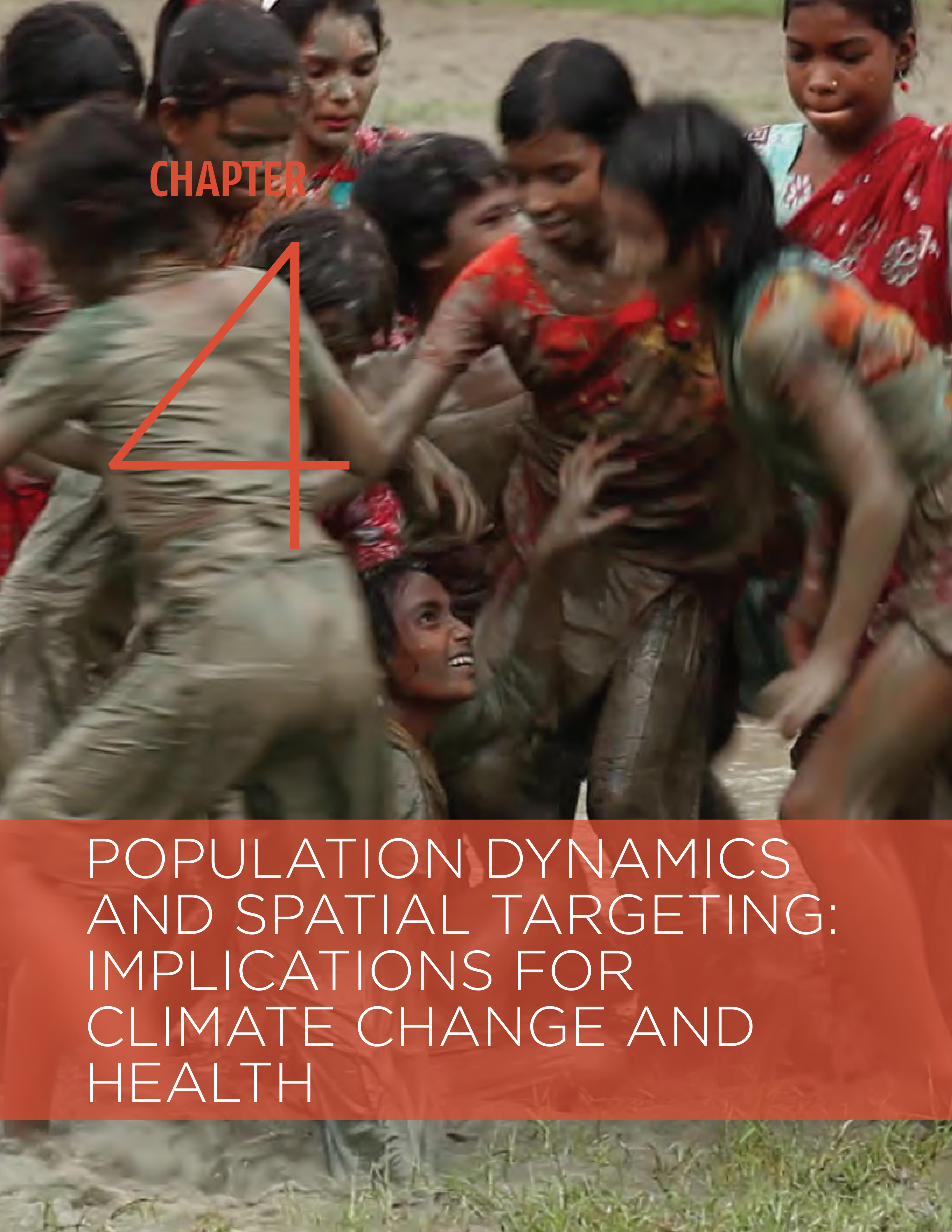
Key Messages

- While the incidents of VBDs are projected to increase with climate change in Bangladesh, as highlighted in the government's Climate Change Strategy and Action Plan, VBDs pose a less critical public health threat than water-borne diseases such as diarrhea or the high prevalence of malnutrition. This is due to the fact that a wide range of non-climatic factors (ecological, environmental, and socio-economic factors) are known to influence the incidence of VBDs and that the health burden associated with VBDs has remained relatively small (1 and 0.9 percent of deaths from malaria and dengue, respectively, compared with 10.7 percent from diarrhea, which is even higher when taking account of malnutrition).
- Addressing existing and emerging VBDs in Bangladesh, future studies should focus on filling in the information gap on the cost-effectiveness of various VBD control interventions. Given the large uncertainties about the impact of climate variability, social and environmental conditions, as well as urbanization and population migration on the replication and movement of microbes and vectors, it is plausible that vector-control programs in the context of Bangladesh may be less cost-effective than case management interventions. However, lack of rigorous cost-effectiveness analysis in this area limits the possibility of providing concrete answers to questions of this nature.
- A first step in this direction is to collect data on the impact and cost of a variety of VBD programs in Bangladesh, covering vector control programs, community-based awareness initiatives, and projects designed to improve access to rapid diagnostic devices and essential drugs.
- To provide information for improving the targeting of resources to address VBDs, efforts should focus on three key areas: (1) improving data collection on VBDs from both public and private clinics to identify correctly the changes in seasonal patterns and geographic distribution of VBDs; (2) integrating epidemiological data with environmental and climate data and promoting interdisciplinary research to improve the robustness of the evidence; and (3) conducting spatial assessment of local health facilities (availability of trained medical staff to diagnose and treat VBD cases and essential drugs and diagnostics equipment) against the projected risk of VBD outbreaks in high-prevalence locations.

23 Although socio-economic factors may influence individual cases, the data collection methods used preclude us from understanding their influence on specific cases.

CHAPTER 4

POPULATION DYNAMICS AND SPATIAL TARGETING: IMPLICATIONS FOR CLIMATE CHANGE AND HEALTH



One of the key features of population dynamics in Bangladesh is the rapid but poorly planned urbanization process that has been taking place over the past few decades, with the share of urban population rising from about 19 percent in the 1980s to about 30 percent in 2012. The large population movement and the increased population density in urban areas—in particular, the rapid expansion of urban slums, driven by a combination of poverty and recurring natural disasters—are likely to alter the patterns and spread of disease, exposing the population to health risks.

The results from the previous two chapters show strong geographic and seasonal patterns of infectious diseases in Bangladesh. While these spatial and temporal characteristics of the transmission of vectors and diseases can be influenced by climate variability and extreme weather events, local adaptation—in particular, living conditions and the treatment and control of disease—play a critical role in mitigating the adverse health consequences of climate risk. For example, malaria was once common in many parts of Europe, but it is no longer found in these regions as a result of improved living conditions (water supply infrastructure, sewerage system, and screening of homes in addition to aggressive vector-control programs).

Therefore, assessing the geographic targeting of measures to fight the prevalence of disease, at the disaggregate level, provides critical information for informing the design and implementation of health adaptation interventions. Such an assessment would help the Government of Bangladesh and its development partners to improve their ability to plan, prioritize, and target policy interventions and investments to reach the population that is most vulnerable to infectious diseases in locations where the health adaptation capacity is more limited.

This chapter focuses on three issues. First, it looks at how population dynamics have evolved over the past decade in Bangladesh. Second, it presents the measurement of adaptation capacity using complementary data sources. Finally, it conducts a spatial mapping of geographic targeting of public financing of health adaptation capacity, including basic environmental infrastructure and health facilities and disease prevalence.

Key Features of Population Dynamics

According to the United Nations population projections, the Bangladesh population will reach 218 million by 2050, from around 147 million in 2012, with urban areas estimated to absorb the additional 70 million of total population growth. While the growth of rural population is projected to halt by 2025,[24] the urban population will increase from the current 34 million to more than 100 million by 2050, predominantly as a result of rural-urban migration (Streatfield and Zunaid 2008).

More alarming, the fastest growth is taking place in urban slums, at around 7 percent a year, twice the average growth rate of the urban population. Based on the most recent data, the proportion of slum population in urban areas is about 35.2 percent on average, but in Dhaka, more than one-third (37.4 percent) of the total population (9,136,182) is currently living in slum areas, compared with about 19.5 percent in Khulna City Corporation.

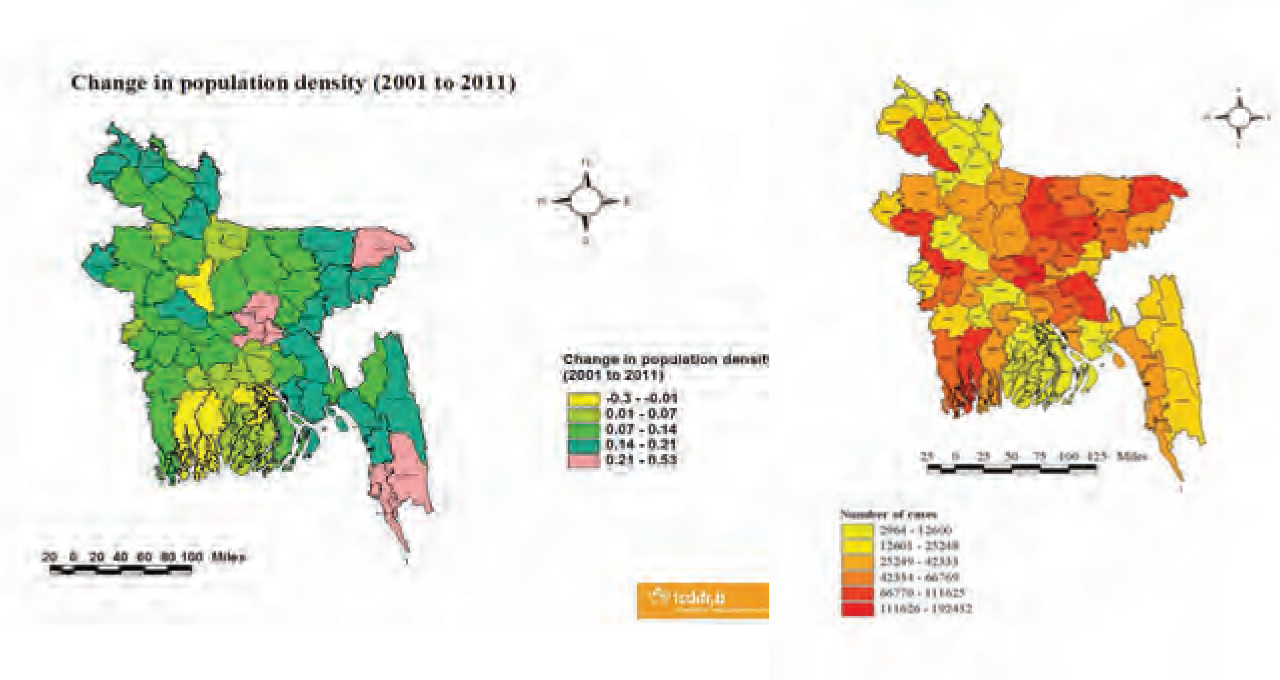
The rapid population growth and rural-urban migration have shaped the spatial distribution of population density. While Bangladesh is the third most densely populated country in the world, substantial variations exist across regions. Map 4.1 presents the current population density in 2011 and changes between 2001 and 2011 for 66 districts using the 2001 and 2011 population censuses. In 2011, the most populated districts were Dhaka, Chittagong, Comilla, Mymensingh, Tangail, Sylhet, Gazipor, and Bogra (ranging from 12 million in Dhaka to 3.4 million in Bogra). The least populated districts were Bandarban, Rangamati, Khagrachhari, Meherpur, Jhalkati, Narail, and Borguna (population between 390,000 in Bandarban to 918,000 in Borguna).

The population growth rate also varies substantially by region. Over the period of 2001 to 2011, the average district population growth rate was about 1.2 percent. However, some districts grew much faster (Gazipur, 6.7 percent; Dhaka, 4.2 percent; Narayanganj, 3.6 percent; Sylhet, 3.4 percent), while a few districts shrank (Barisal, −0.13 percent; Jhalkati, −0.17 percent; Khulna, −0.25 percent; and Bagerhat, −0.47 percent). The underlying reasons for the negative population growth in these districts are not fully established, although extreme weather events, natural disasters, and poverty are all likely to have contributed to the large outflows of population. The complete list of population growth by district is summarized in table D.5 in appendix D.

The district-level information, however, presents only a partial picture, concealing variations of population density between rural and urban areas and, more important, within urban areas. The rapid but poorly planned urbanization in Bangladesh has been associated with many emerging health problems, particularly in urban slums where the population growth rate is the highest. However, the health status of the urban slum population is imprecisely estimated due to sampling biases in current nationally representative household surveys such as the Demographic and Health Surveys (DHSs) and household expenditure surveys. These surveys are important sources of information on the spatial distribution of health status and social-economic conditions, but the sampling design has not adequately captured the new features of population dynamics—in particular, the rapid increase in urban-slum population (see box 4.1).

24 Another approximately 30 million will be added to the current 108 million people living in rural areas by 2050.

Map 4.1 Population Density and Growth



BOX 4.1 Issue of Sampling Bias

National household surveys such as the DHS omit the urban slum population. The health indicators for urban areas across regions, therefore, do not capture a significant proportion of the urban slum population. The recent joint initiatives by the government and the U.S. Agency for International Development (USAID) have attempted to address this issue. The major outcomes of this joint effort are the three waves of Urban Health Surveys (UHSs) conducted in 2006, 2011, and 2013, covering slum and non-slum areas of the major city corporations, including Dhaka, Chittagong, Khulna, Rajshahi, Barisal, and Sylhet.

A comparison of health indicators using the 2006 UHS and the 2007 DHS reveals the extent of sampling bias as a result of inadequate coverage of the slum population in national health surveys. Table B4.1.1 presents the incidence of diarrhea and stunting for Dhaka areas using the two surveys. The comparison shows large discrepancies in these two health indicators. Diarrhea incidence was about 11.3 percent in Dhaka using the DHS data, while it was much lower according to the 2006 UHS (4.3 percent in non-slum areas, 8.2 percent in small- and medium-size slum areas, and 6.8 percent in large slum areas).

Table B4.1.1 Potential Bias of Health Indicators of Urban Population: An Example of Dhaka

Data source	2006 UHS	Lag 1	Lag 2	2007 DHS, all areas
	Large slum	Medium, small slum	Non-slum	
Number of observations	721	664	546	960
Health indicators				
Diarrhea incidence (%)	6.8	8.2	4.3	11.3
Stunting rate (%)	59.4	51.2	39.6	28.2

Note: The survey months are March–July for the 2006 UHS and April–August for the 2007 DHS for urban Dhaka area.

Child malnutrition status in urban areas is significantly underestimated using the DHS data: the average stunting rate among children under five in Dhaka is about 28 percent using the 2007 DHS, compared with the estimate using the 2006 UHS (39 percent in non-slum areas in Dhaka, 51 percent medium- and small-size slums, and 59 percent in large slums).

The average population density in an urban area is about 23,378 per square kilometer (ranging from 7,152 in Barisal City Corporation to 29,857 in Dhaka Metropolitan Area). In Dhaka slums, population density is around 205,415 per square kilometer, which is about 8 times the average for urban areas and almost 300 times the average for rural areas (755 per square kilometer) (Streatfield and Zunaid 2008).

Changing population dynamics and spatial distribution have important implications for public health and the spread of infectious diseases. The risk of disease endemics can be heightened significantly in locations where public investment in basic environmental services such as safe drinking water, sanitation facilities, and sewerage systems are lacking as a result of poor urban planning. A challenge for policy makers is to determine how to prioritize and allocate public resources to support the development of health adaptation capacity in locations where the local population is most vulnerable to health risk and climate shocks and local health and basic environmental infrastructure is particularly lacking.

Measuring Health Adaptation Capacity

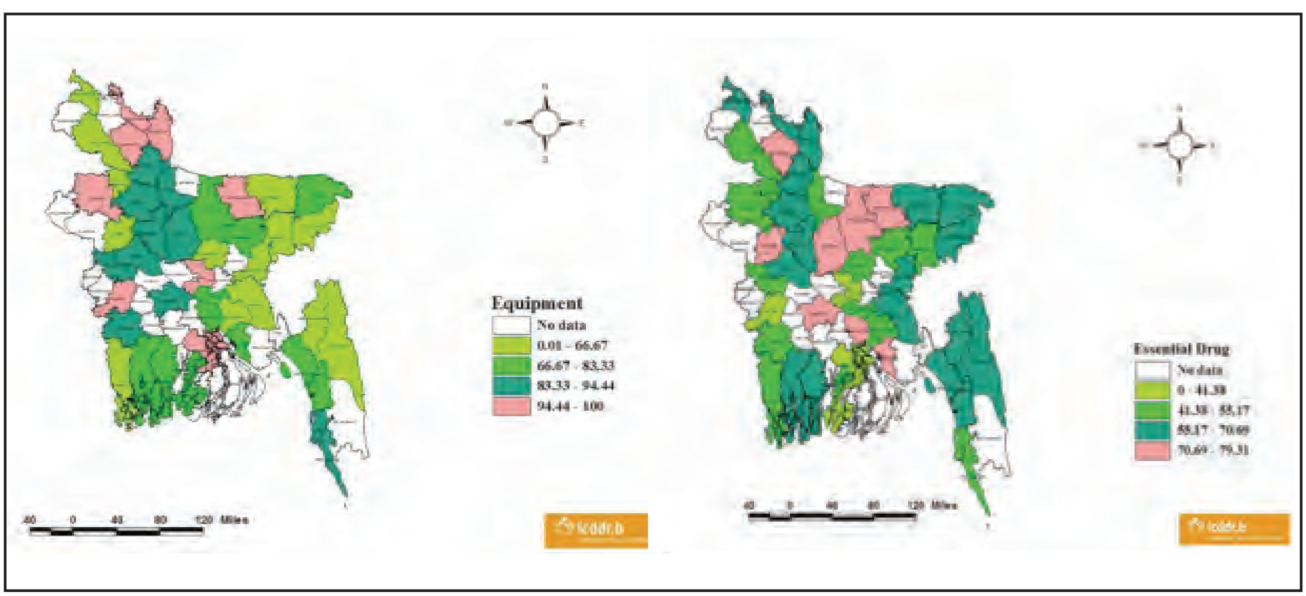
The local capacity to mitigate health risks associated with population migration and high density as well as climate change depends on both health and non-health sectors. Therefore, a comprehensive measure of local health adaptation capacity should cover local preventive and treatment health services (disease surveillance systems and availability of medical staff and essential drugs), local basic environmental infrastructure, and a risk and disaster management system, to name a few. Both public and private sector capacity to address current and future health risks should be incorporated in the measurement of capacity.

In reality, however, information that covers comprehensive measures of adaptation capacity at a disaggregate level are often incomplete or not available. This limits the scope of adaptation capacity assessments that are urgently needed to inform decisions on public resource allocation across both sectors and locations. In this section, the district-level measures of health adaptation capacity are constructed using complementary data sources, including the 2011 Bangladesh health facility survey (HFS) and the 2011 census.

The 2011 HFS collected data on the availability of medical inputs (equipment, drugs, and personnel), the provision of various types of health services, and information on consumer or client satisfaction obtained from both public and private facilities covering all tiers of administrative units (from community clinics to district hospitals). One of the important aspects of health sector capacity is the delivery of quality health services. This capacity, in turn, depends on the availability of equipment, skills, and training of medical personnel and the overall level of management at the facility level. Information on these aspects of health care are often difficult to collect in national health surveys.

In the following analysis, four core health sector–related indicators, covering equipment availability, essential drug availability, staffing quality, and patient satisfaction, are constructed from the 2011 HFS to measure the quality of health service delivery. Capacity in the non-health sector is measured by indicators of environmental infrastructure constructed from the 2011 census, covering the proportion of households with access to safe drinking water, access to sanitary toilet facilities, and access to electricity. The spatial distribution of overall health adaptation capacity in 2011 is presented in map 4.2.

Map 4.2 Spatial Distribution of Overall Health Adaptation Capacity



According to the 2011 census, the districts that have inadequate access to sanitation facilities (defined as less than 30 percent of a population with access to sanitary facilities) include Bandarban, Thakurgraon, Gaibandha, Sunamganj, Nilphamari, Nawabganj, Naogaon, and Rangama. The districts that have inadequate access to safe drinking water (defined as less than 80 percent of the population with access to safe drinking water) include Bangamati, Bandarban, Bagerhat, Khagrachhari, and Sylhet.

These district-level measures of health adaptation capacity, constructed from the 2011 HFS and the 2011 census together with disease data, provide critical information for assessing how well public resources are spatially targeted. That is, do districts with high disease incidence have adequate adaptation capacity measured by the availability of health services and the level of basic environmental infrastructure? The following section assesses the efficiency of spatial targeting using these district-level indicators.

Assessing the Efficiency of Geographic Targeting

Spatial assessment of adaptation capacity involves identifying disease hotspots and analyzing spatial correlation between disease incidence and level of local adaptation capacity. Malaria is concentrated in three districts (Bandarban, Rangamati, and Khagrachhari), which accounted for about 92 percent of total cases during 2007–11. The cases of dengue fever were reported primarily in Dhaka, and the cases of kala-azar were reported mainly in five upazilas of Mymensingh District.

From a public health point of view, information on the availability of diagnostic equipment and essential drugs in high-endemic regions is essential for assessing whether public recourses are well targeted to address the risks of VBDs. Unfortunately, no such information is collected in Bangladesh. However, focus group interviews found that in many locations at high risk of VBDs, lack of diagnostic devices and poorly equipped surveillance systems have been a key issue in monitoring VBDs, suggesting that inadequate resources are being allocated to disease-prevalent locations.

Diarrhea is the most common infectious disease in Bangladesh, accounting for about 10 percent of total deaths every year. The national disease surveillance system provides relatively reliable records of diarrhea cases across the country. The top 12 districts with high incidence of diarrhea cases in 2011, ranked in descending order, are Kushtia, Kishoreganj, Munshiganj, Manikganj, Bandarban, Randarban, Rajshahi, Khagrachhari, Magura, Hennaidah, Satkhira, and Shariyatpur. Table 4.1 presents the spatial distribution of the incidence of diarrheal disease against the ranking of health and environmental services for the top 12 districts of high-diarrhea prevalence. The ranking provides some evidence of poor targeting, with districts of high diarrhea prevalence ranked low in access to safe water and sanitation as well as in essential drug availability.

The efficiency of geographic targeting is further assessed using the Pearson correlation coefficient between the incidence of diarrhea and a range of

Table 4.1 Spatial Analysis: Disease Incidence versus Local Capacity, 2011

Zila	Diarrhea incidence (%)	Improved sanitation (1 best; 65 worst)	Safe drinking water (1 best; 65 worst)	Health equipment availability (1 best; 25 worst)	Essential drug availability (1 best; 25 worst)
Kushtia	4.96	38	14	5	19
Kishoreganj	3.83	52	41	10	21
Munshiganj	3.80	6	27	7	20
Manikganj	3.63	20	19	–	–
Bandarban	3.57	64	63	–	–
Rajshahi	3.48	42	28	–	–
Khagrachhari	3.46	56	61	11	6
Magura	3.38	13	6	–	–
Jhenaidah	3.37	41	10	1	23
Satkhira	3.36	39	57	11	16
Shariyatpur	3.34	5	33	9	1
Khulna	3.30	12	56	9	6
Rajbari	3.11	10	15	–	–
Rangamati	3.10	57	64	11	6

Note: – = no data.

adaptation capacity indicators for 66 districts in 2011.[25] Adaptation capacity is defined as previous investments in water supply and sanitation and in public health service delivery. The results of the correlation analysis, as presented in table 4.2 and figure 4.1, show that, with the exception of access to electricity, all capacity indicators are negatively correlated with the incidence of diarrheal disease. For example, the Pearson correlation between diarrhea incidence and safe water access is −0.3, equipment availability (−0.1), essential drug availability (−0.08), staffing index (−0.04), and patient satisfaction index (−0.03).

These findings provide strong evidence of poor geographic targeting of public resources in the area of health adaptation interventions; locations with larger disease burden, in general, have weaker adaptation capacity. Given that diarrhea is the most common infectious disease in Bangladesh, similar results may be found for other health indicators, suggesting that overall public resources for health adaptation are poorly targeted in Bangladesh.

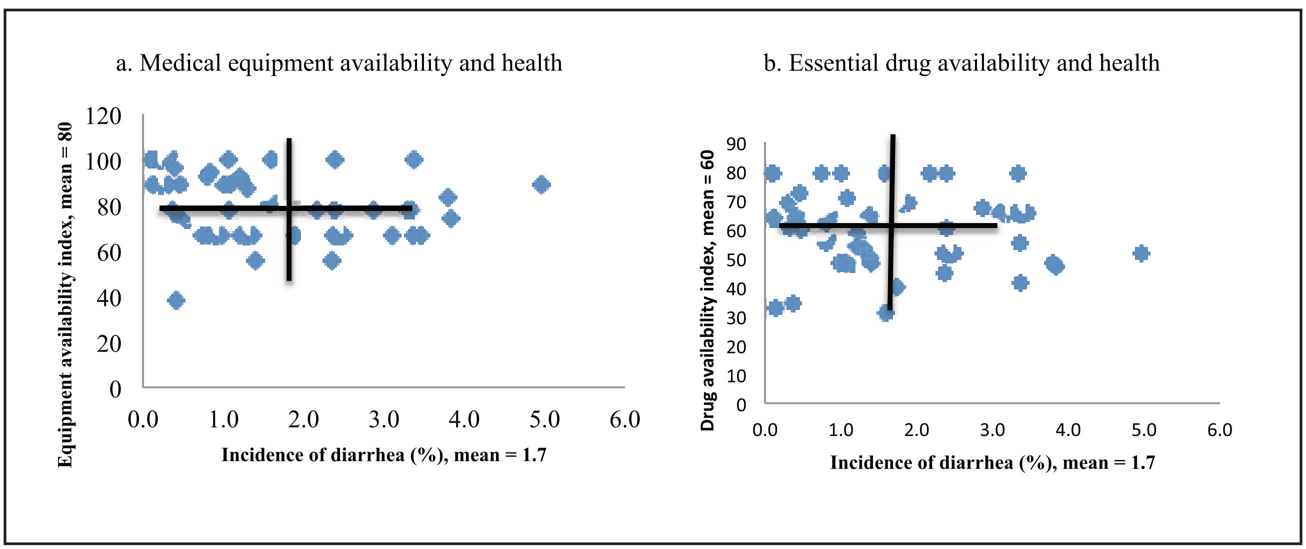
The finding of poor geographic targeting of public resources in the area of public health is consistent with findings from other studies in Bangladesh. Two important spatial assessments have been carried out in

Table 4.2 Pearson Correlation Coefficient between Adaptation Capacity and Disease Incidence: 2011

Indicator	Pearson correlation	Median
Basic infrastructure capacity		
% of households with access to safe drinking water (tap and tube well are defined as safe drinking water)	−0.30	96.30
% of households with access to sanitary toilet facility (water-sealed and non-water-sealed toilets are defined as sanitary)	−0.04	61.45
% of households with access to electricity	0.17	48.65
Basic health service provision capacity		
Equipment availability index (%)	−0.10	66.67
Essential drug availability index	−0.08	50.00
Staffing index	−0.04	61.48
Patient satisfactory index	−0.03	75.20
Incidence of diarrhea (%)		1.39

Sources: Basic infrastructure indicators are from 2011 census, and health service indexes are from 2011 HFS.

FIGURE 4.1 Correlation between Health Facility and Disease Incidence: 2010 District-Level Data



25 The choice of diarrhea reflects the wide geographic coverage of cases, as all the vector-borne diseases under study are concentrated in limited geographic locations.

Bangladesh in recent years, including poverty mapping at the subdistrict level using the income/expenditure measure of poverty (World Bank 2013) and the spatial assessment of multiple indicators covering education and health outcomes, access to health services, and access to safe water and sanitation facilities (UNICEF 2013).

Combining spatial information from both assessments, the 2009 UNICEF report highlights the strong spatial correlation between lack of access to basic social services and income/expenditure poverty. The report recommends the policy of "blanket geographic targeting" of basic social services to the most deprived geographic areas of Bangladesh as a means of achieving MDGs related to equity as well as accelerating the overall reduction in poverty.

The World Bank (2010) also shows that public resources in the health sector are not spent effectively and health facilities are not adequately financed and staffed. In particular, the current resource allocations are not effectively reaching the poor. Inequalities in access to health services remain a key issue and contribute to disparities in health outcomes between the rich and poor.[26]

Key Messages

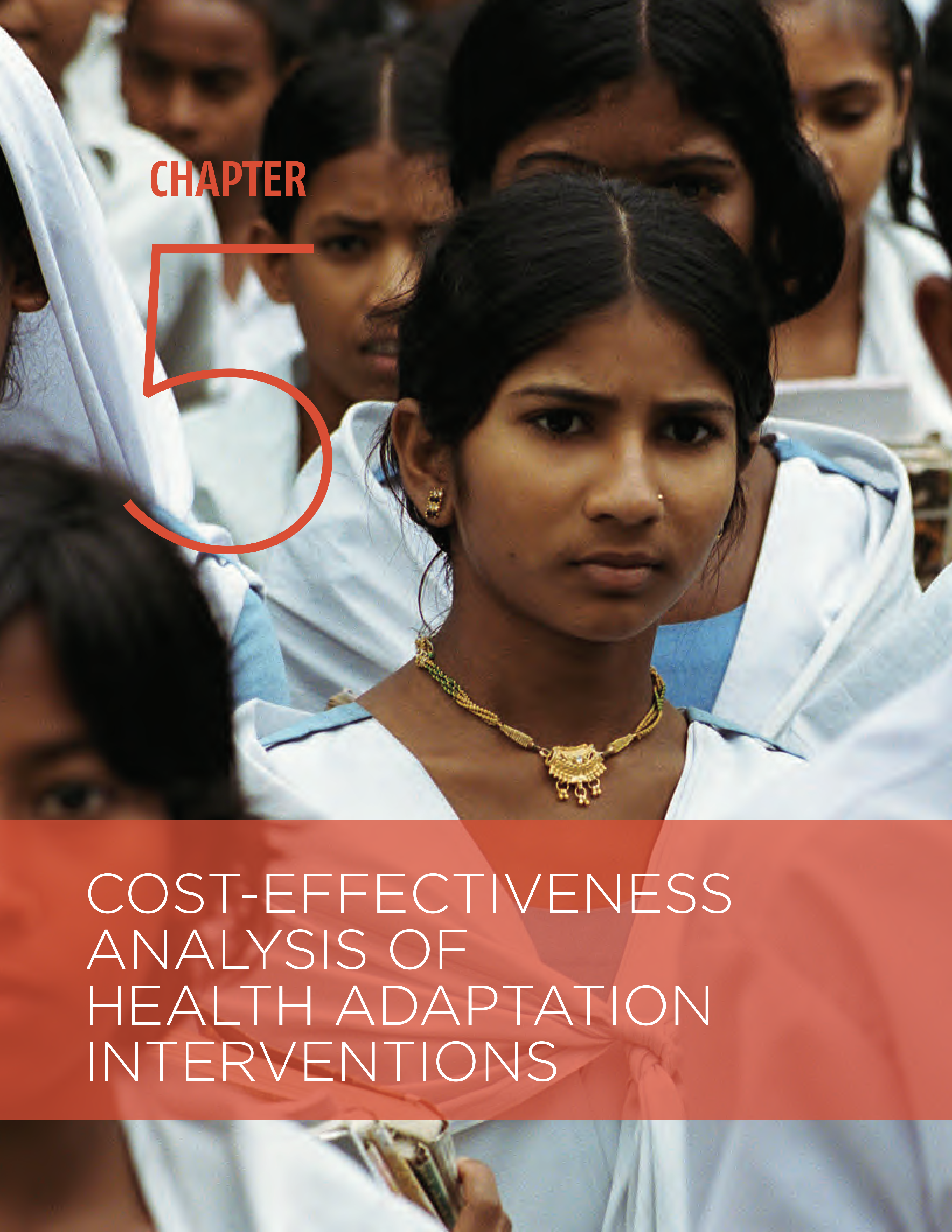
- The results from this chapter, combined with evidence from other spatial assessment studies (World Bank 2010; UNICEF 2013) provide strong evidence of the poor geographic targeting of public resources in health and basic environmental infrastructure in Bangladesh. While these findings are not linked directly to climate change, they suggest that locations with high disease risk are particularly lacking in access to health and basic environmental services that are essential in reducing health risk. However, the findings are only applicable at the aggregate level (districts) because data are lacking at a more disaggregate level in rural areas and in urban slum and non-slum areas. These findings point to the need for better targeting of resources in the future, given the increasing risk of climate change and disease incidence.

- The sampling design of nationally representative surveys such as DHS and expenditure surveys has not been updated to capture adequately the fast-growing urban slum population, one of the most important features of population dynamics in Bangladesh. Indicators constructed from these national surveys should be treated with caution. Given the inadequate sampling of the urban slum population, spatial analysis based on existing national surveys may provide misleading information, in particular, for the spatial targeting of programs or projects to improve access of the population to basic services and disease control.

- The issue of inadequate water and sanitation in urban areas is urgent and needs to be addressed. As the total population of Bangladesh is projected to increase by 64.6 million to about 217.9 million people between 2010 and 2030, with three-fourths of that growth occurring in urban areas, the health implications of these population dynamics and the rapid population growth in urban slums should be rigorously assessed. Policy makers need to recognize the full scale of the health threat posed by rapid but poorly planned urbanization in Bangladesh. The threat will continue to worsen if climate change is overlaid on these existing capacity constraints. It is therefore important for the Government of Bangladesh to act quickly on the issue of inadequate safe water and sanitation services, particularly in slums where the urban population has been growing the fastest.

26 The recent Multiple Indicator Cluster Survey conducted in 2009 shows huge geographic disparities in health outcomes in Bangladesh, with the under-five mortality rate, one of the important measures of population health, ranging from 102 deaths per 1,000 births in the district of Sherpur to only 43 per 1,000 in Pabna.

CHAPTER 5



COST-EFFECTIVENESS ANALYSIS OF HEALTH ADAPTATION INTERVENTIONS

Over the past few decades, Bangladesh has invested extensively in health and education, basic infrastructure, and risk and disaster reduction measures, such as early warning systems and construction of embankment and shelters. These policy interventions have strengthened the country's overall adaptation capacity and resilience to climate risks, contributing to the improvement in development outcomes, especially health outcomes from the reduction in premature deaths. The fundamental policy challenge, for both decision makers in the government and development partners is how to maximize the cost-effectiveness of resources in a fiscally constrained environment.

Cost-effectiveness analysis (CEA) and cost-benefit analysis (CBA) are useful tools for identifying adaptation interventions (programs and projects), guiding decisions about where public resources should be prioritized to maximize development outcomes. In reality, however, these tools are rarely used, which is evident at all levels of policy making. For example, according to some estimates, bilateral and multilateral development partners currently allocate 98 percent of their disaster management funds for relief and reconstruction and only 2 percent for investment in an early warning system and risk reduction measures (Mechler 2005). This is clearly not a cost-effective solution. The review of four decades of World Bank project appraisal documents by the World Bank's Independent Evaluation Group (IEG 2010) concludes that the application of CBA in project appraisal often lacks consistency and objectivity, varies greatly in quality and rigor, and often fails to use the existing data sources and results from impact evaluation studies that are widely available in the published literature for individual countries where projects are taking place.

In Bangladesh, despite extensive public investment over the past several decades, little is known about the cost-effectiveness of different interventions. This is particularly true in the area of health due to the scarcity of impact evaluation studies and cost data. For example, no conclusive impact studies have examined the two large-scale national nutrition projects—the Bangladesh Integrated Nutrition Project (BINP) and the National Nutrition Project (NNP)—despite the significant amount of resources committed to the two projects (see Hossain et al. 2002; White 2006).[27]

This chapter illustrates the use of CEA for evaluating health adaptation interventions using a variety of data sources available in Bangladesh. The first section explains why CEA is preferred to CBA in the context of health adaptation options. The second illustrates how CEA can be applied to rank investment in three key areas central to averting premature deaths, including investment in an early warning system and risk management measures, in improving access to safe drinking water, sanitation services, and electricity, and in nutrition-focused interventions.

Why Cost-Effectiveness Analysis Rather Than Cost-Benefit Analysis?

A large body of literature has been developed to guide practitioners on how to conduct CEA and CBA in different contexts (Levin and McEwan 2001; U.S. Department of Health and Human Services 1996; U.K. Government 2011). CEA calculates the costs of a program in relation to its targeted outcomes (often a single outcome such as children's school enrollment rate or malnutrition rate). In CEA, the ratio of quantifiable outcome or impact of a program or project to a given cost associated with its implementation (or the inverse ratio measuring the amount of cost required to achieve a given impact, referred to as the cost-effectiveness ratio) is calculated to compare cost-effectiveness across alternative programs.

CBA takes this process one step further by comparing costs with total program benefits rather than just the single outcome that is central to the program. For example, many nutrition-focused programs generate multiple benefits, including child health, school attendance, and future earnings. In CEA, only the nutrition benefit is quantified, but in CBA all benefits (nutrition, schooling, and future earnings) are estimated. In CBA, the net benefit is calculated as total benefits minus total costs, discounted back to the present value in the base year of the program when the costs and impact last over many periods. CBA is most useful when policy analysts are studying a single program or policy to determine whether its total benefits to society exceed the costs or when comparing alternative programs in order to identify the one that is achieving the greatest net benefit to society. Decision makers in line ministries, such as health and education, often consider this question.

As a practical tool for guiding decision makers on where to target limited resources for achieving a specific outcome cost-effectively, CEA is generally preferred to CBA in two situations. First, CEA is most useful when policy makers have identified a policy target (for example, reducing the incidence of childhood disease) and want to determine which alternative programs or projects will achieve the greatest outcome for a given budget. In contrast, the questions posed in CBA are broader and may not be of immediate concern to policy makers in line ministries, whose primary objectives are to improve specific outcomes of the population, such as health, education, or employment.

Second, CEA is a better option in cases where the central outcomes or targets are either intangible or otherwise difficult to monetize. For example, placing a monetary value on health, including mobility and mortality, is particularly controversial and subject to large uncertainties. The commonly adopted measure of population health—disability-adjusted life years (DALY)—combines in one measure the time lived with disability and the time lost due to

27 The BINP was carried out between 1996 and 2002, with funding of US$59.8 million, and the NNP was implemented between 2002 and 2011, with funding of US$124.42 million.

premature mortality. The calculation of DALY imposes several subjective assumptions, including societal preferences for giving different weights to the health of people of different ages and to disabilities. The monetary value per DALY is far from agreed on among policy analysts. In this context, CEA is less restrictive, allowing users to apply their own judgment to quantify the health benefits or to avoid placing a monetary value simply by using the number of averted premature deaths as a measure of program impact. For a good review on the choice of CEA and CBA and the applications of CEA, see Dhaliwal et al. (2012) .

In the context of health adaption interventions in Bangladesh, all three key areas of policy interventions (investment in early warning system and risk reduction measures, improved access to safe drinking water and sanitation services, and nutrition-focused programs) have one central objective in common: averting premature deaths. Therefore, CEA is preferred to CBA.

An Application of Cost-Effectiveness Analysis in Health Adaptation Interventions

It is often said that development is the best form of adaptation. This means, while the risk of climate change adds additional challenges to development, policy interventions in traditional areas, such as access to basic services (health care, safe drinking water, and sanitary toilet facilities), female education, and child nutrition, will continue to be important in improving development outcomes, including health. In addition, investment in early warning systems and risk management will enhance the population's resilience to climate shocks, generating substantial benefits measured by a reduction in economic losses, mortality, and disease outbreaks from natural disasters.

This section presents a simplified CEA to compare three interventions with the central objective of reducing premature deaths: (1) achievement of universal household access to safe drinking water, sanitation, and electricity; (2) elimination of stunting through targeted nutrition and health programs; and (3) investment in early warning and risk management capacity.[28]

Benefit estimation

The major difficulty with CEA or CBA is that it is challenging to identify as well as place monetary values on all benefits and costs associated with a program or project. The benefit of policy interventions, in the context of health adaptation, should be measured as the change in health outcomes by comparing the scenarios with and without interventions (that is, the counterfactual), controlling for all confounding factors. Many complementary methods, such as randomization experiments and regression-based methods, have been developed to estimate the benefit of various policy interventions with the choice of methods, depending on data availability (for a review of methods, see Gertler et al. 2010).

In the following CEA analysis, the number of deaths avoided is used as the measure of health benefit from the three interventions. The methods used to quantify the health benefits are summarized in table 5.1.

The estimated health benefit from the first option—achieving 100 percent household access to safe water, sanitation, and electricity—is about 133,000 child deaths averted in 2011 using the World Health Organization (WHO) estimate of 25 percent of deaths caused by childhood illnesses and 2011 population data. The health benefit from the second option—nutrition programs that eliminate stunting—is taken from the policy simulation carried out by USAID and FANTA (2012), which shows that about 160,000 child deaths could be averted through the reduction of stunting in 2011.

The benefit of investing in early warning and risk reduction systems is measured as the number of deaths

Table 5.1 Summary of Methods for Quantifying Benefits

Intervention	Method	Outcome indicator
Reaching 100% household access to safer water, sanitation, and electricity in 2011	The marginal impact of access to water, sanitation, and electricity on the incidence of childhood illness is estimated using regression method. Child deaths averted are estimated using simulation based on the estimated marginal impact and the WHO estimate of 25% of child deaths from illnesses.	Child deaths averted (under 14 years of age)
Eliminating stunting by 2011	Based on estimates from existing studies; about 35–55 percent of deaths among children under five are estimated to be caused by malnutrition (Pelletier et al. 1995; Black et al. 2008; Hossain and Bhuyan 2009)	Child deaths averted (under 15 years of age)
Investing in early warning and risk reduction systems	Control and treatment method	Deaths averted (all ages)

28 These policy targets include (1) universal access to safe drinking water (that is, tube well in rural areas and piped water in urban areas), sanitary toilet facilities, and electricity; (2) female attainment of a secondary education; and (3) elimination of child stunting. They are set in reference to the current level of access to basic services, female education, and child malnutrition estimated from the 2011 DHS and the Millennium Development Goal targets set for 2015 (see appendix 5A, box 5.1).

Table 5.2 Major Cyclones, 1970–2009

Landfall date	Landfall location	Wind speed (kilometers per hour)	Storm surge (meters)	Human casualties (number)
November 12, 1970	Bhola, Meghna, Estuary	224	10	300,000
April 29, 1991	Noakhali Chittagong	235	7.6	133,882
November 15, 2007	Sundarban, Borguna	250	6–8	2,388
November 15, 2007	Burma	240	6–8	138,366

Sources: EMDAT.

avoided using mortality data from past major natural disasters in Bangladesh, focusing on cyclones. Table 5.2 summarizes the major cyclones crossing the Bangladesh coast from 1970 to 2009.

The 1970 and 1991 cyclones were similar in severity, as measured by wind speed and storm surge, and so were the 2007 cyclones that hit Bangladesh and Burma. Therefore, the reduced death tolls from these cyclones can be used to measure the avoided deaths as a result of investments in an early warning system and other disaster risk management measures or the benefit of these interventions. The reduced deaths are about 170,000 by comparing the 1970 and 1991 cyclones and 136,000 by comparing the 2007 cyclones in Bangladesh and Burma. The health benefit—averted mortality—can be attributed largely to investment in an early warning system and other risk mitigation measures, although overall development (such as better housing, cyclone shelters, and roads) also played an important role, suggesting that these numbers are likely the upper-bound estimation of benefits from investing in an early warning systems.

Cost estimation

Quantifying the cost of a program (or policy intervention), covering both investment costs (for example, construction of water pipes) and recurrent costs (like maintenance and management) can also be challenging. First, program costs depend on a wide range of local factors, in particular, local implementation capacity; therefore, cost data are context specific and not easily transferable if no cost data are collected. Second, in most cases, incremental cost, rather than unit cost, should be used to measure program costs, which is not easily constructed. For example, the incremental cost of expanding household access to piped, safe drinking water can be quite low in areas where the system of underground water supply has been built compared with locations without a source of water. The same applies to costing the investment in early warning and risk management systems. A review of the literature shows that very few program impact studies in developing countries report comprehensive cost estimates (Dhaliwal et al. 2012).

In Bangladesh, despite extensive investments in water supply and sanitation and child nutrition programs, the cost data on these projects are hard to come by. Data on operation and maintenance costs, on institutional overhead costs, and on the costs of community-driven health programs, are especially scarce. However, the recent study by USAID and FANTA (2012) provides a good example for estimating the costs of implementing a comprehensive national program for nutrition in Bangladesh for the period of 2011–21.[29]

In the following, the cost estimation of a national nutrition program is taken from the FANTA study. It estimates that the cost of providing effective nutrition services covering the entire territory of Bangladesh is in the range US$130 million–$170 million per year (which is relatively small compared with the annual health sector budget).

The cost estimation of the disaster risk mitigation investment shows that, since 1971, the Government of Bangladesh, with support from international development agencies, has invested more than US$10 billion to make the country more resilient to climate change, covering many areas such as risk and natural disaster management, transportation, and agriculture. This is equivalent to an annualized cost in the range US$120 million–US$200 million. However, it is not possible to disaggregate the total cost of investment to obtain the cost of investment in risk and natural disaster management for the CEA or the annual incremental cost of investment in risk mitigation for the CEA.

The cost data for the three interventions of interest here are summarized in box 5.2.

29 The FANTA estimation exercise covers five procedures: (1) identifying an appropriate structure for the program, (2) selecting the necessary interventions and activities, (3) determining a management structure and a method of service provision, (4) identifying the inputs and obtaining the unit costs of each activity and input, and (5) estimating the program costs for duration of the project.

BOX 5.2 Cost of Adaption Options

- **Early warning system**. More than US$10 billion has been invested in reducing disasters and risks in Bangladesh over the past 50 years. These investments include infrastructure (polders, cyclone shelters, and cyclone-resistant housing) and early warning systems. These investments have significantly reduced the damages and losses from extreme weather events, in particular, the number of deaths and injuries avoided. The average annual cost is assumed to be in the range US$120 million–US$200 million.

- **Nutrition.** The FANTA study estimates that the cost of providing effective nutrition services covering all of Bangladesh are in the range US$130 million–US$170 million per year. This is relatively small compared with the annual health sector budget, and it is achievable.

- **Safe water and sanitation investment.** A water sanitation project report for Bangladesh (World Bank 2005) estimates that the cost of constructing a water point and connecting 500 people to a location is about US$25 per household, for sanitation, it is US$45 per household.

Cost-effectiveness analysis: An illustration

The benefit-cost ratio estimated using FANTA's benefit and cost estimation is presented in the last column of table 5.3. The results show that nutrition programs are highly cost-effective in preventing premature deaths in Bangladesh (more than 600 deaths of children under 14 averted per US$1 million), compared with the other two options. Carrera et al. (2012) carried out a CEA using data from 14 countries on the impact of national health programs on the number of under-five deaths averted. Their results show that about 81 deaths in children under five can be averted by investing US$1 million in national health programs such as early and exclusive breastfeeding, complementary infant feeding, and improved water, sanitation, and hygiene practices. However, these estimates should be interpreted with caution due to uncertainties about some of the model parameters and baseline data.

The result from the CEA should also be treated with caution due to data weakness, and the results should be used mainly for illustration purposes. Drawing policy conclusions regarding the cost-effectiveness of different interventions requires further efforts to collect data on costs, more rigorous impact evaluation studies using a variety of data sources and validation of data, and impact studies using complementary approaches.

Over the past few years, a significant amount of resources have been channeled to improving malnutrition in Bangladesh. Unfortunately, little evidence has been generated from properly designed impact evaluation studies in this area (see box 5.3). Existing studies show a limited impact of nutrition-based programs. It is plausible that nutrition programs can have a much larger impact in reducing malnutrition and disease prevalence when combined with sanitation projects and a hygiene education campaign targeted at mothers. This is obvious based on the well-established medical evidence of the two-way causal effect of disease incidence and malnutrition among young children

Table 5.3 Cost-Benefit Analysis: Comparison of Three Adaptation Options

			Benefit-cost ratio	
Policy option	**Annualized cost (US$ million)**	**Annualized benefit (number of deaths averted)**	**Number of deaths averted per US$1 million**	**DALY per US$1**
100% access of safer water and sanitation	300–500	133,000 (under 14)	260–443	0.04–0.06
Elimination of stunting	130–170	160,000 (under 14)	627–820	0.07–0.09
Early warning and risk management systems	120–200	14, 000 (all ages)	70–116	0.004–0.01

Note: The total number of households is 31,863,396 based on the 2011 census, which is used to estimate the cost of achieving 100% access to safe water and sanitation. The number of deaths avoided from natural disasters as a result of the early warning and risk management systems is calculated under the assumption of a return period of 10 years (that is, a probability of 10 percent for every year). The annualized cost of eliminating stunting is adjusted by a 50% increase from FANTA cost estimates. The DALY is estimated using a disability weight of 0.02 and life expectancy of 75.

and the important health determinants of access to safe water, sanitary toilet facilities, and electricity. Impact evaluation studies on whether integrated programs in health adaptation interventions—such as nutrition, water and sanitation, and hygiene education targeted to the caretakers of children—can effectively reduce child malnutrition as well as disease incidence would provide valuable information needed to guide the design and implementation of future health adaptation interventions.

The analysis presented here illustrates how various complementary approaches, including regression-based impact analysis and policy simulation exercises, can be used to conduct cost-benefit analysis to assess different health adaptation interventions. While the cost-benefit ratio presented in this chapter should be taken with caution due to the weakness of data quantifying both costs and benefits, the CEA exercise identifies an important information deficiency in guiding policy makers seeking to target limited resources to maximize health outcomes.

The key data gaps include lack of cost data on projects and programs related to investment in expanding household access to safe drinking water, sanitation, and electricity, separately for urban and rural areas, investment in an early warning system, and risk management measures. Also lacking are impact evaluation studies that use rigorous evaluation methods based on appropriately collected data including both baseline and follow-up surveys.

Key Messages

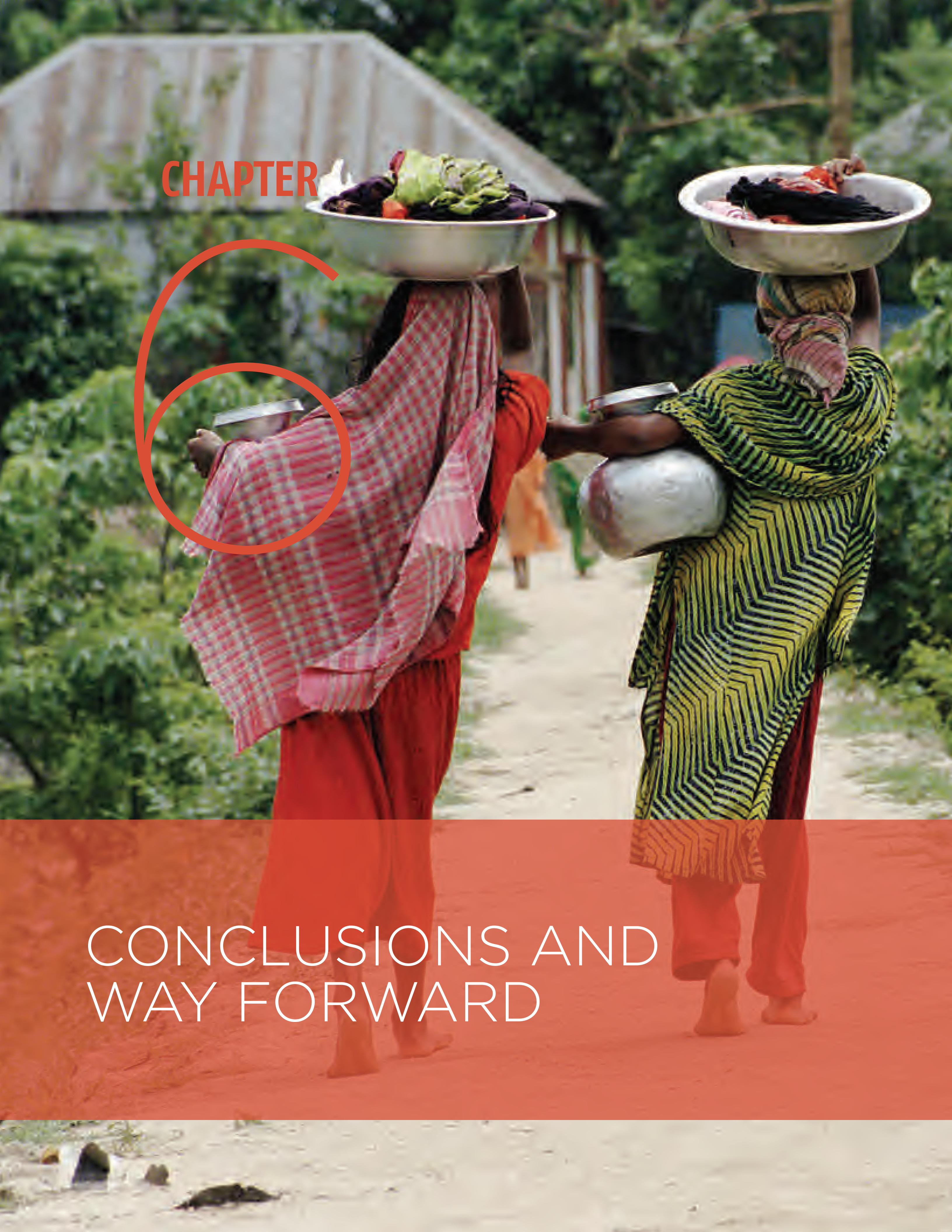
- Given that considerable amount of public resources have been allocated to improving climate change adaptation and resilience in Bangladesh, CEA should be used in policy making to guide the allocation and prioritization of resources. This recommendation should apply both to key government units and to donor agencies.
- The results of CEA should be widely disseminated among stakeholders as a means to improve transparency as well as develop an evidence-based decision-making process for selecting projects and programs and identifying new areas of policy interventions.
- However, without concerted efforts both to collect reliable data on cost and impact of different projects or programs and to implement CEA with rigor and consistency, evidence-based policy making will remain simply an empty promise.

BOX 5.3 Two Major Nutrition Projects

The Bangladesh Integrated Nutrition Project, with funding of a US$59.8 million, was implemented between 1996 and 2002, covering a population of 15.6 million in 59 thanas (a locality with a population of approximately 200,000–450,000 people). The impact evaluation study (Hossain, Duffield, and Taylor 2005) shows no evidence that the project achieved its objectives of reducing child malnutrition, measured by the prevalence of underweight children under the age of two.

The Bangladesh National Nutrition Project, with funding in the amount of US$124.42 million (which is about 7.5 percent of annual aid received by the country), began in 2000, with the objective of supporting the government's 15-year vision to extend community nutrition services to the entire country. Project impact studies found no conclusive evidence regarding the impact of the project (White and Masset 2006).

Based on child nutritional status estimated from the 2000 and 2011 DHS, child nutrition improved moderately: with the prevalence of underweight and stunting at the national level reduced from 47 and 36 percent, respectively, in 2000 to 44 and 41 percent, respectively, in 2011. But how much the reductions at the national level can be attributable to the NNP remains unknown.



CHAPTER 6

CONCLUSIONS AND WAY FORWARD

Bangladesh is one of many countries already facing enormous challenges due to extreme events such as droughts and land and coastal flooding. Added to these challenges are demographic and socio-economic factors, such as rapid population growth and fast urbanization, poverty, poor health conditions, water scarcity, and inadequate sanitary conditions. Climate change is, therefore, an additional stressor that is expected to increase the burden of diseases, notably through increased morbidity and mortality. Bangladesh is particularly vulnerable to outbreaks of infectious, water-borne, and vector-borne diseases.

These risks and diseases are not new, and the health sector is already tackling them. However, the capacity to cope with potentially increasing levels of risks and diseases arising from climate change is still limited in Bangladesh. Furthermore, there is insufficient capacity for assessment, research, and communication on climate-sensitive health risks, as well as insufficient capacity to design and implement mitigation and adaptation programs.

Recognizing the importance of climate change in the broader health context, Bangladesh became one of the first countries to establish a climate change cell in the Ministry of Health. The Climate Change and Health Promotion Unit (CCHPU) has been established under the Ministry of Health and Family Welfare. CCHPU's objectives are (1) to coordinate all health promotional activities of intra- and interministerial initiatives; (2) to increase awareness of the health consequences of climate change; (3) to strengthen the capacity of health systems to provide protection from climate-related risks through e-health and telemedicine; (4) to ensure that health concerns are addressed in decisions to reduce risks from climate change in other key sectors; (5) to conduct research and evaluate and monitor programs related to health promotion and climate change; and (6) to coordinate emergency medical services and school health promotion to reduce health hazards during disasters and emergencies.

Key Messages

Three key messages emerge from this study:

- First, the health impacts of increased climate variability and extreme weather events are projected to be significant by 2050, but well-targeted development investments can mitigate all of the excess health burden attributable to climate change. A simple message is that focusing resources in traditional areas of development, such as improving access of the population to safe drinking, sanitation, electricity, female education, and child nutrition, as well as strengthening the capacity to manage risks can be the best health adaptation option in the face of increased climate risk.
- Second, policy makers need to recognize the full scale of the health threat as a result of rapid but poorly planned urbanization and act quickly on the issue of inadequate safe water and sanitation services, particularly in urban slum areas with the fastest population growth. The evidence of poor geographic targeting of past public investment in health and environmental infrastructure highlights the need to develop a comprehensive spatial database—at a disaggregate level such as in rural areas and slum and non-slum locations in urban areas—for monitoring and improving spatial targeting.
- Third, despite several decades of experience in programs and projects designed to improve health in Bangladesh, evidence on the cost-effectiveness of different interventions is lacking. Considerable resources will be committed to climate change adaptation and resilience in the future, and cost-effectiveness analysis should be conducted routinely when allocating resources to programs and projects, both by government units and by development partners.
- The results of CEA should be widely disseminated among stakeholders as a means to improving transparency as well as developing evidence-based decision making for selecting projects and programs and identifying new areas of policy interventions. The political economy nature of the decision-making process in Bangladesh should be fully recognized, but this is a subject beyond the scope of this study. Without concerted efforts to collect reliable data on cost and impact of different projects or programs and to implement CEA with rigor and consistency, evidence-based policy making will remain simply an empty promise.

Way Forward

There is an urgent need in Bangladesh to incorporate health concerns into the decisions and actions of sectors, as they plan to mitigate and adapt to climate change, so that these decisions and actions enhance health. Measures to mitigate the adverse health impacts of climate change need to be considered beyond the health sector: for example, integrating health concerns in water and sanitation, urban planning, early warning, and a disaster management systems. Resources should be spatially targeted to reach the most vulnerable locations that are likely to be at high climate and health risk to ensure cost-effectiveness.

While the study attempts to use all possible data sources, future efforts should focus on developing the institutional capacity within Bangladesh to develop and manage a database that integrates GIS, health surveys, and a disease surveillance system with local climate information and environmental facilities at the national level. Such capacity is needed to improve research in the area of health and climate change. The research activities should be carried out as part of the government's efforts to develop climate adaptation policies to ensure evidence-based policy making.

To meet these objectives, the CCHPU needs considerable strengthening, particularly in the capacity to collect and analyze data, to conduct community outreach, to implement and evaluate pilot projects to reduce climate health risks, and to mainstream health concerns across various sectors. A stronger CCHPU could play a catalytic role in combating the health impacts of climate change and protecting human health from current and projected risks due to climate change through its analytical, advisory, and outreach services and in collaboration with other research organizations like the International Center for Disease and Diarrhoeal Research, Bangladesh. At the same time, climate change concerns need to be mainstreamed in the Health Nutrition and Population Sector Program for Bangladesh.

APPENDIX A
DATA SOURCE FOR WATER- AND VECTOR-BORNE DISEASES

Three main institutions in Bangladesh are directly involved in collecting health information including data for water- and vector-borne diseases: (1) Directorate General of Health Services (DGHS) under the Ministry of Health and Family Welfare (MoHFW), (2) the Institute of Epidemiology, Disease Control, and Research (IEDCR), and (3) the International Center for Disease and Diarrhea Research in Bangladesh (ICDDR,B). The DGHS is responsible for the Management Information System (MIS) of the health system, and the IEDCR collects information on water- and vector-borne diseases by conducting disease surveillance, investigating outbreaks, and training researchers. The ICDDR,B focuses on diarrheal disease and vector-borne infection surveillance. In addition, the National Institute of Population Research and Training (NIPORT) obtains limited data on water- and vector-borne diseases through nationally representative Demographic and Health Surveys (DHSs) at regular intervals.

The MIS collects information from the regular information systems of different health programs such as malaria, tuberculosis, Essential Service Delivery (ESD), Communicable Disease Control (CDC). Hospitals provide the CDC with information related to water- and vector-borne diseases.[30] Table A.1 shows the status of data for water- and vector-borne diseases.

The IEDCR collects information on water- and vector-borne diseases through its disease surveillance system. Table A.2 shows the systems that are collecting information related to water- and vector-borne disease through the IEDCR surveillance system, the Diarrheal Disease and Enteric Infection surveillance system, and the DHS.[31] Priority communicable disease surveillance (PCDS) and sentinel surveillance (SS) in selected areas obtain information on various diseases, including water- and vector-borne diseases like diarrheal diseases (acute watery diarrhea and bloody dysentery), malaria, and kala-azar.

Table A.1 Health MIS: Diseases and Coverage

Key information	Coverage (year, region)	Name of organization and website
Pneumonia, no pneumonia (cough and cold), diarrhea, fever (malaria), fever (not malaria) among under-five children	2002: 420 upazila in 50 districts and communities in 15 upazilas (monthly)	Integrated Management of Childhood Illnesses (IMCI), (ESD), DGHS (www.dghs.gov.bd)
Malaria burden, P. falciparum, P. vivax, death	13 districts of eastern and northern parts of the country	Communicable Disease Control, DGHS (www.dghs.gov.bd)
Kala-azar (visceral ieishmaniasis), cases, deaths	1999: 100 upazilas; 2000: 26 districts	Communicable Disease Control, DGHS (www.dghs.gov.bd)
Dengue, cases, deaths	2000: reported from facilities and individual doctors	Communicable Disease Control, DGHS (www.dghs.gov.bd)
Diarrhea (demographic, etiologic, clinical, and therapeutic aspects of patients)	2000: reported from facilities, whole country	Communicable Disease Control, DGHS (www.dghs.gov.bd) and ICDDR,B (www.icddrb.org)

30 Computers have been provided to all national and regional tertiary hospitals, 64 district health managers, and many of the 464 subdistrict hospitals. These computers are connected through the Internet. Hospital-based service data are still collected in formats compiled locally, with limited possibility of disaggregation.

31 Upazila health and family planning officers and civil surgeons are responsible for conducting surveillance locally.

Table A.2 Data Sources of Three Surveillance Systems

System and name of organization	Key information	Coverage (years, regions)
IEDCR		
Priority communicable disease surveillance (PCDS)	Diarrheal diseases (acute watery diarrhea and bloody dysentery), malaria, kala-azar	2007 onward; data collected weekly from at least one upazila in each of 64 districts
Institutional disease surveillance	Diarrheal diseases (acute watery diarrhea and bloody dysentery), malaria, kala-azar	Monthly disease profiles from the medical college hospitals and specialized institutions
Sentinel surveillance (SS)	Diarrheal diseases (acute watery diarrhea and bloody dysentery), malaria, kala-azar	Information obtained from eight selected upazilas of eight selected districts; discontinued in 2009 and merged with PCDS
Diarrheal Disease and Enteric Infection surveillance system		
ICDDR,B (www.icddrb.org)	Socio-economic, demographic, housing, and environmental conditions, feeding practices, use of drugs and fluid therapy at home, clinical, anthropometric measurements, and treatments received at facilities	Dhaka hospital from 1979; Matab hospital from 1999; extensive microbiological assessments of fecal samples (microscopy, culture, and enzyme-linked immunosorbent assay)
Demographic and Health Survey		
National Institute of Population Research and Training (NIPORT), (www.niport.gov.bd) and ICF-MACRO (www.measuredhs.com)	Diarrhea, fever, ARI, socio-demographic characteristics	DHS 1993–94, 1996–97, 1999–2000, 2004, 2007, 2011 (national and divisional coverage)

APPENDIX B
CLIMATE AND NATURAL DISASTER DATA

Three key departments are responsible for collecting climate- and disaster-related data: the Bangladesh Meteorological Department (BMD), under the Ministry of Defense; the Bangladesh Water Development Board (BWDB); and the Disaster Management Information Network (DMIN) portal within the Disaster Management Bureau (DMB).

The BMD collects real-time meteorological information from 35 observatories. It also provides routine weather forecasts for the public, farmers, mariners, and aviators and issues warnings for severe weather phenomena such as tropical cyclones, tornados, and floods. It maintains a network of surface and upper-air observatories, radar and satellite stations, agro-meteorological observatories, geo-magnetic and seismological observatories, and a meteorological telecommunication system.

The BWDB collects ground and surface water information and monitors floods and drought situations. The Flood Forecasting and Warning Centre (FFWC) of the BWDB was established in 1972 and became a Division of the Processing and Flood Forecasting Circle of BWDB Hydrology, which, in turn, is under the control of the chief engineer for hydrology. The FFWC is working to develop flood forecast and inundation models, disseminate flood forecast information, and issue warning messages.

The DMIN links 64 districts and 482 subdistrict offices (hardware and software support, Internet, training in information and communication technology) through its DMIN portal with the DMB, the BMD, the FFWC, and the Cyclone Preparedness Program (CPP). It plays an important role in risk reduction by providing information on risks, mapping risk reduction activities, maintaining information databases on disaster management capacity, and operating a national information portal. Table B.1 summarizes the data collection from the three key departments.

Table B.1 Weather and Disaster Management Data System

Key information	Coverage (years, regions)	Data source
Rainfall surface data	Daily up to 2002; three-hourly from 2003	35 weather stations of BMD (www.bmd.gov.bd)
Maximum and minimum temperature	Three-hourly	
Dew point temperature, relative humidity, present and past weather, cloud and height	Daily	
Date and time of magnitude and intensity of earthquake	At the time of occurrence	
Voice data	High-frequency wireless network, 67 stations	Water data from BWDB: Flood Forecasting and Warning Centre (www.ffwc.gov.bd)
Telemetry system satellite imagery	14 stations; GMS, NOAA-12 and NOAA-14	
Monitoring of cloud and depression movements; estimation of precipitation from cloud temperature analysis; cyclone monitoring; flood forecast modeling: one-dimensional fully hydrodynamic model (MIKE 11 HD) incorporating all major rivers and floodplains	Catchment area = 82,000 square kilometers; total length of modeled rivers = 7,270 kilometers; number of catchments = 216; number of forecast stations = 30; flood maps generated from model results via GIS link to model (MIKE 11 GIS)	
Real-time data management: GIS-based map showing water level and rainfall status (flood watch); display of forecast water levels and discharges; automatic generation of flood forecast bulletins	Generation of flood status at upazila level	
Climate change database: natural and geographic; physical and infrastructure; hydrometrological data (temperature, rainfall, sunshine, humidity, evaporation, wind speed, aerosol, water level, and sea surface temperature)		Comprehensive Disaster Management Programme (CDMP), www.cdmp.org.bd

APPENDIX C NATIONAL HEALTH AND FACILITY SURVEY

Health Facility Survey

As shown in table C.1, the nationally representative random sample of public sector health facilities at the district, upazila, and union levels has been selected for the 2011 Health Facility Survey (HFS). Within each tier, especially for maternal and child health centers, subcategories are district hospitals, maternal and child welfare centers, upazila health complexes, union health and family welfare centers, union subcenters and rural dispensaries, and community clinics.

Urban Health Survey

The Government of Bangladesh and the U.S. Agency for International Development jointly conducted the 2006 Urban Health Survey (2006 UHS) designed to obtain a broad health profile of the urban population of Bangladesh. The 2006 UHS is a rich, micro-level survey of the health of communities, households, and individuals throughout the city corporations and a sample of district municipalities.

The 2006 UHS had three main objectives: (1) to obtain a profile of health problems and health care–seeking behavior in urban areas of Bangladesh; (2) to identify vulnerable groups and examine their health profile and health care–seeking behavior; and (3) to examine the individual, household, and neighborhood factors associated with health outcomes and behaviors in urban areas. The 2006 UHS was designed to expand the base of knowledge regarding population health and health-related behavior in urban areas of Bangladesh, with a particular emphasis on understanding vulnerability and environmental risk in urban settings.

The 2006 UHS was based on a multistage sampling scheme under which the primary sampling units were crafted explicitly to reflect a meaningful notion of urban community or neighborhood. The primary sampling units belonged to one of two types of community: slum and non-slum areas of the city corporations. These units served as the basis for the basic statistical domains of the study:

- Dhaka Metropolitan Area large slum areas (by population)
- Dhaka Metropolitan Area small and medium slum areas (by population)
- Dhaka Metropolitan Area non-slum areas
- Chittagong City Corporation slum areas
- Chittagong City Corporation non-slum areas
- Slum areas of the remaining city corporations (Khulna, Rajshahi, Barisal, and Sylhet)
- Non-slum areas of the remaining city corporations (Khulna, Rajshahi, Barisal, and Sylhet)
- District municipalities.

Table C.1 Number of Health Facilities Selected for the 2011 Health Facility Survey

Facility type	Sample size	Total [a]
District hospital	40	59
Maternal and child health center	50	97
Upazila health complex	80	414
Union health and family welfare center	532	3,806
Community clinic	758	9,722
Private facilities at district level	43	2,501

[a] As reported by the Ministry of Health.

APPENDIX D
ANALYTICAL RESULTS

Table D.1 Logit Regression Results Using Full Sample (Odds Ratio) (Random-Effect Estimation)

	Pre-monsoon season (2004 DHS)				Monsoon season (2007 DHS)		
Variable	**Fever**	**Diarrhea**	**ARI**	**Variable**	**Fever**	**Diarrhea**	**ARI**
L_rain_svy |	0.805*	1.392	0.764	L_rain_svy |	1.323	0.953	0.787
rain_heavy1sd_D |	1.815*	1.226	1.473	rain_heavy1sd_D |	0.676*	0.742	1.032
rain_light1sd_D |	0.967	1.278	0.896	rain_light1sd_D |	1.445	0.956	0.963
L_rain_svy_L |	0.837***	1.035	0.879	L_rain_svy_L |	1.267*	1.246	1.023
rain_heavy1sd~L |	1.18	1.09	1.286	rain_heavy1sd~L |	0.724	0.561*	1.084
rain_light1sd~L |				rain_light1sd~L |	0.963	0.856	0.895
avetemp_svymth |	1.212***	0.878	1.135*	avetemp_svymth |	0.928	0.888	0.514*
hum_svymth |	1.041*	1.047	1.058*	hum_svymth |	1.014	1.016	0.976
_Iregion_2 |	2.645	0.739	1.669	_Iregion_2 |	0.541	0.722	0.987
_Iregion_3 |	2.536	0.701	2.307	_Iregion_3 |	0.565	0.752	0.748
_Iregion_4 |	1.329	3.568	2.322	_Iregion_4 |	0.426**	0.627	0.675
_Iregion_5 |	3.353*	0.877	2.089	_Iregion_5 |	0.510*	0.453	0.691
_Iregion_6 |	3.424*	2.422	2.702	_Iregion_6 |	0.188***	0.425	0.534
_Iarea_2 |	0.731*	0.72	0.741	_Iarea_2 |	0.922	0.852	1.102
_Iwealth_du_2 |	1.003	0.724	1.019	_Iwealth_du_2 |	1.08	0.878	0.917
_Iwealth_du_3 |	0.666**	0.510*	0.682*	_Iwealth_du_3 |	1.096	1.062	0.867
_Iwealth_du_4 |	0.600**	0.424*	0.454***	_Iwealth_du_4 |	1.005	0.946	0.704
_Iwealth_du_5 |	0.547**	0.359*	0.493*	_Iwealth_du_5 |	0.95	0.587	0.436**
_Iwater_2 |	0.771	0.230***	0.756	_Iwater_2 |	1.105	0.490*	1.213
_Iwater_9 |	0.905	0.311*	0.939	_Iwater_9 |	0.912	0.422*	0.924
_Itoilet_21 |	1.398	1.107	1.71	_Itoilet_22 |	1.093	0.754	1.003
_Itoilet_22 |	1.219	0.974	1.589	_Itoilet_23 |	1.016	0.607*	0.947
_Itoilet_23 |	1.302	1.345	1.777*	_Itoilet_99 |	0.997	0.905	0.899
_Itoilet_99 |	1.412	1.48	1.828*	_Iwom_edu_1 |	1.134	1.145	1.015
_Ielect_1 |	1.076	1.4	1.334	_Iwom_edu_2 |	1.141	0.962	0.877
_ITV_1 |	1.316*	0.662	0.914	_Iwom_edu_3 |	0.901	0.367**	0.664
_Ireligion_2 |	0.721	1.415	0.574*	_Ibord_new_2 |	0.927	0.892	1.011
_Ireligion_99 |	0.703	1.293	0.549	_Ibord_new_3 |	1.021	0.856	0.981
_Isex_head_2 |	1.014	0.728	0.866	_Ibord_new_99 |	1.065	1.021	0.97
_Iwom_edu_1 |	1.233*	1.273	1.394*	age_chd |	0.883	1.164	0.824
_Iwom_edu_2 |	1.291*	1.117	1.429*	age_chdsq |	0.991	0.921*	0.991
_Iwom_edu_3 |	1.094	1.141	1.092	_cons |	0.22	2.472	1.71e+09*
_Ibord_new_2 |	0.998	1.162	1.07				
_Ibord_new_3 |	1.122	0.892	1.345				
_Ibord_new_99 |	1.158	1.004	1.12				
age_chd |	1.045	1.039	0.781*				
age_chdsq |	0.946*	0.926	1				
_cons |	0.001***	0.085	0.000**				
_cons |	0.044***	0.288*	0.166***	_cons |	0.132***	0.224***	0.110***

*** p<0.001; ** p<0.01; * p<0.05.

Table D.2 Logit Regression Results Using Urban Households (Odds Ratio) (Random-Effect Estimation)

	Pre-monsoon season (2004 UHS)				Monsoon season (2007 DHS)	
Variable	**Fever**	**Diarrhea**	**ARI**	**Variable**	**Fever**	**ARI**
rain_heavy1sd_D |	1.292	0.965	1.838	L_rain_svy |	1.225	1.915*
rain_light1sd_D |	1.224	0.897	1.069	rain_heavy1sd_D |	0.747	0.354**
avetemp_svymth |	1.086***	1.008	0.996	rain_light1sd_D |	1.503	1.599
hum_svymth |	1.023	1.015	0.986	avetemp_svymth |	0.842*	0.752**
_Iwater_urb_2 |	1.072	0.525	1.165	hum_svymth |	1.001	1.038
_Itoilet_ur_21 |	1.34	0.807	1.933**	_Iwater_urb_2 |	1.274	0.98
_Itoilet_ur_22 |	1.241	0.76	1.924*	_Iwater_urb_3 |	2.362	1.152
_Itoilet_ur_23 |	1.202	1.15	1.859*	_Itoilet_ur_2 |	1.835***	1.4
_Itoilet_ur_99 |	1.251	0.771	2.943**	_Itoilet_ur_22 |	1.875**	1.479
_Iregion_2 |	0.803	0.269**	1.169	_Itoilet_ur_23 |	1.278	0.889
_Iregion_3 |	1.026	0.428*	0.747	_Itoilet_ur_99 |	1.684*	1.479
_Iregion_4 |	0.741	0.391*	0.763	_Iregion_2 |	0.699	0.526
_Iregion_5 |	1.178	0.477*	0.711	_Iregion_3 |	1.203	0.452
_Iregion_6 |	1.676	0.516	0.885	_Iregion_4 |	0.981	0.337*
_Iwealth_du_2 |	1.082	1.361	0.975	_Iregion_5 |	1.16	0.298*
_Iwealth_du_3 |	0.929	0.829	0.846	_Iregion_6 |	0.686	0.281
_Iwealth_du_4 |	1.013	1.097	0.796	_Iwealth_du_2 |	0.773	0.65
_Iwealth_du_5 |	1.089	0.552	0.833	_Iwealth_du_3 |	0.751	0.592
_Ielect_1 |	0.778	0.917	1.029	_Iwealth_du_4 |	0.945	0.988
_ITV_1 |	1.01	0.631	0.967	_Iwealth_du_5 |	0.976	0.587
_Ireligion_2 |	0.674	1.425	0.861	_Ielect_1 |	1.684*	1.479
_Ireligion_99 |	2.038	0	5.147	_Ielect_7 |	0.741	1.149
_Isex_head_2 |	1.017	1.357	0.814	_ITV_1 |	0.251	0.595
_Iwom_edu_1 |	1.112	1.033	1.058	_ITV_9 |	0.999	1.00E+00
_Iwom_edu_2 |	1.084	0.895	1.036	_Ireligion_2 |	2.14E+09	0
_Iwom_edu_3 |	0.975	0.986	0.898	_Ireligion_99 |	0.675	0.789
_Ibord_new_2 |	0.89	1.379	0.71	_Isex_head_2 |	1.426	0
_Ibord_new_3 |	1.153	0.597	1.37	_Iwom_edu_1 |	1.256	0.966
_Ibord_new_99 |	1.149	0.878	1.047	_Iwom_edu_2 |	1.517*	0.661
age_chd |	0.951	0.83	0.701*	_Iwom_edu_3 |	1.311	0.552*
age_chdsq |	0.964	0.994	1.023	_Ibord_new_2 |	1.148	0.478*
_cons |	0.018**	0.175	0.803	_Ibord_new_3 |	1.017	1.114
				_Ibord_new_99 |	1.023	1.108
				age_chd |	1.222	1.01
				age_chdsq |	1.053	1.14
				_cons |	0.953	0.926
					16.597	2.439
lnsig2u |				lnsig2u |		
_cons |	0.084***	0	0.062**	_cons |	0.134***	0

*** p<0.001; ** p<0.01; *p<0.05.

Table D.3 Logit Regression Results Using Rural Households (Odds Ratio) (Random-Effect Estimation)

	Pre-monsoon season (2004 DHS)				Monsoon season (2007 DHS)		
Variable	Fever	Diarrhea	ARI	Variable	Fever	Diarrhea	ARI
				L_rain_svy |	1.052	1.141	1.017
rain_heavy1sd_D |	1.494**	1.539	1.232	rain_heavy1sd_D |	0.769	0.641	1.323
rain_light1sd_D |	1.028	0.843	1.049	rain_light1sd_D |	1.079	1.151	1.398
avetemp_svymth |	1.059***	0.97	1.021	avetemp_svymth |	0.806***	0.916	0.835**
hum_svymth |	1.008	1.027	1.023	hum_svymth |	1.018	1.026	1.011
_Iwater_rur_2 |	1.058	0.862	1.435	_Iwater_rur_2 |	0.828	0.925	1.139
_Itoilet_ru_22 |	1.011	0.882	0.774	_Itoilet_ru_22 |	0.796	0.793	0.629*
_Itoilet_ru_23 |	1.159	1.179	0.902	_Itoilet_ru_23 |	0.801	0.688	0.768
_Itoilet_ru_99 |	1.09	1.241	0.761	_Itoilet_ru_99 |	0.78	1.024	0.679
_Iregion_2 |	0.956	1.173	0.738	_Iregion_2 |	0.741	0.962	1.24
_Iregion_3 |	0.657**	0.773	0.570**	_Iregion_3 |	0.906	0.922	0.691
_Iregion_4 |	0.672*	1.561	0.76	_Iregion_4 |	0.722	0.9	0.649
_Iregion_5 |	0.872	0.991	0.552**	_Iregion_5 |	0.876	0.655	0.768
_Iregion_6 |	0.948	1.02	0.679	_Iregion_6 |	0.490*	0.826	0.912
_Iwealth_du_2 |	0.984	0.777	1.054	_Iwealth_du_2 |	1.122	0.921	0.933
_Iwealth_du_3 |	0.811*	0.79	0.852	_Iwealth_du_3 |	1.096	1.133	0.733
_Iwealth_du_4 |	0.734*	0.909	0.625**	_Iwealth_du_4 |	1.043	1.007	0.557**
_Iwealth_du_5 |	0.692*	0.713	0.531**	_Iwealth_du_5 |	0.925	0.636	0.406**
_Ielect_1 |	1.183	1.368	1.182	_Ielect_1 |	0.866	1.486*	0.801
_ITV_1 |	1.076	0.470**	0.94	_Ielect_7 |	1.017	0.603	0.702
_Ireligion_2 |	0.703*	1.006	0.703	_ITV_1 |	1.11	0.629*	1.207
_Ireligion_99 |	0.532	1.889	0.401	_Ireligion_2 |	0.638**	0.621	0.841
_Isex_head_2 |	0.942	0.708	0.934	_Ireligion_96 |	0	0	0
_Iwom_edu_1 |	1.058	1.226	1.094	_Ireligion_99 |	0.457	1.459	0
_Iwom_edu_2 |	1.073	1.021	1.009	_Isex_head_2 |	1.14	0.936	1.035
_Iwom_edu_3 |	0.823	0.679	0.522*	_Iwom_edu_1 |	0.981	1.139	1.095
_Ibord_new_2 |	1.09	1.389	0.968	_Iwom_edu_2 |	1.063	1.133	0.984
_Ibord_new_3 |	0.952	1.399	0.864	_Iwom_edu_3 |	0.839	0.866	0.648
_Ibord_new_99 |	0.973	1.316	0.827	_Ibord_new_2 |	1.033	0.967	1.023
age_chd |	1.036	1.164	0.788*	_Ibord_new_3 |	1.136	0.86	1.093
age_chdsq |	0.950**	0.905**	1.007	_Ibord_new_99 |	1.141	1.087	1.071
_cons |	0.133*	0.020**	0.080*	age_chd |	0.827*	1.229	0.765*
				age_chdsq |	1.002	0.917*	1.006
				_cons |	112.136**	0.112	26.867
_cons |	0.113***	0.156***	0.241***	_cons |	0.153***	0.217***	0.088***

*** p<0.001; ** p<0.01; *p<0.05.

Table D.4 Estimation of Marginal Impact on the Incidence of Childhood Illness and Malnutrition (Odds Ratio), 2011 DHS

	Rural sample				Urban sample		
Variable	**Illnesses**	**WFH<2sd**	**HFA<2sd**	**Variable**	**Illnesses**	**WFH<2sd**	**HFA<2sd**
Monsoon season	1.1	1.2	0.9	Monsoon season	1.07	1.13	0.70*
Water source (reference: tube well)				Water source (reference: piped water)			
Piped water	1.13	0.61	0.55	Tube well	1.34*	0.63*	1.09
No water	1.35	1.47	1	No water	1.25	0.94	1.58
Sanitation (reference: improved latrine)				Sanitation (reference: flush latrine)			
Pit latrine	1.16	1.16	1.40**	Improved latrine	1.09	1	1.09
Open latrine	1.08	1.08	1.67***	Pit latrine	0.97	1.31	1.42*
No latrine	1.06	1.15	2.00***	Open latrine	1.34	1.29	1.4
Flush	1.17	1.12	0.89	No latrine	0.81	0.65	1.42
Has electricity	0.95	0.89	0.83*	Has electricity	0.77	0.78	0.58**
Mother's education (reference: secondary and above)				Mother's education (reference: secondary and above)			
Primary education	1.20*	1.14	1.41***	Primary education	1.19	1.3	1.57***
No education	0.97	1.19	1.67***	No education	1.11	1.26	2.07***
Stunted	1.20**	1.40***		Stunted	1.19	1.39*	
Sex_head = female	1.24*	0.97	1.04	Sex_head = 2	1.31	0.91	0.93
Child age	0.80***	1.06*	1.18***	Child age	0.87***	1.07	1.15***
Constant	0.93	0.10***	0.22***	Constant	0.76	0.14***	0.28***
Number of observations	5,200	5,200	5,200	Number of observations	2,135	2,135	2,135

Note: WFH = weight for height; HFA = height for age; sd = standard deviation.
*** $p<0.001$; ** $p<0.01$; * $p<0.05$.

Four types of health adaptation interventions are found to have a statistically significant health impact: household sanitation facilities, access to electricity, nutritional status, and mother's education. The findings in Bangladesh are broadly consistent with evidence compiled from many low-income countries by the World Health Organization (WHO 2011) showing consistently that children's health status (disease incidence and nutrition status) is influenced by a range of household factors, such as living conditions with access to safe water and sanitary toilet facilities, the availability of diverse and nutrient-rich food, and maternal and child-care practices (hygiene practices).

The magnitude of the net impact of these four policy variables is summarized as follows:

- **Sanitation.** Upgrading household's sanitation facilities has a large impact on reducing the incidence of chronic malnutrition (stunting). In urban areas, holding all other conditions constant, a single intervention—upgrading to a flush latrine or a septic sink from a pit latrine—reduces the incidence of stunting by 42 percent. The health impact is even bigger in rural areas: upgrading to an improved latrine from a pit, an open, or no latrine, on average, reduces the incidence of stunting by 40, 67, and 100 percent, respectively.
- **Electricity.** Access to householdelectricity reduces the incidence of stunting.[32] A child living in a household with electricity is 20 percent less likely to be stunted in rural areas and 40 percent less likely in urban areas, everything else being the same. This finding may be linked to food storage. Unsafe food storage due to a shortage of electricity has been identified as a serious health risk in many parts of Bangladesh due to the long period of heat and humidity in the summer season.
- **Nutrition.** Children's nutritional status is an important determinant of childhood illnesses. Children who are stunted are 20 percent more likely to suffer from illness

32 The health benefits of household access to electricity are much less discussed in policy, although some important evidence exists on the impact of access to electricity on reducing child mortality based on cross-country analysis of DHS data (Wang 2003).

(diarrhea, ARI, or fever) and 40 percent more likely to be underweight, holding other factors constant. The estimated impact of stunting is similar among the urban and rural populations. This finding indicates that significant health benefits can be generated by investing in nutrition-focused programs.

- **Mother's education.** As expected, improving mothers' education has a large impact on reducing incidence of disease and prevalence of malnutrition. The results show that a child living in a household with an uneducated mother is twice as likely to be stunted in urban areas and 30 percent more likely to be stunted in rural areas than a child living in a household with a mother with a secondary education, all factors being the same. Similarly, a child living with a mother with primary education only is about 20 percent more likely to get sick than a child cared for by a mother with secondary education.

Table D.5 District-Level Change in Population, 2001–2010

Zila	Population		Growth rate (%)	Zila	Population		Growth rate (%)
	2001	2011			2001	2011	
Gazipur	2,031,891	3,403,912	6.75	Nator	1,521,336	1,706,673	1.22
Dhaka	8,511,228	12,043,977	4.15	Netrokona	1,988,188	2,229,642	1.21
Narayanganj	2,173,948	2,948,217	3.56	Jhenaidah	1,579,490	1,771,304	1.21
Sylhet	2,555,566	3,434,188	3.44	Chuadanga	1,007,130	1,129,015	1.21
Bandarban	298,120	388,335	3.03	Kushtia	1,740,155	1,946,838	1.19
Cox's Bazar	1,773,709	2,289,990	2.91	Jessore	2,471,554	276,4547	1.19
Sunamganj	2,013,738	2,467,968	2.26	Munshiganj	1,293,972	1,445,660	1.17
Noakhali	2,577,244	3,108,083	2.06	Magura	824,311	918,419	1.14
Moulvibazar	1,612,374	1,919,062	1.90	Gaibandha	2,138,181	2,379,255	1.13
Habiganj	1,757,665	2,089,001	1.89	Meherpur	591,436	655,392	1.08
Brahmanbaria	2,398,254	2,840,498	1.84	Rajbari	951,906	1,049,778	1.03
Panchagar	836,196	987,644	1.81	Tangail	3,290,696	3,605,083	0.96
Narsingdi	1,895,984	2,224,944	1.74	Faridpur	1,756,470	1,912,969	0.89
Rangamati	508,182	595,979	1.73	Jamalpur	2,107,209	2,292,674	0.88
Comilla	4,595,557	5,387,288	1.72	Naogaon	2,391,355	2,600,157	0.87
Khagrachhari	525,664	613,917	1.68	Manikganj	1,285,080	1,392,867	0.84
Nilphamari	1,571,690	1,834,231	1.67	Jaipurhat	846,696	913,768	0.79
Laksmipur	1,489,901	1,729,188	1.61	Shariyatpur	1,082,300	1,155,824	0.68
Pabna	2,176,270	2,523,179	1.59	Satkhira	1,864,704	1,985,959	0.65
Feni	1,240,384	1,437,371	1.59	Chandpur	2,271,229	2,416,018	0.64
Chapai Nawabganj	1,425,322	1,647,521	1.56	Sherpur	1,279,542	1,358,325	0.62
Kurigram	1,792,073	2,069,273	1.55	Borguna	848,554	892,781	0.52
Chittagong	6,612,140	7,616,352	1.52	Patuakhali	1,460,781	1,535,854	0.51
Sirajganj	2,693,814	3,097,489	1.50	Bhola	1,703,117	1,776,795	0.43
Thakurgaon	1,214,376	1,390,042	1.45	Narail	698,447	721,668	0.33
Mymensingh	4,489,726	5,110,272	1.38	Madaripur	1,146,349	1,165,952	0.17
Rajshahi	2,286,874	2,595,197	1.35	Gopalganj	1,165,273	1,172,415	0.06
Rangpur	2,542,441	2,881,086	1.33	Pirojpur	1,111,068	111,3257	0.02
Lalmonirhat	1,109,343	1,256,099	1.32	Barisal	2,355,967	2,324,310	−0.13
Dinajpur	2,642,850	2,990,128	1.31	Jhalkati	694,231	682,669	−0.17
Bogra	3,013,056	3,400,874	1.29	Khulna	2,378,971	2,318,527	−0.25
Kishoreganj	2,594,954	2,911,907	1.22	Bagerhat	1,549,031	1,476,090	−0.47

Table D.6 Spatial Analysis: Disease Incidence versus Local Capacity, 2011

Zila	Diarrhea incidence (%)	Improved sanitation (1 best; 65 worst)	Safe drinking water (1 best; 65 worst)	Health equip-ment avail-ability (1 best; 25 worst)	Essential drug avail-ability (1 best; 25 worst)	Zila	Diarrhea incidence (%)	Improved sanitation (1 best; 65 worst)	Safe drinking water (1 best; 65 worst)	Health equip-ment avail-ability (1 best; 25 worst)	Essential drug avail-ability (1 best; 25 worst)
Kushtia	4.96	38	14	5	19	Comilla	1.37	15	43	11	7
Kishoreganj	3.83	52	41	10	21	Thakurgaon	1.31	63	3	—	—
Munshiganj	3.80	6	27	7	20	Jamalpur	1.30	45	21	6	18
Manikganj	3.63	20	19	—	—	Chapai Nawabganj	1.23	59	31	—	—
Bandarban	3.57	64	63	—	—	Sunamganj	1.21	61	54	11	15
Rajshahi	3.48	42	28	—	—	Cox's Bazar	1.21	44	52	4	17
Khagrachhari	3.46	56	61	11	6	Feni	1.20	17	36	—	—
Magura	3.38	13	6	—	—	Sirajganj	1.08	34	24	5	3
Jhenaidah	3.37	41	10	1	23	Jhalkati	1.07	2	46	9	20
Satkhira	3.36	39	57	11	16	Naogaon	1.06	58	48	1	20
Shariyatpur	3.34	5	33	9	1	Tangail	1.01	31	29	5	1
Khulna	3.30	12	56	9	6	Jaipurhat	0.98	46	23	11	20
Rajbari	3.11	10	15	—	—	Narail	0.86	22	8	—	—
Rangamati	3.10	57	64	11	6	Bogra	0.83	29	9	3	10
Bagerhat	2.87	9	62	9	5	Brahmanbaria	0.81	25	34	11	12
Gopalganj	2.80	3	30	—	—	Jessore	0.80	35	2	4	16
Sherpur	2.52	47	42	—	—	Nator	0.74	27	38	11	1
Chandpur	2.51	28	45	11	19	Nilphamari	0.74	60	22	—	—
Sylhet	2.39	32	60	9	13	Chittagong	0.47	14	44	10	14
Netrokona	2.39	55	51	1	1	Faridpur	0.45	8	16	5	2
Dinajpur	2.37	48	4	11	22	Bhola	0.44	36	32	—	—
Habiganj	2.36	49	53	12	19	Panchagar	0.41	30	37	13	11
Chuadanga	2.24	51	7	—	—	Pirojpur	0.41	16	59	—	—
Laksmipur	2.17	18	49	9	1	Kurigram	0.39	40	17	2	8
Madaripur	2.12	24	25	—	—	Borguna	0.36	19	55	9	24
Narsingdi	2.04	33	11	—	—	Pabna	0.32	26	39	5	13
Moulvibazar	1.89	43	58	11	4	Lalmonirhat	0.31	37	18	1	4
Meherpur	1.60	50	26	—	—	Patuakhali	0.26	21	12	—	—
Dhaka	1.60	1	1	1	26	Barisal	0.13	4	40	1	25
Mymensingh	1.57	53	47	8	1	Gaibandha	0.12	62	35	5	9
Narayanganj	1.42	11	20	—	—	Noakhali	0.12	23	50	—	—
Gazipur	1.40	7	13	12	20	Rangpur	0.11	54	5	1	1

Sources: Diarrhea incidence is from the health Management Information Service, health facility capacity measures are from the 2011 national HFS, water and sanitation access are from the 2011 census.
Note: — = no data.

APPENDIX E
POLICY SIMULATION OF HEALTH IMPACT

The health benefit is estimated under the assumption of achieving the following targets by 2020: (1) universal access to safe drinking water (that is, tube well in rural areas and piped water in urban areas), sanitary toilet facilities, and electricity; (2) female secondary education attainment; and (3) elimination of child stunting. These policy targets are set in reference to both the current level of access to basic services, female education, and child malnutrition estimated from the 2011 Demographic and Household Survey (DHS) and the Millennium Development Goal targets set for 2015 (see table E.1).

Table E.2 presents the estimated health benefits from achieving the policy targets set for 2020 and 2030, respectively, taking account of population growth. The health benefit is measured in terms of the number of reduced cases of illness and malnutrition and the number of deaths averted among children 0–14 years of age. The simulation results show that improving household living conditions (access to safe drinking water, better sanitation facilities, and access to electricity) is estimated to reduce about one-quarter of stunting cases and avert more than 46 percent of deaths among children 0–14 years of age in 2020.[33] Achieving female secondary education attainment alone is projected to reduce about 15 percent of stunting cases and one-third of child deaths.

Policy interventions in improving nutrition are also shown to generate large health benefits. While the exact relationship between malnutrition and mortality is not well established, the policy simulation suggests that eliminating child malnutrition (stunting) could avert more than 93,000 deaths, representing about one-third of total deaths among children 0–14 years of age.[34] The policy simulation by USAID and FANTA (2012), which uses different data sources and modeling methods, found that over the 2011–12 period about 160,000 child deaths could be averted by reducing the prevalence of stunting. The health benefit from the three policy interventions combined is estimated to reduce more than one-third of stunting cases and to avert more than 70 percent of child deaths annually in Bangladesh.

Table E.1 Policy Simulation Targets

Indicator	Current level, 2011	MDG target, 2015	Simulation target, 2020
Rural area			
Access of tube well (%)	85.5	96.5	100
Improved latrine (%)	9.5	55.5	100
Has electricity (%)	43.8		100
Women with secondary and above education (%)	45.8		100
Stunting (height for age z score < 2 standard deviations) (%)	36.8		0
Population (thousands)	112,510		129,849
Urban area			
Access of piped water (%)	38	100	100
Latrine flush to septic (%)	42	85.5	100
Has electricity (%)	82.5		100
Women with secondary and above education (%)	59.7		100
stunting (height for age z score < 2 standard deviations) (%)	28.7		0
Population (thousands)	26,743		80,399

Source: Current levels are based on the 2011 DHS; 2020 population projection is based on U.S. projection.

33 Using the 2007 DHS data, WPS (2011) shows that inadequate sanitation is responsible for economic losses of about US$4.22 billion, equivalent to 6.3 percent of the country's gross domestic product each year based on estimates from the 2007 DHS data, with premature mortality and other health-related diseases and disability accounting for about 84.3 percent of total cost. The World Health Organization (WHO) has estimated that almost 10 percent of the global burden of disease could be prevented through water, sanitation, and hygiene interventions.

34 In Bangladesh, the number of children under five classified as stunted and wasted was 5,958,000, and 2,251,000, respectively, in 2011 (UNICEF 2013). The projected number of stunting and wasting by 2020, under the scenario of "business as usual"—meaning that no health adaptation measures are taken—will rise to 7,690,000 and 2,905,000, respectively (attributable to population growth).

Table E.2 Estimating the Health Benefit of Targeted Policy Interventions

Target	Infrastructure	Women's education	Nutrition	All combined
Reduced stunting, ages 0–5 (thousands)	1,908	1,156	none	2,563
% stunted in 2020	**24.8**	**15.0**	**none**	**33.3**
% stunted in 2030	**20.6**	**12.5**	**none**	**27.6**
Averted death, ages 0–14 (thousands)	133	96	93	212
% deaths averted in 2020	**46.5**	**33.6**	**32.4**	**74.0**
% deaths averted in 2030	**49.8**	**35.9**	**34.6**	**79.2**

Note: The table makes the following assumptions: (1) the proportion of urban population increases from 28 percent in 2011 to 35 percent in 2020 and to 45 percent in 2030, (2) the population ages 0–14 years old is 51 million in 2011 (WHO 2009), 66 million in 2020, and 61.8 million in 2030, (3) the total deaths of people 0–14 years of age is estimated at 221 million in 2011 (WHO and PAHO 2010), 286 million in 2020, and 267 million in 2030, and (4) the population 0–5 years of age is estimated at 19 million in 2011 (UNICEF 2013), 24.5 million in 2020, and 22.9 million in 2030.

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