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CLIMATE VULNERABILITY ASSESSMENT: IMPACTS ON HEALTH OUTCOMES IN SECONDARY CITIES OF BANGLADESH

January 2020

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Cover Photo: View of Khulna City, Goran Hoglund (Kartlasarn), 2016.

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Prepared for:

United States Agency for International Development

Adaptation Thought Leadership and Assessments (ATLAS)

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ACRONYMS

AQI	Air quality index
CDCS	Country development cooperation strategy
DO	Development objective
IPCC	Intergovernmental Panel on Climate Change
MCHN	Maternal and Child Health and Nutrition
PM	Particulate matter
USAID	United States Agency for International Development

EXECUTIVE SUMMARY

OVERVIEW

Bangladesh faces many urban management challenges, including unplanned development, rapid population growth and land conversion. These challenges expose its cities to a variety of natural phenomena that can lead to disasters with loss of life, destruction of natural resources and damage to economic activities, houses and infrastructure. This assessment focuses on two secondary cities in Bangladesh, Khulna and Chattogram, evaluating the current and future risks to maternal and child health and nutrition (MCHN) that climate variability and change present — exacerbating pollution and environmental management challenges—in these rapidly growing cities.[1] It offers insights on the potential investment gaps which need to be addressed to help secondary cities in Bangladesh build resilience against climate risks now and in the future. In order to accomplish spatial analyses specific to city-level vulnerability, the report uses both qualitative and quantitative data to better understand areas of vulnerability.

METHODS

We examine the vulnerability of the cities of Khulna and Chattogram to a changing climate in conjunction with other non-climate stressors which will hinder residents' ability to address climate risks in the future. With a combination of desk-based research, key informant interviews and spatial analyses, this analysis focuses on three questions:

- What parts of the cities are vulnerable and why? (Sensitivity)
- What are they vulnerable to? (Exposure)
- What resources are available to address identified risks? (Adaptive capacity)

WHAT MAKES THESE CITIES VULNERABLE TO CLIMATE RISKS?

A low-lying topography characterized by fairly uniform terrain which is subject to flooding and waterlogging. These cities are located at the confluence of several major rivers and streams (Khulna) and on the Bay of Bengal coast (Chattogram), which contributes to their vulnerability to hydro-meteorological hazards that impact people, economic activities, goods and services. In Khulna City, for example, projections suggest that waterlogging can occur at water levels >30 cm, and the areas projected to reach these levels increase from 29 percent to 35 percent of the cities by the 2030s, and 54 percent by the 2050s for a 1-in-10-year flood event. Furthermore, coastal intrusion and rising salinity levels will reduce water quality through salinization of critical groundwater and shallow tube wells.

[1] Throughout this document, "Khulna" and "Chattogram" refer to the individual city corporations in Bangladesh and do not refer to the respective districts.

Critical changes to the natural landscape reduce capacity to buffer impacts. Sidewalks, pavement, roads and other impermeable surfaces have reduced the absorptive capacity of the soils, exacerbating flood events as the water gets channeled along these impermeable surfaces. Construction in the Chattogram Hill Tracts, leading to the removal of the native vegetation that once helped to stabilize the soil and absorb rainwater upstream of the city, has increased landslide and flood risk in this city, while construction of impermeable surfaces has increased inland flooding and heat islands in Khulna.

Inadequate local governance, including a lack of consistent planning to address increasingly faster demographic growth. Rapid population growth, coupled with increasing in-migration from agricultural areas to the cities, mean that growth in the last several decades has been unplanned, often through spontaneous and chaotic occupation of available lands, in many cases in high-risk areas. Inadequate land use planning and limited capacity to enforce existing regulations allowed for uncontrolled urban expansion into high-risk areas such as the banks of tributaries. The pace of service provision for lifeline utility systems (e.g., water, waste management) has lagged in many of these fast-growing areas, particularly for slum populations of both cities.

Poor knowledge base of vulnerable populations. While Bangladesh has improved its knowledge base by identifying areas at high risk from natural disasters, developing flood risk maps and prioritizing strategic responses, these initiatives have limited reach to the urban poor, who often distrust government and other institutions and are unaware of the risks that climate change may pose to their already vulnerable lives. Awareness-building within these communities to improve residents' understanding of these risks and engaging with them to advocate for adaptation investments will be critical to reducing their vulnerability to a growing combination of social, economic and environmental risks.

Weak institutional capacity and coordination. The analysis and field visits demonstrate that, in spite of the national attention to climate change issues, secondary cities face governance challenges, including the challenge of developing a coordinating framework to manage risks while engaging communities to strengthen responses and build resilience through planning. Both cities lack integrated land use management plans that consider climate risks. Adaptation actions are outsourced to local NGOs working in the peri-urban areas, and no coordination mechanisms exist to encourage cooperation between key city departments such as health, disaster management and transport. On the policy front, activities that aim to harmonize city plans (e.g., waste management and health) before they reach donors could help to reduce negative impacts of sector-specific activities planned and implemented in a vacuum.

RECOMMENDATIONS TO ADDRESS THE RISKS AND IMPACTS OF CLIMATE AND ENVIRONMENTAL CHANGE

Addressing MCHN and environmental issues in Bangladesh's secondary cities requires incorporating activities and targets that explicitly consider the role of urban planning and environmental management in the context of a changing climate. The climate risk insights provided here offer climate change adaptation options grouped in three categories: (1) science and analysis to inform decision-making; (2) improved governance and capacity; and (3) piloting in health and environmental management at the urban scale. The two development objectives (DOs) highlighted below provided entry points to integrating recommendations in this area into the current USAID/Bangladesh country development cooperation strategy (CDCS).

- **Development Objective 3:** Improve the health status of target populations, building on past and on-going successful population, health and nutrition programs while incorporating Global Health Initiative (GHI) principles.
- **Development Objective 4:** Responsiveness to climate change improved.

SCIENCE AND ANALYSIS TO INFORM DECISION-MAKING

Obtaining climate vulnerability and risk information is the first step in identifying areas of intervention. The following recommendations for improved information are offered:

- Improving the understanding of context-specific risks for slum dwellers
- Conducting detailed vulnerability assessments in slums
- Expanding air quality monitoring

IMPROVED GOVERNANCE AND CAPACITY

Neither Chattogram nor Khulna has a strategic plan that addresses climate risks explicitly. In fact, climate change adaptation actions are implemented primarily by local NGOs, not under city leadership. Moreover, existing plans, such as the 2011 Khulna City Corporation Master Plan (the most recent identified in the research for this study), are used solely as instruments for planning permission and development control rather than to lay out a detailed long-range vision for infrastructure investment and land use planning**.**

PILOTING INTEGRATED HEALTH AND ENVIRONMENTAL MANAGEMENT INTERVENTIONS

A range of adaptation options could be considered to achieve intermediate targets of development objectives aimed at improving health and environmental management under a changing climate. These include:

- **Promoting public health awareness on climate change impacts.** USAID/Bangladesh's behavior change campaigns aimed at dietary diversity, exclusive breastfeeding and feeding frequency have clearly been successful in linking home gardens to nutrition. Leveraging these experiences to build awareness of the risks from climate shocks could improve responses.

- **Improving strategies for environmental management in urban landscapes.** USAID/Bangladesh's investments to date have targeted rural environments. Ecosystem services that peri-urban and rural environments provide are critical to the health of a city's population. More needs to be done within cities in order to reduce pollution, manage waste and improve drainage.
- **Expanding access to safe water and improved sanitation.** As the climate changes, heavy downpours are likely to increase in frequency and intensity, leading to more flooding events, which have been linked to increased gastrointestinal illness and diarrheal diseases.
- **Enhancing surveillance, diagnostic and treatment options during high-risk seasons/periods.** Climate risk information on extreme events, such as the largest increase in the heat index occurring between August and September and during the monsoons, can be used to alert high-risk communities and screen for risk factors from heat stress, including cardiovascular and pulmonary status. Climate information could also help secure additional resources for high-risk seasons.
- **Improving health care access among populations vulnerable to climate-sensitive diseases (e.g., heat-related, waterborne illnesses) or exposed to injury from natural disasters**. Better access to health care could require building new facilities, subsidizing service delivery to lower out-of-pocket costs, developing weather-proof transportation infrastructure, strengthening institutional coordination to build health system resilience or bolstering early warning systems.
- **Engaging in multisectoral interventions, including professionals from urban planning, public works, engineering and the health sectors.** Understanding climate sensitivities — especially relationships between seasonal pollution, wind speeds and rainfall — could play a role in formulating partnerships that can identify, improve and scale up interventions to reduce risks.

ENTRY POINTS FOR THE COUNTRY DEVELOPMENT COOPERATION STRATEGY

Addressing the implications of climate variability and change in the next CDCS would help protect human health. Examples of integration include:

- Using climate vulnerability analyses to extend health service access by taking advantage of auxiliary health care providers such as pharmacies and traditional healers in high-risk areas
- Extending diagnostic and treatment options in high-risk areas/periods
- Implementing programs to increase public awareness on climate change impacts, disease/illness control, prevention and treatment
- Using the successful national cyclone early warning system as a foundation to create a similar early warning system to anticipate, monitor and provide communications to communities regarding disease outbreaks
- Working with communities to increase resilience through safety nets or building social capital
- Providing direct support to families to "graduate" themselves out of vulnerability by facilitating movement to less vulnerable locations and by building household livelihood resilience

- Enhancing integrated surveillance, monitoring and control programs for climate-sensitive health outcomes
- Training professional staff in health and other ministries and organizations on the health risks of climate change and developing partnerships between health and other ministries and other organizations to more effectively address the health risks of climate change
- Incorporating initiatives to improve equity and mitigate the effects of gender and other social determinants of health into policies and programs

Indicators can also be added to the CDCS intermediate results targets to monitor progress on managing the health risks of climate variability and change, such as for infectious diseases, as well as indicators to monitor nutritional conditions, such as using seasonal climate information to forecast emerging food security and safety crisis situations.

INTRODUCTION

Climate variability and change has dire implications for every aspect of life, particularly human health. It exposes populations to extremes of weather, alters patterns of infectious disease and compromises food security, safe drinking water and clean air. Bangladesh, home to 164 million people, is one of the countries most vulnerable to the impacts of climate change. It is consistently cited as one of the most disaster-prone countries, exposed to a variety of weather-related shocks and stressors, including cyclones, floods and landslides, the effects of which are expected to become more severe under a changing climate. Sitting in a predominantly low-lying region at the intersections of the Ganga, Meghna and Brahmaputra rivers and the Ganga-Brahmaputra delta, approximately two-thirds of the country is 10 m or less above sea level. This unique topographic feature combined with high population density, rapid urbanization and widespread poverty (roughly one-quarter of the total population and 19 percent of the urban population), exacerbates the impacts of climate change on human health in Bangladesh (United Nations Population Division 2018; Uddin 2018).

Climate shocks and stressors, including natural disasters, increase the vulnerability of Bangladesh's economy and put its development and social, economic and political stability at risk. Resilience to natural hazards is therefore critical to ensuring Bangladesh achieves its goal of being a middle-income country by 2021. Strengthening the resilience and preparedness of Bangladesh's health systems to climate stressors will accelerate the country's progress toward universal health coverage. Nevertheless, challenges remain, especially for secondary cities, around the intersection of climate, human health and environmental management.

Bangladesh is urbanizing at an annual rate of 3.17 percent, which is roughly two million new urban residents each year. Currently, around 36 percent of the country's 164 million population live in urban areas. By 2050, the urban population is projected to account for more than half of Bangladesh's total projected population of 201 million (United Nations Population Division 2018; Uddin 2018). Secondary cities in Bangladesh face the challenges of rapid urbanization, including unplanned expansion, land conversion and rapid population growth, exposing these cities' natural resources and residents to a variety of adverse environmental conditions and intensifying the impacts of natural disasters. This unchecked urban growth hinders economic growth, damages critical infrastructure and has dire consequences for human health. This report focuses on the secondary cities of Chattogram and Khulna, one coastal, the other inland, telling the story of how climate change is exacerbating environmental pollution and water scarcity issues, leading to human health crises. The report offers insights on the potential investment gaps that must be addressed to help secondary cities in Bangladesh build resilience against climate risks now and in the future.

OBJECTIVES OF THIS ASSESSMENT

The objectives of this assessment are to:

- Develop an understanding of the relationship between environmental variables and a range of human illnesses, including noninfectious and infectious diseases, with a focus on maternal and child health and nutrition (MCHN).
- Explore how a changing climate may exacerbate environmental variables and therefore increase risks to human health, especially MCHN.
- Highlight future risks to MCHN across urban areas in Bangladesh, framed by the relationships between environmental variables and climate risk.
- Identify actions to address disease risk, particularly MCHN, in current and future programming.

OVERVIEW OF THE REPORT STRUCTURE

In order to accomplish spatial analyses specific to city-level vulnerability, the report explores both qualitative and quantitative areas of vulnerability. The report is structured as follows:

- Section II summarizes the interactions between climate and environmental change and MCHN as well as the key risks to MCHN outcomes.
- Section III provides a high-level overview of climate and environment risks to the health sector in Khulna and Chattogram.
- Section IV assesses the vulnerability of both secondary cities to climate variability and change, as well as environmental factors.
- Section V offers recommendations for strategic programming to reduce the identified risks in secondary cities.

CLIMATE, ENVIRONMENT AND MATERNAL AND CHILD HEALTH AND NUTRITION

CLIMATE TRENDS AND PROJECTIONS IN BANGLADESH

Over the past decade, climate variabilities, including rise in temperature, irregular monsoon, untimely and heavy rainfall, heat waves, longer dry periods and increased flooding have been observed across the country. Average temperatures nationwide are increasing, especially during the monsoon season (June–September) at 0.07°C per decade and during early winter (September–November) at 0.12°C per decade. While total annual rainfall has not changed significantly, at the seasonal level, Bangladesh has seen an increase in rainfall. Both the rainy and dry seasons have shortened in length, and heavy rainfall also occurs within a shorter timeframe. These changes in the precipitation regime can alter the timing of floods and increase their magnitude, frequency, depth, extent and duration.

Bangladesh has also seen an increase in the incidence and intensity of other extreme events. A significant increase has been observed in heat extremes and cyclone frequency during the "cyclone seasons" in November and May. There is also evidence that the peak intensity of cyclones may increase by 5 to 10 percent, which would contribute to enhanced storm surges and coastal flooding. Some regions of Bangladesh are increasingly prone to drought; reduction of already insignificant rainfall during the dry season months (October to February), combined with higher surface desiccation, would increase moisture stress, especially in the western parts of the country (Ahmed et al. 2009).

The observed climate trends and projections for Bangladesh have significant impacts on human health and nutrition in Bangladesh's cities. These impacts are further magnified by urban, socioeconomic, environmental and disease patterns; women, children and slum-based populations are most vulnerable.

HEALTH AND NUTRITION IN BANGLADESH

Bangladesh has significantly improved public health. Between 1990 and 2015, under-five mortality decreased from 151 to 46 per 1,000 live births. During the same period, maternal mortality decreased from 574 to 176 per 100,000 live births. However, Bangladesh has the lowest expenditure on health as a share of gross domestic product in South Asia, averaging 2.6 percent (Ministry of Health and Family Welfare, World Health Organization, World Bank, and Alliance for Health Policy and Systems Research 2015). Since 2000, the share of domestic government health expenditure in total health expenditures has decreased from more than 28 percent to lower than 14 percent since 2000, while out-of-pocket expenses have increased by 11 percent to 71.8 percent (WHO 2017). As such, while the health system has achieved

significant milestones, it has remained slow and rigid to adapt, especially in the face of rapid urbanization.

Since the 1970s, health and nutrition policies and programs of the Government of Bangladesh (GOB) have focused on delivery of rural health services and improvements. Provision of organized and equitable quality health and nutrition services in urban areas, especially primary care, is lacking and has been challenging to deliver. This is due in part to the unique urban health governance structure in Bangladesh—which divides roles and responsibilities for health care between the Ministry of Local Government, Rural Development and Co-operatives (MOLGRD and C) and the Ministry of Health and Family Welfare (MOHFW). The MOHFW delivers secondary and tertiary care, establishes technical standards, regulation and strategy, and leads policy development. The MOLGRD and C and the city corporations and municipalities that fall under the ministry are responsible for primary health care. Coordination between the two ministries is limited, further constraining the delivery of urban health services (Govindaraj et al. 2018).

Within urban areas, slum populations, which make up 55 percent of the country's urban populace, have received the least amount of attention from the government health system. A recent World Bank study in Dhaka found that most of the average health and nutrition outcomes are poorer for slum residents than for non-slum residents, and some indicators are lower even compared with the rural population (Govindaraj et al. 2018). For example, slum children in city corporations are significantly shorter than non-slum children: their average (height-for-age Z) HAZ score[2] is 0.6 standard deviation lower than that of non-slum children. The moderate-to-severe stunting rate for slum children is 48 percent compared with 38 percent for rural children.

CLIMATE- AND ENVIRONMENT-RELATED IMPACTS ON MCHN

Climate variability and change impacts health in numerous ways, including through increased heat, poor air quality and extreme weather events (e.g., floods, storms, cyclones), as well as through changes in temperature and precipitation that alter vector-borne disease, reduce water quality and decrease food security. The health risks associated with these exposures differ substantially between men and women (Sorensen et al. 2018). Mothers and children are invaluable to their families, communities, societies and economies, and the loss of a mother or child robs their families and economies of their potential (USAID 2019). Women and children, especially of low socioeconomic status, will be disproportionately impacted by climate-related shocks. Climate variability and change threatens to reverse some of Bangladesh's significant gains in improving the status of MCHN across the country.

The heightened vulnerability of women and children will also magnify/compound the existing disparities in social determinants of health (Balasubramanian 2018, Philipsborn and Chan 2018, Sinharoy and Caruso 2019, Sinharoy et al. 2018). Limited access to resources, restricted rights and limited mobility and voice in community and household decision-making due to gender norms make women much more vulnerable than men. Children's physiology and metabolism; incomplete development; higher exposure to air, food and water per unit body weight; unique

[2] HAZ is calculated to assess the child's growth and general nutrition status.

behavior patterns; and dependence on caregivers place them at much higher risk of climate-related health burdens than adults (Ahdoot et al. 2015). Globally, children are estimated to bear the greatest burden of disease due to climate change, with the poorest disproportionately affected (Philipsborn and Chan 2018). For example, the heavy rains during the monsoon season in Pakistan in 2010, increased children's mortality from 94 to 110–120 deaths per 1,000 live births (Stanberry et al. 2018).

Longer-term and indirect effects of climate-related impacts also show important gender differences. For example, droughts in developing countries bring health hazards through reduced availability of water for drinking, cooking and hygiene, and through food insecurity and nutritional deficiencies. In Bangladesh, household food insecurity adversely affects women and children more than men (Nasreen 2008). Due to unequal food distribution in the family, girls receive 20 percent fewer calories than boys (Ikeda 1995, Rylander et al. 2013).

MATERNAL AND NEWBORN HEALTH

The projected increased frequency and/or intensity of natural disasters, including cyclones, droughts, floods and storms, will harm maternal and newborn health in Bangladesh. Without interventions, climate variability and change will increase the risk of infant and maternal mortality, birth complications and poorer reproductive health (Rylander et al. 2013). While data are not available for this subsector, the Intergovernmental Panel on Climate Change (IPCC) estimates that approximately 30 percent of the risks to maternal and newborn health due to climate change could be avoided through adaptation actions (IPCC 2014).

Natural disasters, such as extreme events leading to flooding and landslides, can directly impact health systems. They can destroy medical facilities, disrupt manufacturing plants and distribution networks, and limit patients' access to health care resources. Health care is rarely addressed in disaster response and recovery planning, and, as such, disasters pose greater threats to communities lacking both the access to and resources for health care (e.g., informal slum residents), even as demand for primary health care following a disaster often overwhelms the medical infrastructure (Davis et al. 2010).

Natural disasters also have indirect effects on the health and well-being of women and girls. Violation of women's rights becomes more prominent during disasters (Nasreen 2008). According to the World Disasters Report, women and girls are at higher risk of sexual violence, sexual exploitation and abuse, trafficking and domestic violence during natural disasters (Klynman et al. 2007). Adolescent girls report especially high levels of sexual harassment and abuse in the aftermath of disasters and complain of the lack of privacy in emergency shelters (Bartlett 2008). Natural disasters also exacerbate gender-based violence, such as child marriage in the coastal areas of Bangladesh. Frequent flooding and river erosion mean many families live with the constant threat of insecurity and increased poverty, which impacts decisions about schooling and marriage for girls (Human Rights Watch (HRW) 2015). Both women and girls suffer more from shortages of food and economic resources in the aftermath of disasters (Neumayer and Plümper 2007).

Changes in temperature and precipitation, particularly the increased intensity and frequency of floods, are expected to increase the transmission and spread of vector-borne diseases, increasing the incidence of malaria, dengue and tick-borne encephalitis (Costello et al. 2009).

Worldwide, approximately 125 million pregnant women are infected by malaria each year (Rylander et al. 2013). In Bangladesh, the Chattogram Hill Tracts districts have the highest prevalence of malaria nationally (Hasib and Chathoth 2016). A study of the Chattogram Hill Tracts found that women are more vulnerable to malaria, and pregnancy is a risk factor for asymptomatic *P. falciparum* infection (Khan et al. 2011). Maternal malaria infection may also lead to intrauterine growth restriction and prematurity among newborns, which may put the baby at risk of certain health problems during pregnancy, delivery and after birth (e.g., low birth weight, hypoglycemia, decreased oxygen levels). Additionally, the newborn child is at greater risk of contracting clinical malaria if the mother suffered from an acute malaria-infected placenta during her pregnancy (Rylander et al. 2013).

Regarding dengue, since the country's first major outbreak in 2000, it has emerged as a serious climate-related public health problem and has become predominantly endemic in urban areas, where unplanned, rapid urbanization creates breeding grounds for mosquitos. (Hasib and Chathoth 2016). The majority of dengue cases occur in Dhaka, Chattogram and Khulna. Bangladesh recorded the highest number of dengue cases since 2000, with over 100,000 patients admitted to the hospital as of December 2019, compared to only 9,900 cases in 2018 (ECHO 2019, ProMED 2019). This is an increase of maternal dengue infection has been linked to a number of adverse health effects and pregnancy outcomes, including vertical transmission to the fetus, preterm birth, low birth weight, pre-eclampsia and eclampsia, cesarean delivery, fetal/perinatal death and maternal death (Rylander et al. 2013). Low birth weight in infants can in turn lead to malnourishment in children under 5 years (Rahman et al. 2016, Rahman 2016, Shammi et al. 2019).

Environmental salinity induced by climate change as a result of coastal intrusion, sea level rise and increased storm surge also affects pregnant women and the developing fetus (Rylander et al. 2013). During the monsoon season, Khulna and other southwestern districts are the most salt-encroached areas. Pregnant women living in Bangladesh's Khulna district are especially vulnerable to diseases and complications as they are exposed to exceptionally high levels of sodium in contaminated drinking water (Khan et al. 2011, 2014). In Chakaria district of Bangladesh, researchers found an unexpectedly high rate of miscarriages that was linked to increasing water salinity (BBC 2018). A study in Dacope in the Khulna district found a correlation between increased drinking water salinity levels and increased seasonal hypertension in pregnant women, especially during the dry season when there is less precipitation and diminished river flow (Rahman et al. 2016). Hypertension in pregnancy is associated with increased rates of adverse maternal and fetal outcomes, both acute and long term, including impaired liver function, low platelet count, intrauterine growth restriction, preterm birth and maternal and perinatal deaths. The adverse outcomes are substantially increased in women who develop superimposed (pre)eclampsia (Khan et al. 2011). Finally, increased water salinity and sodium intake could be a major factor in infant and newborn death in coastal Bangladesh. While limited data are available, Shammi et al. found that exposure to saltwater was highly significantly correlated with infant mortality during the last stages of gestation (Shammi et al. 2019).

Poor air quality from the combustion of fossil fuels, especially in urban areas, and increased ground-level ozone resulting from higher temperatures can impair maternal respiratory and

cardiovascular systems and fetal development. Women are disproportionately exposed to air pollutants (e.g., particulate matter, CO_2), which can cross the placenta, deteriorate fetal growth, and lead to stillbirth, intrauterine growth restriction and congenital defects (Sorensen et al. 2018).

Lastly, women and girls who live in water-stressed areas disproportionately suffer health consequences of the burdens associated with travelling farther to collect water, which is a common practice in Bangladesh. For young women, time spent retrieving water can result in missing school (Denton 2002). These impacts are projected to be exacerbated by sea level rise and excessive groundwater withdrawals from aquifers (Khan et al. 2014).

CHILD HEALTH

Numerous studies have found and analyzed the links between climate variability, environmental conditions and childhood health. Climate shocks will increase the risk of vector- and water-borne diseases and are likely to worsen malnutrition (e.g., stunting and wasting) in children.

Several studies point to the increase in the number of waterborne illnesses (e.g., cholera, diarrheal disease) due to changing rainfall patterns in Bangladesh. Cholera continues to be an endemic, major public health problem in many parts of the world, especially in tropical countries like Bangladesh that have poor access to water and proper sanitation. The global estimate of cholera cases is 2.9 million each year, with 95,000 annual deaths (Islam et al. 2018). In Bangladesh alone, there are at least 100,000 cases and approximately 4,500 deaths each year (Ali et al. 2015). Cholera affects all age groups, but the majority of fatal cases occur in children 3–14 years old; children under 5 years of age are most vulnerable (Colombara et al. 2013). Maternal education and breastfeeding status have been found to be key correlates of risk of cholera hospitalization among children under 5 years old in rural and urban Bangladesh (Colombara et al. 2013). A number of climate-related factors, including variable precipitation projections and the increased intensity and frequency of floods, water temperatures and natural disasters will likely increase the distribution and magnitude of cholera outbreaks (Islam et al. 2018). High levels of rainfall have already been associated with both an increased number of reported cholera cases and hospital visits; in Dhaka, Hashizume et al. reported that over half of the patients admitted were children under 15 years old (Hashizume et al. 2008). Recent studies in Bangladesh have also found that higher ambient temperatures and heat waves may also promote cholera and other diarrheal diseases (Hashizume et al. 2008).

Additionally, poor water resource management and a lack of safe water provision are important determinants of outbreaks of cholera and diarrheal diseases in urban areas. Bangladesh is 86th among 142 countries with respect to drinking water quality; sources are contaminated with coliforms, harmful metals and pesticides. Contaminated surface and groundwater as well as untreated water pipes can increase the risk of outbreaks (Haque et al. 2013). Families that rely on surface water, which is frequently contaminated during heavy rainfall and flooding in areas where sewerage systems and sanitation services are poorly constructed, are more likely to see their children contract cholera and/or other diarrheal diseases (Hashizume et al. 2008). In Bangladesh, Wang and Mani found that during the monsoon season, unsanitary toilet facilities (slab, pit or open latrine) in urban areas are a key factor determining the incidence of fever, which is a symptom of many infectious diseases (Wang and Mani 2014).

Rotavirus gastroenteritis is also a major cause of morbidity in Bangladeshi children, accounting for nearly two-thirds of acute gastroenteritis hospitalizations. Single-site studies demonstrate a considerable burden of rotavirus on health care systems. From July 2012 to June 2015, rotavirus was detected in 2,432 (64 percent) of 3,783 children hospitalized in Dhaka for gastroenteritis (Satter et al. 2017).

Climate shocks will also expand the geographical range of vector-borne diseases, including malaria and dengue. Annually, more than 50 million dengue infections are estimated to occur, of which approximately 500,000 result in hospital admissions for severe dengue, primarily among children. Severe dengue fever, if not appropriately managed, may lead to rapid death, particularly in children (Phakhounthong et al. 2018).

As with women, natural disasters also have indirect impacts on children. Disasters during critical childhood growth phrases interrupt health interventions (e.g., immunizations), and natural disasters and other stressful events (e.g., epidemics, tropical diseases, famines) during gestation and the early years of life have been shown to significantly contribute to poor long-run health outcomes (Davis et al. 2010, Datar et al. 2013).

Finally, droughts and variable precipitation projections are also likely to worsen malnutrition, stunting and wasting in children by impacting food security. Although Bangladesh's levels of child undernutrition have been dropping since 1996, as of 2011, nearly 36 percent of children under 5 years (5.5 million) were underweight, 41 percent (6.2 million) were stunted, and 16 percent (2.3 million) were wasted.

CITY PROFILES

KHULNA

Key Risks	Description
Floods and Waterlogging	Rising seas combined with more intense rainfall and poorly maintained drainage infrastructure will increase the risks from floods and waterlogging to the city.
Heat and Droughts	As the number of extremely hot days increases, and rainfall becomes more variable, droughts will impact surface water and the water from shallow tube wells, compromising water availability and quality.

Khulna, located on the Ganges River Delta in the southwest, is the third largest city in Bangladesh and faces risks from rapid population growth, socioeconomic disparities and climate. Globally, Khulna is one of the 15 coastal cities most vulnerable to the impacts of climate change (Fellows of the Capacity Strengthening in the Least Developed Countries for Adaptation to Climate Change (CLACC) and International Institute for Environment and Development (IIED) 2009). The city is Bangladesh's third largest economic center and has a variety of industries, including jute, chemicals, fish and seafood packaging, food processing, sugar milling, power generation and shipbuilding. Almost one-quarter of the city's 663,000 people live in poverty (United Nations Population Division 2018, Bangladesh Bureau of Statistics (BBS) 2011, Roy et al. 2018).[3] Continued population growth and increasing rural-to-urban migration will likely exacerbate competition for water resources, contribute to an increase in greenhouse gas emissions, intensify land use change and increase vulnerability to climate-related hazards. With an already increasingly variable and changing climate, projections of more intense and frequent rainfall, floods and cyclones will create substantial challenges that threaten Khulna's human health, water resources and environment (Roy et al. 2009).

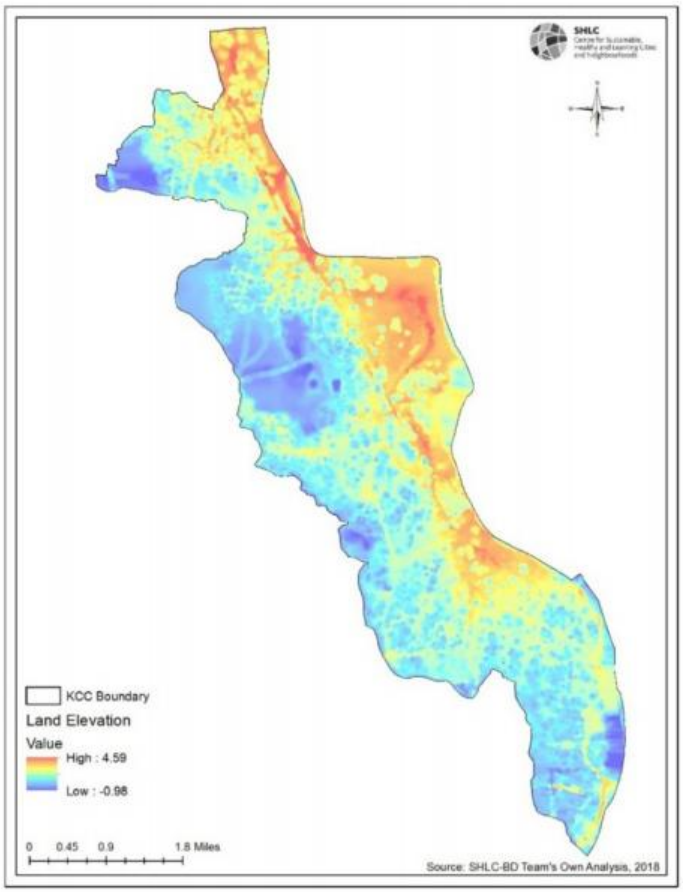
CLIMATE SUMMARY

Khulna has a tropical, monsoon climate owing to its location on the broad deltaic plain of the Ganges River. The Rupsha and Bhairab tributaries of the Ganges River are the two main rivers that flow through the city and influence its land use patterns. On average, the entire metropolitan area is just approximately 2.5 m above sea level, with minimum and maximum altitudes between 0.45 m and 5.40 m (Figure 1); the western areas are at or below sea level and the eastern sections are at higher elevations (Asian Development Bank 2011; Esraz Ul Zanat and Islam 2015). The city has a hot and rainy summer and a pronounced dry season in the winter months (Mondal 2017); annual average rainfall is high, at about 1,900 mm, with over 80 percent of precipitation occurring during the monsoon season of June to September (Asian

[3] The United Nations defines "poverty" as living on $1.90 a day or less.

Development Bank 2011, Ministry of Foreign Affairs of the Netherlands 2018). Average temperatures fluctuate between 19ºC and 30ºC, with the highest temperatures just before the monsoon season and the lowest temperatures during the dry season (October to Febrauary). The combined physical and climatic factors have resulted in poor drainage, frequent flooding, storm surges, cyclones, saltwater intrusion, sedimentation and riverbank erosion. In 2004, tropical cyclone Sidr, which hit Bangladesh's southwestern coast, killed 3,400 people and damaged 1,714 km of roads, with an estimated cost of $1.7 billion (Asian Development Bank 2011, Ministry of Foreign Affairs of the Netherlands 2018).

Figure 1: Digital elevation map of Khulna



Source: SHLC-BD, 2018

Source: Roy et al. 2018

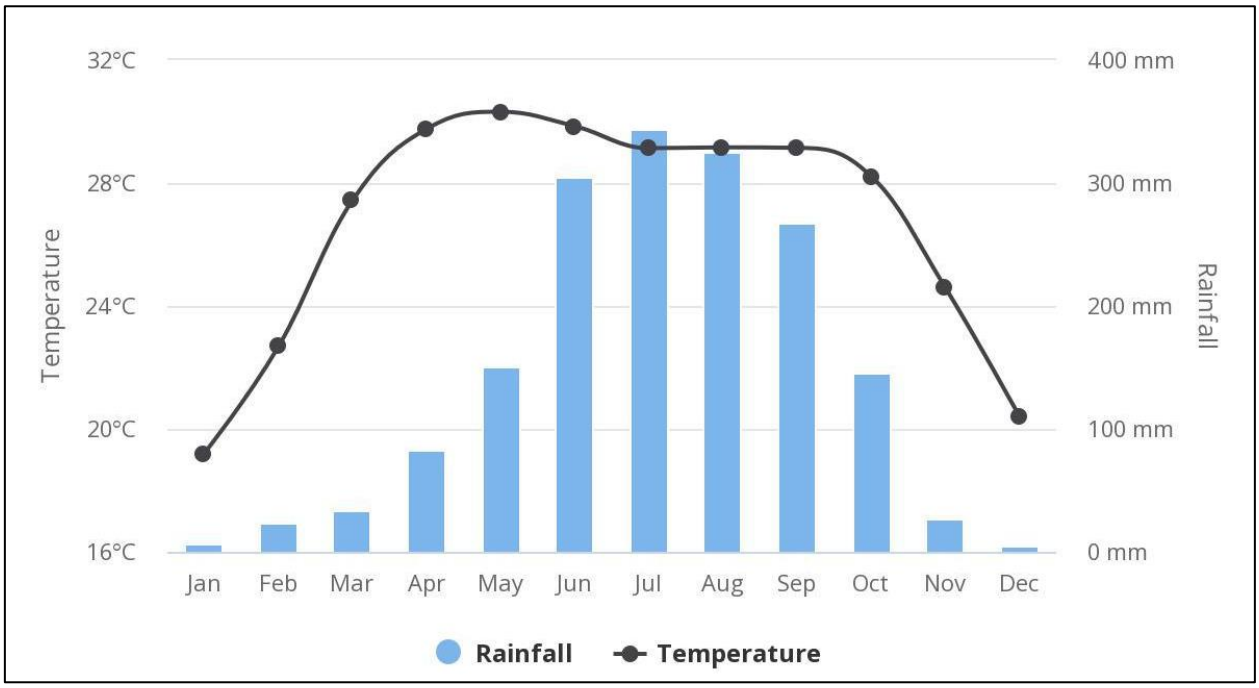
HISTORICAL CLIMATE

Yearly average monthly temperature and rainfall from 1991 to 2016 are shown in Figure 2. Key climate observations through 2015 include:

- Increased mean annual temperatures by 0.05ºC. The monthly maximum, minimum and mean temperatures show a positive trend over Bangladesh.
- More erratic rainfall, with increasing trends of 8 mm (winter), 31 mm (monsoon), 9 mm (postmonsoon), and 6 mm (premonsoon) per decade from 1950 to 2010. Annual total rainfall nationwide from 2005 to 2015 did not show any significant changing trends.

- A three-fold increase in the frequency of severe cyclones in the Bay of Bengal from 1901 to 2007, with a slightly negative trend after 1970. The number of severe cyclones experienced has increased from 1 per year to 3 per year during May, October and November, the main months for cyclone activity in the Bay of Bengal (Aktar and Roy 2017, Ministry of Environment and Forests (MoEF) 2009, Mondal 2017, Singh 2007).

Figure 2: Average monthly temperature and rainfall for Khulna, 1991–2016



Source: World Bank 2019

FUTURE CLIMATE

Projected changes include:

- Increased temperatures of 1.8ºC –2.1°C by the 2050s
- Increase in the days (+10 to +15 days) with maximum temperatures >35°C, with the highest increases between March and May (Figure 3 and Figure 4)
- More variable and uncertain precipitation trends, with some models suggesting an increase of 10–25 mm during the latter part of the rainy season (Figure 5)

Figure 3: Projected change in monthly maximum temperatures for Khulna by the 2050s (2040–2059) (top) with historical (1986–2005) seasonal cycle of temperatures (bottom)

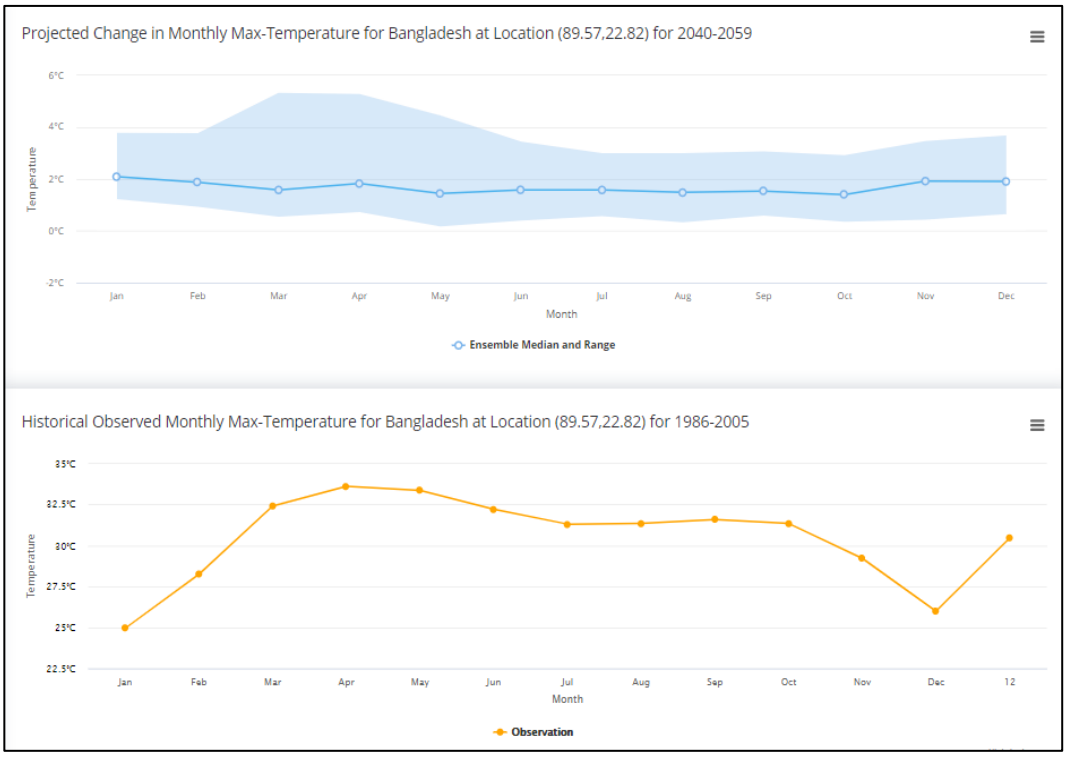
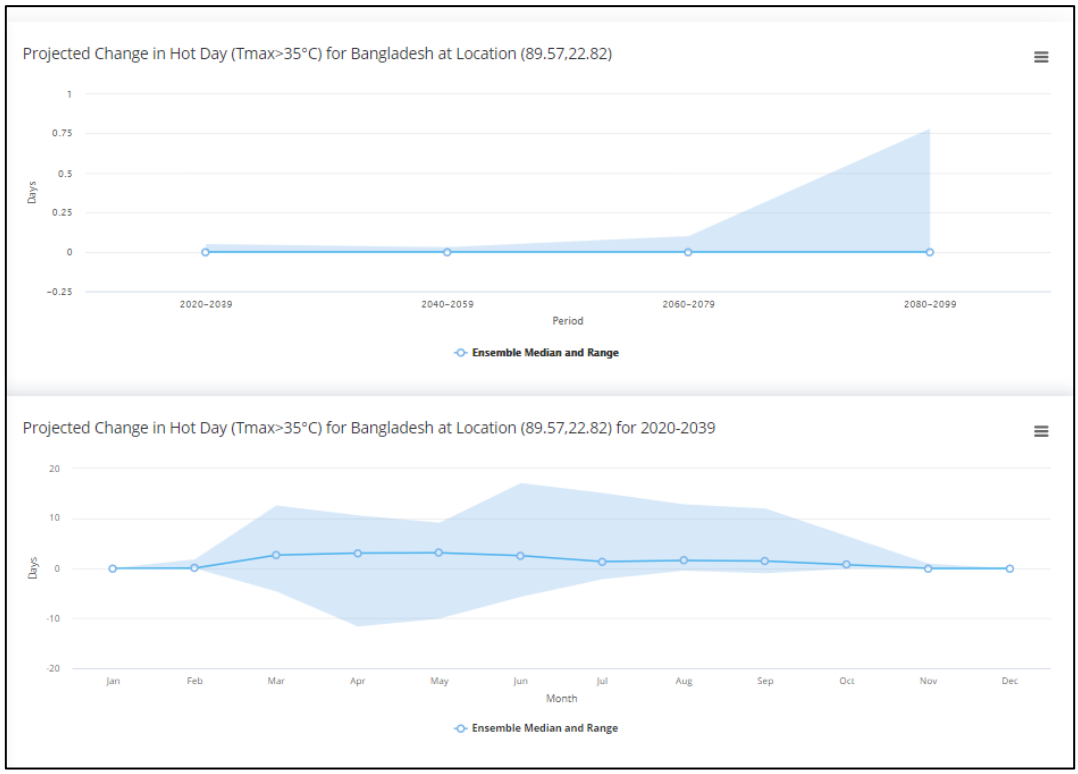
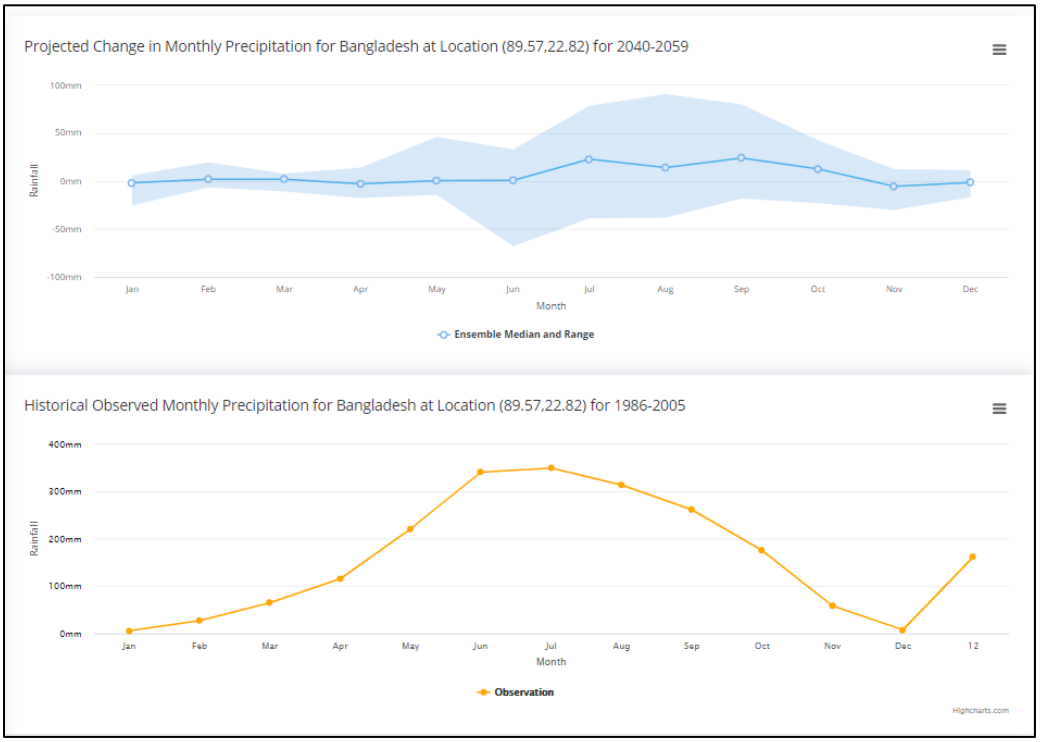


Figure 4: Projected change in the number of days above 35ºC across all time periods (top) and monthly change from these numbers for Khulna by the 2030s (2040–2059) (bottom)



Source: World Bank 2019

Figure 5: Projected change in monthly precipitation for Khulna by the 2050s (2040–2059) (top) with historical (1986–2005) seasonal cycle of rainfall (bottom)



Source: World Bank 2019

SECTOR IMPACTS AND VULNERABILITIES

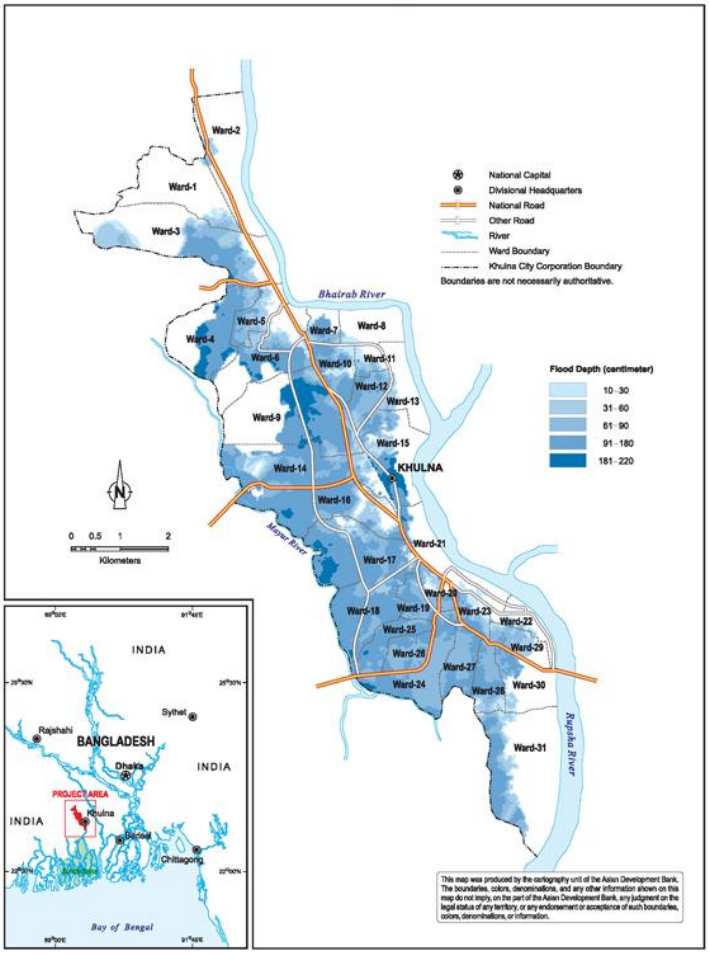
Coupled with population growth, climate stressors—including rising temperatures, more intense precipitation and subsequent flooding, and more frequent cyclones and droughts—are expected to have diverse but mostly negative impacts on Khulna's water availability and quality. Groundwater constitutes the major source of water in the city, however, only 30 percent of households have a piped water supply. The increasing frequency of drought in Khulna also impacts both surface water and shallow tube wells, reducing the availability of freshwater that is safe to drink (Asian Development Bank 2011).

More frequent and intense rainfall has consequences for waterlogging, which has emerged as a serious challenge for Khulna due to poor drainage, unabated encroachment of drainage canals due to road construction or residential development and an inefficient sewerage system. During the rainy season (May to October), sewers are frequently blocked, and one hour of "normal" rain is enough to flood a considerable part of the city. The Mayur and Rupsha rivers have become a dumping ground for untreated wastewater from the central urban zone. Not only has this increased the prevalence of disease, but it has also triggered a reduction in the rivers' fish population (Mridha n.d.). Additionally, sea level rise prevents efficient discharge from the drainage system in the city's eastern, low-lying areas; the resulting contaminated wastewater promotes the occurrence and spread of waterborne illnesses (Asian Development Bank 2011). Lastly, the increasing frequency and intensity of cyclones also have consequences for waterlogging. Cyclone Aila in 2009, which affected nearly 546,000 people in Khulna, destroyed

594 km of embankment, which allowed river water to freely flow inland and resulted in flooding and sustained waterlogged conditions (Roy et al. 2009).

A study assessing the impacts of drainage conditions by assuming future socioeconomic development and no improvement in the drainage system found that the waterlogged area with damaging water depths (>30 cm) will increase from 29 percent to 35 percent of the city by 2030 and to 54 percent by 2050 for a 1-in-10-year flood event (Asian Development Bank 2011). Figure 6 shows the projected waterlogged area for the 1-in-10-year flood event in 2050. Compared with base conditions, the population exposed to damaging floods will increase from 24 percent to 41 percent in 2030 and 58 percent in 2050.

Figure 6: Waterlogging map for a 1-in-10-year return period flood in 2050



Source: Asian Development Bank 2011

Coastal intrusion and rising salinity levels due to a combination of prolonged dry weather, sea level rise, cyclones, storm surges and upstream withdrawals of freshwater may reduce the availability of safe drinking water in Khulna (Khan et al. 2011). Salinity levels in Khulna have increased in the last several years, as a result of both climatic and infrastructure changes. Following the construction of Farakka Barrage in India in 1975, the flow of freshwater from the Gorai River— a distributary of the Ganges, which is a major source of freshwater to the Rupsha, Bhairab and Mayur rivers surrounding Khulna—has decreased considerably, resulting in

increased river/water salinity (Asian Development Bank, 2011; Khan et al. 2011). Increased salinity levels have consequences for groundwater resources, which is the main source of water for urban residents. Groundwater from deep and shallow tube wells has become scarcer and more saline due to reduced availability and increased extraction, especially during the dry season. In Dacope, a coastal subdistrict in the Khulna division, Khan et al. found that its population is consuming 5–16 g per day of sodium in drinking water alone (not including food sources) during the dry season, which exceeds the recommended dietary intake of sodium of 2 g per day (Khan et al. 2011).

The city's large urban slum and squatter population also exacerbate challenges to water quality and availability in Khulna, already impacted by a changing climate. Since 2005, there has been an influx of rural-to-urban migrants into the city from the districts of Satkhira and Bagherat to pursue employment opportunities as a result of livelihood insecurity. Rahaman et al. found that 79.3 percent of 400 migrants settling in Khulna cited livelihood insecurity as the primary reason for displacement (Rahaman et al. 2018). Given the socioeconomic conditions from which these migrants come, they cannot afford proper accommodation. As such, they settle in overcrowded urban slums with limited access to amenities, including water, proper hygiene, education, health care and social services. Most of these slums are situated in low-lying, flood-prone areas and are highly vulnerable to frequent inundation due to poor drainage systems. As a result, these migrants are at increased risk of health issues, including food and waterborne diseases (e.g., cholera, diarrhea, typhoid and hepatitis), with diarrheal disease being the most common (Rahaman et al. 2018).

CHATTOGRAM

Key Risks	Description
 **Landslides**	Deforestation and land conversion in the Chattogram Hill Tracts, combined with more intense rainfall events, will increase the city's risk of landslides.
 **Droughts**	As rainfall becomes more erratic during the dry season, the availability and quality of surface and groundwater is declining.

Chattogram, spanning 100 km^2 along the coast of the Bay of Bengal, is Bangladesh's second largest city. As a port city, it is the commercial capital of the country and plays a vital role in the Bangladeshi economy (Arafat 2015). The Port of Chattogram is the busiest international seaport on the Bay of Bengal and the third busiest in South Asia. Chattogram is surrounded by the Chattogram Hill Tracts, a hilly region at the steps of the Himalayas. Chattogram's population is estimated to be over 4 million, of which about 50 percent live in urban slums (BBS 2011; Uddin 2018). While Chattogram's coastal location has many economic advantages, the city is at risk of sea level rise, more frequent and intense cyclones, waterlogging and landslides. The city and surrounding coastal areas have experienced numerous cyclones over the last several decades. The 1991 cyclone in Bangladesh, which was one of the most severe tropical cyclones to hit Chattogram, killed more than 138,000 people, destroying one million homes and leaving 10 million people homeless. Industrial losses were estimated at US$390 million (Haque et al. 2013). Climate variability and change combined with rapid urbanization, increased population density, improper land use and alterations in the surrounding hilly regions will increase Chattogram's vulnerability and pose challenges to human health, water resources and the environment.

CLIMATE SUMMARY

Chattogram has a tropical, monsoon climate. Along the south of the city runs the Karnaphuli River, which empties into the Bay of Bengal through an estuary located 15 km to the west of the city's core. The coastal plain lies to the west, and to the east lies the Halda River plain. Average temperatures fluctuate between 19ºC and 28ºC (Figure 7), with the highest temperatures occurring just before the monsoon season (June to September) and the lowest temperatures occurring during the dry season (October to February). Annual average rainfall in Chattogram is about 1,800 mm, and over 80 percent of the rains occur between May and October, before, during and after the monsoon season.

HISTORICAL CLIMATE

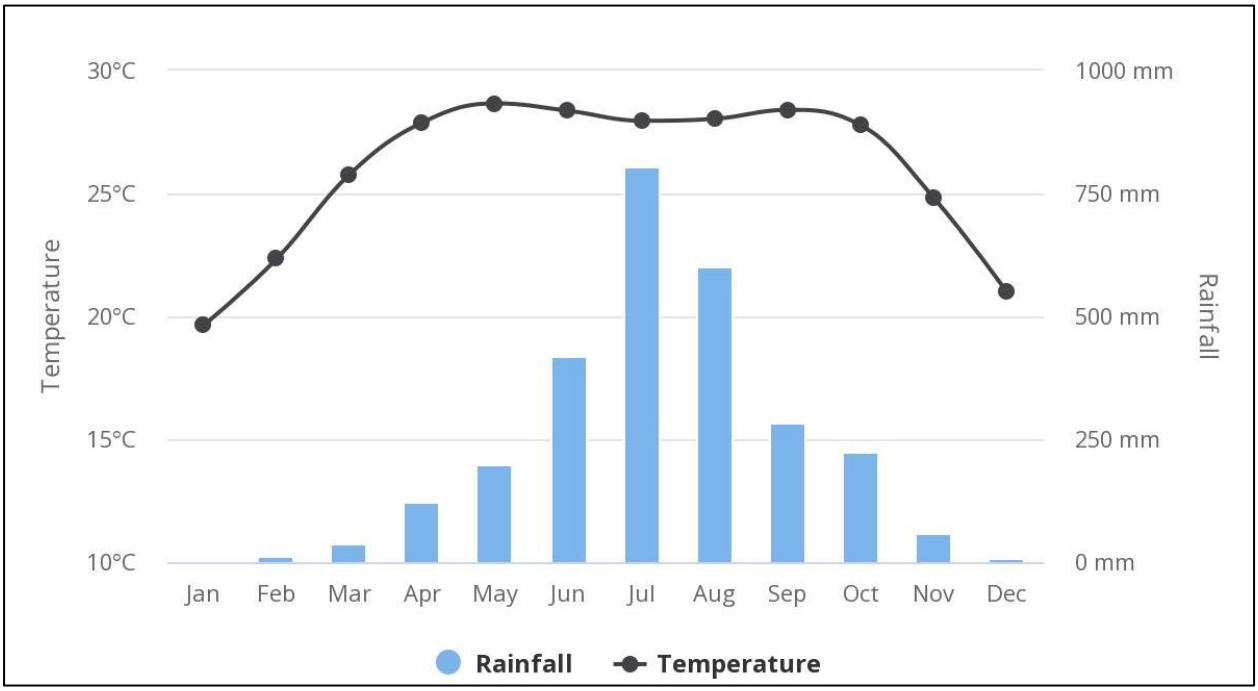
Key climate observations through 2016 are shown in Figure 7 and include:

- Increased mean maximum temperatures of 0.039°C and mean minimum temperatures of 0.001°C from 1976 to 2008; the monthly maximum, minimum and mean temperatures

show a positive trend over Bangladesh. Although these increases are nominal, urban heat islands (described below) amplify these increases.

- Variable rainfall trends, with an increase in average rainfall from 1979 to 2008 of 0.8 m, with stronger increases recorded in the pre-monsoon season in the southeast, hilly region of the city. Total rainfall decreases during the winter.
- A threefold increase in the frequency of severe cyclones in the Bay of Bengal from 1901 to 2007, with a slightly negative trend after 1970. The number of severe cyclones experienced has increased from 1 per year to 3 per year during May, October and November, the main months for cyclone activity in the Bay of Bengal (Aktar and Roy 2017, Ministry of Environment and Forests (MoEF) 2009, Mondal 2017, Shahid 2010, Singh 2007).

Figure 7: Average monthly temperature and rainfall for Chattogram, 1991–2016



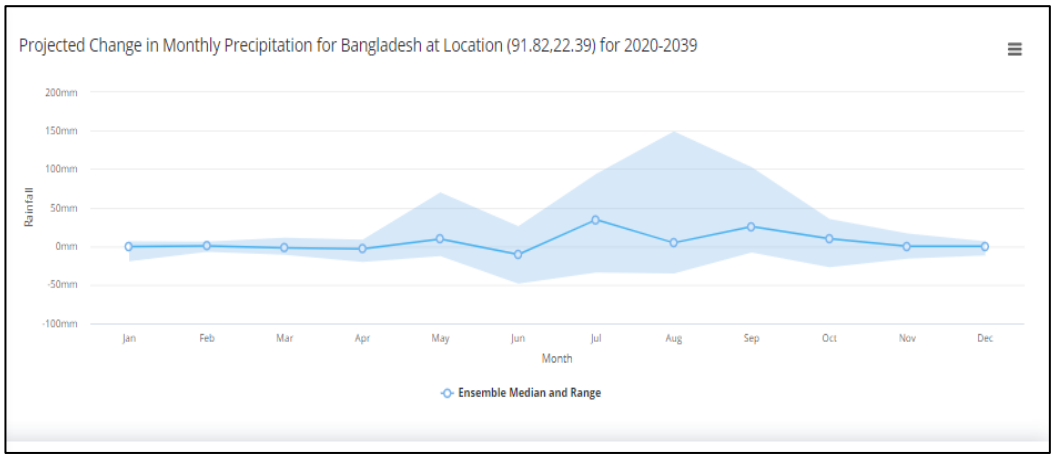
Source: World Bank 2019

FUTURE CLIMATE

Projected changes include:

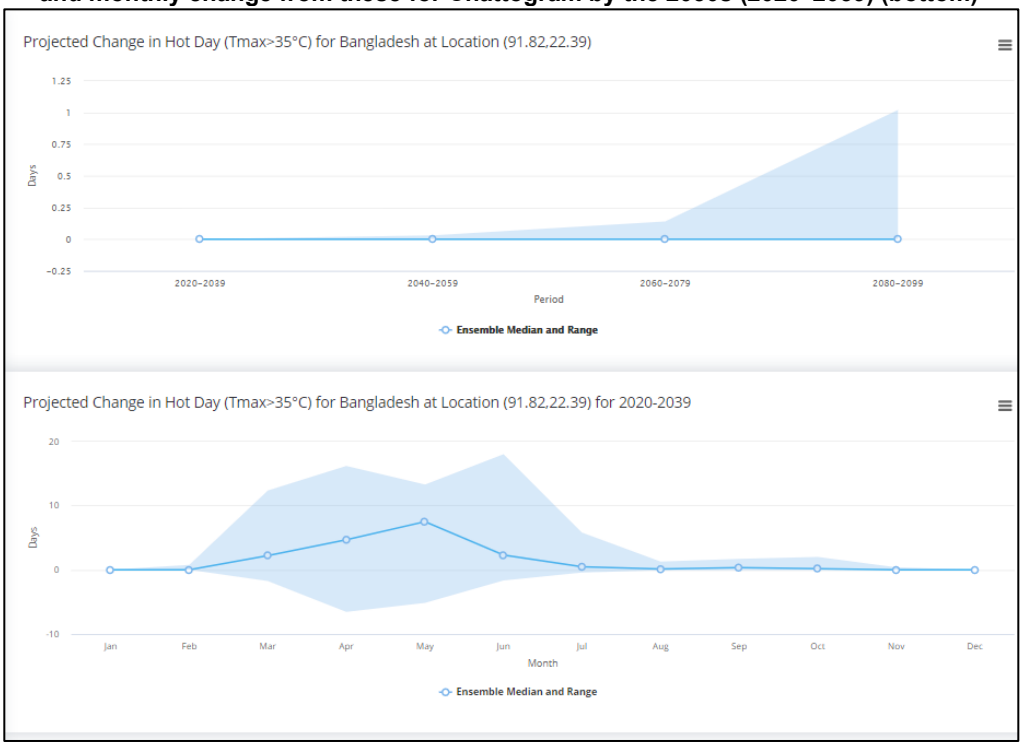
- Increased mean annual temperatures by 1.8°C –2.1°C by the 2050s
- Although significant uncertainties exist in modeling future rainfall, projections for Chattogram in monthly rainfall values by the 2030s suggest a potential increase in rains of 10–25 mm/month during the latter part of the rainy season (Figure 8)
- Increase in the days with maximum temperatures >35°C, with the highest increases between March and May (Figure 9)
- Sea level rise of 0.73–1.58 m (minimum) and 2.73–3.58 m (maximum) by 2100 (Arafat 2015)

Figure 8: Projected change in monthly precipitation for Chattogram by the 2030s (2020–2039)



Source: World Bank 2019

Figure 9: Projected change in the number of days above 35°C across all time periods (top) and monthly change from these for Chattogram by the 2030s (2020–2039) (bottom)



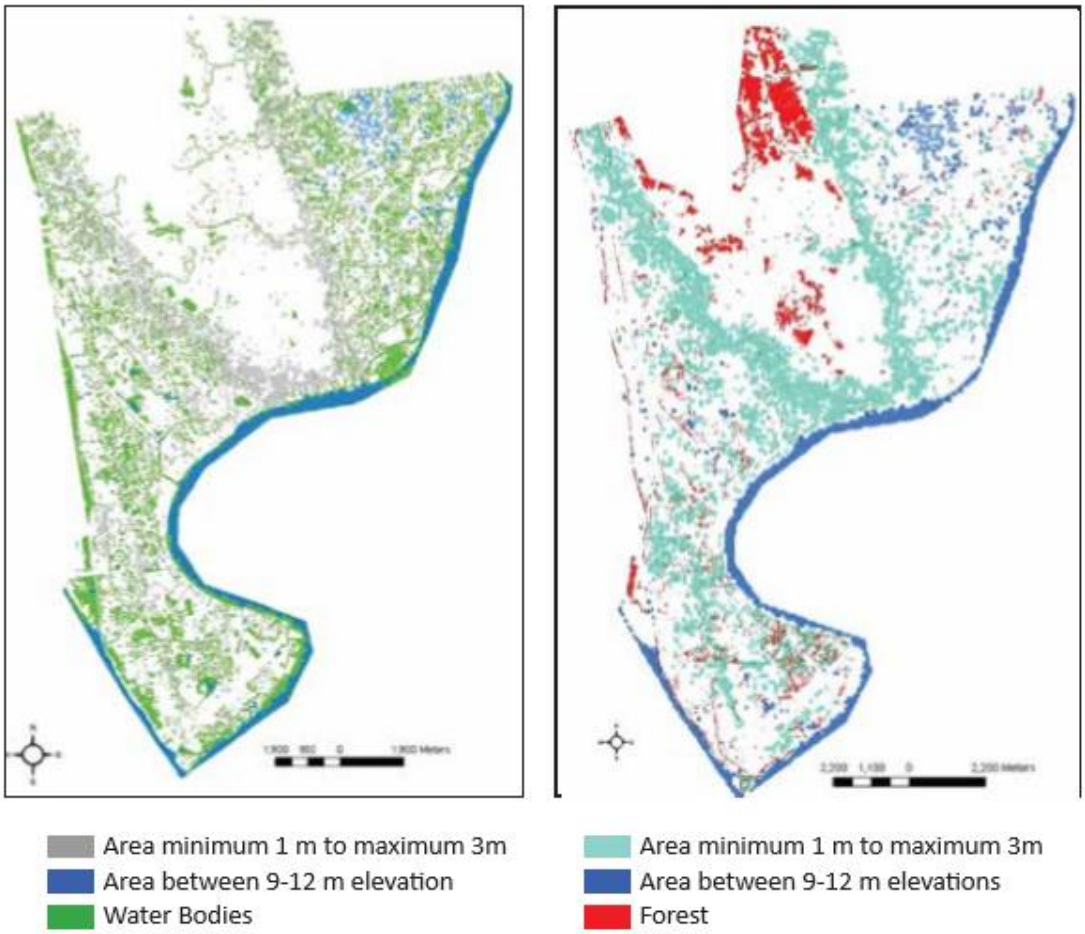
Source: World Bank 2019

SECTOR IMPACTS AND VULNERABILITIES

Coupled with population growth, urbanization and land use change, climate stressors including heavier precipitation, sea level rise and more intense and frequent extreme weather events are expected to impact Chattogram's water and environmental resources, with subsequent impacts on urban public health.

Coastal inundation as a result of sea level rise poses a risk to the city's low-lying areas (Figure 10). Arafat found that although the city is not susceptible to coastal flooding as a result of a 1 m rise in sea level, a 3 m rise could submerge approximately 6 percent of the city. Inundation may be permanent or episodic, depending on the location; the intrusion of saline water will affect informal settlements and both access to and the quantity of safe drinking water (Arafat 2015).

Figure 10: Land area susceptible to direct inundation under 1–3 m rise in sea level and storm surges of 12 m in height. The right panel shows forest cover and the left panel water bodies.



Due to the city's location below the Chattogram Hill Tracts, landslides are a frequent hazard to the city. Human activities such as deforestation, jhoom cultivation and other agricultural practices and illegal hill cutting aggravate landslide vulnerability by further destabilizing hillslopes (Islam et al. 2018, Islam et al. 2017). Over the last five decades, the Hill Tracts suffered about 12 major landslides, with the most destructive landslides occurring in 2007 and 2017. The 2017 landslides demolished foothill settlements and slums, killing over 152

inhabitants. Heavier precipitation during the monsoon season, coupled with these human activities, could lead to accelerated rain cut erosion and larger and more frequent landslides. Landslides also result in siltation in the Karnaphuli River and other tributaries, which reduces the quantity and quality of surface water resources.

More erratic and low rainfall during the dry season October to February is also reducing the availability of both surface and groundwater (Ministry of Environment and Forests 2009). Groundwater levels are declining due to over-exploitation of both drinking water and irrigation, while surface water capacities are decreasing due to increased water pollution, unplanned waste management, industrial effluents, use of chemicals and increased use of pesticides (Ministry of Environment and Forests 2009). Poor drainage infrastructure in the lowlands has also resulted in waterlogging, while groundwater degradation due to iron and salinity is a major problem for ensuring safe drinking water in the city's coastal plain area.

VULNERABILITY

The fate of urban inhabitants and the services on which they rely will depend on the interplay of population pressures, economic development, land use changes and changes in air quality, as well as changes in water quantity and quality. Each is linked to the others, which poses complex problems for health practitioners and city planners. The impact of weather and climate on MCHN outcomes is often exacerbated by anthropogenic factors, such as poor waste management and inadequate access to clean water and sanitation, as well as by health services, all of which can increase vulnerability. Climate variability and change will multiply these pressures on governance mechanisms.

This assessment of the cities of Khulna and Chattogram sheds light on these pressures. As a starting point, this assessment recognizes that risks to MCHN are a function of both direct risk from climate-related hazards as well as the propensity of patients and parts of the city to be adversely affected by weather and climate events. Vulnerability is a function of sensitivity, exposure and adaptive capacity, where:

- *Sensitivity* is the predisposition to be adversely affected, defined as the resources available to an individual or region to withstand a climate shock.
- *Exposure***,** a function of location, is the direct and indirect risk posed by weather- and climate-related hazards.
- *Adaptive capacity* identifies the resources available to bounce back from a shock or climate disturbance.

This vulnerability assessment aims to answer the following questions:

- What parts of the cities are vulnerable and why? (Sensitivity)
- What are they vulnerable to? (Exposure)
- What resources are available to address identified risks? (Adaptive capacity)

To accomplish analyses specific to vulnerability, both quantitative and qualitative indicators are explored. Indicators of vulnerability are noted in Table1 and explored at the upazila scale due to the availability of information. Clearly, there are other potential indicators that could have been explored, but these were limited by the available data.

Table 1: Indicators of vulnerability explored

CATEGORY	RATIONALE	INDICATORS
Sensitivity	Represents the propensity to be adversely affected by weather and climate events; it is a function of living conditions as well as climate risks.	Projected population increases Percent of land area classified as “built up” (ha) Population living in slums

CATEGORY	RATIONALE	INDICATORS
Exposure	Represents the direct risk from climate-related hazards to women and children	Flooded area Urban heat island potential
Adaptive Capacity	Represents the resources available to address risks that emerge	Green spaces (% of land area) Access to clean water (% of the population) Poverty levels
Future Climate Exposure	Includes variables related to principal risks under a changing climate, such as increased cyclone and drought frequency, sea level rise and associated storm surge, increased intensity of rainfall events and extreme heat	Land area at elevation below 2 m

CLIMATE STRESSORS

The main climate threats to the cities of Khulna and Chattogram are rising temperatures, rising seas and extreme events. Table 2 summarizes the current trends and projections for these variables. These current and projected climate changes directly impact human health and environmental conditions, including available natural resources. Key messages include:

Temperatures will continue to rise. By themselves, increases in temperature can have a significant impact on critical city services and governance. For example:

- ***Higher temperatures and evapotranspiration could exacerbate the tensions*** that already exist between agriculture and other water uses, especially during the dry season when tensions are and will be more pronounced.
- ***Higher temperature will impact energy demands***. There may be increased needs for cooling, particularly in the tourist areas, due to higher temperatures.
- ***Extreme weather events could increase***. Future rainfall patterns in the area under a changing climate are difficult to quantify. This is due to large model uncertainties regarding localized climate patterns, which are difficult to resolve in the coarse resolution models of climate change. What is clear, however, is that ***in the future there will be increased climate variability and incidences of extreme events.*** The resulting impacts are potentially large, not only in human terms, but also in economic and financial terms, as the floods of 2007 showed.

Table 2: Climate stressors, trends, observations and projections for Khulna and Chattogram

Climate stressor	Trends and observations	Projections
Temperature 	Temperatures in Bangladesh have risen: • Observed data indicate that the temperature is generally increasing in the monsoon season (June–September). • Average monsoon season maximum and minimum temperatures show an increasing trend annually at the rate of 0.05°C and 0.03°C, respectively. • An increasing trend of about 1°C in May and 0.5°C in November during the 14-year period from 1985 to 1998 has been observed. The heat index has increased across all months, with the most significant increases between August and September.	• Mean temperatures across Bangladesh are projected to increase between 1.8°C and 2.1°C by 2050 and 2100, respectively. This warming is expected to be more pronounced in the winter months (December–February).
 **Rainfall**	• The analysis of rainfall data for 63 years in Khulna (1948–2010) indicates that rainfalls have increasing trends of 8 mm, 31 mm, 9 mm and 6 mm per decade during the winter, monsoon, postmonsoon and premonsoon seasons. • The erratic nature of rainfall and temperature has increased in Bangladesh. • Annual rainfall has increased by approximately 53 mm/decade.	• Climate model results indicate an increase in the frequency of extreme rainfall events of shorter duration (6 hours) at Khulna in the future. The rainfall trend is found to be consistent in general with the sunshine and humidity trends in Khulna. • It is difficult to project rainfall changes for the Ganges River flood plain, with some models projecting wetter and others projecting drier conditions.
Sea Level Rise 	• N/A	• Sea level rise of showed 10 cm, 25 cm and 1 m rise in sea level by 2020, 2050 and 2100.
Extreme Events 	• Significant increasing trends have been observed in the cyclone frequency over the Bay of Bengal during November and May, the main months for cyclone activity in the Bay of Bengal.	• The frequency of tropical cyclones in the Bay of Bengal may increase and, according to the IPCC's Third Assessment Report, there is "evidence that the peak intensity may increase by 5% to 10% and precipitation rates may increase by 20% to 30%" (Cooper et al. 2008). Cyclone-induced storm surges are likely to be exacerbated by a potential rise in sea level of over 27cm by 2050.

Sources: MoEF 2005; Christensen et al. 2007

RISING TEMPERATURES, URBAN HEAT ISLANDS AND POLLUTION

Heat islands form as vegetation is replaced by dirt paths, asphalt or concrete for roads, buildings and other structures to accommodate growing populations. These surfaces absorb rather than reflect the sun's heat, causing surface temperatures and overall ambient temperatures to rise. Displacing agricultural lands, trees and vegetation minimizes the natural cooling effects of shading and evaporation of water from soil and leaves (evapotranspiration). Buildings and narrow streets can heat air trapped between them and reduce air flow. Waste heat from vehicles, factories and air conditioners may add warmth to their surroundings, further exacerbating the heat island effect.

In both cities, the majority of the land area occupies developed spaces which contribute to heat islands. The highest concentrations of built-up areas (>70 percent of total land area) dedicated to structures in Khulna are in Khan Jahan Ali, Khalishpur and Khulna Sadar upazilas. In Chattogram, while the land area within upazilas considered built up is across the board less than 50 percent of each upazila, those with the highest concentrations of built-up areas include Pahartali, Panchilaish, Kotwali and Double Mooring (Figures 11 and 12). These concentrated areas of structures clearly point to heat risks for the city's residents.

Figure 11: Built-up area in Khulna (left) and Chattogram (right)

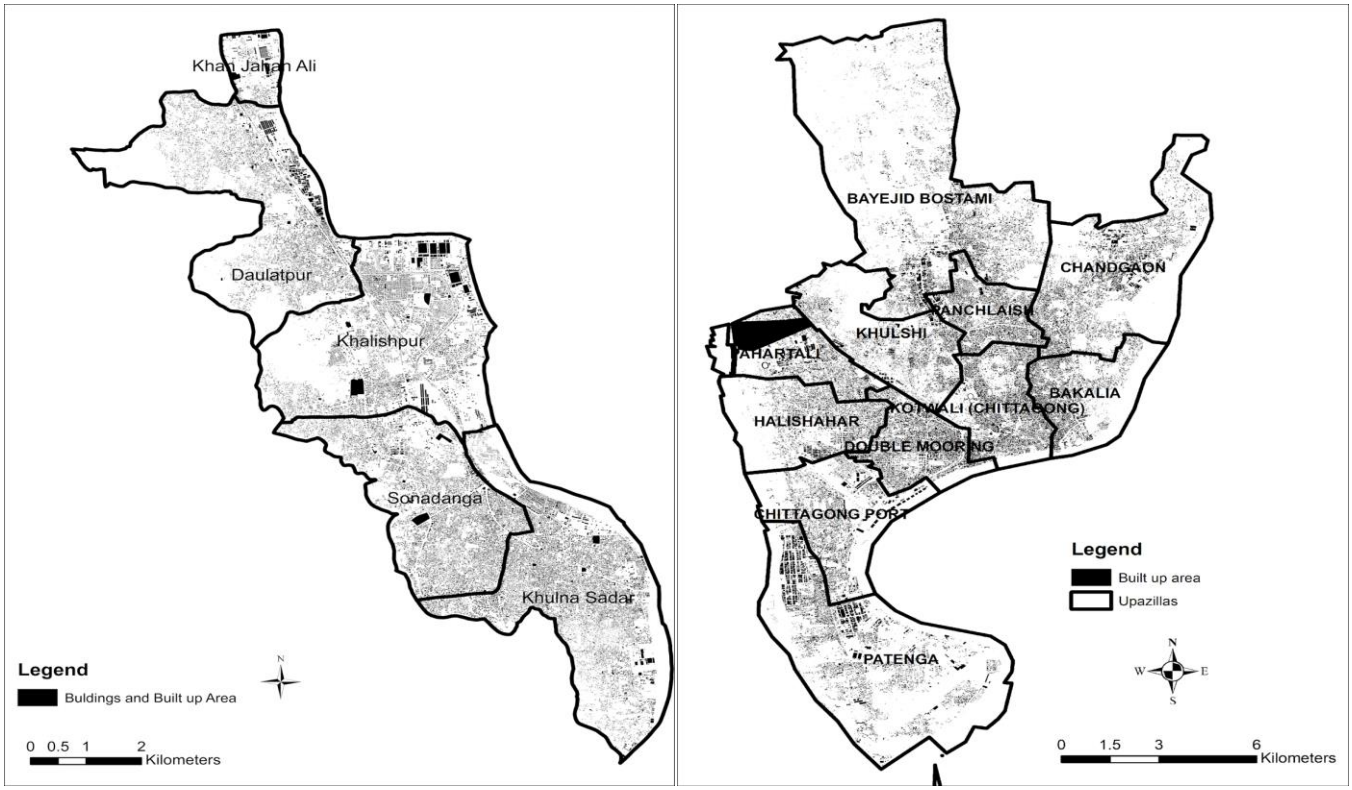
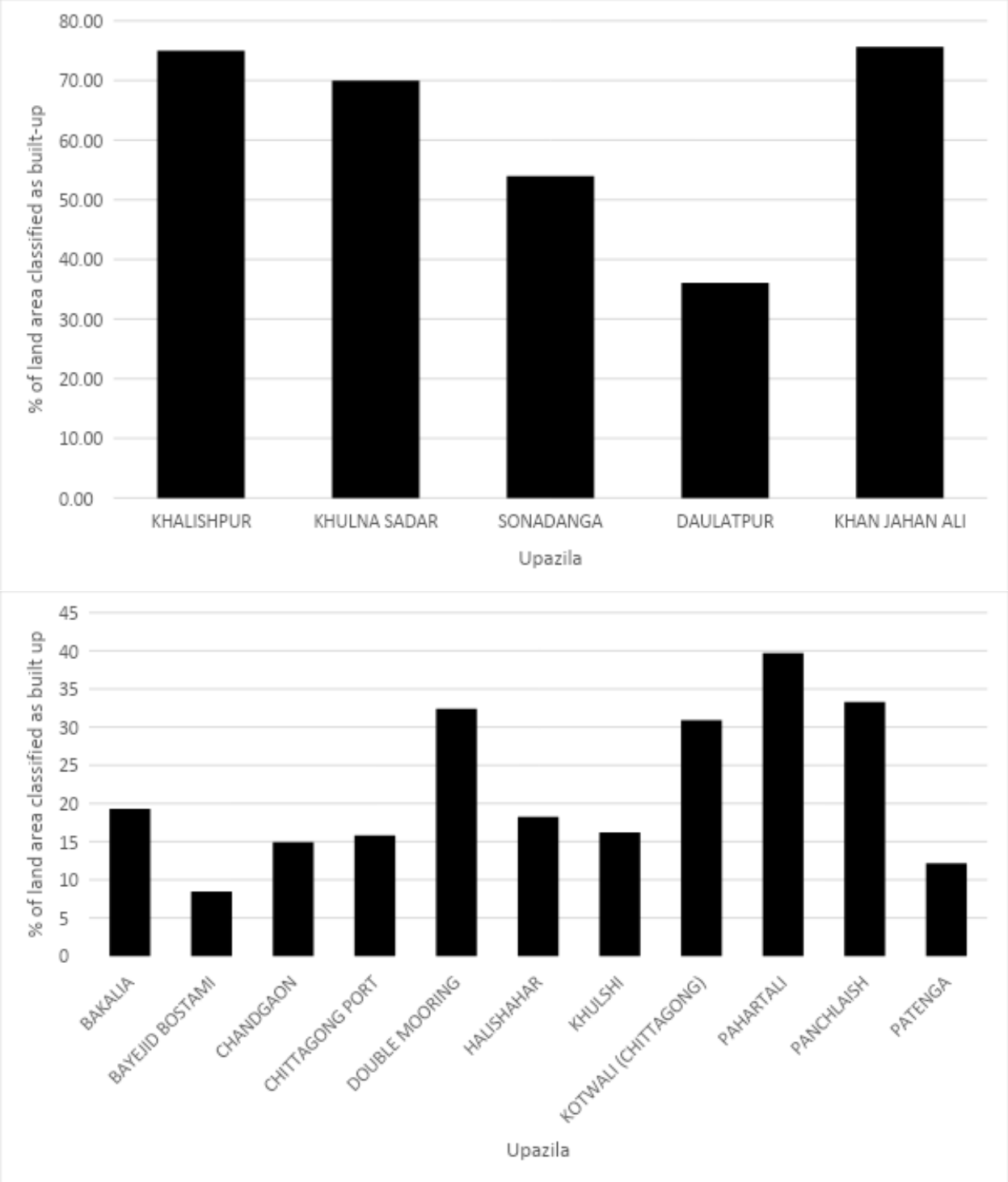


Figure 12: Percent of land area within upazilas of Khulna and Chattogram classified as built up. Top (Khulna), Bottom (Chattogram)



Urban heat islands can both directly and indirectly influence the health and welfare of urban residents. According to WHO, an estimated 6,000 people have died from heat waves in India

alone since 2010 (Guleria and Gupta, n.d.). Furthermore, high levels of pollutants such as fine matter and ozone can change the radiative properties of the atmosphere, intensifying the heat island effect (Begum et al. 2013).

Air pollution is significant in Bangladesh's cities, with approximately 123,000 deaths attributed to air pollution nationwide in 2017 (Health Effects Institute and Institute for Health Metrics and Evaluation 2019). In 2018, Bangladesh's Department of Environment (DOE) reported that Chattogram experienced 138 days of unhealthy, very unhealthy or extremely unhealthy air quality. Khulna experienced 96 days, 39 of which were classified as "extremely unhealthy" (Alam 2019). The Bangladesh government's Clean Air and Sustainable Environment project tracks air quality in cities through a series of indicators, including five pollutants: particulate matter (PM_{10} and $PM_{2.5}$), NO_2, CO, SO_2 and O_3, which are combined in an air quality index (AQI); standards for each pollutant are set by the Ministry of Environment and Forests. Air quality data from July to December 2011 in both cities (Table 3) show that while concentrations of gaseous pollutants are well within the national air quality standards, PM_{10} and $PM_{2.5}$ far exceed both the nationwide standards and WHO guidelines (Bari 2016). Traffic, motor vehicle usage and industry are major sources of PM_{10} and $PM_{2.5}$ and the principal sources of pollution in both Khulna and Chattogram, especially two-wheel motorcycles/bikes and diesel heavy trucks. Another significant source is brick manufacturing, which is the fastest growing industrial sector in Bangladesh. Brick kilns (about 1,500 in Chattogram and almost 900 in Khulna), which are fueled by wood and coal, are responsible for spikes in pollution during the dry season (October to February) when the majority of production occurs; 36 percent of PM_{10} in Chattogram comes from biomass and brick kiln emissions (Darain et al. 2013, Guttikenda et al. 2012, Ahmed and Ali 2012).

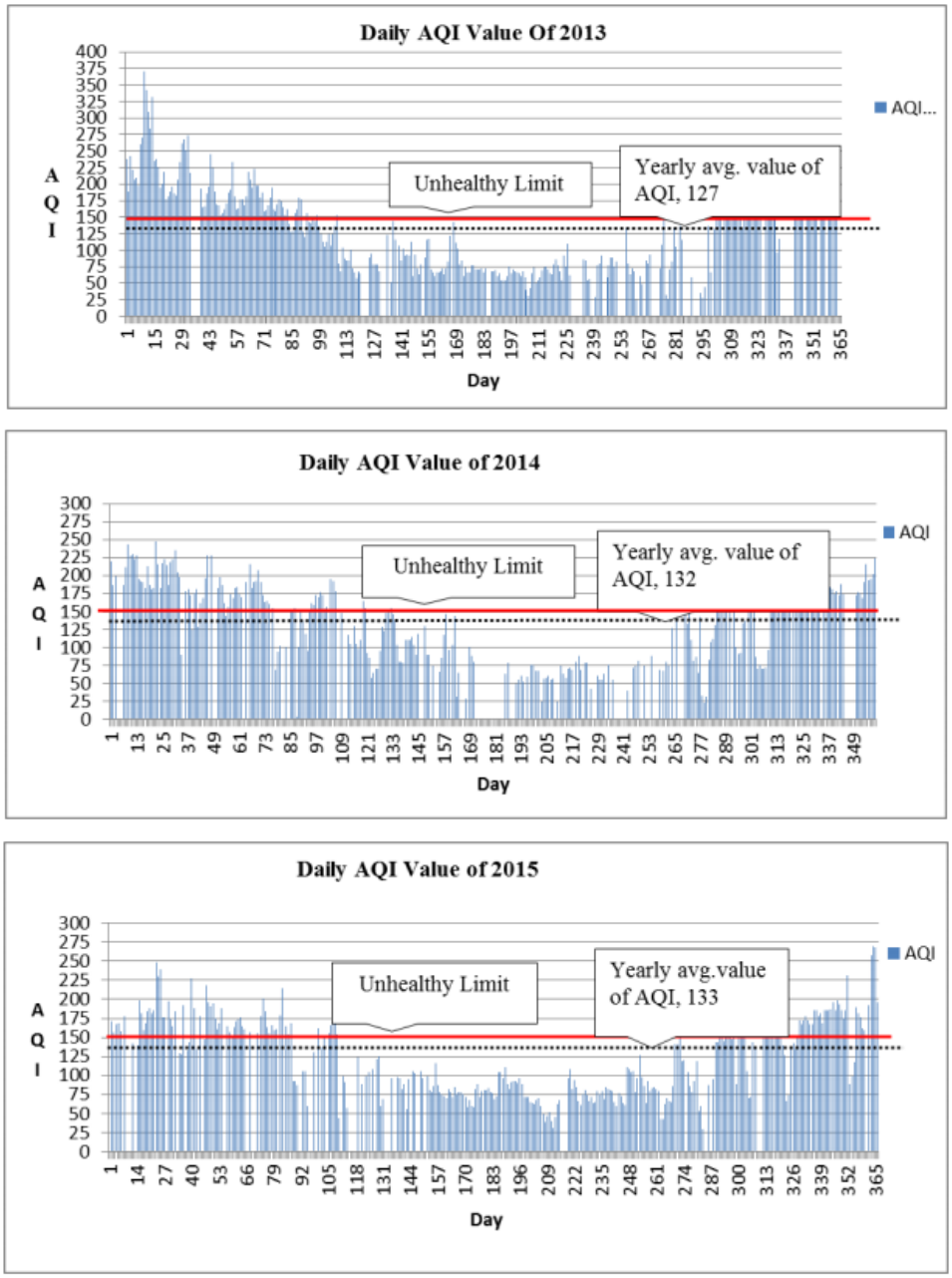
Additionally, pollution trends for both cities point to worsening air quality. The AQI tracked for Chattogram from 2013 to 2015 (Figure 13) points to a higher air quality index, which is indicative of a trend towards poorer air quality (Hossen et al. 2016). Pollutant concentrations in both Khulna and Chattogram are linked to meteorological parameters; in Chattogram, for example, high PM levels are correlated with the dry season, while the lowest levels of PM are observed during the monsoon period from June to September when rainfall and wind speeds are high. Other gaseous pollutants (e.g., NO_2 and O_3) exhibit the same seasonal trends (Rana and Biswas 2018).

Table 3: Average air quality index values for July–December 2011 for Khulna and Chattogram

Pollutant	Unit	National Air Quality Standards for Bangladesh	WHO Guidelines	Concentration	
				Khulna	Chattogram
SO_2 (annual)	ppm	0.03	--	0.0057	0.0059
NO_2 (annual)	ppm	0.053	--	(not available)	0.0205
Ozone (8 hr)	ppm	0.08	0.051	0.0057	0.0047
CO (8 hr)	ppm	9	9	0.8400	0.8850
PM_{10} (24 hr)	ug/m3	150	50	193.89	212.51
$PM_{2.5}$ (24 hr)	ug/m3	65	25	129.35	70.97

Source: Bari 2016

Figure 13: Daily air quality index values for 2013, 2014 and 2015 in Chattogram



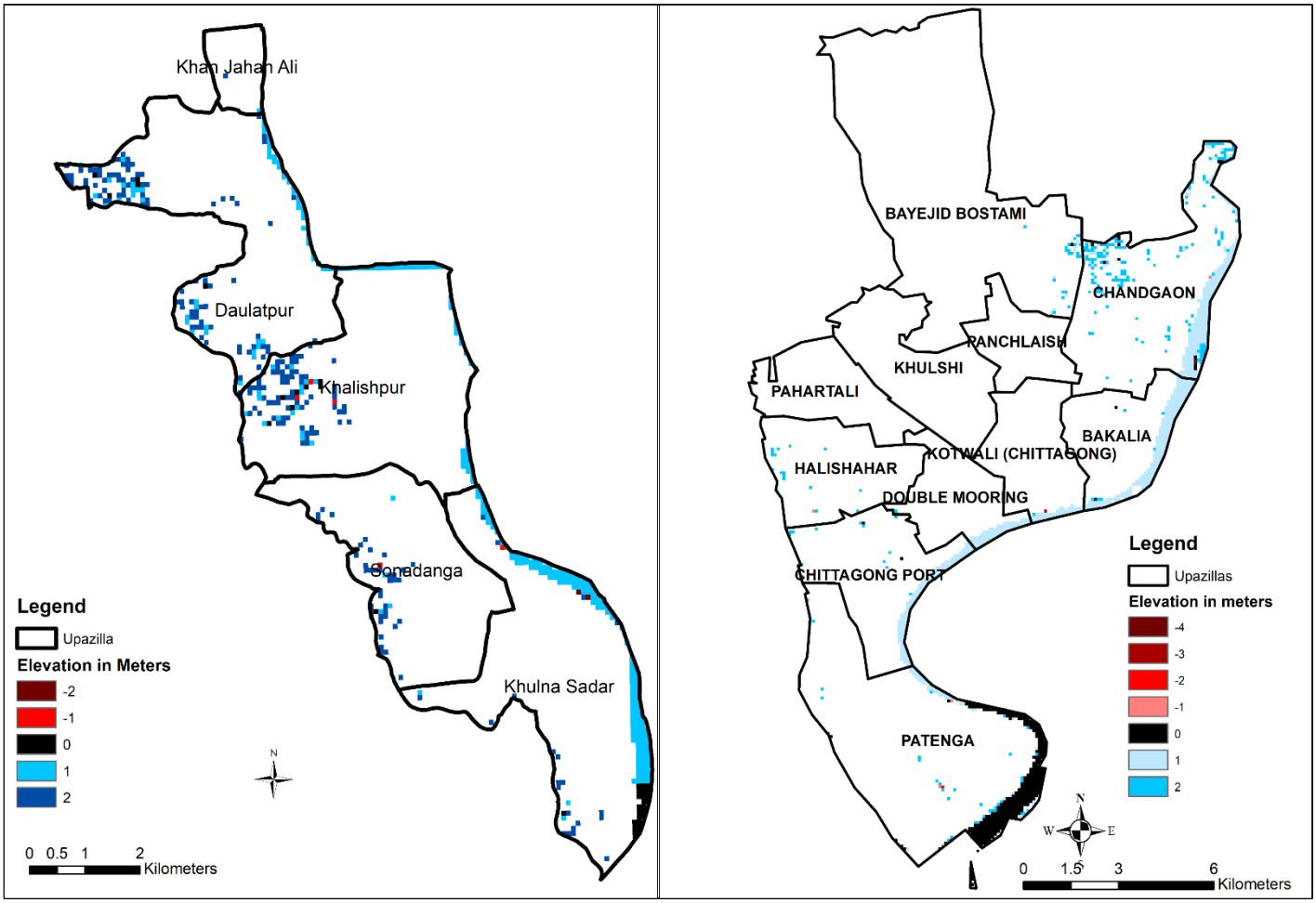
Source: Hossen et al. 2016

SEA LEVEL RISE

About 10 percent of Bangladesh is only 1 meter above the mean sea level, and one-third is under tidal excursions (Figure 14). According to the IPCC, a 30- to 45-cm sea level rise could displace more than 35 million people from coastal districts in Bangladesh. A World Bank study showed 10 cm, 25 cm and 1 m rise in sea level by 2020, 2050 and 2100 in Bangladesh, affecting 2 percent, 4 percent and 17.5 percent of total land mass, respectively (Faisal and Parveen 2004). Sea level is projected to rise between the baseline (1979–2010) and the end of this century (2100) by 26 to 98 cm according to the IPCC Fourth Assessment (IPCC 2007).

Nevertheless, it is not just rising seas but poor drainage that can lead to significant damage to infrastructure and lives through inland flooding, as explained below.

Figure 14: Areas in Khulna (left) and Chattogram (right) which are below 2 m in elevation



EXTREME RAINS AND FLOODS

As previously noted, floods are a normal phenomenon in Bangladesh, usually occurring during the monsoon season (June to September). Poor drainage conditions led to flooding of several roads and many homes and buildings during monsoons in Chattogram in 2007 (Figure 15) and in Khulna in 2011, 2012 and 2013 (Figure 16). Linking the flooding in Khulna to the city's elevation shows that floods were not limited to low-lying areas; rather, areas with elevations from 0 to 3 m were the most affected by floods across the city, though the extensive 2013 floods also impacted areas up to 10 m in elevation (Figure 17).

Figure 15: Extent of floods of 2007 in Chattogram

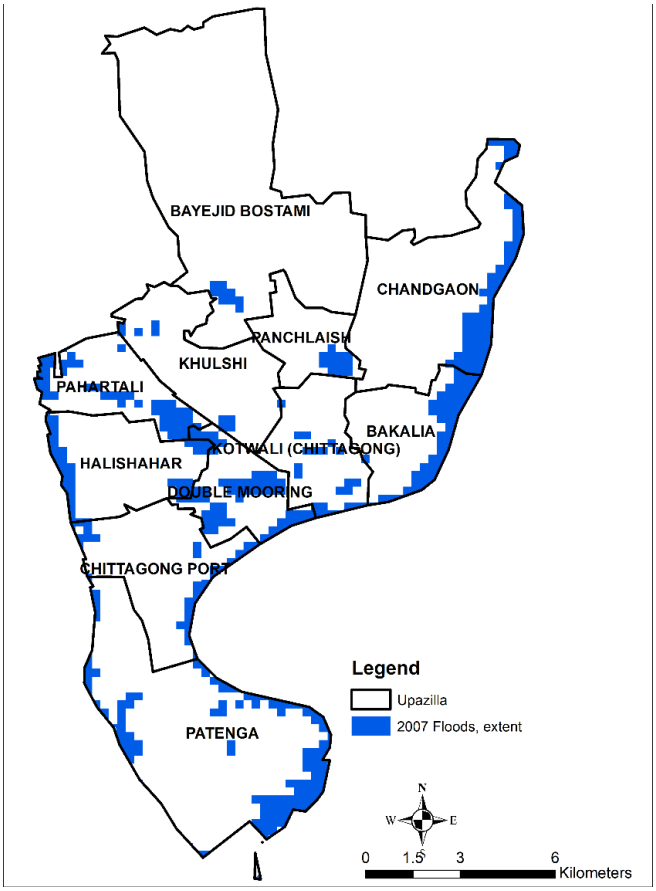


Figure 16: Extent of flooded areas, including buildings and roads, in Khulna 2011–2013

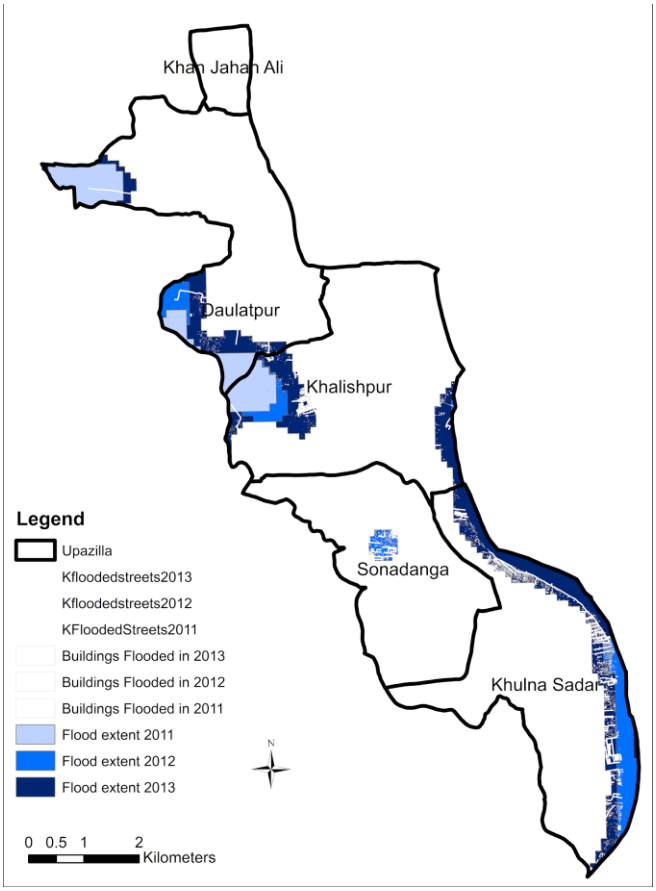
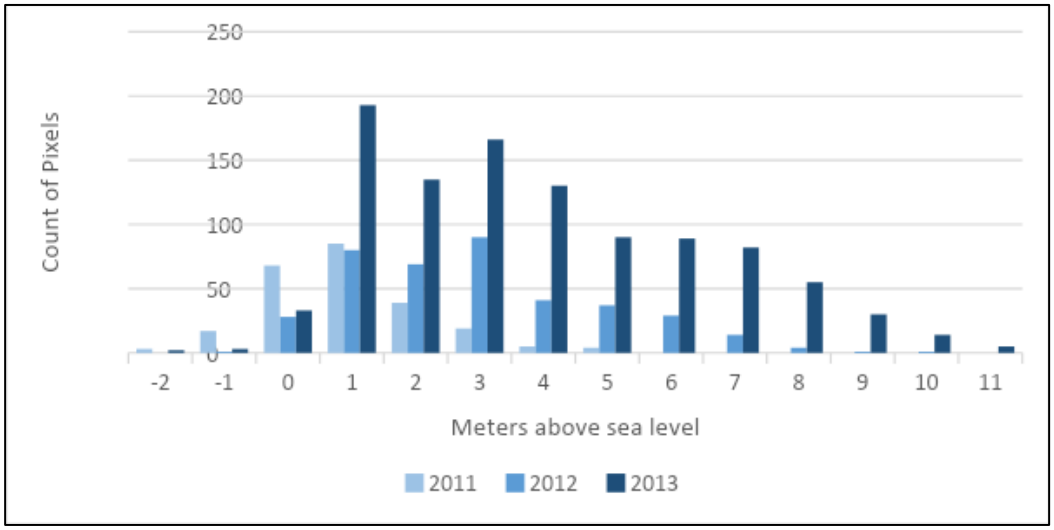


Figure 17: Average elevation of flooded areas in Khulna from 2011 to 2013



NON-CLIMATE STRESSORS

Climate impacts will exacerbate existing non-climate stressors on people and health. Non-climate stressors include population, environmental degradation and the availability of green spaces, along with the concurrent growth of urban environments and impermeable surfaces which contribute to heat islands and poor flood regulation. These stressors have important indirect impacts on Khulna and Chattogram as well as the potential to manage for resilience in these cities.

Bangladesh is urbanizing rapidly, with 23 percent of people now living in urban areas (Govindaraj et al. 2017). Between 2001 to 2011, the country's urban population expanded by 35 percent. By 2050, Bangladesh will experience unprecedented urbanization, with the urban population projected to account for more than half of Bangladesh's total population (Govindaraj et al. 2017). There has been a concurrent increase in slum settlements with high population densities, inferior public water and sanitation services and poor-quality housing contributing to massive health challenges for urban areas. In 2014, the government counted 14,000 slum settlements across the country (Govindaraj et al. 2017). Significant variations exist between slum and non-slum areas in both cities, where the average health and nutrition outcomes are much poorer for slum residents (National Institute of Population Research and Training (NIPORT) et al. 2016).

POPULATION

Population growth puts pressure on a city's resources through the unsustainable extraction of natural assets (including from shallow tube wells), conversion of green spaces and agriculture, and unplanned urban and peri-urban growth. Cities across the world continue to struggle to accommodate their rising populations and address the multidimensional challenges they pose, for example, to infrastructure and service provision (Uddin 2018). Khulna and Chattogram have a population of roughly 663,000 and more than 4 million people, respectively. The population density in Bangladesh is roughly 1,300 inhabitants per km^2, which is three or more times higher than in nearby countries, including India and Sri Lanka (Roy et al. 2018, World Bank 2018).

SLUM POPULATIONS

Approximately 55 percent of the urban population in Bangladesh lives in urban poor settlements commonly known as "slums" across Bangladesh. The 2014 slum census provided initial figures for slum populations. In Khulna, the approximately 5 percent of the city's population lived across the 30 recognized urban slums (Table 4), and projections suggest this number rose to 11 percent by 2018 (Uddin 2018).

Table 4: Population of slums in Khulna in 2014

Ward Number	Slum Name	Total Population
1	Moheshwore Pasha Basti	428
1	Mail Post Basti	173
1	Jugipol Dighir par	258
2	Megna Company Basti	746
2	Raligate Basti	200
2	Dhaka Trading Basti	315
2	Dighirpar Basti	516
2	Rail line Basti	304

Ward Number	Slum Name	Total Population
3	Daulatpur Thana Basti	892
9	Bastuhara	4,735
9	Mujgunni Basti	179
9	Mujgunni Missionpara	118
9	Gowalkhali Railline Basti	305
11	Platinum Jute Mill Colony	4,027
11	Peoples Pachtola Colony	347
17	Madrasa Road Khalpar	261
17	Sonadanga UCEF School Basti	466
18	Moyur Nodir Par Basti	307
18	Sabuzbagh 4 no goli	36
18	Arambagh Basti	179
18	Alir Club	76
21	Green Land basti	4,407
21	Railway New Colony	932
26	Talukdar Community Center Basti	249
31	Rahman Ricemill	87
31	Faruk Ricemill	98
31	Mabud Basti	66
31	Jamal Ricemill	117
31	Sonali Ricemill	45
31	Sluicegate Basti	114

Source: Bangladesh Bureau of Statistics (BBS) 2015

In Chattogram, there are approximately 2,215 slums inhabited by about 1.8 million dwellers (Table 5), about 22 percent of total city population (Uddin 2018).

Table 5: Population of slums in Chattogram

Ward Number	Slum Name	Total Population
2	Muktizoddha Colony	4,476
2	CNB Colony	2,449
2	Driver Colony	1,310
2	Astananagar Colony	2,385
2	Bokari Colony	1,091
2	Barma Colony	2,313
2	Dabarpar Colony	3,389
7	Santinagar	3,345
7	Aturerdipu	703
7	Roufabad	3,533
7	Shohidnagar	1,388
7	Barma Colony	3,993
7	Amin Colony (Lohar Bridge)	3,116
17	Bogarbil	5,119
18	Murgiwala Colony	2,246
19	Balurmath	1,710
9	Beltoli	3,601
9	01 No. Jheel	6,233
9	Golpahar	4,411
13	Xchange	5,630

Ward Number	Slum Name	Total Population
29	Badsha Colony	1,576
29	SRB	1,125
30	Jelepara	1,464
35	Rajakhali	1,049
35	Bastuhara	9,009
35	Sea Beach Colony	1,890
35	Chairman Colony	1,008
35	Vera Market	2,435
37	Akota Colony	1,031
37	TC Colony	1,070

Source: Bangladesh Bureau of Statistics (BBS) 2015

Residents in slums and squatter settlements are the most affected in terms of quality and access to services and facilities, including safe drinking water, waste management and access to other services such as electricity, clean latrines as well as health care (Table 6). In fact, only 2 percent of the slum population in Khulna sources their water from municipal taps, and only 1 percent have use of toilets that are linked to either a sewer or a septic tank. Additionally, slum settlers face different environmental burdens, notably air pollution, traffic congestion and surface water pollution (Uddin 2018). A 2009 study of slum clusters in 41 wards in Chattogram found that unsanitary toilets were connected with surface water systems in 41 percent of households, which has serious implications for public health. More than half of households in Khulna and Chattogram shared a latrine with six or more households (Table 7). In 29 percent of cases, respondents said that their children used open defecation when they were infants. In 42 percent of cases, feces were not collected and safely disposed of (Angeles et al. 2009).

Table 6: Access to services in Khulna and Chattogram (%)

City	Drinking water from municipal tap	Drinking water from tube well	Drinking water source within slum	With electricity	Regular garbage collection	Toilet linked to sewer/ septic tank	Water sealed latrine
Chattogram	28.7	65.2	81.75	87.4	24.7	10.9	6.4
Khulna	2.1	97.9	58.85	72.5	19.6	1	9.1

Source: Angeles et al. 2009

Table 7: Conditions of latrines for slum populations in Khulna and Chattogram (%)

City	Latrine not shared	Latrines shared by 2–5 households	Latrines shared by 6–10 households	Latrines shared by 11–20 households	Latrines shared by more than 20 households
Chattogram	2.5	40.8	37.5	13.8	5.3
Khulna	1.5	41.9	42.9	11.1	2.5

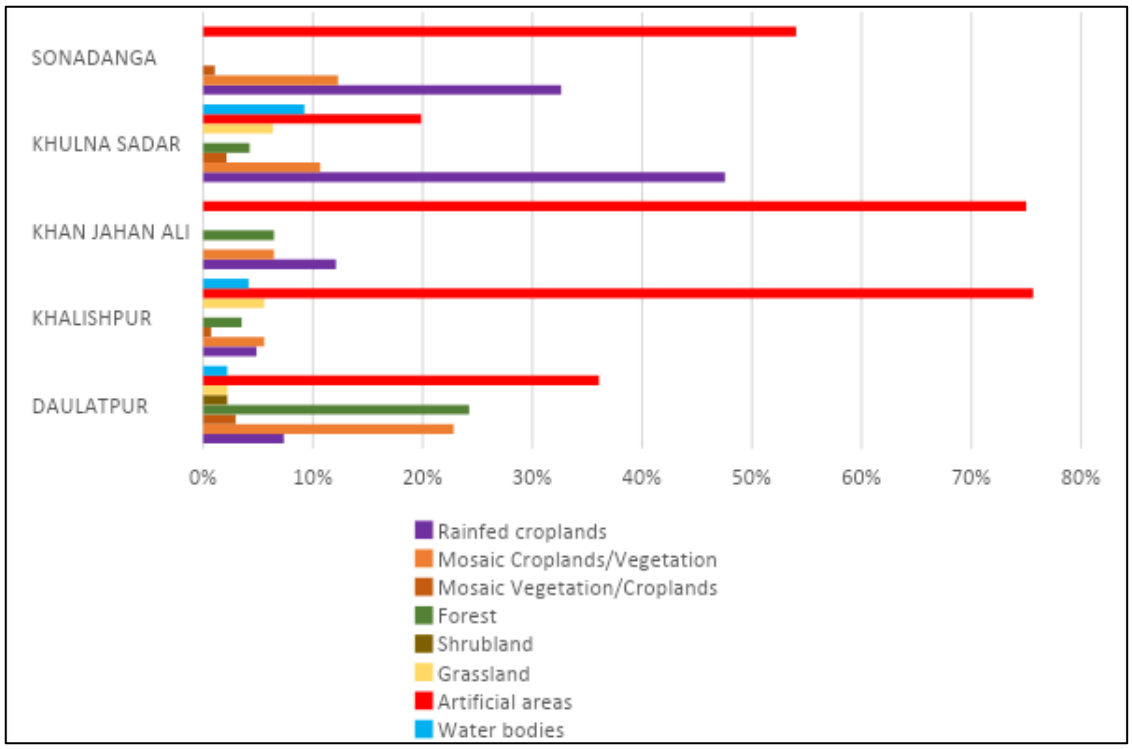
Source: Angeles et al.2009

LAND USE DYNAMICS

From an environmental perspective, the percentage of artificial or built-up area in a city can offer an indicator of the potential for the city dwellers to suffer from heat island effects and provide insights on the potential drainage capacity of the city infrastructure to intense rainfall events and overall quality of life. Heat islands describe local-scale temperature differences, generally between urban and rural areas. In contrast, global warming refers to a gradual rise of the earth's surface temperature. While they are distinct phenomena, summertime heat islands may contribute to global warming by increasing demand for air conditioning, which results in additional power plant emissions of heat-trapping greenhouse gases. Strategies to reduce heat islands, therefore, can also reduce the emissions that contribute to global warming. The heat island effect can also complicate studies of long-term trends. By accurately measuring heat islands, scientists can remove the heat island effect from global temperature records.

In Khulna, the upazilas with the greatest percentage of risk, with at least 50 percent or more of the land area in this category, include Khan Jahan Ali, Khalishpur and Sonadanga (Figure 18). Green spaces, parks and woodlands provide a multitude of benefits to urban populations. By improving physical fitness and reducing depression, the presence of green spaces can enhance the health and well-being of people living and working in cities. Green spaces also indirectly impact our health by improving air quality and limiting the impact of heat waves by reducing urban temperatures. In addition, urban vegetation stores carbon, helping to mitigate climate change, and reduces the likelihood of flooding by storing excess rainwater. In Khulna, urban green spaces are clearly limited, covering less than 30 percent of the land area of the city. The greatest amount of green space in Khulna is located in the Daulatpur Upazila, covering

Figure 18: Land use and land cover by upazila in Khulna



Source: Author's calculations based on 2009 European Space Agency Land Cover Data V 2.3 (Defourny et al. 2009)

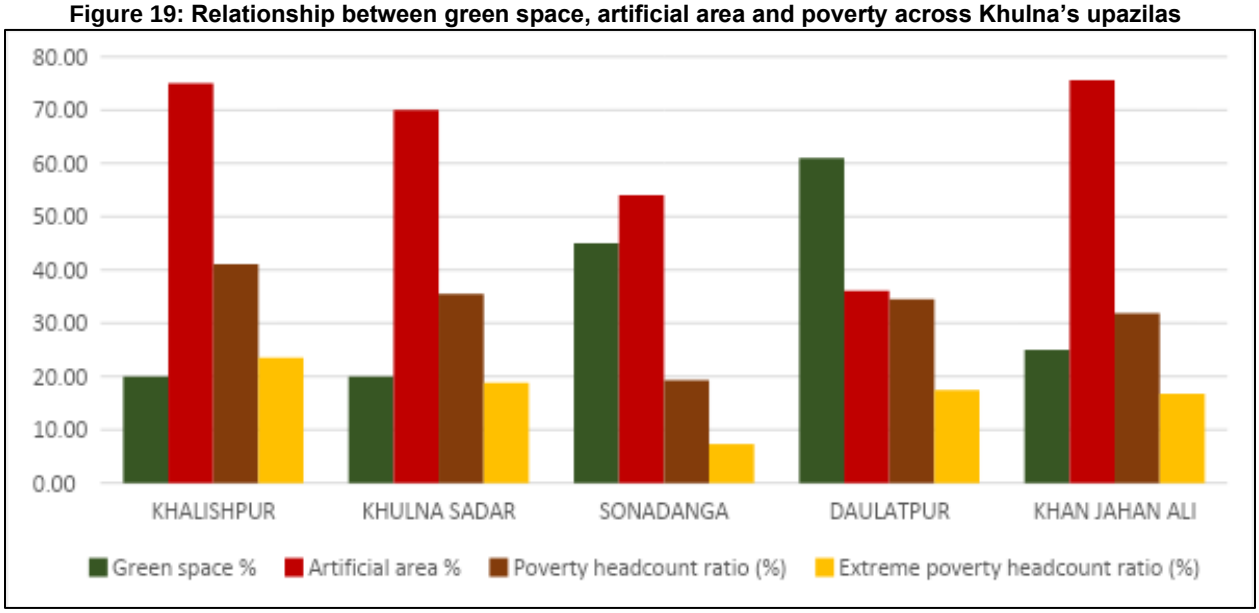
approximately 22 percent of its total land area. Nevertheless, there are no clear associations between the availability of green spaces and poverty in the upazilas, as shown in Figures 19 and 20.

POVERTY

Poverty contributes to climate vulnerability by limiting a population's access to resources that could reduce their risk, while climate vulnerability can itself perpetuate poverty via repeated shocks to those already vulnerable. Furthermore, actions that do not explicitly consider the interplay of poverty and climate vulnerability can often lead to undesired results, increasing one or the other. For example, establishing shrimp farming as a way of increasing incomes can reduce poverty but will likely also lead to the conversion of wetlands and mangroves, increasing vulnerability to cyclones and thus potentially exacerbating poverty (Adger et al. 2005).

An understanding of the dimensions of poverty across cities is thus a critical first step toward identifying adaptive actions that can both contribute to poverty reduction while also building community resilience. The following maps consider two measures of poverty derived from the 2010 Bangladesh Poverty Maps (poverty head count ratios), the 2011 Population and Housing Census (primary employment of working population) and data compiled from the World Food Program (WFP) based on data from the 2012 Child and Mother Nutrition Survey of Bangladesh and the 2011 Health and Morbidity Status Survey (child health indicators). The working hypothesis is that greater concentrations of heat islands as measured by built-up areas by upazila will track with other indicators of poverty and nutrition. While no statistically significant relationships were uncovered (Figure 19), the following figures show the spatial dynamics of these variables across a selection of the city's upazilas.

Figure 19: Relationship between green space, artificial area and poverty across Khulna's upazilas

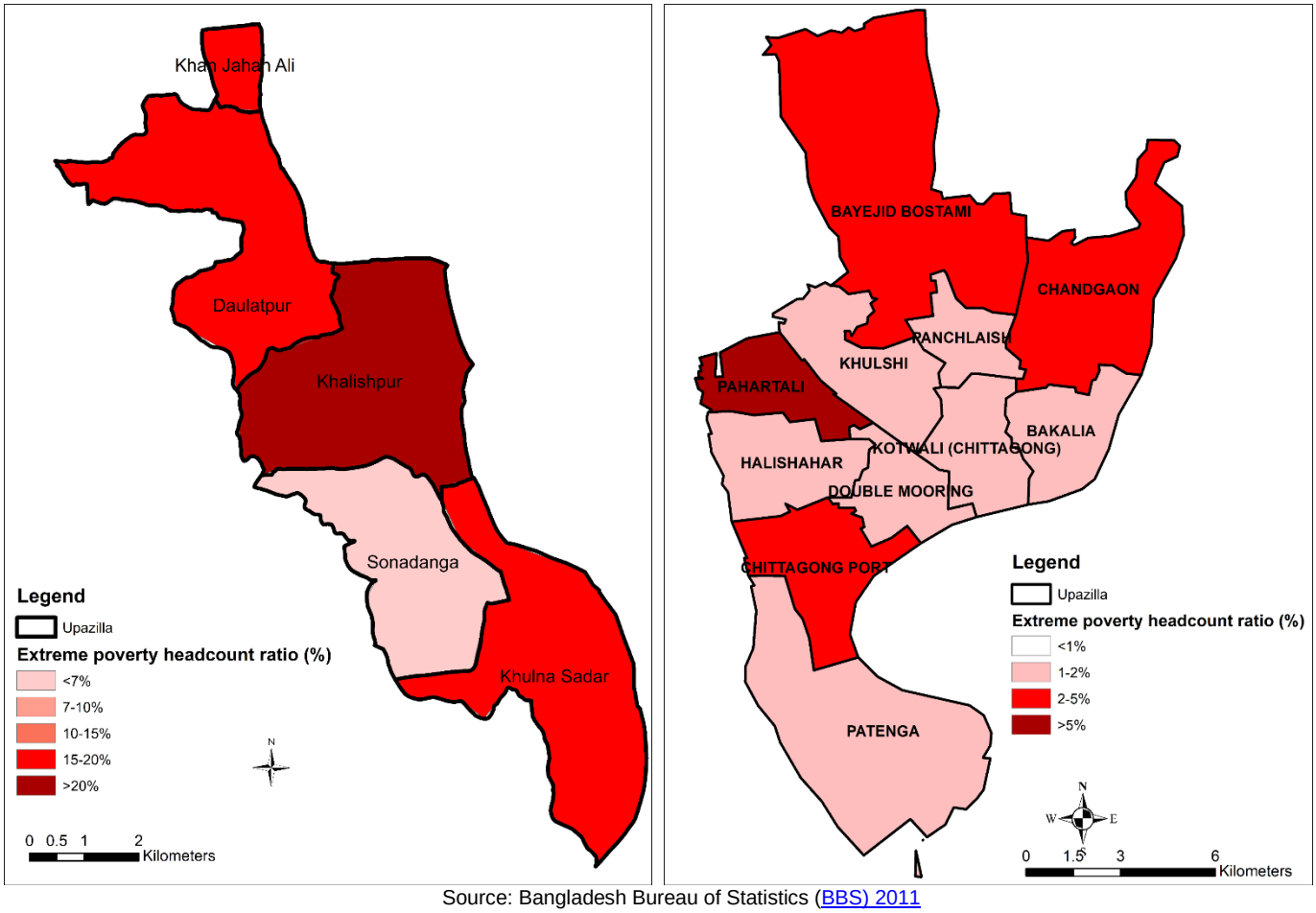


Source: World Bank et al. 2014

According to the World Bank, approximately 13.8 percent of the population in Bangladesh was living below the poverty line in 2016 (World Bank 2018). In Khulna, these poverty rates are higher, ranging from 19 to 49 percent of the population in 2010.The highest concentration of impoverished people live in Khalishpur in Khulna and in Pahartali in Chattogram, which ranked

410 and 181 out of 544 upazilas nationally in poverty rates, respectively (Figure 20). In Khulna, the majority (70 percent) of those living in Khalishpur are employed in the formal and informal service industry. In contrast, only one upazila in Chattogram, Pahartali, hosts over 5 percent of a population living under extreme poverty conditions, with others at or below 2 percent.

Figure 20: Percent of population classified as extremely impoverished in 2010 in Khulna (left) and Chattogram (right)



Source: Bangladesh Bureau of Statistics (BBS) 2011

CHILD HEALTH INDICATORS

Bangladesh has made notable improvements in a number of health and nutrition indicators over the past two decades, including child immunization coverage, total fertility, reduction in the incidence of malnutrition and communicable diseases and reduction in infant and maternal mortality rates. However, undernutrition is still a key concern in both Khulna and Chattogram (Table 8) . Malnourished children are physically, emotionally and intellectually less productive than well-nourished children and are at increased risk of suffering from chronic illnesses and disabilities. There is also strong evidence that children who are suffering from stunting are more likely to be affected by infectious diseases, such as malaria, diarrhea and pneumonia (Saha et al. 2019).

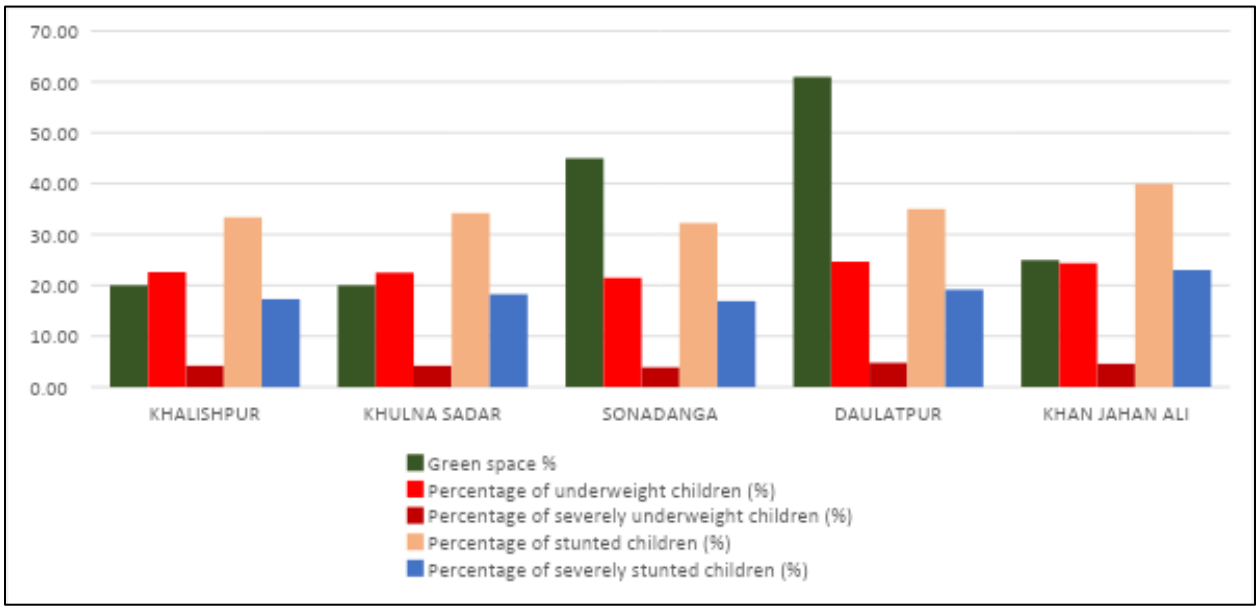
Table 8: Undernutrition in Khulna and Chattogram

Category	Khulna Division (% of children under 5 yrs)	Chattogram Division (% of children under 5 yrs)
Underweight	19%	37%
Stunting	35%	44%
Wasting	15%	16%

Source: Saha et al. 2019

Health indicators across Khulna show limited correlation between malnourishment, built-up areas and available green spaces (Figure 21). Nevertheless, this may be a feature of the level of granularity of the data rather than the direct links themselves.

Figure 21: Relationship by Khulna upazila of childhood nutrition indicators and available green spaces



Source: Bangladesh Poverty Maps 2010

OPPORTUNITIES AND RECOMMENDATIONS

We describe the spatial distribution of climate and non-climate stressors in two secondary cities of Bangladesh to show the cities' potential sensitivities and the adaptive capacities of the cities are to address these risks. Although a fully quantitative analysis was not possible, we demonstrate that there is a wealth of readily available information to understand the risks that secondary cities in Bangladesh face, which are significant and merit investment and attention in order to safeguard progress achieving sustainable development objectives for the country.

Addressing MCHN issues in Bangladesh's secondary cities requires incorporating activities and targets that explicitly consider the role of urban planning and environmental management in the context of a changing climate. The USAID CDCS for Bangladesh is an opportunity to begin increasing MCHN resilience to a future that will be characterized by different weather patterns, resulting in different magnitudes and patterns of climate-sensitive health outcomes. The costs of preparing for an uncertain climate future are likely to be less if started now rather than reacting later when the impacts are larger and more difficult to control. Specifically, it would be more efficient to begin preparing now for the challenges that will arise from climate change affecting the ability to provide and deliver health services. Postponing actions will leave already vulnerable populations and individuals at substantially increased risk from illness and disease exacerbated in a changing climate.

USAID's CDCS 2011–2019 for Bangladesh includes two goals of relevance to this work:

- **Development Objective 3:** Improve the health status of target populations, building on past and on-going successful population, health and nutrition programs while incorporating GHI principles.
- **Development Objective 4:** Responsiveness to climate change improved.

The climate risk insights provided here offer climate change adaptation options grouped in three categories: (1) science and analysis to inform decision-making; (2) improved governance and capacity; and (3) piloting in health and environmental management at the urban scale. The two DOs highlighted above provided entry points to integrating recommendations in these areas into the current USAID/Bangladesh CDCS.

SCIENCE AND ANALYSIS TO INFORM DECISION-MAKING

Development of explicit climate vulnerability and risk information is a necessary first step in identifying areas of intervention. While there is general understanding of current associations between weather and climate variables and a range of adverse health outcomes, derived from studies conducted in other countries, improved knowledge and understanding of current and projected context-specific climate risks affecting MCHN for urban areas of Bangladesh is needed to formulate evidence-based policies and programs. This is especially true for urban and peri-urban environments outside of Dhaka, for which the evidence base is limited. Also, because there are drivers other than weather and climate for these health outcomes, such as the status and quality of housing and transport infrastructure, it would be helpful to develop research and analyses in collaboration with stakeholders in other sectors. This collaboration could provide critical information and perspectives, including the variables decision-makers and technical staff in these related sectors are monitoring, that could be relevant for health-related activities, and additional indicators (e.g., air quality) that would be useful to monitor and evaluate. This collaboration might also bring to light causal relationships among these sectors on one hand, and health and climate on the other, given the complex and dynamic nature of the variables at play.

Improve understanding of the context-specific risks for slum dwellers. Accurate health information from slums has been traditionally difficult to obtain, and traditional health statistics rarely report on critical differences among different populations within a city. The dearth of longitudinal and disaggregated data on urban health (e.g., for slum communities) can mask significant health disparities that exist within a city. To date, most of the information available on health burdens relies on clinic and hospital registry data, undercounting incidence for populations not accessing traditional health systems. Lacking these detailed data, health officials are limited in their ability not only to detect potential threats, but also to allocate limited resources. One key factor explaining the data challenge is the fact that 10–20 percent of urban slums in both Khulna and Chattogram are located on public lands, making many residents fearful of reprisal for reporting disease incidence.

Conduct detailed vulnerability assessments in slums. Such assessments would identify the specific health care needs of slums (involving auxiliary health care providers such as pharmacies and traditional healers) and immediate actions that can reduce risks, such as waste disposal or providing soap and hygiene education. A significant share of ill health in slums stems from poor access to sanitation and clean drinking water. Flooded areas and ditches, latrines and septic tanks are key reservoirs that perpetuate diarrheal disease, cholera, and vector-borne illnesses such as malaria in urban areas. The high population density and overcrowding of slums can rapidly expand epidemic-prone infections such as influenza and TB.

Expand air quality monitoring. The National Ambient Air Quality Monitoring Program, which is implemented by the Ministry of Environment and Forests, has collected data for several cities in Bangladesh, including Khulna and Chattogram, since 2011. While these monitoring stations have been useful in defining the nature and severity of pollution in the cities and identifying pollution trends in the country, they do not provide the granular level of information to understand the variability in air quality across a city. Extending the air quality monitoring network

to areas across the city could help to understand the variability of resident exposure to poor air quality. This information could be instrumental in guiding urban planning initiatives to help more efficiently reduce exposure to pollution at the most important times and in optimal places. For example, a decision about where to build a new school or hospital should be based on proximity of the location to major roads, industrial facilities and other sources of air pollution, as daily exposure to highly polluted areas can greatly increase the likelihood that children will suffer from respiratory illnesses. Similarly, hospitals in polluted areas are likely to see suboptimal outcomes for patients.

IMPROVED GOVERNANCE AND CAPACITY

The capacity of secondary cities to shape their responses to climate-related risks under a changing climate depends on robust institutions with personnel who not only understand climate risks (and effective adaptation measures to respond to them), but who can also help raise awareness of the risks and use planning mechanisms and capital investment to address the risks. These personnel should seek funding and support from public agencies to address urgent climate risks, recognizing that public resources at the national, regional and local levels are limited. Ideally, these planning mechanisms and investments should be firmly rooted in an understanding and appreciation of the extent of the risks that climate change presents to economic growth and reflected in a strategic vision of climate risk management (and related planning documents). Specific, rigorous climate vulnerability assessments provide the evidence to justify these expenditures.

Currently, neither Chattogram nor Khulna has a strategic plan that addresses climate risks explicitly. In fact, climate change adaptation actions are implemented primarily by local NGOs and are not under the leadership of the city. Moreover, existing plans, such as the 2011 Khulna City Corporation Master Plan (the most recent identified in the research for this study), are used solely as instruments for planning permission and development control rather than to lay out a detailed long-range vision for infrastructure investment and land use development (Rahaman et al. 2018).

PILOTING INTEGRATED HEALTH AND ENVIRONMENTAL MANAGEMENT INTERVENTIONS

A range of adaptation options could be considered in intermediate results targets of development objectives aimed at improving health and environmental management under a changing climate. The scientific analyses and information presented above can inform the prioritization of specific options, and where and when implementation would be more effective. These options include:

- **Promoting public health awareness on climate change impacts, sanitation and hygiene.** Perception is an important component of behavior change and plays a major role in public response to environmental and climate exposure. USAID/Bangladesh's behavior change campaigns aimed at dietary diversity, exclusive breastfeeding and feeding frequency have clearly been successful in linking home gardens to nutrition. Leveraging these experiences to build awareness of the risks from climate shocks could improve responses. There is clearly a significant amount of social capital in slums, such as community groups or religious institutions, that could be leveraged to involve

residents in design and responses to climate risks. For example, communities and individuals should take even more significant precautions in treating drinking water during flood events, as floodwaters can increase the risk of waterborne illnesses, such as diarrheal disease.

- **Improving strategies for environmental management in urban landscapes.** The current CDCS DO4[4] provides a framework for improved management of natural resources, livelihood diversification and clean energy. Nevertheless, investments to date have been targeted at rural environments. While the ecosystem services these peri-urban and rural environments provide are critical to the health of a city's population, more needs to be done within the cities in order to reduce pollution, manage waste and improve drainage, all potentially improving health outcomes.
- **Expanding access to safe water and improved sanitation.** Policies should be formulated to promote good hygiene and sanitation. As the climate changes, the number of heavy downpours is likely to increase in frequency and intensity, leading to more flooding events, which have been linked to increased gastrointestinal illness and diarrheal diseases.
- **Enhancing surveillance and diagnostic and treatment options during high-risk seasons/periods.** Climate risk information on extreme events, such as the largest increase in the heat index occurring between August and September and during the monsoons, can be used to alert high-risk communities and screen for risk factors from heat stress, including cardiovascular and pulmonary status. Climate information could also help secure additional resources for high-risk seasons.
- **Improving health care access among populations vulnerable to climate-sensitive diseases (e.g., heat-related, waterborne illnesses) or exposed to injury from natural disasters.** Better access could mean building new facilities, subsidizing service delivery to lower costs, weather-proofing transportation infrastructure, strengthening institutional coordination and bolstering emergency preparedness systems. These partnerships can identify, improve and scale up interventions to reduce risks.
- **Engaging in multisectoral interventions, including professionals from urban planning, public works, engineering and the health sectors**. For example, air pollution measures implemented in Dhaka, such as banning highly polluting 2-stroke engines, introducing lower-sulfur fuel, improving the mobility of vehicles and introducing new technology, which is still under consideration for brick production, could be expanded to other major cities in order to reduce PM emissions. Understanding climate sensitivities, in this case, the relationship between pollution and wind speeds and rainfall, could play an important role in formulating effective policies, since it is in wintertime that there appears to be a trailing effect of particulate matter movement from northwest to southeast Bangladesh.

[4] DO 4: *Improved management of natural resources, livelihood diversification, climate risk management and enhanced capacity for low-emissions development will address adaptation and mitigation of Global Climate Change (GCC), while providing sustainable economic benefits and clean energy resources.*

ENTRY POINTS FOR THE COUNTRY DEVELOPMENT COOPERATION STRATEGY

Explicitly addressing the implications of climate variability and change in the next CDCS would help protect human health as the climate continues to change. Examples of this consideration under the current development objectives are outlined in Table 9 below.

Additionally, indicators can be added to the CDCS intermediate results targets to monitor progress on managing the health risks of climate variability and change, such as for infectious diseases: use of seasonal climate information to forecast malaria, diarrheal disease and other infectious diseases; functioning of integrated surveillance, monitoring and control programs; increase in diagnostic and treatment options in high-risk regions/periods; proportion of the population with access to safe drinking water sources (climate resilient) and improved sanitation facilities. Similar indicators could be developed to monitor nutritional conditions, including the use of seasonal climate information to forecast emerging food security and safety crisis situations.

Table 9: Examples of integration of climate change into a new country development cooperation strategy

Current DO	Example from current intermediate results (IRs)	Examples of changes to incorporate climate change
DO3	Strengthened health systems and governance	• Using climate vulnerability analyses to extend health service access by taking advantage of auxiliary health care providers such as pharmacies and traditional healers • Extend diagnostic and treatment options in high-risk areas/periods
	Increased use of integrated essential family planning, health and nutrition services	• Implement programs to increase public awareness on climate change impacts, disease/illness control, prevention and treatment • Prepare communication plans for health-related aspects of climate change, including risks and ways to reduce them
DO4	Increased adaptation capacity and resilience to shocks	• Using the successful national cyclone early warning system as a foundation, create a similar early warning system to anticipate, monitor and provide communications to communities regarding disease surveillance • Build community resilience to shocks by building social capital • Provide direct support to families to “graduate” themselves out of vulnerability by facilitating movement to less vulnerable locations and by building household livelihood resilience
Cross-cutting issues		• Enhance integrated surveillance, monitoring and control programs of climate-sensitive health outcomes • Enhance human resources and skills in coping with climate variability and change • Train professional staff in health and other ministries and organizations on the health risks of climate change • Develop partnerships between health and other ministries and other organizations to more effectively address the health risks of climate change • Ensure that gender, equity and other social determinants of vulnerability and resilience are incorporated into policies and programs

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