CLIMATE RISK COUNTRY PROFILE

BANGLADESH

WORLD BANK GROUP

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Graphic Design: Circle Graphics, Inc., Reisterstown, MD.

ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles developed by Climate Change Group of the World Bank Group (WBG). The country profiles aim to present a high-level assessment of the climate risks faced by countries, including rapid-onset events and slow-onset changes in climate conditions, many of which are already underway, as well as summarize relevant information on policy and planning efforts at the country level.

The country profile series are designed to be a reference source for development practitioners to better integrate detailed climate data, physical climate risks and need for resilience in development planning and policy making.

This effort is managed and led by MacKenzie Dove (Technical Lead, CCKP, WBG), Pascal Saura (Task Team Lead, CCKP, WBG) and Megumi Sato (Climate Change Specialist, WBG).

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Unless otherwise noted, data is sourced from the WBG's Climate Change Knowledge Portal (CCKP), the WBG's designated platform for climate data. Climate, climate change and climate-related data and information on CCKP represents the latest available data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments received from climate and development specialists, as well as climate research scientists and institutions for their advice and guidance on the use of climate related datasets.

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FOREWORD

Climate change is a major risk to good development outcomes and presents an existential threat to the World Bank Group's (WBG) twin goals of ending extreme poverty and promoting shared prosperity in a sustainable way. The WBG is thus committed to supporting client countries to invest in a low-carbon and climate-resilient future.

Our approach is outlined in the *WBG Climate Change Action Plan (CCAP) 2021–2025*, which focuses on helping countries integrate climate into their development agendas, with the goal to combine mitigation and adaptation with economic growth and poverty reduction. Guided by the *CCAP*, the WBG prioritizes climate action across five key systems: energy; agriculture, food, water, and land; cities; transport; and manufacturing. Only through transforming these systems can we begin to address climate change, achieve a resilient and low-carbon future, and support natural capital and biodiversity, while achieving development goals.

A key element of this strategy relies on the capacity to systematically incorporate and manage climate risks in development operations. We are thus investing in processes and tools that allow us to inform lending with climate data.

The Climate Change Knowledge Portal (CCKP) is an online 'one-stop-shop' for foundational climate data at the global, regional, and country levels. CCKP provides inputs to the WBG's Climate and Disaster Risk Screening Tool, which contributes to assessing short- and long-term climate and disaster risks in operations as well as national or sectoral planning processes.

Supplementing this effort, the *Climate Risk Country Profile* you are about to read is a signature product of CCKP which supports a better understanding of the impacts of physical climate risks. Guided by the Climate Risk Country Profile, WBG, key external partners, and development practitioners may conduct initial assessments of climate risks and opportunities that will eventually inform upstream country diagnostics, policy dialogue, and strategic planning for developing countries.

It is my hope that these efforts will spur the prioritization of long-term risk management and deepen the WBG's commitment to integrate adaptation planning into strategic country engagements and lending operations.

Jennifer J. Sara
Global Director
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KEY MESSAGES

- **Observed Climate:** Bangladesh has a moist, humid, tropical monsoon climate (average mean temperature of 25.71°C) with one rainy and dry season (2,174.10 mm annually), influenced interannually by the El Niño Southern Oscillation (ENSO) and Indian Ocean Dipole (IOD).
- **Observed Temperature:** Between 1971 and 2020, Bangladesh's mean temperature increased by 0.16°C per decade, with a significantly increasing number of hot and humid days.
  - **Eastern divisions** observed the greatest mean temperature changes over this period during summer and fall months.
- **Projected Temperature:** Under SSP3-7.0, Bangladesh's temperatures are homogeneously projected to increase 0.41°C (–0.19°C, 0.76°C) from the historical reference period to 26.03°C (25.26°C, 26.65°C) for the period 2020–2039, and 0.89°C (0.45°C, 1.70°C) to 26.59°C (25.78°C, 27.56°C) for the period 2040–2059.
- **Extreme Heat Risk:** By midcentury, Bangladesh is likely to experience higher minimum and maximum temperatures, and hotter apparent conditions due to high atmospheric moisture content. The following key metrics for temperature illustrate these risks under the SSP3-7.0 scenario for the period of 2040–2059, compared to the historical reference period of 1995–2014.
  - Number of High Heat Index Days, Days Surpassing Heat Index of 35°C: Bangladesh's high atmospheric moisture content over certain seasons makes the number of days surpassing the Heat Index >35°C increase from roughly two months annually during the reference period to 133.47 (85.88, 172.12) total nationwide by midcentury. This not only exacerbates human health concerns, but also presents risks to water and food security.
    - **Coastal southern divisions** featured the greatest increase in number of high Heat Index days annually by midcentury, especially during pre-monsoon spring months.
  - Number of Tropical Nights, T-min>26°C: The number of tropical nights with a minimum temperature >26°C is projected to increase 55.66 (31.01, 82.58) nationwide from the reference period to 133.19 (92.81, 166.30) total days annually by midcentury. The combination of increased high heat days and tropical nights disproportionately concern: the elderly, pregnant women, children and newborns, people with chronic illnesses and disabilities, outdoor workers, low-wage earners, and people living in areas with poorly equipped and ill-prepared health services.
    - **The northern and eastern floodplains** are projected to experience the greatest increases during the summer months by midcentury.
- **Observed Precipitation:** Over the 50-year period of 1971–2020, Bangladesh experienced regionally, seasonally, and interannually varied changes in annual precipitation per decade. Over this period:
  - **Eastern divisions** were significantly drier annually, especially during spring pre-monsoon months.
  - **Western divisions** were significantly wetter annually, especially during post-monsoon fall months.
- **Projected Precipitation:** Projected precipitation volumes under SSP3-7.0 nationally signal annual increases by midcentury, but seasonal and regional shifts with a wide range of uncertainty.
  - **Southern divisions** are expected to experience an annual decrease in precipitation by 2020–2039 under SSP3-7.0, especially during spring pre-monsoon months.
  - **Northern divisions** are expected to experience the greatest increase in annual precipitation by 2040–2059, especially during the summer monsoon months.
  - **The central region (Dhaka Division)** is not projected to change much in yearly volume by midcentury but increases overall.

- **<u>Precipitation Risk:</u>** By midcentury, Bangladesh is likely to experience more intense precipitation though the timing and severity of extreme anomalies vary by region. The following key metrics for precipitation illustrate these shifts for the period of 2040–2059 under SSP3-7.0, compared to the historical reference period of 1995–2014.
    - <u>Average Largest 5-Day Precipitation:</u> Increases in the average highest precipitation amount over a 5-day period, which rise 24.96 mm (–97.20 mm, 143.48 mm) nationwide from the reference period to 326.24 mm (219.38 mm, 473.81 mm) by midcentury, pose risks for flood management and do not always coincide with months experiencing the largest anomalies in total projected precipitation volumes.
        - **Northern divisions** are expected to experience the biggest changes in average largest 5-day precipitation by midcentury, with the greatest increases during summer monsoon months.
- **<u>Extreme Precipitation Occurrence:</u>** By midcentury, Bangladesh is likely to more frequently experience extreme precipitation event occurrence. The future return period of a 100-year event associated with 1-day largest cumulative precipitation amounts is projected to become 57.97 (19.48, 195.85) years by midcentury. These conditions pose risks for flood-related safety, health, and critical infrastructure.
    - **Northern divisions** are projected to be nearly twice as likely to experience extreme events with 1-day cumulative precipitation amounts and 100-year historical return periods by midcentury under SSP3-7.0.
- **<u>Climate-Related Hazards:</u>**
    - Sea level rise and inundation will increasingly threaten Bangladesh's **deltaic coastal zones**, causing a significant retreat of the coastline by the end of the century without mitigation measures.
    - The frequency and intensity of flooding **along major river systems** and droughts in **northwest divisions** have increased and will likely continue to persist.
    - Climate variability can exacerbate Bangladesh's moderately high seismic risk conditions. Earthquake and landslide hazards pose the greatest risk **along the northern and eastern borderlands**.

For National Policies, see key documents linked at the end of this profile.

COUNTRY OVERVIEW

Bangladesh, located in South Asia between 20°N-27°N latitude, is one of the most densely populated countries in the world, grouped into eight subnational divisions as of 2019 that border India, Myanmar, and the Bay of Bengal (**see Figures 1a and 1b**). Most of Bangladesh's 130,170 km^2 land area between the Himalayan Mountains and the Bay of Bengal consists of low-lying deltaic floodplains less than 15 meters (m) above sea level. Five major river systems out of roughly 230 in the country shape the landscape.[1] The (1) Ganges or Padma River flows from the northwest and meets the (2) Brahmaputra or Jamuna River flowing from the north at a point just west of the capital Dhaka. Two slightly elevated (>15 meter) areas of jungle-covered alluvium, the Barind Tract (Rajshahi) and Madhupur Tract (Dhaka), stand out amongst the western floodplain basins (**see Figure 1a**). The main course of the Brahmaputra until 1787, (3) the Old Brahmaputra, is now a much smaller river that travels from the Jamuna's confluence with the Tista River to Dhaka Division's active delta. The Sylhet-Surma and Kusiyara Rivers, which flow from the Sylhet Hills in the northeast along the Indian border, merge to form the (4) Meghna River which joins the Padma River further downstream from its confluence with the Jamuna before emptying into the Bay of Bengal. Bangladesh's southwestern coast (Khulna) is defined by the Sundarbans, vast tidal deltas and estuarine islands with extensive mangrove forests. In the southeast, (5) the Karnaphuli among other minor rivers drain from the Chittagong Hills (approximately 700–1,000 meters) into the Bay of Bengal via a narrow coastal plain.

According to the World Bank's DataBank,[2] Bangladesh has an estimated 2022 population of 171.2 million with an annual population growth rate of 1.1% (**see Table 1**). Only 40% of the population lives in urban areas as of 2022, centered around Dhaka, Chittagong, and Khulna, though half of the urban population lives in slums. Overall, Bangladesh ranks 129 out of 191 on the Human Development Index for 2021, a medium level of human development considering factors such as life expectancy, education, and income per capita.[3] As a lower-middle-income country, it has a 2022 Gross Domestic Product (GDP in current $US) of $460.2 billion, high annual GDP growth rate of 7.1%, and GDP per capita of roughly $2,700 (current $US). About one-quarter of Bangladesh's (2019) population lives below the national poverty line and widening disparities in urban areas persist. However, Bangladesh's strong economic growth since the 1970s reduced its poverty levels from 11.8% in 2010 to 5.0% in 2022, measured according to $2.15 a day (2017) purchasing power parity.[4] The agricultural sector (including forestry, fisheries, and livestock) remains a dominant employer, accounting for 37.09% of the workforce in 2021, despite the rising importance of the industrial and service sectors. Rice, wheat, and pulses are key crops followed by jute, tea, shrimp, and fish for foreign export.[5] Industrialization in the late 20th and early 21st centuries led to the growth of ready-made garments, textile mills, paper mills, and fertilizer factories, as well as other cottage industries.[6] Most urban and industrial expansion occurs in the capital, the main port of Chittagong in the southeast, and the growing commercial and industrial center of Khulna in the southwest. Scattered rural settlements along the Bay of Bengal, Old Brahmaputra River, and parts of the Sylhet and Chittagong Hills continue to experience gaps in adequate electricity and safe drinking water access (**see Table 1**).

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1 Tinker, H. R., and Husain, S. S. (2023). Bangladesh. Encyclopedia Britannica. URL: https://www.britannica.com/place/Bangladesh
2 World Bank (2023). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators
3 UNDP (2022). Human Development Report 2021/2022. URL: https://hdr.undp.org/system/files/documents/global-report-document/hdr2021-22pdf_1.pdf
4 World Bank (2023). Bangladesh Overview. URL: https://www.worldbank.org/en/country/bangladesh/overview
5 Tinker, H. R., and Husain, S. S. (2023). Bangladesh. Encyclopedia Britannica. URL: https://www.britannica.com/place/Bangladesh; CIAT and World Bank (2017). Climate-Smart Agriculture in Bangladesh. URL: https://cgspace.cgiar.org/bitstream/handle/10568/83337/CSA_Profile_Bangladesh.pdf?sequence=2&isAllowed=y
6 Tinker, H. R., and Husain, S. S. (2023). Bangladesh. Encyclopedia Britannica. URL: https://www.britannica.com/place/Bangladesh

FIGURE 1A. Relief Map of Bangladesh[7]

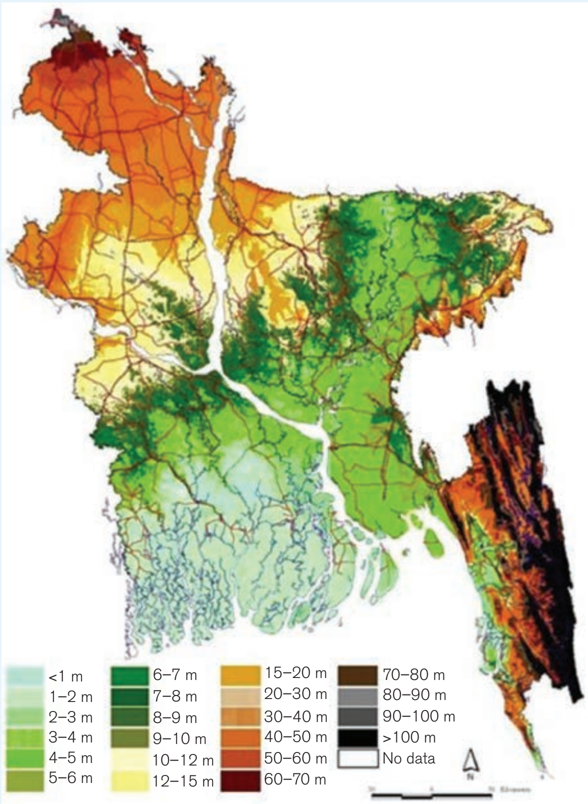


FIGURE 1B. Administrative Map of Bangladesh[8]

Bangladesh ratified the Paris Agreement and released its Intended Nationally Determined Contribution (INDC) in 2015, Interim Nationally Determined Contribution (NDC) in 2020, and Updated Nationally Determined Contribution in 2021. Bangladesh's Third National Communication to the UNFCCC (NC3) (2018) identifies the impacts of climate change in key sectors such as agriculture, water resources, coastal areas, and human health as priority concerns. Bangladesh's updated (2021) NDC established target actions for climate mitigation and adaptation by 2030. To meet its mitigation target, it would reduce greenhouse gas emissions by at least 27.56 Mt CO2e (6.73%) below business-as-usual by 2030. In its energy sector, Bangladesh supports renewable energy projects and technology, improving fuel efficiency through enhancing road traffic congestion, and shifting to a rail transport system. In its agriculture sector, Bangladesh plans to reduce emissions from rice fields, fertilizer, enteric fermentation, and manure management. Additionally, Bangladesh plans to increase forest cover by 150,000 hectares in coastal islands and degraded areas. The Ministry of Environment, Forest, and Climate Change (MoEFCC) is the coordinating agency of Bangladesh's central government on all matters related to the environment and sets the climate change strategy for the country. The country's National Plan for Disaster Management (2021–2025) (NPDM) and Standing Orders on Disaster (2019) guide Bangladesh's planning and response to disaster risks. These strategies are further

[7] CGIAR Consortium for Spatial Information (2018). SRTM 90m DEM Digital Elevation Database. URL: https://SRTM.csi.cgiar.org
[8] UN OCHA (2019). Bangladesh National Reference Map. URL: https://reliefweb.int/map/bangladesh/bangladesh-national-reference-map-24-jan-2019

supported by the Second Perspective Plan of Bangladesh (2021–2041), 8th Five-Year Plan for economic growth and development, and Bangladesh Delta Plan 2100, all approved in 2020. As of 2023, Bangladesh's comprehensive National Adaptation Plan (NAP) is still under development.[9]

TABLE 1. Key Development Indicators[10]

Key Demographic Indicators	Most Recent Value	Global Rank
Population Density (people per sq km, 2021)	1,301.04	9 (out of 216)
Life Expectancy (for total population in years, 2021)	72.38	103 (out of 209)
Fertility Rate (total births per woman, 2021)	1.98	112 (out of 210)
Dependency Ratio (dependents per 100 working-age people, 2022)	47.09	167 (out of 217)
Key Economic and Social Development Indicators	**Most Recent Value**	**Global Rank**
GDP per Capita (in current $US, 2022)	$2,688.30	135 (out of 185)
% Population Below National Poverty Line (2019)[11]	24.3%	65 (out of 100)
Unemployment Rate (% of total labor force, 2022)	4.70%	112 (out of 183)
% Employed in Agriculture (2021)	37.09%	44 (out of 185)
% Employed in Industry (2021)	21.71%	68 (out of 185)
% Employed in Services (2021)	41.20%	154 (out of 185)
% Population with Access to Electricity (2021)	98.99%	138 (out of 215)
% Population Using at Least Basic Sanitation Services (2022)	59.30%	148 (out of 191)

Data for each indicator's most recently measured year is ranked compared to all countries and entities globally in the far-right column, as tracked by the World Bank's Data Bank. Global ranking for the population below the national poverty line only includes countries classified as developing by UNDP.

OBSERVED AND CURRENT CLIMATE

Data Overview

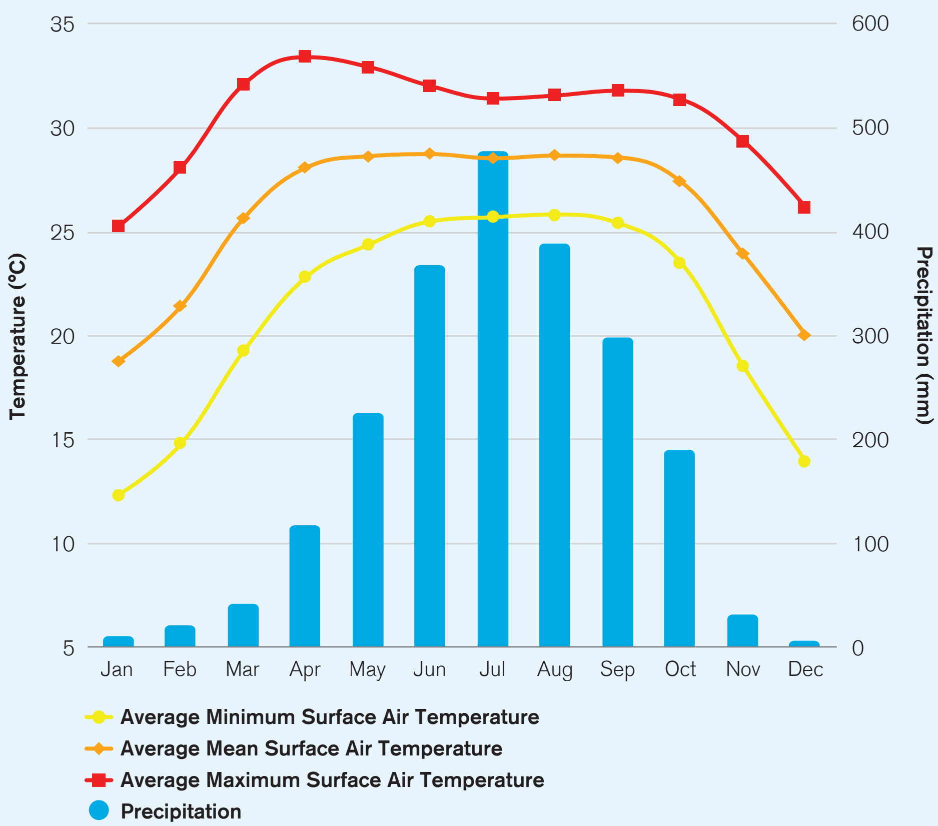
The data presented are from the World Bank Group's Climate Change Knowledge Portal (CCKP).[12] Historical, observed data is derived from the Climatic Research Unit, University of East Anglia (CRU), CRU TS version 4.07 gridded dataset (data available 1901–2022) and ERA5 reanalysis collection from ECMWF (1950–2020).

[9] UNDP (2023). Bangladesh. URL: https://climatepromise.undp.org/what-we-do/where-we-work/bangladesh
[10] World Bank (2023). DataBank – World Development Indicators. URL: https://databank.worldbank.org/source/world-development-indicators
[11] UNDP (2022). Global Multidimensional Poverty Index 2022. URL: https://hdr.undp.org/system/files/documents/hdp-document/2022mpireportenpdf.pdf
[12] World Bank Climate Change Knowledge Portal (2023). Bangladesh Climatology. URL: https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-historical

Climate Overview

Bangladesh has a moist, humid, tropical monsoon climate with one rainy and dry season annually, influenced interannually by ENSO and IOD. Over the current climatology (1991–2020, **see Figure 2**), Bangladesh observed a mean annual temperature of 25.71°C. During the 1991–2020 period, the warmest month of June ranged from an average minimum temperature of 25.49°C to an average maximum temperature of 32.01°C, while the coolest month of January ranged from a minimum average temperature of 12.31°C to a maximum average temperature of 25.26°C. As shown in **Table 2**, the warmest average temperatures occur between May and August nationwide during the rainy monsoon season. Khulna on the southwest coast possesses the warmest monthly mean temperature (29.87°C) in May and warmest annual mean temperature (26.36°C) in Bangladesh. The coolest monthly average temperatures occur in January during the dry winter monsoon season. Sylhet in the hilly northeast possesses the coolest monthly average temperature (17.59°C in January) and coolest annual average temperature (24.40°C).

FIGURE 2. Observed Monthly Climatology of Bangladesh's Temperature and Precipitation, 1991–2020



Note the wider temperature range from October to April and the highest median temperatures during the rainy monsoon season (April to October), which peaks in July.

Bangladesh is a very wet country, with a mean annual precipitation of 2,174.10 mm over the current climatology (1991–2020) at the national level. During this period, the western floodplains received between 1,500 mm and 2,200 mm annually while the eastern floodplains and hills received between 2,100 mm to 3,200 mm annually. **Table 2** illustrates Bangladesh's precipitation patterns subnationally according to geographic and hydrological regions. Bangladesh has four seasons: a hot pre-monsoon season (March to May), hot and humid monsoon season (June to October), warm and drier post-monsoon season (October to November), and the cool winter dry season (December to February).[13] The pre-monsoon season has the highest average maximum temperatures and northwesterly winds that can produce tropical cyclones. By June, a shift to southwesterly winds that carry warm moist air from the Indian Ocean drive the wet monsoon season until October. Precipitation volumes peak during July nationally (478.48 mm on average), however the extent of monthly totals account for variations in annual precipitation. Sylhet in the northeast observed Bangladesh's wettest annual average precipitation over the most recent climatology (3,227.65 mm) with the heaviest average monthly maximum in July of 648.02 mm, followed by Chittagong in the southeast (622.15 mm in July). Compared to the divisions located closest to the Himalayas, which trap in moisture, the western floodplains exhibited monthly rainfall peaks between 300–400 mm, except for Barisal in the south. As the Intertropical Convergence Zone (ITCZ) migrates south, a transitional post-monsoon period registers the greatest number of tropical cyclones on average under unstable atmospheric conditions. Winds predominantly blow from the north-northeast interior during the colder dry season beginning in December, resulting in the lowest monthly precipitation totals. The northern floodplains contain the driest monthly average precipitation during this month (2.15 mm in Mymensingh, followed by 2.98 mm in Rajshahi). The driest annual average precipitation over the same time period (1,565.16 mm) occurred in Rajshahi in the northwest floodplains, which also observed the lowest precipitation in July.

Another critical factor that influences interannual precipitation variability is the presence of ENSO and the Indian Ocean Dipole or IOD, which tend to produce different effects if particular phases of the two phenomena co-occur.[14] Anomalously warm sea surface temperatures in the central and eastern Pacific and consequently weaker easterly winds characterize an El Niño phase, which tend to result in drier conditions over the northern Indian subcontinent during the wet monsoon summer months and raise the risk of poor agricultural yields and famine. Anomalously cool sea surface temperatures in the same locations result in the stronger easterly winds that characterize a La Niña phase, producing heavier flooding as well as tropical cyclone occurrence over the northern Indian subcontinent.[15] However, the IOD modulates these effects if it occurs simultaneously with ENSO and produces heterogeneous effects across the Ganges, Brahmaputra, and Meghna River basins.[16] Anomalously warm sea surface temperatures in the western Indian Ocean and strengthened equatorial easterly winds correspond with a positive IOD phase, while the opposite set of features characterize a negative IOD phase. A positive IOD phase can counteract the effects of an El Niño if they co-occur, especially in the Ganges River watershed which extends into northern India and

[13] Ministry of Environment, Forest, and Climate Change (2018). Third National Communication. URL: https://unfccc.int/documents/192278
[14] Pervez, M. S., and Henebry, G. M. (2015). Spatial and seasonal responses of precipitation in the Ganges and Brahmaputra river basins to ENSO and Indian Ocean dipole modes: implications for flooding and drought. Natural Hazards and Earth System Sciences, 15(1), 147–162. DOI: https://doi.org/10.5194/nhess-15-147-2015
[15] Wahiduzzaman, M. (2021). Major floods and tropical cyclones over Bangladesh: clustering from ENSO timescales. Atmosphere, 12(6), 692. DOI: https://doi.org/10.3390/atmos12060692
[16] Pervez, M. S., and Henebry, G. M. (2015). Spatial and seasonal responses of precipitation in the Ganges and Brahmaputra river basins to ENSO and Indian Ocean dipole modes: implications for flooding and drought. Natural Hazards and Earth System Sciences, 15(1), 147–162. DOI: https://doi.org/10.5194/nhess-15-147-2015

Nepal. But a positive IOD phase alone tends to produce positive precipitation anomalies during the wet monsoon season across the Ganges River watershed at the same time it tends to produce negative precipitation anomalies across the Brahmaputra River watershed, which extends into western China and Bhutan. Such correlations suggest the greater influence of contributors outside the Indian monsoon trough region on precipitation anomalies in the Brahmaputra and Meghna River basins.[17] La Niña phases tend to produce positive precipitation anomalies in both basins, with or without a negative IOD phase, though more extreme anomalies in the Brahmaputra River basin. Further details on ENSO are provided in the profile's section on climate-related hazards.

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Bangladesh's Divisions

Climatic-Topographic Region and Division	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Bangladesh (national)	Jun: 28.73°C (25.49°C, 32.01°C)	Jun (367.90 mm) W: Jul (478.48 mm) Aug (388.87 mm)	2,174.10 mm
	Jan: 18.76°C (12.31°C, 25.26°C)	D: Dec (5.44 mm)	
Western Floodplains (Tropical Moist)			
Barisal (south)	May: 28.98°C (25.17°C, 32.83°C)	Jun (381.61 mm) W: Jul (515.60 mm) Aug (437.51 mm)	2,290.86 mm
	Jan: 19.16°C (12.71°C, 25.67°C)	D: Dec (8.08 mm)	
Khulna (southwest)	**May: 29.87°C** (25.26°C, 34.53°C)	Jun (301.35 mm) W: Jul (360.92 mm) Aug (324.40 mm)	1,757.78 mm
	Jan: 19.10°C (12.41°C, 25.84°C)	D: Dec (6.38 mm)	
Rajshahi (northwest)	June: 29.61°C (25.99°C, 33.27°C)	Jun (254.28 mm) W: Jul (348.69 mm) Aug (279.28 mm)	**1,565.16 mm**
	Jan: 18.53°C (11.98°C, 25.13°C)	D: Dec (2.98 mm)	
Dhaka (central north)	Aug: 29.01°C (26.18°C, 31.88°C)	Jun (326.11 mm) W: Jul (363.24 mm) Aug (308.83 mm)	1,904.16 mm
	Jan: 18.90°C (12.26°C, 25.58°C)	D: Dec (4.48 mm)	

(*continues*)

[17] Chowdhury, M. R., and Ward, N. (2004). Hydro-meteorological variability in the greater Ganges–Brahmaputra–Meghna basins. International Journal of Climatology: A Journal of the Royal Meteorological Society, 24(12), 1495–1508. DOI: https://doi.org/10.1002/joc.1076

TABLE 2. Observed Temperature and Precipitation Trends for 1991–2020 Climatology Across Bangladesh's Divisions (*Continued*)

Climatic-Topographic Region and Division	Observed Warmest (Top) and Coolest (Bottom) Months by Mean Temp.	Observed Wettest and Driest Months per Season	Observed Annual Precip.
Northern and Eastern Floodplains and Hills (Tropical and Subtropical Moist)			
Rangpur (northwest)	Aug: 29.06°C (26.17°C, 32.01°C)	Jun (390.54 mm) W: Jul (510.35 mm) Aug (382.76 mm)	2,180.88 mm
	Jan: 17.68°C (11.12°C, 24.29°C)	D: Dec (3.49 mm)	
Mymensingh (northeast)	Aug: 28.85°C (26.05°C, 31.71°C)	Jun (416.21 mm) W: Jul (443.61 mm) Aug (374.86 mm)	2,272.13 mm
	Jan: 18.37°C (12.01°C, 24.78°C)	**D: Dec (2.15 mm)**	
Sylhet (northeast)	Aug: 28.05°C (24.91°C, 31.23°C)	Jun (584.69 mm) **W: Jul (648.02 mm)** Aug (510.95 mm)	**3,227.65 mm**
	Jan: 17.59°C (10.92°C, 24.32°C)	D: Dec (4.68 mm)	
Chittagong (southeast)	May: 28.46°C (24.52°C, 32.45°C)	Jun (386.79 mm) W: Jul (622.15 mm) Aug (490.27 mm)	2,486.02 mm
	Jan: 19.60°C (13.60°C, 25.65°C)	D: Dec (8.38 mm)	

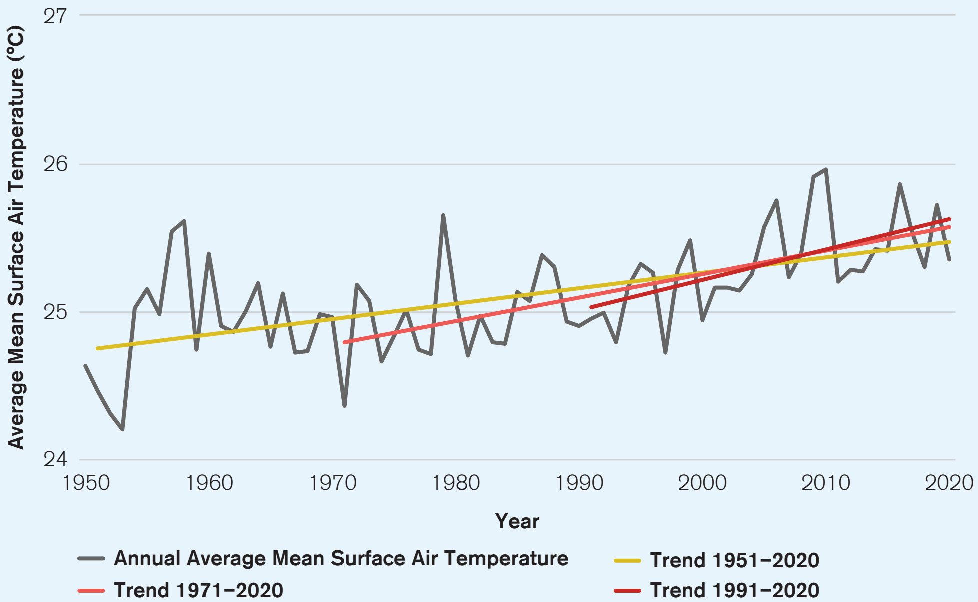
Climatic zones are classified according to characteristics in Sayre et al. and grouped by topo-geographic region (western floodplains shaded light green, northern and eastern floodplains and hills shaded dark green).[18] Each division's warmest month generally corresponds with the beginning or middle of the rainy season and the coolest month during the dry season. For the column listing mean monthly temperatures, the minimum (left) and maximum (right) temperatures are shown in parentheses. Precipitation regimes indicate wettest (W) and driest (D) months, both further interpreted in the text.

Temperature

Between 1971 and 2020, Bangladesh's average mean temperature increased by 0.16°C per decade (see Figure 3), with the greatest changes observed in the eastern divisions and most widespread warming during the summer and fall months. Nationwide, average minimum temperatures increased 0.20°C per decade between 1971–2020, while average maximum temperatures increased 0.18°C per decade over the same period. The northeastern division of Sylhet recorded the highest annual average mean temperature increases per decade (0.24°C) and minimum temperature increases per decade (0.29°C). The southeastern division of Chittagong recorded the highest maximum temperature increases per decade (0.28°C). By comparison, the lowest significant temperature increases over this period occurred in the western divisions. Khulna (southwest) observed a 0.11°C mean increase

[18] Sayre, R., Karagulle, D., Frye, C., Boucher, T., Wolff, N. H., Breyer, S., et al. (2020). An assessment of the representation of ecosystems in global protected areas using new maps of World Climate Regions and World Ecosystems. Global Ecology and Conservation, 21, e00860. DOI: https://doi.org/10.1016/j.gecco.2019.e00860

FIGURE 3. Average Annual Mean Temperature Trends Nationally per Decade, 1951–2020



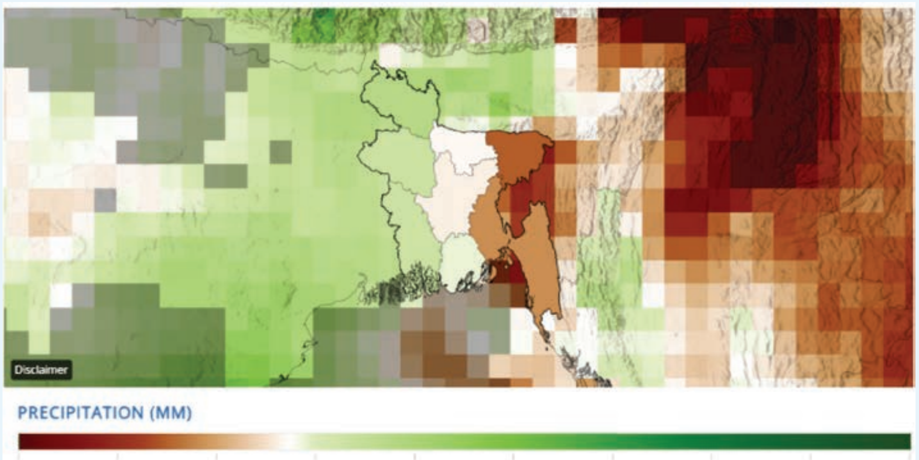
Significantly positive trendlines over the 30-year, 50-year, and 70-year climatologies indicate a steadily rising rate of mean temperature increases, from an increase of 0.11°C per decade between 1951–2020 (yellow line) to an increase of 0.20°C per decade between 1991–2020 (red line).

per decade, Barisal (south) observed a 0.11°C minimum increase per decade, and Rajshahi (northwest) observed a 0.10°C maximum increase per decade. Summer months exhibited the greatest seasonal mean, minimum, and maximum increases in temperature per decade, with changes greater than 0.20°C extending to all divisions. During summer months, Sylhet and Mymensingh (northeast) recorded an average mean temperature increase of 0.28°C per decade. During fall months, Sylhet recorded an average maximum temperature increase of 0.34°C per decade and it recorded a minimum temperature increase of 0.33°C per decade during winter months. Observed number of days >35°C on the Heat Index from 1971–2020 significantly increased 14.04 days per decade nationally.

Precipitation

Over the 50-year period of 1971–2020, Bangladesh experienced seasonally varied and significant decreases in precipitation per decade across the eastern divisions but significant increases per decade across the western divisions (see Figure 4). During the 1971–2020 climatology, the eastern divisions of Sylhet and Chittagong observed the largest total decreases in precipitation per decade (–67.26 mm and –47.74 mm, respectively), with the strongest effects during spring (pre-monsoon) months. The geographically central divisions of Dhaka and Mymensingh observed a significant but weaker decline in precipitation per decade, with the greatest drying during the summer (wet monsoon) months (–9.93 mm and –14.66 mm, respectively). Barisal (south) also observed a significantly drier pre-monsoon season, but a slightly positive annual trend due to the largest seasonal increase during fall months (+24.09 mm per decade). In contrast, the western divisions observed significant precipitation increases over the same time period, especially during fall (monsoon and post-monsoon) months. Rangpur (northwest) observed

FIGURE 4. Observed Precipitation Trend per Decade (1971–2020) Annually



Note significant decreases in eastern provinces and significant increases in western provinces.

the largest annual increase per decade (+52.04 mm), followed by Rajshahi (+29.47 mm) and Khulna (+27.79 mm). Overall, there were no significant observed changes for the largest 1-day and 5-day precipitation events, especially given the historical influence of interannual ENSO variability.

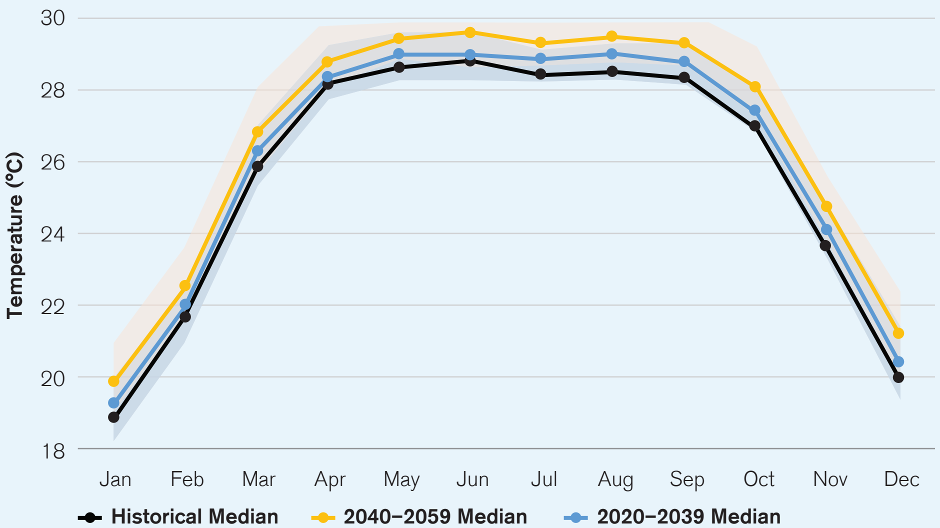
PROJECTED CLIMATE

Data Overview

Modeled climate data is derived from CMIP6, the Coupled Model Intercomparison Project, Phase 6. The CMIP efforts are overseen by the World Climate Research Program, which supports the coordination for the production of global and regional climate model compilations that advance scientific understanding of the multi-scale dynamic interactions between the natural and social systems affecting climate. CMIP6 is the foundational data used to present global climate change projections presented in the Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC). CMIP6 relies on the Shared Socioeconomic Pathways (SSPs), which represent possible societal development and policy scenarios for meeting designated radiative forcing (W/m^2) by the end of the century. Scenarios are used to represent the climate response to different plausible future societal development storylines and associated contrasting emission pathways to outline how future emissions and land use changes translate into responses in the climate system. Model-based, climate projection data is derived from the Coupled Model Inter-comparison Project-Phase 6 (CMIP6). CMIP is a standard framework for the analysis of coupled atmosphere-ocean general circulation models (GCMs) providing projections of future temperature and precipitation according to designated scenarios. CMIP6 projections are shown through five shared socio-economic pathway (SSP) scenarios defined by their total radiative forcing (a cumulative measure of GHG emissions from all sources) pathway and level by 2100. These represent possible future greenhouse gas concentration trajectories adopted by the IPCC.

The following assessment explores projected climate conditions and changes under multiple scenarios[19] for the near (the 2030s; 2020–2039) and medium term (2050s; 2040–2059) using data presented at a 0.25° × 0.25° (25 km × 25 km) resolution.[20] This risk profile focuses primarily on SSP3-7.0. Other SSPs are highlighted where appropriate given different trends and outlooks that should be noted. Projections for extreme precipitation events use data presented at a 1.00° × 1.00° (100 km × 100 km) resolution.[21]

FIGURE 5. Projected Climatology of Mean Temperature Countrywide for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



Areas shaded orange indicate 10th and 90th percentiles for 2040–2059, while areas shaded blue indicate 10th and 90th percentiles for 2020–2039. The projected climatology of mean temperature countrywide for each month (2040–2059 period) increases more than two times the projected climatology for 2020–2039 above the reference period.

[19] SSP3-7.0 represents a higher emissions scenario and is considered a more realistic worst-case scenario in which warming reaches ~3.5-4°C by 2100. When considering 'risk' it is most prudent to use higher scenarios in order to not dangerously under-estimate potential changes and risk conditions.

[20] World Bank Climate Change Knowledge Portal (2023). Bangladesh Climate Projections. URL: https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-projections

[21] World Bank Climate Change Knowledge Portal (2023). Bangladesh Extreme Events. URL: https://climateknowledgeportal.worldbank.org/country/bangladesh/extremes

Temperature

Under SSP3-7.0, Bangladesh's temperatures are projected to homogeneously increase further (see Figure 5). Mean temperature nationwide increases from the historical reference period of 1995–2014 to 26.03°C (25.26°C, 10th percentile, 26.65°C, 90th percentile) for the period 2020–2039, and to 26.59°C (25.78°C, 27.56°C) for the period 2040–2059. Minimum temperature nationwide increases from the historical reference period to 21.90°C (21.17°C, 22.56°C) for the 2020–2039 period, and 22.53°C (21.76°C, 23.49°C) for 2040–2059. Maximum temperature increases to 30.15°C (29.30°C, 30.81°C) for the 2020–2039 period, and 30.65°C (29.72°C, 31.65°C) for 2040–2059. However, projected maximum temperature changes under SSP2-4.5 and SSP1-2.6 are higher.[22] Under SSP3-7.0, the largest seasonal change occurs during winter months, when Sylhet's mean temperature increases 1.24°C from the reference period by midcentury, compared to 1.00°C in Khulna. Minimum and maximum temperatures increase with spatial and seasonal trends similar to projected mean temperatures, except slightly higher for the former and slightly lower for the latter.

Under future climate conditions, Bangladesh would be exposed to much higher heat risks nationally by midcentury, even considering regional and seasonal variations. The number of days surpassing the Heat Index >35°C increase countrywide annually according to the SSP3-7.0 scenario from the historical reference period (1995–2014) to 99.66 (55.70, 129.48) days annually over the 2020–2039 climatology and to 133.47 (85.88, 172.12) days annually over the 2040–2059 climatology. As **Table 3a** illustrates, higher atmospheric moisture content during the summer monsoon months and pre-monsoon spring months makes the number of days surpassing the Heat Index >35°C increase by a greater extent in southern divisions by 2040–2059. While Khulna possesses the highest annual number of high heat days during the reference period, the greatest annual and spring seasonal increase (nearly 100 days and nearly 50 days, respectively) is projected for Barisal in the western floodplains by midcentury. In the hillier northern and eastern provinces, the greatest seasonal increase occurs in Mymensingh over 2020–2039 (more than 30 days) but the greatest annual increase occurs in Chittagong in the southeast by midcentury (roughly 70 days). For an even higher threshold of projected days surpassing the Heat Index >41°C by midcentury, westernmost provinces are impacted most. Compared to minimal median days surpassing this threshold over the 2020–2039 period, the number of more extreme high heat days (Heat Index >41°C) increases from the reference period by roughly one month in the western provinces by midcentury – to 31.08 (10.33, 75.56) days in Khulna, 28.91 (6.90, 74.02) days in Rajshahi, and 20.60 (4.94, 65.06) days in Dhaka. An escalating trend of Warm Spell Duration Index (WSDI) over time, reaching roughly 200 warm spell days across the country by 2100, also illustrates a shift in long-term temperatures from the historical baseline.[23] Barisal and Chittagong in the south are projected to experience the highest WSDI values, increasing to 104.75 (46.83, 175.76) and 102.97 (46.26, 168.02) warm spell days annually, respectively. As a whole, these projected

[22] Under SSP1-2.6, minimum temperature nationwide increases to 22.46°C (21.93°C, 23.14°C) and under SSP2-4.5, increases to 22.54°C (21.91°C, 23.34°C) by 2040–2059, roughly the same as under SSP3-7.0 for the same time period. Under SSP1-2.6, maximum temperature increases nationwide to 30.86°C (30.21°C, 31.58°C), and under SSP2-4.5, increases to 30.83°C (30.00°C, 31.62°C) by 2040–2059.

[23] This value indicates the number days with consecutive daily maximum temperatures greater than the 90th percentile of daily maximum temperature calculated over a five-day window annually. Warm Spell Duration Index projections use 1.00° × 1.00° (100km × 100km) data resolution.

TABLE 3A. Projected Number of High Heat Index Days by Division for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

Division	2020–2039			2040–2059		
	Annual	Spring (MAM)	Summer (JJA)	Annual	Spring (MAM)	Summer (JJA)
High Heat Index Days (No. Days T-max >35°C)						
Barisal (south)	**128.79** (72.06, 160.18)	**63.84** (31.06, 75.00)	25.41 (12.64, 35.28)	**171.27** (116.16, 202.95)	**82.18** (54.98, 88.56)	39.38 (22.20, 50.99)
Khulna (southwest)	142.13 (88.55, 166.91)	73.60 (42.43, 82.29)	26.49 (13.84, 34.27)	173.94 (123.95, 200.37)	85.60 (61.86, 90.22)	38.25 (22.52, 48.42)
Rajshahi (northwest)	119.43 (70.05, 148.19)	71.99 (44.14, 81.76)	24.76 (13.20, 33.33)	146.78 (95.44, 181.40)	83.12 (54.76, 89.22)	34.70 (21.29, 47.02)
Dhaka (central north)	119.19 (68.11, 148.30)	67.23 (39.24, 77.26)	26.33 (14.30, 35.75)	151.64 (97.82, 186.63)	81.03 (54.49, 87.49)	37.82 (21.15, 49.28)
Rangpur (northwest)	91.95 (47.98, 122.33)	61.64 (34.40, 72.47)	18.68 (9.21, 29.25)	122.29 (82.72, 162.37)	76.43 (55.22, 84.77)	29.09 (18.63, 44.52)
Mymensingh (northeast)	**86.56** (44.59, 116.17)	**57.04** (30.77, 67.94)	19.59 (9.85, 29.46)	118.41 (71.49, 160.26)	**72.99** (45.68, 82.96)	30.56 (17.33, 45.26)
Sylhet (northeast)	68.65 (38.00, 95.71)	46.09 (25.57, 57.87)	17.63 (10.09, 26.69)	100.31 (62.47, 140.83)	62.87 (41.03, 75.42)	28.14 (16.85, 41.32)
Chittagong (southeast)	57.86 (26.54, 92.41)	29.33 (11.55, 43.29)	12.18 (5.95, 21.34)	**97.88** (52.50, 149.23)	47.53 (24.81, 65.23)	24.00 (12.37, 40.17)

10th percentile and 90th percentile values shown in parentheses. Largest anomalies (>50 days) from the reference period are shaded orange and the largest anomalies in each region are bolded. Note high Heat Index anomalies increase the most in southern divisions. See text for interpretation.

changes likely indicate the seasonal expansion of hot and humid conditions and raise the risk of heat waves and associated human health impacts.[24]

Daytime temperature increases coupled with high nighttime temperatures (i.e., tropical nights) exacerbate Bangladesh's potential for extreme heat risks, the combination of which disproportionately impacts western divisions. On nights temperatures do not go below 20°C, the human body reaches a biophysiological threshold where it cannot adequately cool down to achieve restorative sleep. Since Bangladesh maintains a relatively high historical number of nights with minimum temperatures above 20°C (a median of roughly eight months), it only increases to 253.48 (235.74, 268.64) nights annually by midcentury under SSP3-7.0. However, the number of tropical nights with a minimum temperature >26°C, an even higher threshold, illustrates a more widespread shift in future heat conditions. Compared to the historical reference period, such tropical nights increase the most in the northern and eastern divisions during summer months by midcentury (2040–2059). As illustrated in **Table 3b**, Sylhet is projected to experience the largest annual increase of 63.52 (38.85, 89.38) nights by 2040–2059, more than half of which occur during summer months. However, the projected change in Dhaka of 54.91 (29.47, 82.19) nights annually by midcentury exposes a large number of people to higher heat risks. The SSP3-7.0 scenario forecasts a roughly similar number of tropical nights >26°C by midcentury compared to the SSP1-2.6 and SSP2-4.5 scenarios, however the annual number increases much higher by the end of the century under SSP3-7.0 (see Annex).

[24] Im, E. S., Pal, J. S., and Eltahir, E. A. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Science advances, 3(8), e1603322. DOI: https://www.science.org/doi/10.1126/sciadv.1603322

TABLE 3B. Projected Tropical Night Anomalies by Division for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

Division	2020–2039				2040–2059			
	Annual	Spring (MAM)	Summer (JJA)	Fall (SON)	Annual	Spring (MAM)	Summer (JJA)	Fall (SON)
Tropical Nights (No. Nights T-min >26°C)								
Barisal (south)	**26.95** (7.24, 41.64)	7.89 (–1.03, 13.03)	8.35 (–1.85, 14.39)	10.93 (–0.05, 17.42)	47.60 (31.60, 66.50)	16.49 (8.92, 25.24)	12.27 (6.41, 17.55)	19.73 (9.11, 26.44)
Khulna (southwest)	25.08 (0.16, 40.07)	6.95 (–1.22, 12.98)	7.42 (–4.84, 15.07)	9.56 (–1.09, 17.63)	47.67 (27.57, 66.92)	15.65 (6.59, 24.78)	13.53 (2.63, 19.07)	19.69 (9.33, 27.66)
Rajshahi (northwest)	21.57 (–6.76, 38.07)	2.98 (–2.27, 12.68)	8.15 (–9.02, 20.57)	9.27 (0.15, 16.85)	48.48 (20.84, 73.21)	8.53 (2.74, 24.35)	18.91 (4.96, 27.43)	19.03 (9.14, 28.60)
Dhaka (central north)	26.56 (0.18, 47.14)	4.56 (–0.77, 11.08)	**11.11** (–7.91, 23.56)	10.19 (0.40, 20.01)	**54.91** (29.47, 82.19)	11.86 (4.62, 26.03)	**21.85** (9.80, 30.85)	21.31 (9.81, 30.25)
Rangpur (northwest)	28.91 (3.88, 48.94)	2.07 (–0.87, 8.08)	15.55 (–3.29, 30.51)	8.29 (2.74, 16.90)	58.90 (30.74, 83.63)	5.60 (1.28, 18.91)	33.26 (16.28, 42.27)	18.40 (9.49, 30.01)
Mymensingh (northeast)	**31.77** (4.83, 48.28)	1.55 (–0.39, 5.48)	17.56 (–4.46, 32.70)	8.69 (2.81, 19.04)	60.31 (32.13, 92.46)	4.49 (0.95, 15.77)	35.00 (17.71, 50.57)	20.10 (8.31, 30.93)
Sylhet (northeast)	29.54 (12.18, 50.05)	1.10 (0.06, 3.48)	**18.64** (2.99, 33.04)	9.18 (3.81, 17.47)	**63.52** (38.85, 89.38)	3.09 (0.60, 12.14)	**38.14** (21.68, 52.05)	20.88 (10.21, 29.00)
Chittagong (southeast)	26.90 (10.58, 52.43)	4.99 (0.71, 11.32)	13.41 (2.37, 28.76)	8.32 (3.24, 17.12)	62.07 (36.67, 97.71)	12.51 (5.71, 24.65)	30.43 (16.04, 46.98)	19.41 (10.13, 30.14)

10th percentile and 90th percentile values shown in parentheses. Largest anomalies (>50 days) are shaded orange and smallest relative anomalies from the reference period are shaded gray. The largest anomaly in each region is bolded. Note tropical nights increase most along the northern and eastern divisions, especially during summer months. See text for interpretation.

Precipitation

Projected precipitation patterns under SSP3-7.0 demonstrate regional and seasonal changes in intensity by midcentury but increases in both overall. At the national level, annual precipitation totals increase from the 1995–2014 reference period to 2,282.40 mm with relatively high uncertainty (1,863.53 mm, 2,841.22 mm) over 2040–2059 under SSP3-7.0. Southern divisions over this timeframe are projected to experience declines in annual precipitation, northern divisions are projected to experience the greatest increases in annual precipitation, while central Dhaka is not projected to change much in yearly volume. **Table 4** captures the distinct regional and monthly projected anomalies for 2020–2039 and 2040–2059 compared to the reference period.

SSP3-7.0 predicts that the three southern divisions will experience annual decreases in precipitation over 2020–2039, but not significantly over 2040–2059. The greatest annual precipitation decrease occurs in Barisal from the reference period to 2,052.18 mm (1,680.90 mm, 2,483.85 mm) over 2020–2039, with the largest monthly declines

TABLE 4. Projected Annual and Monthly Median Precipitation (mm) for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0

2020–2039													
Division	**Annual**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Bangladesh	2250.09 (1864.39, 2707.41)	8.51 (4.79, 12.85)	17.39 (10.71, 23.89)	51.29 (37.96, 71.46)	170.50 (132.98, 209.34)	303.02 (250.94, 376.43)	437.90 (358.82, 496.88)	426.67 (372.51, 502.85)	357.55 (320.64, 415.27)	289.62 (243.58, 350.29)	153.80 (117.50, 196.54)	30.02 (13.02, 43.84)	3.81 (0.94, 7.78)
Barisal	2052.18 (1680.90, 2483.85)	2.64 (1.22, 4.51)	14.36 (8.36, 20.19)	37.98 (24.96, 48.79)	120.70 (93.99, 142.97)	201.27 (167.06, 279.17)	388.94 (303.77, 421.42)	413.62 (373.22, 496.12)	354.22 (316.89, 427.10)	290.04 (235.10, 351.96)	**175.57** (135.30, 211.02)	47.83 (20.21, 69.30)	5.01 (0.82, 11.32)
Khulna	1779.82 (1455.86, 2155.74)	7.98 (4.38, 12.67)	16.13 (9.90, 23.72)	34.27 (23.47, 45.25)	105.81 (79.61, 125.67)	178.32 (145.45, 236.41)	319.07 (249.96, 361.84)	372.73 (327.28, 431.94)	319.42 (286.05, 369.94)	254.81 (208.80, 307.85)	137.29 (107.47, 184.14)	32.40 (13.31, 51.93)	1.59 (0.18, 4.39)
Rajshahi	**1838.81** (1501.27, 2240.64)	12.14 (6.85, 18.36)	18.52 (11.85, 24.24)	27.60 (20.02, 40.43)	112.60 (84.08, 134.47)	252.17 (206.22, 305.07)	356.64 (299.12, 412.85)	363.04 (307.45, 447.47)	299.41 (263.56, 350.07)	251.13 (203.03, 307.46)	127.14 (92.28, 168.71)	17.66 (6.77, 28.47)	0.76 (0.04, 3.02)
Dhaka	2053.69 (1684.22, 2466.07)	10.09 (5.33, 14.93)	18.59 (11.75, 25.51)	54.15 (39.57, 73.71)	180.02 (136.82, 223.56)	301.38 (252.13, 366.19)	382.24 (311.45, 424.29)	361.29 (321.88, 428.04)	310.76 (273.20, 360.60)	263.83 (214.72, 319.71)	144.47 (107.37, 187.52)	25.81 (9.84, 39.17)	1.06 (0.16, 2.84)
Rangpur	**2372.52** (1951.55, 2837.83)	12.88 (8.86, 19.19)	15.33 (8.18, 18.83)	25.95 (18.44, 37.63)	152.36 (123.34, 178.73)	367.12 (305.46, 428.06)	508.97 (416.36, 617.10)	463.63 (388.37, 547.52)	369.99 (328.68, 423.24)	311.80 (261.48, 369.78)	132.41 (88.50, 179.02)	10.97 (3.69, 15.75)	1.12 (0.19, 2.98)
Mymensingh	2647.88 (2202.78, 3197.34)	12.61 (6.84, 17.95)	16.37 (10.75, 22.92)	61.02 (48.28, 86.13)	252.75 (194.42, 307.62)	450.01 (377.07, 535.06)	**533.15** (446.12, 604.11)	458.20 (393.87, 569.36)	386.93 (344.52, 443.80)	309.78 (264.07, 378.88)	146.83 (108.72, 198.42)	18.22 (7.58, 28.42)	2.02 (0.53, 4.69)
Sylhet	3647.61 (3070.92, 4338.05)	10.74 (6.00, 14.73)	28.12 (19.28, 37.98)	149.49 (117.83, 206.86)	422.68 (337.47, 531.44)	601.97 (497.03, 720.73)	690.74 (581.94, 786.28)	616.43 (531.15, 716.26)	516.42 (475.33, 574.80)	389.56 (341.62, 459.79)	187.99 (149.51, 240.68)	27.85 (11.76, 37.04)	5.64 (1.99, 11.48)
Chittagong	2247.26 (1891.00, 2701.60)	3.23 (1.46, 5.58)	15.00 (8.64, 21.43)	50.15 (36.56, 72.35)	140.13 (111.26, 177.56)	250.64 (207.10, 334.76)	448.17 (368.14, 495.80)	441.76 (394.86, 503.11)	369.13 (335.60, 437.87)	293.87 (257.01, 359.54)	178.59 (144.52, 212.75)	46.87 (23.21, 64.03)	9.73 (2.65, 16.83)

(*continues*)

TABLE 4. Projected Annual and Monthly Median Precipitation (mm) for 2020–2039 and 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0 (*Continued*)

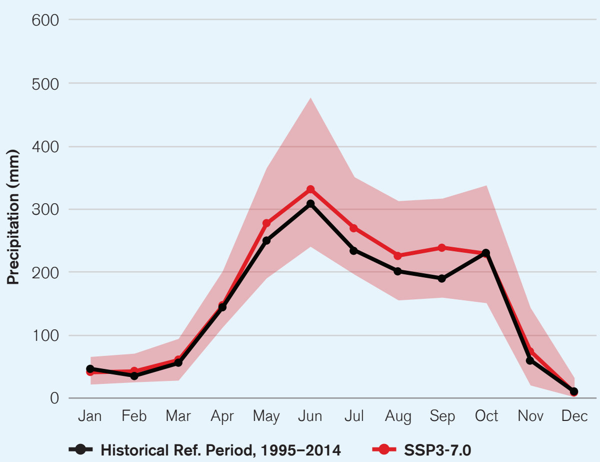
2040–2059													
Division	**Annual**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Bangladesh	2282.40 (1863.53, 2841.22)	8.10 (4.00, 13.90)	19.10 (11.34, 26.54)	54.83 (34.50, 75.48)	171.30 (140.89, 217.68)	308.35 (246.00, 399.24)	436.73 (350.95, 529.02)	427.67 (374.85, 529.49)	370.59 (319.50, 449.16)	298.11 (244.84, 351.30)	157.12 (121.19, 194.01)	28.13 (14.75, 46.91)	2.37 (0.73, 8.48)
Barisal	2081.33 (1668.28, 2629.92)	2.42 (0.97, 4.57)	15.19 (7.95, 20.04)	39.00 (23.28, 55.06)	120.22 (86.33, 169.54)	205.95 (161.05, 291.47)	381.54 (288.64, 475.88)	416.59 (361.39, 519.99)	**373.32** (328.01, 443.10)	304.08 (241.41, 355.45)	177.26 (142.15, 206.49)	43.38 (26.11, 74.52)	2.38 (0.98, 13.81)
Khulna	1812.95 (1435.91, 2306.12)	7.90 (3.44, 13.57)	18.07 (10.30, 26.39)	36.77 (20.08, 50.04)	99.95 (77.63, 141.87)	175.35 (134.99, 264.40)	328.43 (242.74, 406.41)	370.01 (315.66, 462.95)	336.65 (291.96, 399.52)	266.46 (212.53, 312.64)	143.34 (112.21, 176.49)	29.10 (14.15, 46.79)	0.92 (0.22, 5.02)
Rajshahi	**1872.11** (1512.97, 2425.89)	12.47 (5.64, 19.98)	20.38 (14.21, 28.92)	30.44 (17.79, 44.69)	113.80 (94.41, 137.49)	248.77 (199.72, 341.06)	367.12 (295.43, 447.80)	362.30 (311.65, 484.65)	307.58 (259.07, 396.18)	258.07 (214.36, 322.09)	134.60 (95.54, 170.71)	15.93 (5.13, 29.15)	0.65 (0.01, 3.18)
Dhaka	2058.90 (1677.97, 2591.62)	9.00 (3.92, 16.26)	20.19 (12.34, 27.94)	57.38 (33.90, 79.91)	176.28 (146.79, 219.53)	303.47 (242.61, 397.55)	376.56 (298.68, 462.76)	362.35 (311.45, 454.61)	314.81 (280.18, 392.45)	267.70 (223.71, 321.06)	145.86 (113.67, 175.94)	24.44 (10.65, 39.73)	0.86 (0.06, 3.88)
Rangpur	**2402.34** (1980.14, 2977.40)	12.98 (8.36, 20.34)	16.03 (9.97, 20.89)	28.35 (19.75, 39.02)	160.52 (133.22, 182.33)	365.46 (307.85, 460.79)	502.82 (445.10, 593.04)	**471.65** (406.28, 578.85)	382.41 (304.66, 486.95)	316.09 (249.81, 379.79)	134.92 (91.42, 194.60)	10.37 (3.61, 18.75)	0.77 (0.10, 2.07)
Mymensingh	2668.74 (2275.24, 3312.43)	11.75 (5.63, 20.25)	18.05 (11.12, 25.61)	68.39 (47.04, 91.68)	254.75 (224.11, 300.72)	457.60 (394.84, 568.68)	520.66 (447.60, 630.75)	456.60 (414.93, 594.39)	397.42 (337.71, 481.22)	312.29 (262.77, 368.11)	152.13 (122.83, 193.28)	17.25 (6.40, 33.27)	1.84 (0.26, 4.47)
Sylhet	3708.44 (3127.30, 4432.22)	9.25 (5.12, 17.22)	32.95 (18.12, 47.48)	165.18 (110.32, 205.26)	433.22 (377.17, 522.36)	614.24 (513.99, 743.95)	695.39 (582.57, 803.36)	603.03 (552.89, 723.45)	537.93 (465.91, 623.62)	399.47 (321.43, 453.03)	188.34 (163.68, 238.09)	24.87 (14.50, 43.97)	4.57 (1.60, 10.44)
Chittagong	2291.14 (1840.46, 2814.57)	2.86 (1.28, 5.50)	16.15 (8.98, 21.60)	50.39 (31.50, 76.60)	140.43 (107.47, 199.97)	268.98 (189.96, 335.66)	442.51 (337.65, 543.12)	448.42 (396.59, 527.53)	383.81 (339.24, 452.54)	305.90 (259.98, 351.41)	180.43 (137.70, 209.06)	45.83 (28.13, 72.70)	5.43 (1.99, 18.89)

10th percentile and 90th percentile values are shown in parentheses. Medians bolded in black indicate the greatest increases from the historical reference period per region. Medians bolded in red indicate negative anomalies from the reference period. Medians shaded orange indicate positive anomalies > 50 mm from the reference period. Medians shaded gray indicate minimal change from the reference period (anomalies <5 mm). Note little change nationally during the winter dry season and negative anomalies in southern divisions during the spring pre-monsoon season. See text for interpretation.

(median anomalies < –10 mm) during the pre-monsoon and early wet monsoon season. By comparison, northern divisions are expected to experience the greatest annual precipitation increases by midcentury. The largest increase from the reference period by midcentury is projected for Rangpur, with 2,402.34 mm (1,980.14 mm, 2,977.40 mm) annually and the largest monthly precipitation increase in July to 471.65 mm (406.28 mm, 578.85 mm). **Table 4** illustrates how the greatest precipitation increases by midcentury occur during the end of the wet monsoon season and extend into the pre-monsoon season for the wetter northern divisions. Meanwhile, the decreases in southern divisions during the pre-monsoon spring months over the 2020–2039 period become less extreme by midcentury. Dhaka is projected to experience minimal annual change over both 2020–2039 and 2040–2059. The largest monthly anomalies over 2020–2039 occur in Barisal during October, but shift to summer by 2040–2059 like those in the northern and eastern floodplains. While SSP3-7.0 predicts the driest annual precipitation nationally by midcentury compared to SSP1-2.6 and SSP2-4.5, it predicts the wettest annual precipitation by the end of the century (see Annex for more detail).

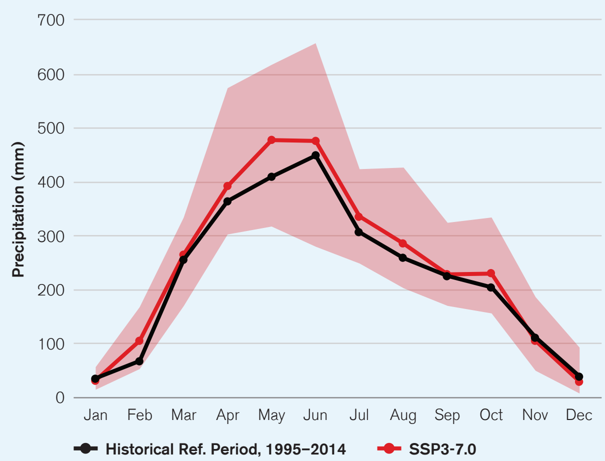
Bangladesh's future precipitation intensities, measured by average largest 5-day cumulative anomalies, vary by region and month but increase nationally by 24.96 mm (–97.20 mm, +143.48 mm) by midcentury compared to the 1995–2014 reference period and roughly correspond to trends in projected precipitation volume. Precipitation intensities increase 58.00 mm (–163.20 mm, 205.45 mm) in Sylhet (northeast, **see Figure 6b**) by midcentury, the most annually under SSP3-7.0. This trend likely reflects the orographic effect of the division's topography. Intensities change little from the historical reference period in the south, with Khulna and Dhaka projected to experience monthly anomalies >20 mm at the onset of the wet monsoon season. However, Rajshahi (northwest) is additionally projected to experience monthly anomalies >20 mm at the end of the winter dry season and the end of the wet monsoon season. The anomalous pattern is different for Rangpur (**see Figure 6a**), which is expected to experience monthly increases >20 mm throughout the entire wet monsoon season, and for Sylhet

FIGURE 6A. Rangpur's (Northwest) Projected Average Largest 5-Day Cumulative Precipitation Anomaly for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



Note an anomalous monthly increase in intensity >20 mm for May through September, with the largest increase in September.

FIGURE 6B. Sylhet's (Northeast) Projected Average Largest 5-Day Cumulative Precipitation Anomaly for 2040–2059 (Ref. Period 1995–2014) Under SSP3-7.0



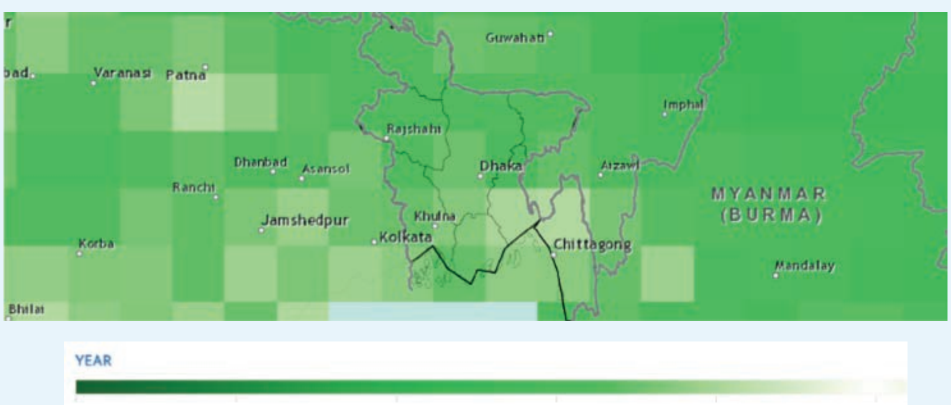
Note even larger anomalous monthly increases in intensity >20 mm for February, April through August, and October, with the largest increase in May. Also note higher x-axis range compared to Rangpur.

(**see Figure 6b**), which is expected to experience increases much larger at the end of the winter dry season, most of the pre-monsoon season, and nearly the entire wet monsoon season. Notably, while Rangpur's 10th to 90th percentile distribution exhibits a similar range of probability (239.61 mm to 476.65 mm during June and 149.97 mm to 337.08 mm during October), Sylhet displays much larger uncertainty during the pre-monsoon season and onset of the wet monsoon season (279.28 mm to 656.81 mm during June, compared to 155.44 mm to 333.41 mm during October). The effects of interannual ENSO cycles of extreme precipitation, both wet and dry, are discussed further in the section on climate-related hazards.

Extreme Precipitation Events

By midcentury, Bangladesh is likely to more frequently experience extreme precipitation event occurrence. For the projected period of 2035–2064, the largest 1-day precipitation amounts associated with 100-year historical return periods will be nearly two times more likely or more to occur in northern divisions (**see Figure 7b**). The greatest change in future return periods is projected for Rangpur (48.35 years), followed by Sylhet (51.30 years) and Rajshahi (54.08 years). The least change is projected for Chittagong and Khulna in the south (63.99 years and 62.70 years, respectively). However, the rate of change is lower for 25-year and 50-year events, and less than 1.5 times more likely for 10-year events nationwide except for the northernmost provinces. The projected future return periods for 10-year events shift the most for the same regions (6.45 years for Rangpur, 6.48 years for Sylhet, and 6.82 years for Rajshahi), with the future return periods for Chittagong and Khulna in the south changing the least (7.41 years and 7.28 years, respectively) by midcentury (**see Figure 7a**). SSP1-2.6 forecasts lower frequencies for 100-year return periods (a national average of only 1.51 times more likely, especially in the north), but SSP2-4.5 does not forecast extreme event frequencies at significantly different rates than SSP3-7.0 for 2035–2064. More frequently occurring extreme precipitation events underscore future health risks related to flood impacts, agricultural yields, disease ranges, and critical infrastructure, including for water, sanitation, and hygiene.

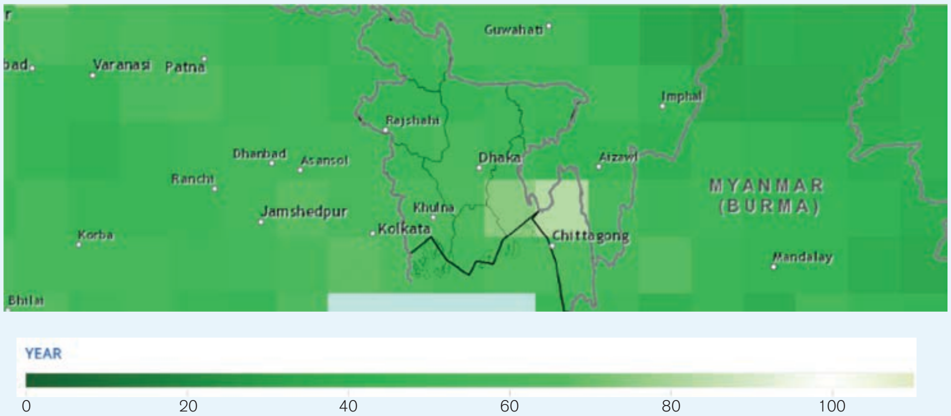
FIGURE 7A. Future Return Period of Largest 1-Day Precipitation, 10-Year Event Under SSP3-7.0 (2035–2064, Center 2050)



Note the greatest change in future return periods projected for northern divisions.[25]

[25] For extreme event projections at this resolution, data for the division of Mymensingh is combined with data for the division of Dhaka.

FIGURE 7B. Future Return Period of Largest 1-Day Precipitation, 100-Year Event Under SSP3-7.0 (2035–2064, Center 2050)



Note the greatest change in future return periods for the same divisions.

CLIMATE-RELATED NATURAL HAZARDS

Bangladesh has some of the highest risk levels in the world to climate-related hazards such as cyclones and floods (flash, riverine, and coastal flooding).[26] More than 90 million Bangladeshis (56% of the population) are estimated to live in "high climate exposure areas" affected by multiple hazards (**see Figures 8a–b**).[27] Projected sea level rise of 0.5 meters would nearly double exposed assets in coastal areas and contribute to millions of internal migrants by midcentury.[28] Tropical cyclones, which make landfall in Bangladesh once every two to three years and can trigger deadly storm surge and coastal flooding, result in average annual losses of roughly US$1 billion that disproportionately affect lower-income households in southern divisions.[29] One-third of agricultural GDP may be lost due to climate variability and extreme events by 2050, such as riparian flooding in central Bangladesh and drought in northwestern Bangladesh.[30] The frequency of intense floods and droughts associated

[26] European Commission (2023). INFORM Index for Risk Management. Bangladesh Country Profile. URL: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Risk-Profile

[27] USAID (2018). Fragility and Climate Risks in Bangladesh. URL: https://www.strausscenter.org/wp-content/uploads/Country-Brief-Fragility-and-Climate-Risks-in-Bangladesh-2018.pdf

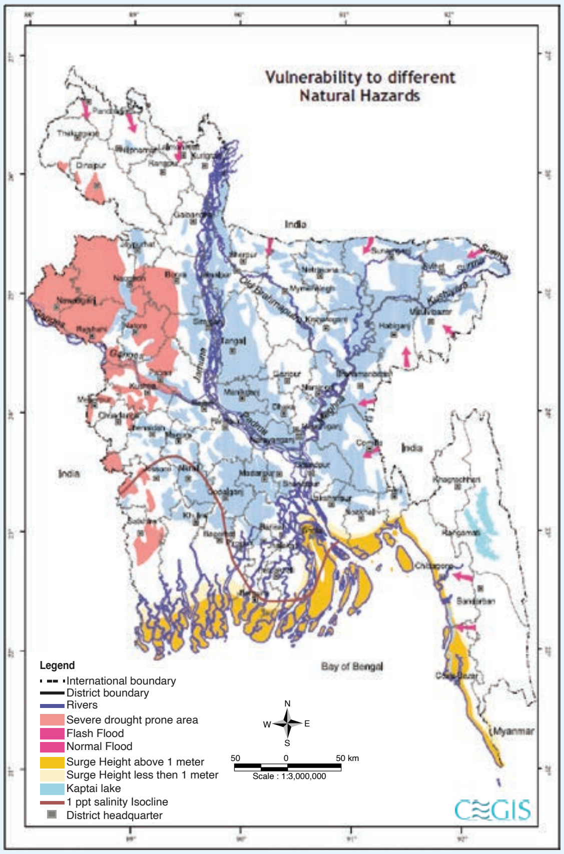
[28] Kazi, S., Urrutia, I., van Ledden, M., Laboyrie, J. H., Verschuur, J., Haque Khan, Z. U., Jongejan, R., Lendering,K., and Mancheño, A. G. (2022). Bangladesh: Enhancing Coastal Resilience in a Changing Climate. World Bank. URL: https://elibrary.worldbank.org/doi/abs/10.1596/38004; Rigaud, K. K., De Sherbinin, A., Jones, B., Bergmann, J., Clement, V., Ober, K., Schewe, J., Adamo, S., McCusker, B., Heuser, S., and Midgley, A. (2018). Groundswell: Preparing for internal climate migration. World Bank. URL: https://openknowledge.worldbank.org/entities/publication/2be91c76-d023-5809-9c94-d41b71c25635

[29] Alam, E., and Dominey-Howes, D. (2015). A new catalogue of tropical cyclones of the northern Bay of Bengal and the distribution and effects of selected landfalling events in Bangladesh. International Journal of Climatology, 35(6), 801–835. DOI: https://doi.org/10.1002/joc.4035; Ozaki, M. 2016. Disaster Risk Financing in Bangladesh. Asian Development Bank South Asia Working Paper Series No. 46. URL: https://www.adb.org/sites/default/files/publication/198561/sawp-046.pdf

[30] World Bank (2022). Country Climate and Development Report: Bangladesh. URL: https://openknowledge.worldbank.org/server/api/core/bitstreams/6d66e133-e49d-5ad9-b056-7b1a6c6206ed/content

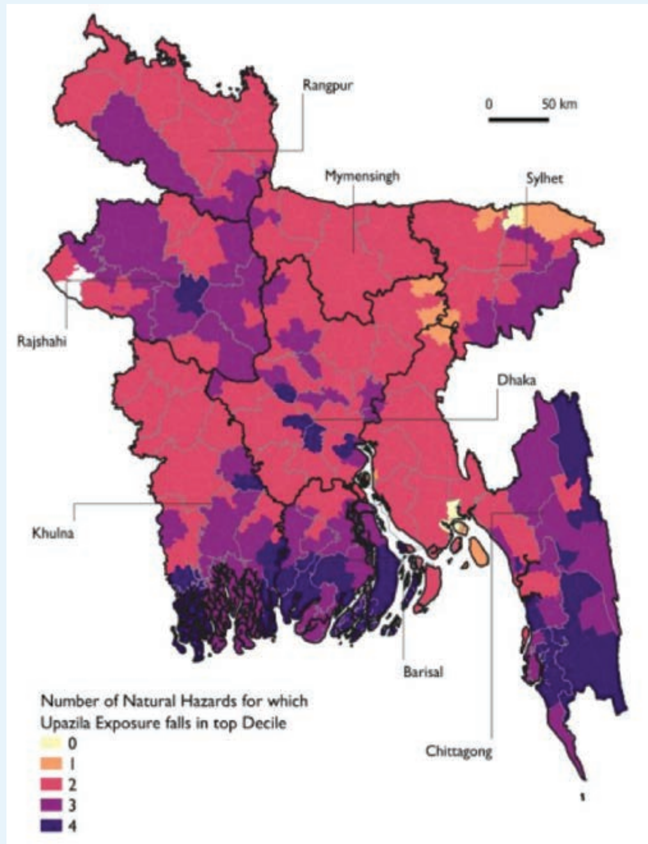
with ENSO and IOD will likely become more common in the future. By midcentury in total, climate impacts will likely cost Bangladesh an additional 2% of its GDP on top of baseline losses from climate-related hazards, potentially rising to 9% of GDP by the end of the century without further mitigation.[31] In addition to these hazards, seismic risks and landslides directly threaten the northern and eastern hill tracts. Past and future impacts associated with each of Bangladesh's notable hazards are discussed below.

FIGURE 8A. Bangladesh's Climate-Related Hazards[32]



See text for interpretation of spatial extent.

FIGURE 8B. Multi-Hazard Exposure of Bangladesh's *Upazilas* (Subdistricts)[33]



Hazards include river floods, coastal floods, tropical cyclones, drought, heat stress, landslides, and air pollution. Note highest exposure in eastern Chittagong, Barisal, southern Khulna, Rajshahi, and parts of Dhaka.

[31] Ahmed, M., and Suphachalasai, S. (2014). Assessing the costs of climate change and adaptation in South Asia. Asian Development Bank. URL: https://www.adb.org/publications/assessing-costs-climate-change-and-adaptation-south-asia

[32] Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

[33] World Bank (2022). Country Climate and Development Report: Bangladesh. URL: https://openknowledge.worldbank.org/server/api/core/bitstreams/6d66e133-e49d-5ad9-b056-7b1a6c6206ed/content

Sea Level Rise and Sea Surface Temperature

Bangladesh's observed sea surface temperatures have increased over the last few decades.[34] Sea surface temperature trends in the Bay of Bengal reflect numerous factors including oceanic and atmospheric circulations, precipitation patterns, coastal upwelling, river discharge, and ENSO and IOD over interannual timescales. Average monthly observed (1985–2009) sea surface temperatures form a bimodal seasonal distribution (two warm and cool seasons) in the northern Bay of Bengal. They range from a primary minimum of 22°C during winter months, a primary maximum of 30°C near the end of the pre-monsoon spring months, a secondary minimum of 27°C near the end of the summer months, and a secondary maximum of 30°C in October at the end of the wet monsoon season. Sea surface temperatures over this period rose by about 0.02°C per year, a faster rate than during previous decades with higher increases observed between 15°N-19°N latitude. This may contribute to more active or intense tropical cyclone activity in the future.

Sea level rise and coastal inundation will increasingly threaten Bangladesh's deltaic coastal zones, which house roughly one-third of the country's population.[35] In the Ganges tidal floodplain on the southwest coast (Point Hiron, Khulna Division), sea level rise is projected to increase 0.25 m (0.16 m, 0.35 m) by 2050 and 0.76 m (0.52 m, 1.05 m) by 2100 under SSP3-7.0 with a historical baseline of 1995–2014.[36] Sea level rise occurs at a much slower pace on the southeast coast; it increases along Cox's Bazaar (Chittagong) 0.16 m (0.08 m, 0.26 m) from the reference period by 2050 and 0.57 m (0.34 m, 0.86 m) by 2100. By contrast, in areas closer to the Meghna Floodplain along the central Bangladeshi coast (Khepupara, Barisal Division), sea level rise is projected to increase much more rapidly, 0.44 m (0.36 m, 0.54 m) from the reference period by 2050 and 1.17 m (0.94 m, 1.46 m) by 2100. This significant increase would not only result in a loss of shoreline, mangrove forests, and agriculture and fishery yields, but also lead to the displacement of nearly one million people by 2050 from southern divisions.[37]

Sea level rise along Bangladesh's coastlines exhibit discernible differences under different scenarios depending on the rate of local land subsidence.[38] Under SSP3-7.0, sea level rise is projected to increase 0.50 meters above the historical baseline along the southwest coast of Khulna (Hiron Point) after 2070 (**see Figure 9a**). However, this rate of change is slower under SSP2-4.5 and SSP1-2.6, as sea level rise does not reach this threshold until around 2090 and with higher relative uncertainty. Compared to SSP3-7.0 which rises 0.76 m (0.52 m, 1.05 m) by 2100, SSP2-4.5 rises 0.64 m (0.42 m, 0.91 m) while SSP1-2.6 rises 0.54 m (0.32 m, 0.80 m) over the same timeframe. Due to its location in the low-lying Sundarbans, vertical subsidence of 0.12 m (–0.02 m, 0.26 m) accounts for a portion of effective sea level rise across all scenarios by 2100.

By comparison, sea level rise is projected to increase 0.50 meters above the historical baseline the fastest along the southern coast of Barisal (Khepupara) around 2060 under all highlighted scenarios **(see Figure 9b)**. By 2100,

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[34] Chowdhury, S. R., Hossain, M. S., Shamsuddoha, M., and Khan, S. M. M. H. (2012). Coastal fishers' livelihood in peril: sea surface temperature and tropical cyclones in Bangladesh. Dhaka, Bangladesh: Center for Participatory Research and Development. URL: https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=5938c5e6f80d8810882cbc60adceda366df35d36

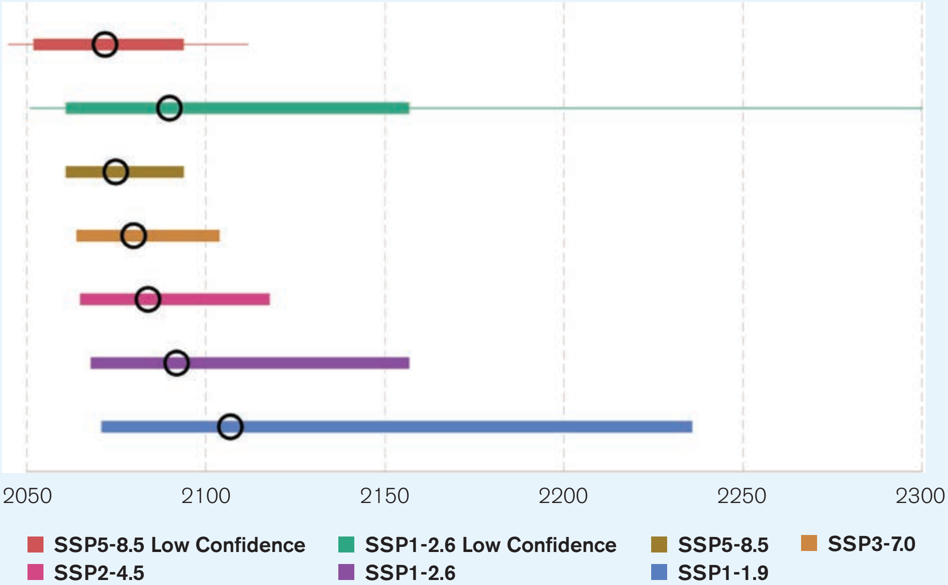
[35] Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

[36] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool; note the figures inside parentheses represent 17th and 83rd percentiles, respectively.

[37] Davis, K. F., Bhattachan, A., D'Odorico, P., and Suweis, S. (2018). A universal model for predicting human migration under climate change: examining future sea level rise in Bangladesh. Environmental Research Letters, 13(6), 064030. DOI: https://doi.org/10.1088/1748-9326/aac4d4

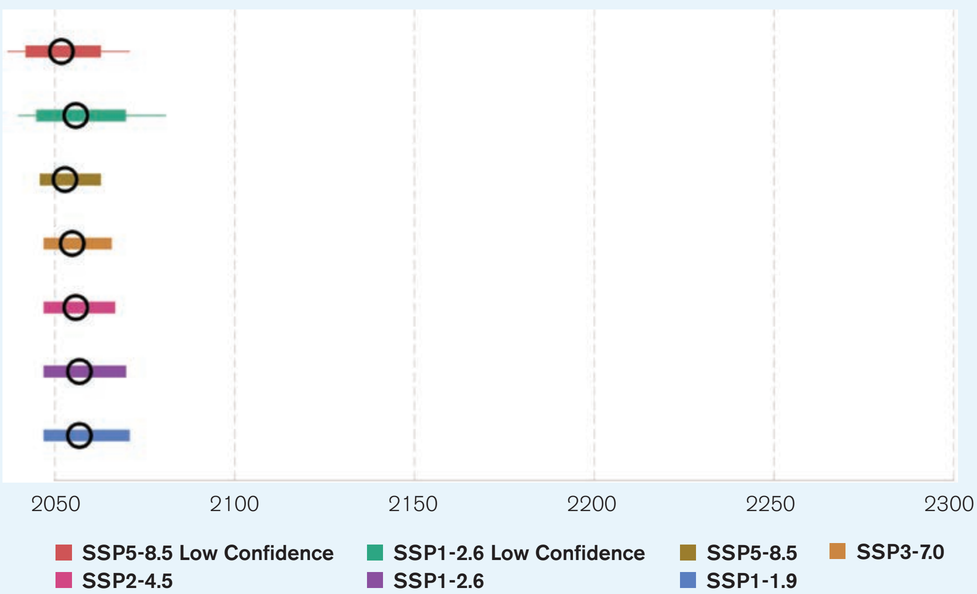
[38] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

FIGURE 9A. Projected Timing of 0.5-Meter Sea Level Rise Along Hiron Point's (Khulna's) Coast Under Various Scenarios (Ref. Period 1995–2014)[39]



Thick bars show 17th-83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios.

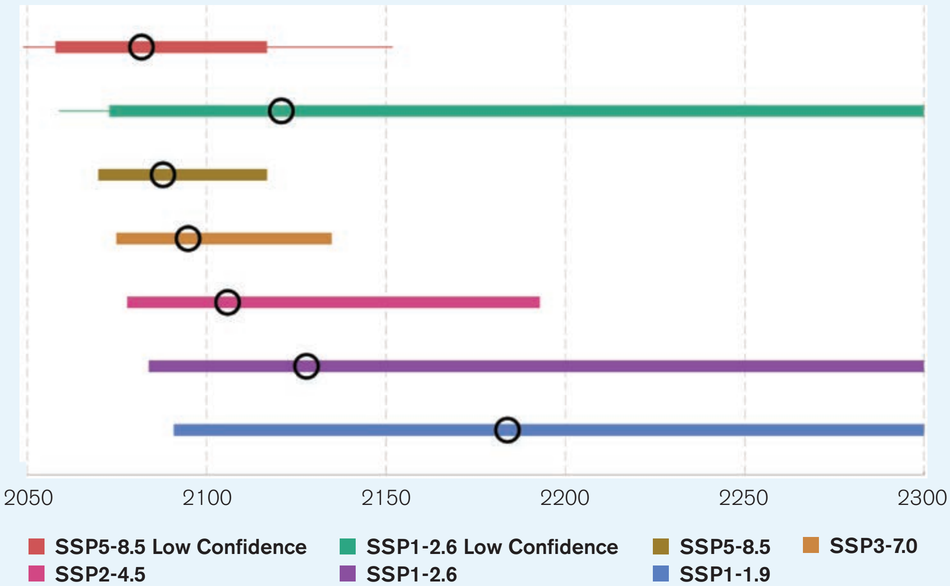
FIGURE 9B. Projected Timing of 0.5-Meter Sea Level Rise Along Khepupara's (Barisal's) Coast Under Various Scenarios (Ref. Period 1995–2014)[40]



Thick bars show 17th-83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios. Note the much lower ranges of uncertainties and earlier thresholds for all scenarios compared to Point Hiron (**Figure 9a**).

[39] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool
[40] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

FIGURE 9C. Projected Timing of 0.5-Meter Sea Level Rise Along Cox's Bazaar's (Chittagong's) Coast Under Various Scenarios (Ref. Period 1995–2014)[41]



Thick bars show 17th–83rd percentile ranges, and black circles show median value. Thin bars also show 5th–95th percentile ranges for SSP1-2.6 Low Confidence and SSP5-8.5 Low Confidence scenarios. Note the much higher ranges of uncertainties and later thresholds for all scenarios compared to Point Hiron (**Figure 9a**).

sea level rise is projected to increase 1.17 m (0.94 m, 1.46 m) under SSP3-7.0 and 0.96 m (0.74 m, 1.21 m) under SSP1-2.6, nearly double the rate under the same scenario for Hiron Point, Khulna. This larger increase is due to a high rate of land subsidence near the eastern edge of the Sundarbans, contributing to 0.53 m (0.39 m, 0.57 m) of effective sea level rise across all scenarios by 2100, or more than four times that of Hiron Point.

However, Cox's Bazaar (Chittagong, **see Figure 9c**) in the southeast is projected to experience a much slower rate of sea level rise, reaching the threshold of 0.50 meters above the historical baseline around 2090 (median) under SSP3-7.0. Under SSP2-4.5, sea level rise does not reach the 0.50 m threshold until around 2100 (median) and under SSP1-2.6, sea level rise does not reach this threshold until approximately 2130 (median). However, scenarios SSP2-4.5 and SSP1-2.6 possess higher ranges of uncertainty than at Point Hiron. Sea level in Cox's Bazaar increases 0.57 m (0.34 m, 0.86 m) by 2100 under SSP3-7.0, but 0.36 m (0.14 m, 0.62 m) under SSP1-2.6 over the same timeframe. Outside of the Greater Ganges-Brahmaputra Delta, Cox's Bazaar is projected to experience –0.07 m (-0.21 m, 0.07 m) in effective vertical land motion by 2100, which would carry important implications for future settlement along Bangladesh's coast.

Coastal flooding, saltwater intrusion, and storm surge pose major additional risks along the southern coast. As illustrated in **Figure 8a**, saltwater intrusion levels >1 ppt currently impact water resources, agriculture, fisheries, and local ecosystems throughout Khulna Division. The land area critically affected by saltwater intrusion (5–10 ppt)

[41] NASA (2023). Sea Level Projection Tool. URL: https://sealevel.nasa.gov/ipcc-ar6-sea-level-projection-tool

is projected to increase 68% by 2050, mostly in the southwest, which further threatens water supplies and livelihoods.[42] The aftermath of Cyclone Sidr in 2007 demonstrates how sea level rise also exacerbates storm surge from tropical cyclones. Sidr resulted in more than 5 m of storm surge – particularly along the southwest coast – causing more than 3,000 casualties and more than $1.7 billion in damages (3% of GDP), including hundreds of thousands of homes destroyed, severe losses to crops and livestock, and degradation to one-quarter of the Sundarbans mangrove forest.[43] Studies show tropical cyclone activity increased in the Bay of Bengal between 1981–2010 and that in the future, a single tropical cyclone with a 10-year return period and associated storm surge would produce more than $9 billion in losses and damages.[44] Put another way, a storm with the same strength and surge as Cyclone Sidr would produce an inundated area 53% larger by 2100.[45] The net impact of climate change in Bangladesh's coastal zone will ultimately be affected by planned adaptation activities in the region, including potential polder construction and enhancement, habitat restoration initiatives, and a potential coastal greenbelt, as outlined in the Bangladesh Delta Plan 2100.[46]

Flood and Drought Risk

Incidents of both flooding and drought in Bangladesh will likely occur with greater intensity and frequency in the future and are strongly influenced by ENSO. The country's main contributors to flooding include local and regional monsoon rainfall, water levels in the major rivers and tributaries, tidal and wind conditions in the Bay of Bengal, and human activities in the floodplains.[47] As illustrated in **Figure 8a**, flash flooding occurs along the northern and eastern borderlands while riparian flooding is concentrated along the Ganges, Brahmaputra, and Meghna Rivers that converge in Dhaka Division. Average flooding during the wet monsoon season results in inundation of up to 25% of the country's area, but inundation beyond this threshold occurred at least half a dozen times over the last six decades.[48] For example, a 100-year flood in 1998 inundated more than two-thirds of the country and left $2.2 billion in damages (4.5% of GDP) that disproportionately affected the agriculture, infrastructure, and health sectors. Major floods in 2004 and 2007 also resulted in $1.8 billion and $1.1 billion in damages, respectively.

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42 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

43 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

44 Balaguru, K., Taraphdar, S., Leung, L. R., and Foltz, G. R. (2014). Increase in the intensity of post-monsoon Bay of Bengal tropical cyclones. Geophysical Research Letters, 41(10), 3594–3601. DOI: https://doi.org/10.1002/2014GL060197; Bandyopadhyay, S., Dasgupta, S., Khan, Z., Wheeler, D. (2018). Cyclone storm landfalls in Bangladesh, West Bengal and Odisha, 1877–2016. World Bank Group. URL: http://documents.worldbank.org/curated/en/904751516818659880/pdf/WPS8316.pdf

45 Jisan, M. A., Bao, S., and Pietrafesa, L. J. (2018). Ensemble projection of the sea level rise impact on storm surge and inundation at the coast of Bangladesh. Natural Hazards and Earth System Sciences, 18(1), 351–364. DOI: https://doi.org/10.5194/nhess-18-351-2018

46 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

47 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

48 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

Paltan et al. (2018) demonstrate that even under lower emissions pathways, nearly all Asian countries face an increase in the frequency of extreme river flows.[49] Under a 2°C warming scenario (1986–2005 baseline), Mohammed et al. (2018) estimate a 29%, 24%, and 38% increase in the magnitude of a 1-in-100-year flow event along the Ganges, Brahmaputra, and Meghna Rivers, respectively.[50] Additionally, all three rivers will possess a greater likelihood of reaching peak flood stages simultaneously. By 2035–2044, researchers calculate a potential increase of 6–12 million people affected by extreme floods, or a 40% increase in population exposed to river flooding by midcentury.[51] Multiple factors lead to such changes, including climate change-driven melting of Himalayan glaciers and increased precipitation intensities in upstream regions of these watersheds. However, projected changes could also be subject to future economic development trajectories. Increases in extreme river flows are likely to place pressure on Bangladesh's flood defense system that without adaptation action are expected to increase the risk of extreme fluvial flood events and disproportionately impact informal urban developments. If flood levels from 2004 repeated in Dhaka under the influence of future climate change by the 2050s, damages would rise $23 million assuming present-day infrastructure and economic values.[52]

The national government estimates droughts of different intensities affect three to four million hectares of arable land each year.[53] Agricultural droughts, influenced by precipitation deficits or hydrological deficits, typically occur during the pre-monsoon season in the northwest (Rangpur, Rajshahi) and pose ongoing threats to food security. For example, a drought in 1997 produced $500 million in crop losses. However, over the period of 1979–2018, wet monsoon and post-monsoon season droughts increased in frequency and intensity in the northwest according to the Effective Drought Index (EDI), especially during the 2010s.[54] For instance, Bangladesh experienced a monsoon season with 19% less precipitation than average in 2010.[55] The World Bank calculates the probability of agricultural drought will remain elevated over the 2041–2060 period compared to its 1995–2014 baseline.[56] Western divisions (Rangpur, Rajshahi, Khulna) with a historically large number of consecutive dry days each year will also experience more short-term dry episodes under higher emission scenarios. The potential relationship between ENSO and hydrological deficits in the Ganges River basin and between IOD and precipitation deficits (see earlier overview of Bangladesh's climate) prompt particular attention for agriculture, water resources, and health sectors in particular.

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49 Paltan, H., Allen, M., Haustein, K., Fuldauer, L., and Dadson, S. (2018). Global implications of 1.5 C and 2 C warmer worlds on extreme river flows. Environmental Research Letters, 13(9), 094003. DOI: https://doi.org/10.1088/1748-9326/aad985

50 Mohammed, K., Islam, A. K. M. S., Islam, G. M. T., Alfieri, L., Khan, M. J. U., Bala, S. K., and Das, M. K. (2018). Future Floods in Bangladesh under 1.5°C, 2°C, and 4°C Global Warming Scenarios. Journal of Hydrologic Engineering, 23(12), 04018050. DOI: https://doi.org/10.1061/(ASCE)HE.1943-5584.0001705

51 Willner, S., Levermann, A., Zhao, F., Frieler, K. (2018). Adaptation required to preserve future high-end river flood risk at present levels. Science Advances: 4:1. URL: https://advances.sciencemag.org/content/4/1/eaao1914; Winsemius, H. C., Jongman, B., Veldkamp, T. I., Hallegatte, S., Bangalore, M., and Ward, P. J. (2018). Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts. Environment and Development Economics, 23(3), 328–348. DOI: https://doi.org/10.1017/S1355770X17000444

52 Dasgupta, S., Zaman, A., Roy, S., Huq, M., Jahan, S., and Nishat, A. (2015). Urban Flooding of Greater Dhaka in a Changing Climate: Building local resilience to disaster risk. World Bank Publications. URL: http://documents.worldbank.org/curated/en/683381468001782892/pdf/100228-PUB-REVISED-Box393232B-PUBLIC-PUBDATE-10-26-15-DOI-10-15969781464807107-EPI-1464807108.pdf

53 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

54 Mondol, M. A. H., Zhu, X., Dunkerley, D., and Henley, B. J. (2021). Observed meteorological drought trends in Bangladesh identified with the Effective Drought Index (EDI). Agricultural Water Management, 255, 107001. DOI: https://doi.org/10.1016/j.agwat.2021.107001

55 Ministry of Environment, Forest, and Climate Change (2018). Third National Climate Change Communication. URL: https://unfccc.int/sites/default/files/resource/TNC%20Report%20%28Low%20Resolation%29%2003_01_2019.pdf

56 World Bank (2022). Country Climate and Development Report: Bangladesh. URL: https://openknowledge.worldbank.org/server/api/core/bitstreams/6d66e133-e49d-5ad9-b056-7b1a6c6206ed/content

Earthquake and Landslide Hazards

Climate variability exacerbates medium-level seismic risks across Bangladesh, including the eastern divisions and dense urban areas. Bangladesh is situated on the eastern end of the Indian Plate, which moves in a northeast direction and subducts beneath the Eurasian Plate to the north and the Burmese Plate to the east (**see Figures 10a–b**). As pictured in **Figure 10a**, these collisions form the Himalayan Arc north of Rangpur Division, the Shillong Plateau north of Mymensingh and Sylhet Divisions along the Dauki Fault (300 km long), and the Burma Arc to the east from the faults along eastern Sylhet (300 km long) through Chittagong Division (800 km long). Additionally, the 150 km Madhupur Fault runs between the Madhupur Tract and the Brahmaputra (Jamuna) Floodplain close to the capital Dhaka. Seismic records (**see Figure 10b**) document the greatest frequency of major earthquakes along the eastern border, particularly where the Dauki Fault and Sylhet-Assam Fault meet. The Global Earthquake Model (GEM) Foundation identifies the greatest potential for seismic movement – peak ground acceleration > 0.35 g with a 10% probability of being exceeded in 50 years – in the interior border areas of Mymensingh, Sylhet, and Chittagong.[57] However, the highest annual average earthquake losses occur in Dhaka and Chittagong (>US$150 million each). All coastal divisions possess a medium risk (>10% probability) of experiencing a potentially damaging tsunami in the next 50 years according to WBG's Global Facility for Disaster Risk Reduction (GFDRR).[58] The 6.1 magnitude Bandarban earthquake in 1997, which resulted in more than twenty casualties, and the 5.7 magnitude Rangamati earthquake in 2003, which damaged hundreds of buildings, were notable seismic events inside Bangladesh.[59] However, many stronger earthquakes occur along fault boundaries outside of its borders with implications for the country, such as the 6.8 magnitude Sikkim earthquake in 2011 north of Rangpur. Scholars note that the rapidly growing capital with large amounts of substandard buildings has not experienced a direct hit from a major earthquake for at least a century but remains vulnerable without mitigation measures. When it comes to assessing landslide hazard risk, the hill regions in the northeast (Sylhet) and southeast (Chittagong) possess high levels of risk but heavy precipitation episodes, not seismic activity, act as the primary trigger.[60] For example, between 2000–2018, more than 200 landslides resulted in 727 casualties, principally driven by heavy rain over a short duration of the wet monsoon season in the southeast.

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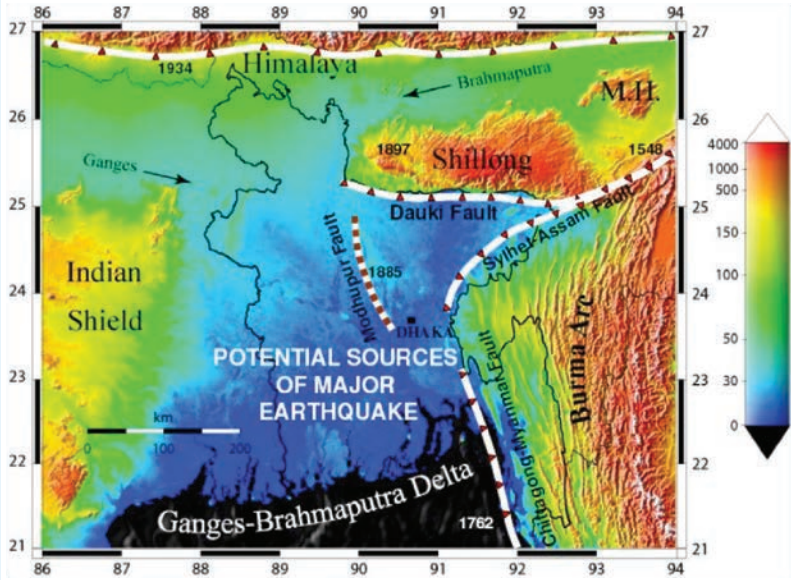
57 Global Earthquake Model Foundation (2019). Bangladesh. URL: https://downloads.openquake.org/countryprofiles/BGD.pdf

58 Global Facility for Disaster Risk Reduction (2020). Bangladesh. URL: https://thinkhazard.org/en/report/23-bangladesh

59 Akhter, S. H. (2010). Earthquakes of Dhaka. Environment of Capital Dhaka—Plants wildlife gardens parks air water and earthquake. Asiatic Society of Bangladesh, 401–426.URL: https://www.academia.edu/429823/Earthquakes_of_Dhaka

60 Sultana, N. (2020). Analysis of landslide-induced fatalities and injuries in Bangladesh: 2000–2018. Cogent Social Sciences, 6(1), 1737402. DOI: https://doi.org/10.1080/23311886.2020.1737402

FIGURE 10A. Bangladesh's Major Seismic Features[61]



Note the fault boundaries along the country's northern and eastern borders.

FIGURE 10B. Recorded Earthquakes (>5.0 Magnitude) in and Near Bangladesh Since 1900 According to USGS[62]

Note the high frequency of major earthquakes along the eastern boundaries of the country.

KEY NATIONAL DOCUMENTS

- Country Climate and Development Report (CCDR) (2022)
- Updated Nationally Determined Contribution (2021)
- First Nationally Determined Contribution (NDC Interim Update) (2020)
- Third National Communication to the UNFCCC (NC3) (2018)
- Climate-Smart Agriculture Profile (2017)
- Intended Nationally Determined Contribution (INDC) (2015)
- Climate Change and Gender Action Plan (CCGAP) (2013)
- Second National Communication to the UNFCCC (2012)
- National Adaptation Programme of Action (NAPA) (2009)
- Climate Change Strategy and Action Plan (BCCSAP) (2009)
- Initial National Communication to the UNFCCC (2002)

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[61] Akhter, S. H. (2010). Earthquakes of Dhaka. Environment of Capital Dhaka—Plants wildlife gardens parks air water and earthquake. Asiatic Society of Bangladesh, 401–426.URL: https://www.academia.edu/429823/Earthquakes_of_Dhaka

[62] Apu, N., and Das, U. (2021). Tectonics and earthquake potential of Bangladesh: a review. International journal of disaster resilience in the built environment, 12(3), 295–307. DOI: https://doi.org/10.1108/IJDRBE-06-2020-0060

ANNEX OF PROJECTED CLIMATE SCENARIOS

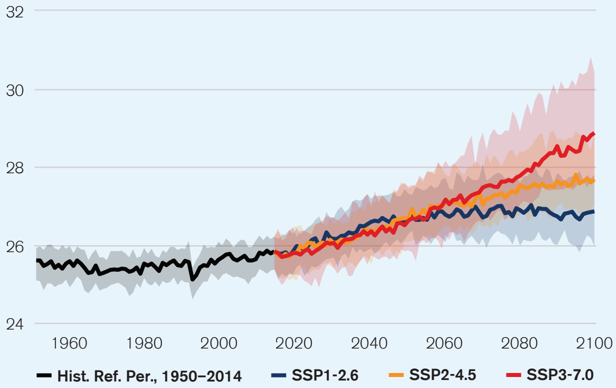
Compared to SSP3-7.0, which results in the greatest temperature and precipitation shifts nationally across all key metrics by the end of the century (see Table 5), SSP1-2.6 and SSP2-4.5 demonstrate Bangladesh's lower overall rates of change and severity of climate impacts as a result of carbon emission reductions. The differences between projected temperatures under the three scenarios are particularly pronounced (**see Figure 11a**). SSP1-2.6 has the lowest annual mean temperature increase – an anomaly close to 1°C by 2080–2099. Mean temperature rises by an anomaly of nearly 2°C by end-of-century under SSP2-4.5 and greater than 2.5°C by end-of-century under SSP3-7.0 by comparison. The number of tropical nights (T-min >26°C)

TABLE 5. Key National-Level Projected Anomalies Through End-of-Century (Ref. Period 1995–2014) Under SSP1-2.6, SSP2-4.5, and SSP3-7.0 Scenarios

Metric	SSP1-2.6 Projection		
	2020–2039	2040–2059	2080–2099
Annual Mean Temperature	0.53°C (0.16°C, 0.86°C)	1.08°C (0.62°C, 1.45°C)	1.15°C (0.63°C, 1.93°C)
Tropical Nights (No. Nights T-min >26°C) Annually	32.16 (8.89, 48.07)	53.09 (27.63, 74.21)	58.65 (20.48, 86.12)
Annual Precipitation (mm)	68.30 (–111.55, 250.21)	**134.54** (–98.88, 372.99)	**161.93** (–49.12, 351.83)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	8.07 (–84.26, 105.28)	21.36 (–78.45, 110.80)	24.78 (–76.62, 128.46)
Metric	**SSP2-4.5 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.43°C (–0.02°C, 0.76°C)	1.04°C (0.59°C, 1.67°C)	1.99°C (1.30°C, 2.82°C)
Tropical Nights (No. Nights T-min >26°C) Annually	25.58 (5.10, 47.99)	57.36 (27.72, 79.04)	**87.11** (61.61, 112.50)
Annual Precipitation (mm)	50.57 (–153.10, 297.48)	39.12 (–125.65, 382.38)	**159.81** (–98.40, 371.72)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	21.46 (–83.89, 117.77)	25.38 (–89.54, 131.14)	28.60 (–91.33, 125.97)
Metric	**SSP3-7.0 Projection**		
	2020–2039	**2040–2059**	**2080–2099**
Annual Mean Temperature	0.41°C (–0.19°C, 0.76°C)	0.89°C (0.45°C, 1.70°C)	**2.69°C** (1.93°C, 4.13°C)
Tropical Nights (No. Nights T-min >26°C) Annually	26.73 (3.97, 46.22)	55.66 (31.01, 82.58)	**108.92** (79.75, 138.93)
Annual Precipitation (mm)	12.97 (–180.74, 268.33)	37.29 (–167.27, 409.39)	**173.68** (–60.45, 729.46)
Average Largest 5-Day Cumulative Precipitation (mm) Annually	13.15 (–100.86, 124.80)	24.96 (–97.20, 143.48)	**56.63** (–73.77, 199.99)

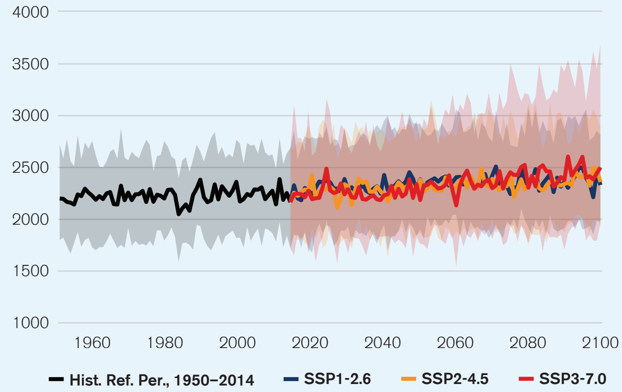
10th percentile and 90th percentile values are shown in parentheses. Key values or shifts over time are shaded orange and bolded. See text for interpretation.

FIGURE 11A. Projected Average Mean Temperature in Degrees Celsius Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note clearly higher increase of SSP3-7.0 starting midcentury.

FIGURE 11B. Projected Precipitation in Millimeters Nationwide (Ref. Period 1995–2014) Under Various Scenarios



Shaded areas indicate ranges of 10th–90th percentiles. Note the greatest uncertainty under SSP3-7.0 compared to SSP1-2.6 and SSP2-4.5 but similar medians for all scenarios by the end of the century. Probability ranges for all scenarios extend above and below the historical reference period, indicating a potential likelihood for precipitation decreases or increases.

experienced nationally by the end of the century under SSP1-2.6 (an increase of roughly two months above the reference period annually) contrasts projections of the other two scenarios. SSP2-4.5 projects an increase in number of tropical nights of roughly three months above the historical reference annually by the end of the century, while SSP3-7.0 projects the greatest increase of more than three months annually for this metric over the same time period. Most of the change in tropical nights is concentrated in the northern and eastern floodplains by the end of the century. The anomalous annual number of high Heat Index days above the reference period for 2080–2099 likewise increases the most under SSP3-7.0 nationally by roughly four months. By comparison, SSP2-4.5 projects an increase of roughly one month less and SSP1-2.6 projects an increase of about two months less.

The projected precipitation patterns countrywide under the three scenarios produce little differences by the end of the century but noticeable variation in the near-term and medium-term (**see Figure 11b**). Whereas the annual precipitation forecasted by SSP1-2.6 rises steadily across the century, precipitation under SSP2-4.5 and SSP3-7.0 rises dramatically (>100 mm) from midcentury to the end of the century. Bangladesh is expected to experience a slightly larger anomaly of annual precipitation of 173.68 mm (–60.45 mm, 729.46 mm) from the reference period under SSP3-7.0 by the end of the century. However, SSP3-7.0 displays the largest range of uncertainty (>700 m) while SSP2-4.5 possesses the greatest potential for experiencing negative anomalies by the end of the century. Precipitation intensity, as measured by the average largest 5-day cumulative precipitation annually, increases the most from the reference period by the end of the century (>50 mm) under SSP3-7.0. By contrast, SSP2-4.5 projects the highest increase for the 2020–2039 but remains relatively constant until the end of the century. The divisions closest to the northern hills experience the greatest increases in intensity under SSP2-4.5 and SSP3-7.0 by the end of the century.

CLIMATE RISK COUNTRY PROFILE

BANGLADESH

WORLD BANK GROUP