CLIMATE RISK COUNTRY PROFILE

CAMBODIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

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ACKNOWLEDGEMENTS

This profile is part of a series of Climate Risk Country Profiles that are jointly developed by the World Bank Group (WBG) and the Asian Development Bank (ADB). These profiles synthesize the most relevant data and information on climate change, disaster risk reduction, and adaptation actions and policies at the country level. The profile is designed as a quick reference source for development practitioners to better integrate climate resilience in development planning and policy making. This effort is co-led by Veronique Morin (Senior Climate Change Specialist, WBG), Ana E. Bucher (Senior Climate Change Specialist, WBG) and Arghya Sinha Roy (Senior Climate Change Specialist, ADB).

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Climate and climate-related information is largely drawn from the Climate Change Knowledge Portal (CCKP), a WBG online platform with available global climate data and analysis based on the latest Intergovernmental Panel on Climate Change (IPCC) reports and datasets. The team is grateful for all comments and suggestions received from the sector, regional, and country development specialists, as well as climate research scientists and institutions for their advice and guidance on use of climate related datasets.

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FOREWORD

Climate change is a major risk to good development outcomes, and the World Bank Group is committed to playing an important role in helping countries integrate climate action into their core development agendas. The World Bank Group (WBG) and the Asian Development Bank (ADB) are committed to supporting client countries to invest in and build a low-carbon, climate-resilient future, helping them to be better prepared to adapt to current and future climate impacts.

Both institutions are investing in incorporating and systematically managing climate risks in development operations through their individual corporate commitments.

For the World Bank Group: a key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy planning, investment design, implementation and evaluation of development outcomes. For all International Development Association and International Bank for Reconstruction and Development operations, climate and disaster risk screening is one of the mandatory corporate climate commitments. This is supported by the World Bank Group's Climate and Disaster Risk Screening Tool which enables all Bank staff to assess short- and long-term climate and disaster risks in operations and national or sectoral planning processes. This screening tool draws up-to-date and relevant information from the World Bank's Climate Change Knowledge Portal, a comprehensive online 'one-stop shop' for global, regional, and country data related to climate change and development.

For the Asian Development Bank (ADB): its Strategy 2030 identified "tackling climate change, building climate and disaster resilience, and enhancing environmental sustainability" as one of its seven operational priorities. Its Climate Change Operational Framework 2017–2030 identified mainstreaming climate considerations into corporate strategies and policies, sector and thematic operational plans, country programming, and project design, implementation, monitoring, and evaluation of climate change considerations as the foremost institutional measure to deliver its commitments under Strategy 2030. ADB's climate risk management framework requires all projects to undergo climate risk screening at the concept stage and full climate risk and adaptation assessments for projects with medium to high risk.

Recognizing the value of consistent, easy-to-use technical resources for our common client countries as well as to support respective internal climate risk assessment and adaptation planning processes, the World Bank Group's Climate Change Group and ADB's Sustainable Development and Climate Change Department have worked together to develop this content. Standardizing and pooling expertise facilitates each institution in conducting initial assessments of climate risks and opportunities across sectors within a country, within institutional portfolios across regions, and acts as a global resource for development practitioners.

For common client countries, these profiles are intended to serve as public goods to facilitate upstream country diagnostics, policy dialogue, and strategic planning by providing comprehensive overviews of trends and projected changes in key climate parameters, sector-specific implications, relevant policies and programs, adaptation priorities and opportunities for further actions.

We hope that this combined effort from our institutions will spur deepening of long-term risk management in our client countries and support further cooperation at the operational level.

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KEY MESSAGES

- Cambodia is projected to experience warming of 3.1°C by the 2090s, against the baseline conditions over 1986–2005 under the highest emissions pathway, RCP8.5.
- Increases in annual maximum and minimum temperatures are expected to be larger than the rise in average temperature, increasing pressures on human health, livelihoods, and ecosystems.
- Increased incidence of extreme heat represents a major threat to human health in Cambodia, especially for outdoor laborers and urban populations for whom heat rises are compounded by the urban heat island effect.
- Climate change may also increase the likelihood of transmission of water and vector-borne diseases, but this is an area requiring further research.
- Without action, the population exposed to an extreme river flood could grow by around 4 million by the 2040s, however human development factors such as the damming of the Mekong River as well as the large-scale dams built on its tributaries, may alter future flood dynamics.
- Climate change and human influences, such as upstream dam construction and deforestation, over the Mekong River's hydrological regime threaten to reduce the productivity of the Tonle Sap Lake and Cambodia's fisheries – a significant threat to the livelihoods and nourishment of many poor, rural communities.
- Projected climate change trends indicate more severe floods and droughts, which is expected to affect Cambodia's GDP by nearly 10% by 2050
- Significant adaptation efforts are required to manage loss of yields due to the projected increases in the incidence of extreme heat during the growing season of staple crops such as rice, particularly for poorer communities operating at subsistence level and reliant upon rain-fed agriculture.
- The impacts outlined above may significantly exacerbate existing issues of wealth and income inequality and will hinder poverty alleviation efforts.

COUNTRY OVERVIEW

Cambodia is part of Southeast Asia, bordered by Laos, Thailand, and Vietnam and with a coastal region on the Gulf of Thailand. The Mekong River is a prominent geographical feature of the country, flowing from Laos in the north to the Mekong Delta of Vietnam in the south; feeding into the Tonle Sap Lake. The Tonle Sap is a vital natural resource, covering almost 10% of the nation's surface area during the peak of the Southwest Monsoon season and constituting the nation's primary protein source. Cambodia's topography includes the low-lying central plains of the Mekong, which are surrounded by mountainous and highland regions.

The population of Cambodia is approximately 16.5 million people (2019). While 76% of the population currently lives in rural areas, Cambodia is experiencing a rapid rate of urbanization. Cambodia's population relies heavily on agriculture and fisheries, providing 25% of GDP and employing 49% of the country's labor force. Industry and services form rapidly growing sectors of the economy. Cambodia faces high disaster risks from flood and drought, due both to high levels of exposure and vulnerability.[1] The rate of undernourishment in Cambodia remains high, at around 15%, as does the national poverty rate (**Table 1**).[2] Natural resource dependence is also high, and the changes in the dynamics of the Mekong River, expected due to the largescale damming on the Mekong River and its tributaries, which is ongoing in most of the Mekong countries, may have negative ramifications for precarious livelihoods in Cambodia.[3]

The Royal Government of Cambodia launched the first Climate Change Strategic Plan – 2014–2023 (CCCSP) in 2013. The CCCSP captures the main strategic objectives and directions for climate-smart development in Cambodia over the next 10 years. Cambodia submitted its Initial Nationally Determined Contribution in 2016 and submitted its Updated Nationally Determined Contribution in December, 2020, which established the country's commitment to its mitigation and adaptation efforts. These documents build synergies with existing government policies to ensure strategic cohesion to address a wide range of climate change issues linked to adaptation, greenhouse gas mitigation, and low-carbon development.

Cambodia's Second National Communication to the UNFCCC (NC2) (2016) identifies the impacts of climate change in Cambodia upon human lives and the expected significant damage to economic development and natural resources. These include intensified floods, droughts, saline intrusion and extreme weather events. Cambodia remains highly vulnerable to the impacts of climate change due to its high dependency on climate-sensitive sectors such as agriculture, water resources, forestry, fisheries, tourism, etc., which form the critical foundation of its economic growth and support the livelihoods of a significant majority of its population.[4] The country is also committed to meeting its greenhouse gas emission targets and ensuring appropriate mitigation and environmental management efforts across key sectors. Current emissions projections indicate that the Forestry and Land Use sector is expected to have 49.2% of sectoral emissions by 2030, followed by Energy at 22.2%, Agriculture at 17.5%, Industry at 9.0% and Waste at 2.1%. Cambodia's NC2 outlines its measures to mitigate and adapt to climate change and related plans, programs and projects in these areas; financial commitments, technology transfer and international cooperation; systematic research and observation; education, training and public awareness; and constraints, gaps and related financial, technical and capacity needs.[5]

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[1] G. Oudry, K. Pak, C. Chea, (2016). Assessing Vulnerabilities and Responses to Environmental Changes in Cambodia. International Organization for Migration, Phnom Penh,. URL: https://environmentalmigration.iom.int/sites/default/files/publications/MECC_Cambodia%20report.pdf

[2] World Bank (2020). World Bank DataBank. World Development Indicators, Cambodia. [Accessed 10 March 2021]. URL: https://databank.worldbank.org/source/world-development-indicators

[3] Cambodia (2016). Cambodia's Second National Communication submitted under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/khmnc2.pdf

[4] World Bank (2020). Valuing the Ecosystem Services Provided by Forests in Pursat Basin, Cambodia. URL: http://documents1.worldbank.org/curated/en/589931596202203080/pdf/Valuing-the-Ecosystem-Services-Provided-by-Forests-In-Pursat-Basin-Cambodia.pdf

[5] Cambodia (2016). Cambodia's Second National Communication submitted under the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/khmnc2.pdf

Green, Inclusive and Resilient Recovery

The coronavirus disease (COVID-19) pandemic has led to unprecedented adverse social and economic impacts. Further, the pandemic has demonstrated the compounding impacts of adding yet another shock on top of the multiple challenges that vulnerable populations already face in day-to-day life, with the potential to create devastating health, social, economic and environmental crises that can leave a deep, long-lasting mark. However, as governments take urgent action and lay the foundations for their financial, economic, and social recovery, they have a unique opportunity to create economies that are more sustainable, inclusive and resilient. Short and long-term recovery efforts should prioritize investments that boost jobs and economic activity; have positive impacts on human, social and natural capital; protect biodiversity and ecosystems services; boost resilience; and advance the decarbonization of economies.

This document aims to succinctly summarize the climate risks faced by Cambodia. This includes rapid onset and long-term changes in key climate parameters, as well as impacts of these changes on communities, livelihoods and economies, many of which are already underway. This is a high-level synthesis of existing research and analyses, focusing on the geographic domain of Cambodia, therefore potentially excluding some international influences and localized impacts. The core data presented is sourced from the database sitting behind the World Bank Group's Climate Change Knowledge Portal (CCKP), incorporating climate projections from the Coupled Model Inter-comparison Project Phase 5 (CMIP5). This document is primarily meant for WBG and ADB staff to inform their climate actions. The document also aims and to direct the reader to many useful sources of secondary data and research.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[6]	14.5% (2017–2019)	FAO, 2020
National Poverty Rate[7]	12.9% (2018)	ADB, 2020
Share of Income Held by Bottom 20%	Unknown	
Net Annual Migration Rate[8]	–0.19% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[9]	2.4% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[10]	3.25% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[11]	55.7 (2020)	UNDESA, 2019
Urban Population as % of Total Population[12]	24.2% (2020)	CIA, 2020
External Debt Ratio to GNI[13]	58.2% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP[14]	21.5% (2019)	ADB, 2020b

6 FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Transforming food systems for affordable healthy diets. FAO. Rome. URL: http://www.fao.org/documents/card/en/c/ca9692en/

7 ADB (2020a) Poverty data: Cambodia. URL: https://www.adb.org/countries/cambodia/poverty [accessed 17/12/20]

8 UNDESA (2019). World Population Prospects 2019: MIGR/1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

9 UNDESA (2019). World Population Prospects 2019: MORT/1-1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

10 UNDESA (2019). World Urbanization Prospects 2018: File 6. URL: https://population.un.org/wup/Download/ [accessed 17/12/20]

11 UNDESA (2019). World Population Prospects 2019: POP/11-A. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]

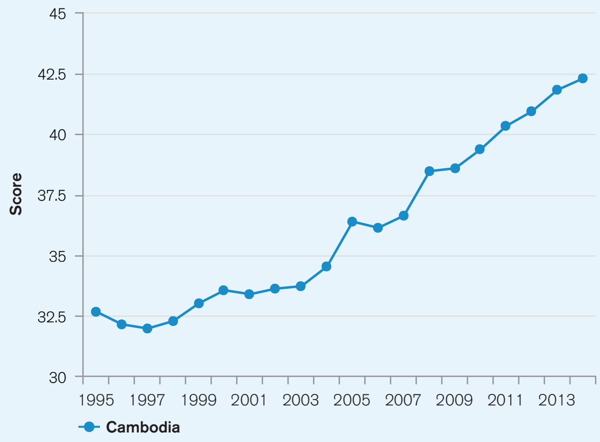
12 CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

13 ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. Manila. URL: https://www.adb.org/sites/default/files/publication/632971/ki2020.pdf

14 ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. Manila URL: https://www.adb.org/sites/default/files/publication/632971/ki2020.pdf

Due to a combination of political, geographic, and social factors, Cambodia is recognized as vulnerable to climate change impacts, ranked 140th out of 181 countries in the 2020 ND-GAIN Index[15] The ND-GAIN Index ranks 181 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. The more vulnerable a country is the lower their score, while the more ready a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st. **Figure 1** is a time-series plot of the ND-GAIN Index showing Cambodia's progress.

FIGURE 1. The ND-GAIN Index summarizes a country's vulnerability to climate change and other global challenges in combination with its readiness to improve resilience. It aims to help businesses and the public sector better prioritize investments for a more efficient response to the immediate global challenges ahead.



CLIMATOLOGY

Climate Baseline

Overview

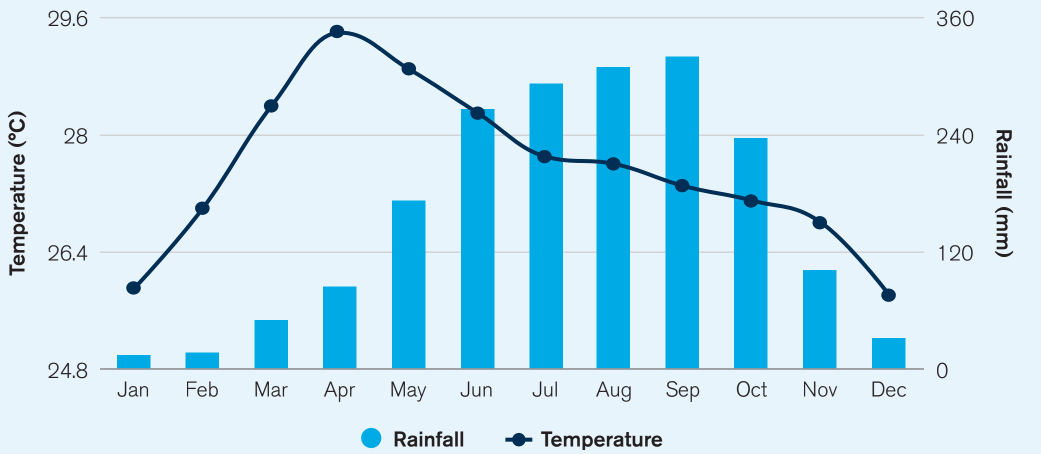
Cambodia's climate is tropical, with high temperatures, and two distinct seasons: a monsoon-driven rainy season (May-October) with south-westerly winds ushering in clouds and moisture that accounts for anywhere between 80%–90% of the country's annual precipitation, and a dry season (November-April), with cooler temperatures, particularly between November and January, as shown in the latest climatology, 1991–2020 (**Figure 2**). Average temperatures are relatively uniform across the country, but are highest in the early summer months before the rainy season begins, when maximum temperatures often exceed 32°C. Temperatures remain between 25°C–27°C throughout the rest of the year. The wet season arrives with the summer monsoon, in May through November, bringing the heaviest rainfall to the southeast and northwest. The annual average rainfall is typically 1,400–2,000 millimeters (mm) with higher rates in the coastal and highland areas and lower rates in other inland regions. Inter-annual variations in

[15] University of Notre Dame (2019). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

climate result from the El Niño Southern Oscillation, which influences the nature of the monsoons in the region. El Nino events generally bring warmer and drier than average winter conditions across Southeast Asia, while La Niña episodes bring cooler than average conditions. **Figure 3** shows observed spatial variation for temperature and precipitation across Cambodia.

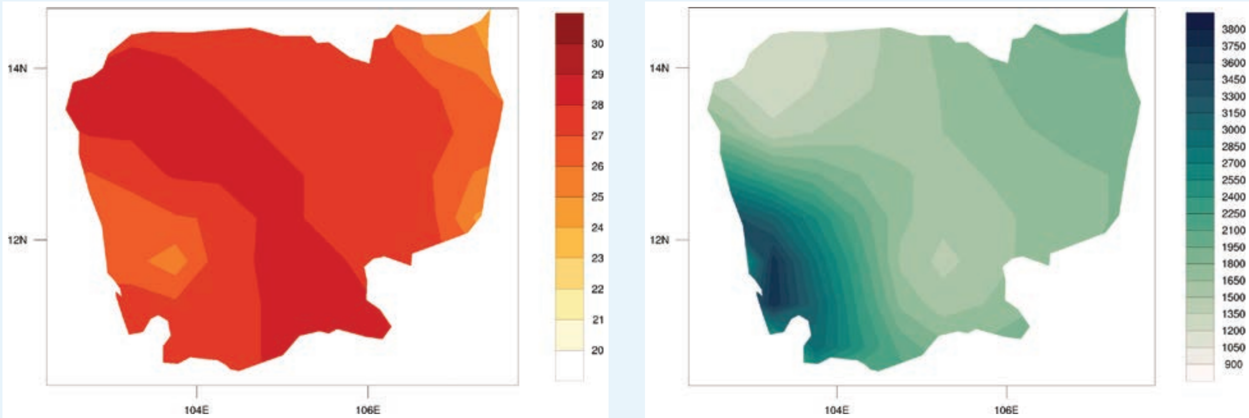
Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Cambodia (1991–2020)[16]



Spatial Variation

FIGURE 3. Annual mean temperature (°C) (left), and annual mean rainfall (mm) (right) in Cambodia over the period 1991–2020[17]



[16] WBG Climate Change Knowledge Portal (CCKP, 2021). Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-historical

[17] WBG Climate Change Knowledge Portal (CCKP, 2021). Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-historical

Key Trends

Temperature

Temperatures in Cambodia are generally consistent throughout the year, averaging between 25°C and 27°C. Average maximum temperatures can reach 38°C(April) and average minimum temperatures reaching 17°C. Temperature increases have been observed, with an approximate increase of 0.18°C per decade since the 1960s.[18] Temperature increases have increased most rapidly during the country's dry season (November to April), increasing by 0.20°C to 0.23°C per decade. Temperatures have increase during the rainy season (May to October), but not as significantly, with increases between 0.13°C and 0.16°C per decade. The number of 'hot days' in the country has increased over the last century, by as much as 46 days per year.[19]

Precipitation

Rainfall in Cambodia varies widely across the country. Average annual rainfall can be as low as 1,400 mm in the central lowlands and as high as 4,000 mm near the Cardamom mountains and nearby coastal areas in the southwest. The country's eastern plains receive approximately 2,000 to 2,600 mm of rainfall annually and may exceed those amounts in the mountainous areas in the Northeast.[20] While rainfall was observed to increase in some areas since the 1960s, no statistically significant changes were detected over the 20th century, either in terms of annual rainfall or extreme events. However, precipitation variability is linked to the El Niño Southern Oscillation phenomenon, with years of strong El Niño correlated with years of moderate and severe drought over the 20th century.[21]

A Precautionary Approach

Studies published since the last iteration of the IPCC's report (AR5), such as Gasser et al. (2018), have presented evidence which suggests a greater probability that earth will experience medium and high-end warming scenarios than previously estimated.[22] Climate change projections associated with the highest emissions pathway (RCP8.5) are presented here to facilitate decision making which is robust to these risks.

[18] UNDP (2012). UNDP Climate Change Country Profiles: Cambodia. United Nations Development Program. URL: https://www.geog.ox.ac.uk/research/climate/projects/undp-cp/UNDP_reports/Cambodia/Cambodia.hires.report.pdf
[19] USAID (2019). Cambodia – Climate Risk Profile. Fact Sheet. URL: https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID_Cambodia%20CRP.pdf
[20] USAID (2019). Cambodia – Climate Risk Profile. Fact Sheet. URL: https://www.climatelinks.org/sites/default/files/asset/document/2019_USAID_Cambodia%20CRP.pdf
[21] Lyon, B. (2004). The strength of El Nino and the spatial extent of tropical drought. Advances in Geosciences, 31. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2004GL020901
[22] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience, 11, 830–835. URL: http://pure.iiasa.ac.at/id/eprint/15453/

Climate Future

Overview

The main data source for the World Banks' Climate Change Knowledge Portal (CCKP) is the Coupled Model Intercomparison Project Phase 5 (CMIP5) models, which are utilized within the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), providing estimates of future temperature and precipitation. Four Representative Concentration Pathways (i.e. RCP2.6, RCP4.5, RCP6.0, and RCP8.5) were selected and defined by their total radiative forcing (cumulative measure of GHG emissions from all sources) pathway and level by 2100. In this analysis RCP2.6 and RCP8.5, the extremes of low and high emissions pathways, are the primary focus RCP2.6 represents a very strong mitigation scenario, whereas RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database.

For Cambodia, these models show a trend of continued, consistent warming that varies by emissions scenario. However, the projections in rainfall are less certain. However, projected trends do show a likely increase in the frequency and intensity of heavy rainfall events as well as an increase in the amount of rainfall received during these events. **Tables 2** and **3** below, provide information on temperature projections and anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Cambodia for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table is showing the median of the CCKP model ensemble and the 10–90th percentiles in brackets.[23]

	Average Daily Maximum Temperature		Average Daily Temperature		Average Daily Minimum Temperature	
Scenario	**2040–2059**	**2080–2099**	**2040–2059**	**2080–2099**	**2040–2059**	**2080–2099**
RCP2.6	0.8 (–0.5, 2.7)	1.1 (–0.5, 2.8)	0.9 (–0.1, 2.3)	1.0 (–0.2, 2.3)	1.0 (–0.1, 2.0)	1.0 (–0.2, 2.1)
RCP4.5	1.3 (–0.3, 3.1)	1.7 (0.2, 3.8)	1.3 (0.1, 2.6)	1.8 (0.6, 3.3)	1.4 (0.2, 2.4)	1.9 (0.7, 3.1)
RCP6.0	1.1 (–0.5, 2.8)	2.2 (0.5, 4.2)	1.1 (0.0. 2.4)	2.2 (0.8, 3.8)	1.2 (0.0, 2.2)	2.3 (0.8, 3.6)
RCP8.5	1.7 (0.0, 3.5)	3.6 (1.5, 6.0)	1.7 (0.5, 3.1)	3.7 (2.1, 5.5)	1.8 (0.6, 2.9)	3.8 (2.2, 5.4)

[23] WBG Climate Change Knowledge Portal (CCKP, 2021). Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-projections

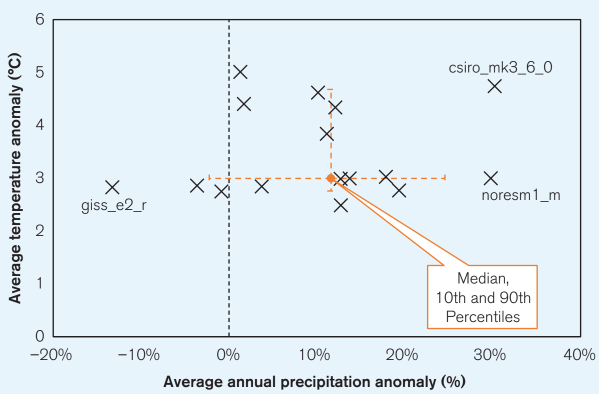
TABLE 3. Projections of average temperature anomaly (°C) in Cambodia for different seasons (3-monthly time slices) over different time horizons and emissions pathways, showing the median estimates of the full CCKP model ensemble and the 10th and 90th percentiles in brackets[23]

Scenario	2040–2059 Jun–Aug	2040–2059 Dec–Feb	2080–2099 Jun–Aug	2080–2099 Dec–Feb
RCP2.6	0.8 (0.5, 1.3)	0.9 (0.4, 1.5)	0.8 (0.4, 1.5)	0.9 (0.3, 1.9)
RCP4.5	1.1 (0.9, 1.5)	1.2 (0.5, 2.2)	1.5 (1.2, 2.4)	1.7 (0.7, 3.1)
RCP6.0	1 (0.7, 1.4)	1 (0.6, 1.6)	1.9 (1.5, 2.7)	2 (1.1, 3.1)
RCP8.5	1.5 (1.2, 2)	1.6 (1, 2.5)	3 (2.7, 4.7)	3.1 (2.2, 5.2)

Model Ensemble

Climate projections presented in this document are derived from datasets made available on the World Bank's Climate Change Knowledge Portal (CCKP), unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) developed by climate research centers around the world and evaluated by the IPCC for quality assurance in the CMIP5 iteration of models (for further information see Flato et al., 2013).[24] Collectively, these different GCM simulations are referred to as the 'model ensemble'. Due to the differences in the way GCMs represent the key physical processes and interactions within the climate system, projections of future climate conditions can vary widely between different GCMs, this is particularly the case for rainfall related variables and at national and local scales. Exploring the spread of climate model outputs can assist in understanding uncertainties associated with climate models. The range of projections from 16 GCMs on the indicators of average temperature anomaly and annual precipitation anomaly for Cambodia under RCP8.5 is shown in **Figure 4**. Spatial representation of future projections of annual temperature and precipitation for mid and late century under RCP8.5 are presented in **Figure 5**.

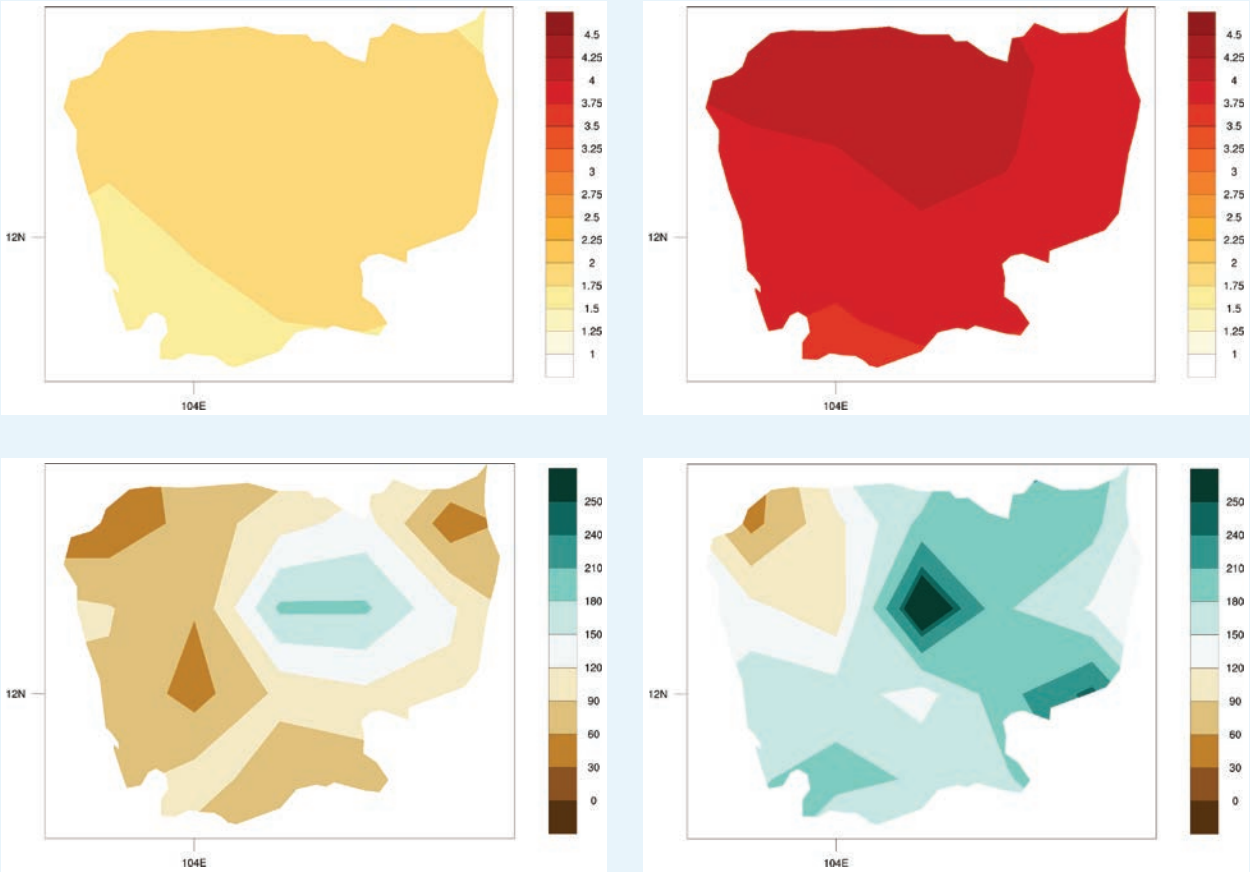
FIGURE 4 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Cambodia. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and therefore are most robust for comparison.[23] Three models are labelled.



[24] Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W., . . . Rummukainen, M. (2013). Evaluation of Climate Models. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 741–866. URL: https://pubs.giss.nasa.gov/abs/ip06000g.html

Spatial Variation

FIGURE 5. CMIP5 ensemble projected change (32 GCMs) in annual temperature (top) and precipitation (bottom) by 2040–2059 (left) and by 2080–2090 (right) relative to 1986–2005 baseline under RCP8.5[25]



Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes (anomalies) in daily maximum and daily minimum temperatures over the given time period, as well as changes in the average temperature. **Figures 6** and **7** display the annual and monthly average temperature projections. While similar, these three indicators can provide slightly different information. Monthly/annual average temperatures are most commonly used for general estimation of climate change, but the daily maximum and minimum can explain more about how daily life might change in a region, affecting key variables such

[25] WBG Climate Change Knowledge Portal (CCKP 2021). Cambodia Climate Data. Projections. URL: https://climateknowledgeportal.worldbank.org/country/cambodia/climate-data-projections

as the viability of ecosystems, health impacts, productivity of labor, and the yield of crops, which are often disproportionately influenced by temperature extremes. The impact of higher temperatures, particularly for Cambodia's increasingly fragmented forests is likely to increase forest fires, reduce water retention capacity and further reduce the essential services from ecosystems.[26]

FIGURE 6. Historic and projected average annual temperature in Cambodia under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.[27]

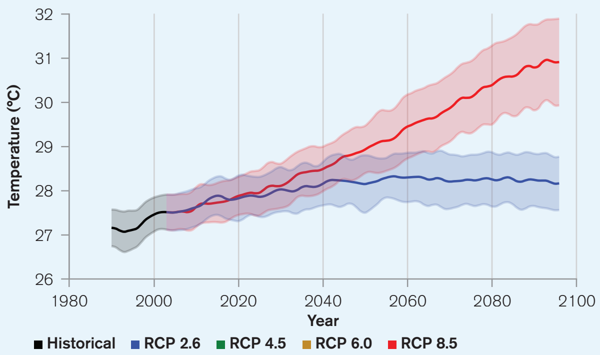
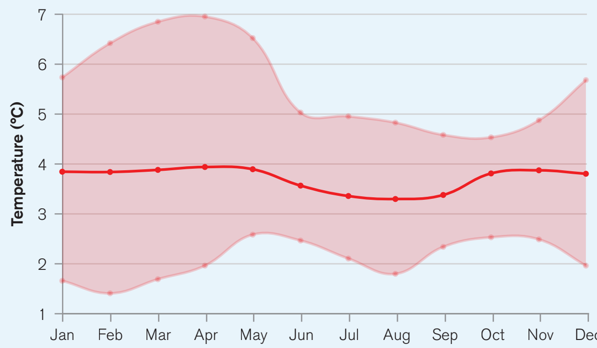


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Cambodia for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles.[27]



Cambodia faces temperature rises of up to 3.6°C by the 2090s on the highest emissions pathway (RCP8.5), compared with the 1986–2005 baseline. The lower rates of warming projected under lower emissions pathways highlight the potential benefits of aggressive global emissions reductions over the 21st century (**Table 2**). The projected warming is slightly below the global average of 3.7°C. The number of hot days are expected significantly by the 2060s. There is a distinct difference between average temperature rises and rises in minimum and maximum temperatures. Annual minimum and maximum temperatures are typically projected to rise 10–20% faster than average temperatures (**Table 2**). Temperature changes are estimated to be slightly higher in winter months (October to May). The global model ensemble also suggests increases will be weaker in the vicinity of the coast and stronger inland, particularly at higher altitudes.

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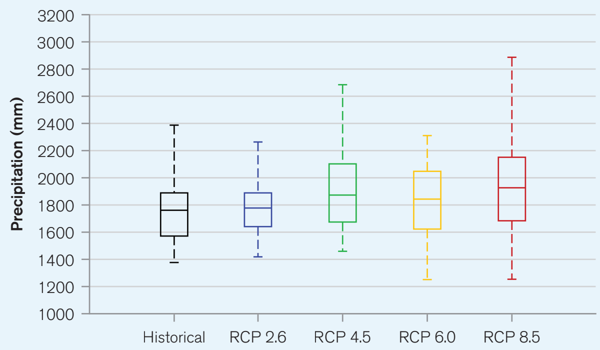
[26] World Bank (2020). Valuing the Ecosystem Services Provided by Forests in Pursat Basin, Cambodia. URL: http://documents1.worldbank.org/curated/en/589931596202203080/pdf/Valuing-the-Ecosystem-Services-Provided-by-Forests-In-Pursat-Basin-Cambodia.pdf

[27] WBG Climate Change Knowledge Portal (CCKP, 2021). Cambodia. Agriculture Interactive Climate Indicator Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=KHM&period=2080-2099

Precipitation

Considerable uncertainty surrounds projections of local long-term future precipitation trends. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature, a finding supported by evidence from different regions of Asia.[28] The limited available research specific to Cambodia broadly supports this trend;[29] however, further research is required. For Cambodia, an increase is expected for seasonal rainfall between June and August in the northwest regions of the country, but the northeast of the country should expect a decrease in annual average precipitation. While most models in the ensemble project greater annual rates of precipitation, with increasing levels under higher emissions pathways (**Figure 8**), uncertainty remains high as reflected in the range of model estimates. This uncertainty is also seen in the very limited number of studies applying downscaling techniques to assessing precipitation changes.[29] The poor performance of global climate models in consistently projecting precipitation trends has been linked to their poor simulation of the El Niño phenomenon[30,31], an important area for future development.

FIGURE 8. Projected average annual precipitation for Cambodia in the period 2080–2099[27]



CLIMATE RELATED NATURAL HAZARDS

Cambodia faces high disaster risk levels, ranked 55 out of 191 countries by the 2019 Inform Risk Index (**Table 4**), driven particularly by its exposure to flood hazard. Cambodia has extremely high exposure to flooding (ranked joint 4th), including, riverine and flash flooding. Cambodia also has some limited exposure to tropical cyclones and their associated hazards and the country's drought exposure is slightly lower, but still is of significant concern, as highlighted by the severe drought of 2015–2017. Cambodia's overall ranking on the INFORM risk index is somewhat exacerbated by its lack of coping capacity and to a lesser extent by the vulnerability of the population. The section analyses climate change influences on the exposure component of climate risk in Cambodia.

[28] Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G., Roberts, N. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. Reviews of Geophysics, 52, 522–555. URL: https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2014RG000464

[29] Lacombe, G., Hoanh, C. T., & Smakhtin, V. (2012). Multi-year variability or unidirectional trends? Mapping long-term precipitation and temperature changes in continental Southeast Asia using PRECIS regional climate model. Climatic Change, 113(2), 285–299. URL: https://ccafs.cgiar.org/publications/multi-year-variability-or-unidirectional-trends-mapping-long-term-precipitation-and#.XkM5JFJKhBw

[30] Yun, K.S., Yeh, S.W. and Ha, K.J. (2016). Inter-El Niño variability in CMIP5 models: Model deficiencies and future changes. Journal of Geophysical Research: Atmospheres, 121, 3894–3906. URL: http://repository.hanyang.ac.kr/handle/20.500.11754/69469?mode=full

[31] Chen, C., Cane, M.A., Wittenberg, A.T. and Chen, D. (2017). ENSO in the CMIP5 simulations: life cycles, diversity, and responses to climate change. Journal of Climate, 30, 775–801. URL: https://journals.ametsoc.org/doi/full/10.1175/JCLI-D-15-0901.1

TABLE 4. Selected indicators from the INFORM 2019 Index for risk management for Cambodia. For the sub-categories of risk (e.g. "flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st. Global average scores are shown in brackets.

Flood (0–10)	Tropical Cyclone (0–10)	Drought (0–10)	Vulnerability (0–10)	Lack of Coping Capacity (0–10)	Overall Inform Risk Level (0–10)	Rank (1–191)
9.5 [4.5]	4.0 [1.7]	4.6 [3.2]	3.9 [3.6]	6.2 [4.5]	4.8 [3.8]	55

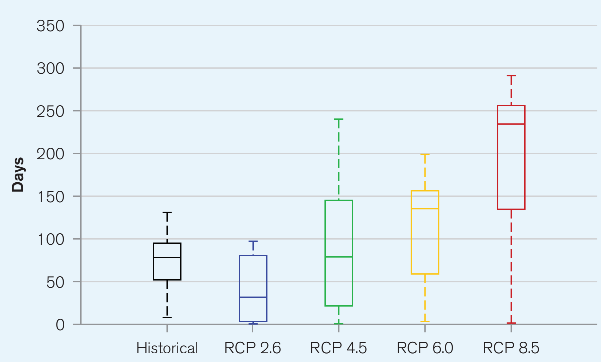
The section that follows analyses climate change influences on the exposure component of risk in Cambodia. As seen in **Figure 1**, the ND-GAIN Index presents an overall picture of a country's vulnerability and capacity to improve its resilience. In contrast, the Inform Risk Index identifies specific risks across a country to support decisions on prevention, preparedness, response and a country's overall risk management.

Heatwaves

Cambodia already experiences some of the highest temperatures in the world, with an estimated national average of 64 days per year when the maximum temperature exceeds 35°C. The current median probability of a heat wave (defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) is around 3%.[27] An increase in the frequency and intensity of heatwaves has been observed across recent decades. Thirumalai et al. (2017) suggest climate change made a 29% contribution to the extreme temperatures experienced across Southeast Asia in April 2016, while ENSO contributed 49%.[32] There is sufficient existing data to infer that Cambodia also faces a transition to a state of permanent heat stress as a result of temperatures which regularly surpass levels safe for humans and biodiversity.

While heatwaves refer to the occurrence of exceptionally high heats (based on a static baseline), the incidence of permanent (chronic) heat stress is likely to increase significantly in Cambodia under all emissions pathways. At the national level the extent of this risk can be captured in the prevalence of days with Heat Index >35°C, this represents the combination of temperature and humidity to produce conditions dangerous for human health. As shown in **Figure 9**, the average annual frequency of dangerous days is expected to increase under all emissions pathways by the 2090s, with a particularly large potential increase under the highest emissions pathway, RCP8.5.

FIGURE 9. Box plots showing historical (1986–2005) and projected (2080–2099) average annual frequency of days with Heat Index >35°C[33]



[32] Thirumalai, K., DiNezio, P. N., Okumura, Y., & Deser, C. (2017). Extreme temperatures in Southeast Asia caused by El Niño and worsened by global warming. Nature Communications: 8: 15531. URL: https://pubmed.ncbi.nlm.nih.gov/28585927/

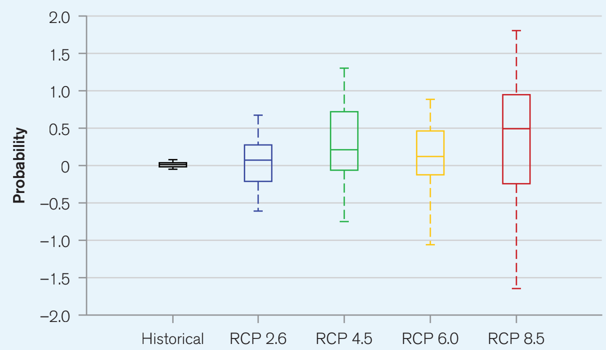
[33] WBG Climate Change Knowledge Portal (CCKP, 2021). Cambodia Agriculture Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=KHM&period=2080-2099

Drought

Two primary types of drought may affect Cambodia, meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). At present Cambodia faces an annual median probability of severe meteorological drought of around 4%,[27] as defined by a standardized precipitation evaporation index (SPEI) of less than –2.

Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[34] Projections for Southeast Asia suggest that the return periods of droughts will reduce. This trend is less significant under lower levels of global warming, but once warming reaches 2–3°C events that presently occur only once in every hundred years may return at frequencies greater than once in every fifty years. **Figure 10** shows the model ensemble's projection of drought probability for the period 2080–2099 in Cambodia under different emissions pathways. Uncertainty remains high, but all emissions pathways indicate an increase in median annual probability from 4% to 5–9%.

FIGURE 10. Boxplots showing the annual probability of experiencing a 'severe drought' in Cambodia (–2 SPEI Index) in 2080–2099 under four emissions pathways[35]



Flood

The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of flood exposure.[36] As of 2010, assuming protection for up to a 1 in 25-year event, the population annually affected by flooding in Cambodia is estimated at 90,000 people and expected annual urban damage is estimated at $105 million. Economic development and climate change are both expected to increase these figures. The climate change component can be isolated and by 2030 is expected to increase the annually affected population by 70,000 people, and urban damage by $226 million under the RCP8.5 emissions pathway (AQUEDUCT Scenario B).

Paltan et al. (2018) demonstrate that even under lower emissions pathways, consistent with the Paris Climate Agreement, almost all Asian countries face an increase in the frequency of extreme river flows.[37] What would historically have been a 1 in 100-year flow, could become a 1 in 5- year or 1 in 25-year event in most of South, Southeast, and East Asia. There is good agreement among models about this trend. Increases in the intensity of

34 Naumann, G., Alfieri, L., Wyser, K., Mentaschi, L., Betts, R. A., Carrao, H., . . . Feyen, L. (2018). Global Changes in Drought Conditions Under Different Levels of Warming. Geophysical Research Letters, 45(7), 3285–3296. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2017GL076521

35 WBG Climate Change Knowledge Portal (CCKP 2021). Cambodia. Water Sector Interactive Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=KHM&period=2080-2099

36 WRI (2018). AQUEDUCT Global Flood Analyzer. URL: https://floods.wri.org/# [Accessed: 22/11/2018]

37 Paltan, H., Allen, M., Haustein, K., Fuldauer, L., & Dadson, S. (2018). Global implications of 1.5°C and 2°C warmer worlds on extreme river flows Global implications of 1.5°C and 2°C warmer worlds on extreme river flows. Environmental Research Letters, 13. https://doi.org/10.1088/1748-9326/aad985. URL: https://www.researchgate.net/publication/326964132_Global_implications_of_15_C_and_2_C_warmer_worlds_on_extreme_river_flows

extreme precipitation events are also increasing the risk of surface (pluvial) flooding, associated impacts include infrastructural damage in urban environments, and landslide risk in rural areas. Coastal flooding issues are also expected to worsen, these are addressed in the following section.

In terms of the proportion of the population affected Cambodia is one of the world's most flood-exposed countries in the world.[38] Willner et al. (2018) suggest that around 4 million people, or 25% of the population, are affected when an extreme river flood strikes (**Table 5**).[39] Another study conducted by the World Bank put the increase in the population exposed to flood by 2050 at 19%.[40] The UNISDR estimate that Cambodia experiences over $250 million in average annual losses (just over 1% of GDP). Vastila et al. (2010) show that increases in rainfall during the wet season (i.e. increasing extremes) resulting from climate change have strong potential to increase the peak discharge of the Mekong River and hence increase the population exposed to river flooding in the vicinity of its floodplains.[41] However, the impact of upstream hydropower development along the Mekong and its tributaries may act to offset the climate change signal, causing dry season flows to increase and wet season flows to reduce.[42]

TABLE 5. Estimated number of people in Cambodia affected by an extreme river flood (extreme river flood is defined as being in the 90th percentile in terms of numbers of people affected) in the historic period 1971–2004 and the future period 2035–2044. Figures represent an average of all four RCPs and assume present day population distributions.[39]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	4,035,515	4,219,445	183,930
Median	4,239,603	4,413,765	174,162
83.3 Percentile	4,369,511	4,567,258	197,747

Cyclones and Storm Surge

Climate change is expected to interact with cyclone hazard in complex ways which are currently poorly understood. Known risks include the action of sea-level rise to enhance the damage caused by cyclone-induced storm surges, and the possibility of increased windspeed and precipitation intensity. Modelling of climate change impacts on cyclone intensity and frequency conducted across the globe points to a general trend of reduced cyclone frequency

38 Kundzewicz, Z. W., Kanae, S., Seneviratne, S. I., Handmer, J., Nicholls, N., Peduzzi, P., . . . Sherstyukov, B. (2014). Flood risk and climate change: global and regional perspectives. Hydrological Sciences Journal, 59(1), 1–28 URL: https://www.tandfonline.com/doi/full/10.1080/02626667.2013.857411

39 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

40 Winsemius, Hessel C.; Jongman, Brenden; Veldkamp, Ted I.E.; Hallegatte, Stephane; Bangalore, Mook; Ward, Philip J. (2015). Disaster risk, climate change, and poverty: assessing the global exposure of poor people to floods and droughts (English). Policy Research working paper; no. WPS 7480. Washington, D.C.: World Bank Group. URL: http://documents.worldbank.org/curated/en/965831468189531165/pdf/WPS7480.pdf

41 Vastila, K., Kummu, M., Sangmanee, C., & Chinvanno, S. (2010). Modelling climate change impacts on the flood pulse in the Lower Mekong floodplains. Journal of Water and Climate Change, 1(1), 67–86. URL: https://iwaponline.com/jwcc/article-abstract/1/1/67/31006/Modelling-climate-change-impacts-on-the-flood?redirectedFrom=fulltext

42 Lauri, H., de Moel, H., Ward, P. J., Rasanen, T. A., Keskinen, M., & Kummu, M. (2012). Future changes in Mekong River hydrology: impact of climate change and reservoir operation on discharge. Hydrology and Earth System Sciences, 16(12), 4603–4619. URL: https://www.hydrol-earth-syst-sci.net/16/4603/2012/

but increased intensity and frequency of the most extreme events.[43] This is broadly supported by recent trends over Southeast Asia, which have seen cyclone activity moving eastward and away from the Mekong Basin. Consequence include a reduction in peak runoff volumes, and hence a reduction in sediment transport.[44] Further research is required to better understand potential changes in cyclone seasonality and routes, and the potential for cyclone hazards to be experienced in unprecedented locations. Cambodia's coastal zones are known to hold exposure to cyclone and tsunami-induced storm surge, albeit at lower levels than a number of other Southeast Asian nations. Without adaptation sea-level rise is likely to increase the overall risk faced by the agricultural communities in the country's southwestern region.[45]

CLIMATE CHANGE IMPACTS

Natural Resources

Water

Water resources in Cambodia are in a state of flux as a result of major human development interventions impacting on the Mekong River and Tonle Sap Lake.[46] Various have shown that a lack of modern irrigation infrastructure is holding back agricultural production in Cambodia, and potentially enhancing the nation's vulnerability to climatic extremes.[47] Cambodia is simultaneously highly dependent on the resources provided by the natural river flow regime and the flood regime. In a context of dramatic changes to future water flows, likely exacerbated by climate change, a key focus area discussed in Cambodia's NC2 is on maintaining the flow levels necessary to sustain ecosystem services. It is hoped this will be achieved through management of irrigation, dams, and domestic water demand. As discussed in the UNDP's overview of climate change impacts on the water sector (2011) a failure to maintain the necessary productivity of the ecosystem supporting Cambodia's inland fisheries would represent a major threat to the nation's primary source of protein.[48] Similarly, with a large proportion of the Cambodian population still dependent on natural water sources for domestic consumption, drought and other reductions to the natural water supply could have serious human consequences.

[43] Walsh, K., McBride, J., Klotzbach, P., Balachandran, S., Camargo, S., Holland, G., Knutson, T., Kossin, J., Lee, T., Sobel, A., Sugi, M. (2015). Tropical cyclones and climate change. WIREs Climate Change: 7: 65–89. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/wcc.371
[44] Darby, S. E., Hackney, C. R., Leyland, J., Kummu, M., Lauri, H., Parsons, D. R., . . . Aalto, R. (2016). Fluvial sediment supply to a mega-delta reduced by shifting tropical-cyclone activity. Nature, 539(7628), 276–279. URL: https://www.ncbi.nlm.nih.gov/pubmed/27760114
[45] Dasgupta, S., Laplante, B., Murray, S. and Wheeler, D. (2011). Exposure of developing countries to sea-level rise and storm surges. Climatic Change, 106(4), pp. 567–579. URL: https://link.springer.com/article/10.1007/s10584-010-9959-6
[46] ICEM (2020). Improving Climate-Smart Decision Making with the Cambodia Mekong Delta Digital Atlas tool. Summary Report for Decision Meeting. [4 June, 2020].
[47] Chun, J. A., Li, S., Wang, Q., Lee, W.-S., Lee, E.-J., Horstmann, N., . . . Vang, S. (2016). Assessing rice productivity and adaptation strategies for Southeast Asia under climate change through multi-scale crop modeling. Agricultural Systems, 143, 14–21. URL: https://koreauniv.pure.elsevier.com/en/publications/assessing-rice-productivity-and-adaptation-strategies-for-southea
[48] UNDP (2011). Climate change and water resources. Cambodia Human Development Report 2011. United Nations Development Program. URL: http://hdr.undp.org/sites/default/files/cambodia_2011_nhdr.pdf

Tonle Sap Lake

The Tonle Sap Lake is a unique and vital natural resource in Cambodia. The lake's complex hydrological interactions with the Mekong River make it vulnerability to changes in the Mekong River basin, including development-focused interventions taking place in upstream nations as well as climate change.[49] ENSO also has an inter-annual influence over the hydrological regime.[50] The ongoing damming of the Mekong is likely to very significantly alter the services provided by the lake.[51] Research shows that alterations to the tropical cyclone regime over the Mekong Basin, driven by climate change, may be having an impact on its hydrological flows.[52] Any climate changes which modify the flood pulse which feeds the Tonle Sap Lake during the peak monsoon season will have significant implications for its unique wetlands, forest[53] and aquatic ecosystems.[54]

The Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44–0.74 m by the end of the 21st century by the IPCC's Fifth Assessment Report,[55] but some studies published more recently have highlighted the potential for more significant rises (**Table 6**). The impacts of sea-level rise in Cambodia are understudied. While the Cambodian section of the Mekong Delta and Cambodia's western coastline are high enough above sea-level to afford some protection, several studies have suggested that future impacts will be material. For example, the UK Met Office's estimate (**Table 7**), puts the population flooded by sea-level rise at a maximum of 30,000 without adaptation by 2070–2100 under RCP8.5,[56] and the World Bank show that 1m of sea-level rise (slightly above the RCP8.5 estimate) could flood around 80,000 people and cost 0.5–1% of GDP.[57] Additional risks require further research, these include issues such as coastal erosion, saltwater intrusion and the impact of changes in the hydrology of the Mekong Delta on Cambodia. Most existing studies focus primarily on the Vietnamese portion of the Delta. These risks must also be viewed in the context of extensive ongoing and proposed damming of the Mekong River and its tributaries.

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49 ICEM (2020). Improving Climate-Smart Decision Making with the Cambodia Mekong Delta Digital Atlas tool. Summary Report for Decision Meeting. [4 June, 2020].

50 Frappart, F., Biancamaria, S., Normandin, C., Blarel, F., Bourrel, L., Aumont, M., Azemar, P., Vu, P.L., Le Toan, T., Lubac, B. and Darrozes, J. (2018). Influence of recent climatic events on the surface water storage of the Tonle Sap Lake. Science of the Total Environment, 636, pp. 1520–1533. URL: https://www.ncbi.nlm.nih.gov/pubmed/29913613

51 Arias, M. E., Cochrane, T. A., Kummu, M., Lauri, H., Holtgrieve, G. W., Koponen, J., & Piman, T. (2014a). Impacts of hydropower and climate change on drivers of ecological productivity of Southeast Asia's most important wetland. Ecological Modelling, 272, 252–263. URL: https://research.aalto.fi/en/publications/impacts-of-hydropower-and-climate-change-on-drivers-of-ecological-productivity-of-southeast-asias-most-important-wetland(52afb37f-9eb0-4fa9-b635-b41ce1076124).html

52 Darby, S. E., Hackney, C. R., Leyland, J., Kummu, M., Lauri, H., Parsons, D. R., . . . Aalto, R. (2016). Fluvial sediment supply to a mega-delta reduced by shifting tropical-cyclone activity. Nature, 539, 276. URL: https://www.ncbi.nlm.nih.gov/pubmed/27760114

53 World Bank (2020). Valuing the Ecosystem Services Provided by Forests in Pursat Basin, Cambodia. URL: http://documents1.worldbank.org/curated/en/589931596202203080/pdf/Valuing-the-Ecosystem-Services-Provided-by-Forests-In-Pursat-Basin-Cambodia.pdf

54 Arias, M., Cochrane, T., & Elliot, V. (2014b). Modelling future changes of habitat and fauna in the Tonle Sap wetland of the Mekong. Environmental Conservation, 41(2), 165–175. URL: https://www.cambridge.org/core/journals/environmental-conservation/article/modelling-future-changes-of-habitat-and-fauna-in-the-tonle-sap-wetland-of-the-mekong/7D7092517BEB0FE4740AECB1C77C9984

55 Church, J. a., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., . . . Unnikrishnan, A. S. (2013). Sea level change. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1137–1216). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. URL: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf

56 UK Met Office (2014). Human dynamics of climate change: Technical Report. Met Office, UK Government. URL: https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/climate/human-dynamics-of-climate-change/hdcc_alternative_version.compressed.pdf

57 Dasgupta, S., Laplante, B., Meisner, C., Wheeler, D., Yan, J. (2007). The impact of sea-level rise on developing countries: A comparative analysis. World Bank Policy Research Working Paper 4136. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/7174/wps4136.pdf?sequence=1&isAllowed=y

TABLE 6. Estimates of global mean sea-level rise by rate and total rise compared to 1986–2005 including likely range shown in brackets, data from Chapter 13 of the IPCC's Fifth Assessment Report with upper-end estimates based on higher levels of Antarctic ice-sheet loss from.[58]

Scenario	Rate of Global Mean Sea-Level Rise in 2100	Global Mean Sea-Level Rise in 2100 Compared to 1986–2005
RCP2.6	4.4 mm/yr (2.0–6.8)	0.44 m (0.28–0.61)
RCP4.5	6.1 mm/yr (3.5–8.8)	0.53 m (0.36–0.71)
RCP6.0	7.4 mm/yr (4.7–10.3)	0.55 m (0.38–0.73)
RCP8.5	11.2 mm/yr (7.5–15.7)	0.74 m (0.52–0.98)
Estimate inclusive of high-end Antarctic ice-sheet loss		1.84 m (0.98–2.47)

TABLE 7. The average number of people experiencing flooding per year in the coastal zone in the period 2070–2100 under different emissions pathways (assumed medium ice-melt scenario) and adaptation scenarios for Cambodia.[56]

Scenario	Without Adaptation	With Adaptation
RCP2.6	9,820	40
RCP8.5	30,660	80

Economic Sectors

Agriculture

Climate change will influence food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation and temperatures. Indirect effects include through impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest and disease profiles, the arrival of invasive species, and decline in arable areas due to the submergence of coastal lands and desertification. On an international level, these impacts are expected to damage key staple crop yields, even on lower emissions pathways. Tebaldi and Lobell (2018) estimate 5% and 6% declines in global wheat and maize yields respectively even if the Paris Climate Agreement is met and warming is limited to 1.5°C. Shifts in the optimal and viable spatial ranges of certain crops are also inevitable, though the extent and speed of those shifts remains dependent on the emissions pathway.[59]

Rice is a staple crop in Cambodia, crucial to national food security and subsistence livelihoods. Li et al. (2017) suggest that Cambodia faces some of the highest net rice yield losses in Southeast Asia, as a result of climate change.[60] Without adaptation, but with the benefits of increased atmospheric concentrations of CO_2 included, the authors report expected yield losses of 10–15% by the 2040s under both RCPs4.5 and RCP8.5. These losses

[58] Le Bars, D., Drijhout, S., de Vries, H. (2017). A high-end sea level rise probabilistic projection including rapid Antarctic ice sheet mass loss. Environmental Research Letters: 12:4. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aa6512

[59] Tebaldi, C., & Lobell, D. (2018). Differences, or lack thereof, in wheat and maize yields under three low-warming scenarios. Environmental Research Letters: 13: 065001. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aaba48

[60] Li, S., Wang, Q., & Chun, J. A. (2017). Impact assessment of climate change on rice productivity in the Indochinese Peninsula using a regional-scale crop model. International Journal of Climatology, 37(April), 1147–1160. URL: https://rmets.onlinelibrary.wiley.com/doi/full/10.1002/joc.5072

link primarily to increases in the average temperature during the growing season. Li et al. (2017) do suggest, however, that it may be possible to mitigate most of the projected yield losses through adaptations such as changes to the planting date.[60] The yield reductions projected in Cambodia's NC2 are more significant, and are not mitigated by planting date changes. The vulnerability of Cambodia's rice agriculture is linked particularly to the very high prevalence of rain-fed (rather than irrigated) systems, which are susceptible to damage from both lack and excess of water.

A further, and perhaps lesser appreciated influence of climate change on agricultural production is through its impact on the health and productivity of the labor force. Work by Dunne et al. (2013) suggests that global labor productivity during peak months has already dropped by 10% as a result of warming, and that a decline of up to 20% might be expected by the 2050s under the highest emissions pathway (RCP8.5).[61] Further research is required to evaluate the severity of this potential impact on Cambodia. In combination, it is highly likely that the above processes will have a considerable impact on national food consumption patterns both through direct impacts on internal agricultural operations, and through impacts on the global supply chain. An increase in the frequency of very hot days (>35°C) (**Figure 11**) is likely to impact water resource limitations and damage yields.[62] There is however, significant differences between emissions pathways, with higher emissions scenarios resulting in notably larger increases in daily maximum temperatures (**Figure 12**).

FIGURE 11. Increase in the annual average number of hot days (>35°C) in Cambodia under two emissions pathways. RCP2.6 (blue) and RCP8.5 (red).[63]

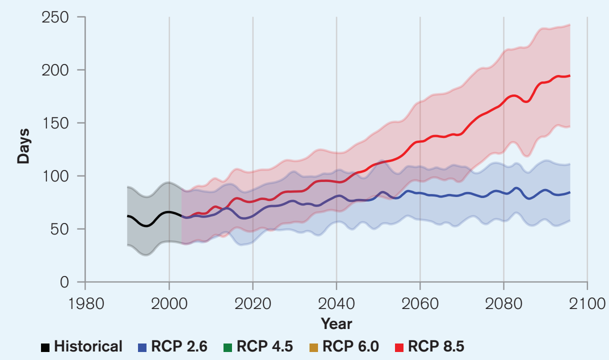
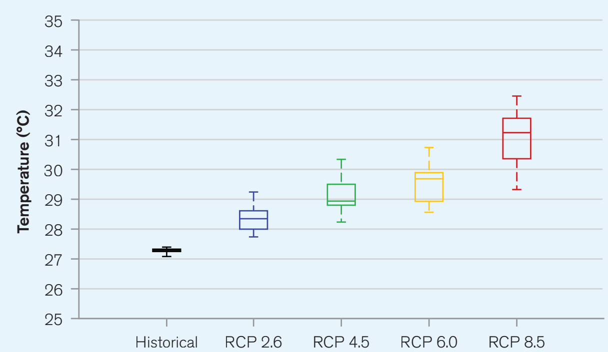


FIGURE 12. Average temperature in Cambodia under four emissions pathways over the period 2080–2099.



[61] Dunne, J. P., Stouffer, R. J., & John, J. G. (2013). Reductions in labour capacity from heat stress under climate warming. Nature Climate Change, 3(6), 563–566. URL: http://www.precaution.org/lib/noaa_reductions_in_labour_capacity_2013.pdf

[62] Elliott, J., Deryng, D., Müller, C., Frieler, K., Konzmann, M., Gerten, D., [. . .] Wisser, D. (2014). Constraints and potentials of future irrigation water availability on agricultural production under climate change. Proceedings of the National Academy of Sciences: 111: 3239–3244. URL: https://www.pnas.org/content/111/9/3239

[63] WBG Climate Change Knowledge Portal (CCKP 2021). Cambodia. Water Sector Interactive Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=KHM&period=2080-2099

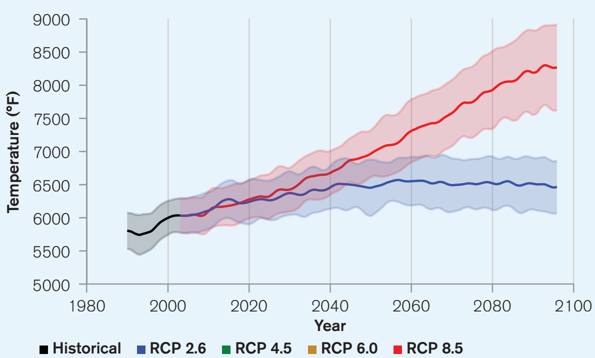
Urban

Research has established a reasonably well constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[64] In general terms the impact of an increase in temperature on these indicators depends on whether the temperature rise moves the ambient temperature closer to, or further away from, the optimum temperature range. The optimum range can vary depending on local conditions and adaptations.

The effects of temperature rise and heat stress in urban areas are increasingly compounded by the phenomenon of the Urban Heat Island (UHI). Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[65] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C to 3°C for global mega-cities. Particularly high urban heat island levels have been reported in Cambodia's capital Phnom Penh, with the temperature differential between rural and urban areas reaching as high as 4°C during the daytime according to Furuuchi et al. (2006).[66] As well as impacting on human health (see Communities) the temperature peaks that will result from combined UHI and climate change, as well as future urban expansion, are likely to damage the productivity of the service sector economy. These may occur both through direct impacts on labor productivity, but also through the additional costs of adaptation.

Research suggests that on average a one degree increase in ambient temperature can result in a 0.5–8.5% increase in electricity demand.[67] Notably this serves business and residential air-cooling systems. This increase in demand places strain on energy generation systems which is compounded by the heat stress on the energy generation system itself, commonly due to its own cooling requirements, which can reduce its efficiency.[68] **Figure 13** highlights the large projected increase in cooling demand in Cambodia, doubling under RCP8.5.

FIGURE 13. Historic and projected annual cooling degree days in Cambodia (cumulative degrees above 65°F) under RCP2.6 (blue) and RCP8.5 (red). The values shown represent the median of 32 GCM model ensemble with the shaded areas showing the 10–90th percentiles.[69]



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[64] Mani, M., Bandyopadhyay, S., Chonabayashi, S., Markandya, A., Mosier, T. (2018). South Asia's Hotspots: The Impact of Temperature and Precipitation changes on living standards. South Asian Development Matters. World Bank, Washington DC. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/28723/9781464811555.pdf?sequence=5&isAllowed=y

[65] Cao, C., Lee, X., Liu, S., Schultz, N., Xiao, W., Zhang, M., & Zhao, L. (2016). Urban heat islands in China enhanced by haze pollution. Nature Communications, 7, 1–7. URL: https://www.ncbi.nlm.nih.gov/pubmed/27551987

[66] Furuuchi, M., Murase, T., Yamashita, M., Oyagi, H., Sakai, K.-I., Tsukawaki, S., . . . Hata, M. (2006). Temperature Distribution and Air Pollution in Phnom Penh , Cambodia - Influence of Land Use and the Mekong and Tonle Sap. Aerosol and Air Quality Research, 6(2), 134–149. URL: http://www.aaqr.org/article/detail/AAQR-06-06-OA-0003

[67] Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2015). On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. Energy and Buildings, 98, 119–124. URL: https://pdfs.semanticscholar.org/17f8/6e9c161542a7a5acd0ad500f5da9f45a2871.pdf

[68] ADB (2017a). Climate Change Profile of Pakistan. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/357876/climate-change-profile-pakistan.pdf

[69] WBG Climate Change Knowledge Portal (CCKP 2019). Cambodia. Water Sector Interactive Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/water/land-use-/-watershed-management?country=KHM&period=2080-2099

Communities

Poverty and Inequality

Many of the climate changes projected are likely to disproportionately affect the poorest groups in society. For instance, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[70] Poorer businesses are least able to afford air conditioning, an increasing need given the projected increase in cooling days. Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation.

Poverty reduction in Cambodia has been rapid, yet climate change threatens to slow progress. The current impacts from the COVID-19 pandemic are also likely to increase the country's poverty levels, with potential to move people back into poverty in the immediate to medium term. Two key features of progress in Cambodia are highlighted by ADB (2016): first the rate of poverty decline is broadly outpaced by the rate of GDP growth, indicating that growth is not inclusive and inequality may be growing, though data is scarce; second, poverty declines are strongly centered in urban areas, with changes considerably slower in rural areas.[71] Rural areas face some of the most serious climate change threats, for instance a potential increase in ambient temperatures towards levels unsafe for outdoor laborers. As subsistence agriculture remains prevalent in Cambodia, and rates of undernourishment high, the threat of yield reductions in staple crops and the potentially high cost of adaptation also represent major risks. While climate change is only one of many pressures on livelihoods in the vicinity of the Tonle Sap Lake, the low adaptive capacity of rural communities in this area, particularly their limited ability to diversify income sources, demands attention[72]. Ultimately, research has shown that if increases in environmental stressors make traditional livelihoods less stable or tenable migration is likely to result.[73] Migration may take many forms: migration from rural to urban areas is already happening at a rapid pace, as is international migration (**Table 1**). Without adequate planning such migration can often lead to transfer or creation of new types of risk.

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[70] Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., Hyatt, O. (2016). Heat, human performance, and occupational health: A key issue for the assessment of global climate change impacts. Annual Review of Public Health: 37: 97–112. URL: https://www.ncbi.nlm.nih.gov/pubmed/26989826

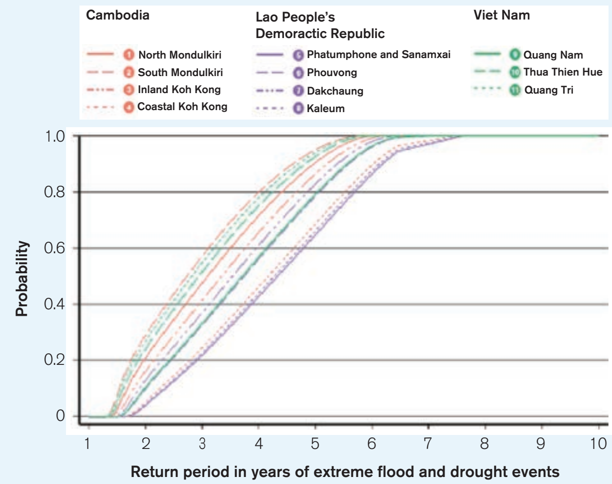
[71] ADB (2016). Measuring multidimensional poverty in three Southeast Asian countries using ordinal variables. ADBI Working Paper Series No. 618. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/214871/adbi-wp618.pdf

[72] Nuorteva, P., Keskinen, M., & Varis, O. (2010). Water, livelihoods and climate change adaptation in the Tonle Sap Lake area, Cambodia: Learning from the past to understand the future. Journal of Water and Climate Change, 1(1), 87–101. URL: https://research.aalto.fi/en/publications/water-livelihoods-and-climate-change-adaptation-in-the-tonle-sap-lake-area-cambodia-learning-from-the-past-to-understand-the-future(08b8d642-b3ea-41e4-9a20-d4db9265e67d)/export.html

[73] Bylander, M. (2015). Depending on the Sky: Environmental Distress, Migration, and Coping in Rural Cambodia. International Migration, 53(5), 135–147. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/imig.12087

Work by ADB (2017b) suggests that many households in Cambodia have a high probability of falling into extreme poverty even when exposed to relatively low intensity flood and drought events.[74] For example, an event at a frequency of once in every three years impacting in the four highly exposed communities analyzed by ADB (**Figure 14**) has approximately a 50% chance of pushing a household into extreme poverty. This highlights the precarious nature of life in Cambodia for many households even under current conditions. While many households will not have the same level of exposure, climate change threatens to enhance and expand exposure through its impacts on extreme events.

FIGURE 14. Probability of falling into extreme poverty by return period of combined flood and drought events (data from Cambodia, Vietnam and Laos from ADB, 2017b).[74]



Gender

An increasing body of research has shown that climate-related disasters have impacted human populations in many areas including agricultural production, food security, water management and public health. The level of impacts and coping strategies of populations depends heavily on their socio-economic status, socio-cultural norms, access to resources, poverty as well as gender. Research has also provided more evidence that the effects are not gender neutral, as women and children are among the highest risk groups. Key factors that account for the differences between women's and men's vulnerability to climate change risks include: gender-based differences in time use; access to assets and credit, treatment by formal institutions, which can constrain women's opportunities, limited access to policy discussions and decision making, and a lack of sex-disaggregated data for policy change.[75]

Human Health

Nutrition

As of 2019 an estimated 14.5% of the Cambodian population was undernourished.[76] The World Food Programme estimate that without adaptation the risk of hunger and child malnutrition on a global scale could increase by 20% respectively by 2050.[77] Work by Springmann et al. (2016) has assessed the potential for excess, climate-related deaths associated with malnutrition.[78] The authors identify two key risk factors that are expected to be the primary

[74] ADB (2017b). Risk financing for rural climate resilience in the greater Mekong subregion. Greater Mekong Subregion Core Environment Program. Asian Development Bank. P. 30. URL: https://www.adb.org/sites/default/files/publication/306796/risk-financing-rural-climate-resilience-gms.pdf

[75] World Bank Group (2016). Gender Equality, Poverty Reduction, and Inclusive Growth. URL: http://documents1.worldbank.org/curated/en/820851467992505410/pdf/102114-REVISED-PUBLIC-WBG-Gender-Strategy.pdf

[76] FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Transforming food systems for affordable healthy diets. FAO. Rome. URL: http://www.fao.org/documents/card/en/c/ca9692en/

[77] WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Programme. URL: https://docs.wfp.org/api/documents/WFP-0000009143/download/

[78] Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., . . . Scarborough, P. (2016). Global and regional health effects of future food production under climate change: a modelling study. The Lancet: 387: 1937–1946. URL: https://www.ncbi.nlm.nih.gov/pubmed/26947322

drivers: a lack of fruit and vegetables in diets, and health complications caused by increasing prevalence of people underweight. The authors' projections suggest there could be approximately 59.24 climate-related deaths per million population linked to lack of food availability in Cambodia by the year 2050 under RCP8.5. While Cambodia's health system has seen significant improvements in financing over the past two decades, improved investment for targeted care can be directed at universal health coverage, the rural poor and maternal and child health.[79]

Heat-Related Mortality

Research has placed a threshold of 35°C (wet bulb ambient air temperature) on the human body's ability to regulate temperature, beyond which even a very short period of exposure can present risk of serious ill-health and death.[80] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change is expected to push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves. Cambodia faces a very significant increase in the frequency of temperatures over 35°C under all emissions scenarios and these temperatures should be seen in the context of rapid urbanization and significant urban heat island effect further increasing temperatures.

Honda et al. (2014) used the A1B emissions scenario from CMIP3 (most comparable to RCP6.0) to show that without adaptation, annual heat-related deaths in the South-East Asian region, could increase 295% by 2030 and 691% by 2050.[81] Unfortunately data on the baseline level of heat-related mortality is not currently available. The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[82]

Disease

Climate change pressures, such as increased incidence of drought, extreme rainfall and flood, as well as higher temperatures, represent environmental drivers of vector and water-borne diseases. Disease transmission is known to be sensitive to temperature, as demonstrated by research into dengue fever incidence in Cambodia. Higher average, maximum, and minimum temperatures all correlate with greater dengue incidence.[83] Cambodia also has exposure to water-related diseases, such as diarrheal diseases, typhoid fever, leptospirosis, melioidosis, viral hepatitis, and schistosomiasis.[84] While human development in the Mekong Basin may act to regulate flows and

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[79] Asanta, A. et al., (2019). Who benefits form healthcare spending in Cambodia? Evidence for a universal health coverage policy. *Health Policy and Planning.* 34(Suppl 1):i4-i13. DOI: 10.1093/heapol/czz011

[80] Im, E. S., Pal, J. S., & Eltahir, E. A. B. (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Science Advances, 3(8), 1–8. URL: https://advances.sciencemag.org/content/3/8/e1603322.full

[81] Honda, Y., Kondo, M., McGregor, G., Kim, H., Guo, Y-L, Hijioka, Y., Yoshikawa, M., Oka, K., Takano, S., Hales, S., Sari Kovats, R. (2014). Heat-related mortality risk model for climate change impact projection. Environmental Health and Preventive Medicine 19: 56–63. URL: https://www.ncbi.nlm.nih.gov/pubmed/23928946

[82] Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6181199/

[83] Choi, Y., Tang, C. S., McIver, L., Hashizume, M., Chan, V., Abeyasinghe, R. R., . . . Huy, R. (2016). Effects of weather factors on dengue fever incidence and implications for interventions in Cambodia. BMC Public Health, 16(1), 1–7. URL: https://www.ncbi.nlm.nih.gov/pubmed/26955944

[84] McIver, L. J., Chan, V. S., Bowen, K. J., Iddings, S. N., Hero, K., & Raingsey, P. P. (2016). Review of Climate Change and Water-Related Diseases in Cambodia and Findings from Stakeholder Knowledge Assessments. Asia Pacific Journal of Public Health, 28(2_suppl), 49S–58S. URL: https://journals.sagepub.com/doi/abs/10.1177/1010539514558059

floods in Cambodia the climate change driver is likely to increase the intensity of flooding through its impact on precipitation extremes. Intense rainfall can trigger surface (pluvial) flooding, and in extreme cases can force dams to be opened or overtopped.[85] Disease transmission is known to worsen during and after flood events in Cambodia, demonstrated for example in the spread of diarrheal disease.[86]

Diarrheal disease is a significant health risk to children in Cambodia and represents around 6% of all under five deaths in Cambodia.[87] While overall deaths are projected to decline significantly, modelling by WHO estimates the change in the number of diarrheal deaths in under fifteen-year-olds attributable to climate change under the A1B scenario in the Southeast Asia region. Climate change is projected to increase the number of deaths in 2030 by around 3%–10% and by around 4%–14% in 2050.[88] These relationships highlight the need for both further research and adaptation initiatives in public health and other inter-related sectors.

POLICY AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 8. Key national adaptation policies, plans and agreements

Policy/Strategy/Plan	Status	Document Access
Nationally Determined Contribution to Paris Climate Agreement	Submitted	February, 2017
National Communication to the UNFCCC	Two submitted	Latest: January, 2016
Technology Needs Assessment and Technology Action Plans for Climate Change Adaptation	Completed	March, 2013
Strategic National Action Plan for Disaster Risk Reduction	Enacted	December, 2008
National Adaptation Program of Action to Climate Change (Napa)	Enacted	October, 2006

Climate Change Priorities of ADB and the WBG

ADB – Country Partnership Strategy

Cambodia's Country Partnership Strategy (2019–2023) with the Asian Development Bank will be delivered through four pillars. Climate change issues are addressed in Pillar 1: Accelerate competitiveness and economic diversification, and Pillar: Foster green, inclusive and sustainable development.

[85] Cambodia (2018). National Multisectoral Action Plan for the Prevention and Control of Noncommunicable http://moh.gov.kh/content/uploads/2017/05/NMAP-NCD_-13-06-2018-Signed_En.pdf Diseases (2018–2017). URL:
[86] Davies, G. I., McIver, L., Kim, Y., Hashizume, M., Iddings, S., & Chan, V. (2015). Water-borne diseases and extreme weather events in Cambodia: Review of impacts and implications of climate change. International Journal of Environmental Research and Public Health, 12(1), 191–213. URL: https://www.ncbi.nlm.nih.gov/pubmed/25546280
[87] UNICEF (2021). Data: Diarrhoeal Disease. URL: https://data.unicef.org/topic/child-health/diarrhoeal-disease/ [accessed 29/01/2019]
[88] WHO (2014). Quantitative risk assessment of the effects of climate change on selected causes of death, 2030s and 2050s. World Health Organization. URL: https://www.who.int/globalchange/publications/quantitative-risk-assessment/en/

Under Pillar 1, ADB will introduce innovative features such as climate and disaster risk resilient infrastructure and nature-based solutions to help create cities that are attractive to local and international businesses. ADB will also continue to invest in renewable energy and seek energy efficiency investments through grid extensions, including cross-border power imports.

Under Pillar 2, ADB will help the government develop a green and low-carbon growth pathway and achieve its NDC. ADB operations are designed to (i) promote sustainable management of natural resources, including along the Mekong River, the Tonle Sap Lake, and the national biodiversity conservation corridors linked to the GMS subregion; (ii) increase the share of renewable energy in the overall mix and promote energy efficiency; and (iii) advance policy dialogue and pricing incentives. ADB will also support the creation of a national water resources information center and strengthen the national climate and flood forecasting system by building on its current support for hydrometeorological systems. To promote the blue economy ADB will also invest in fisheries value chain development. Vulnerable communities will be made more aware of and resilient to disasters through ADB's operations in transport, agriculture, energy, water supply and sanitation and education sectors. ADB will continue to allocate grants and lending resources for disaster risk reduction, including flood risk.

WBG – Country Partnership Framework

Cambodia has a Country Partnership Framework (2019–2023) with the WBG. Climate change issues represent a cross-cutting theme and are addressed most explicitly under its third focus area, which looks to improve agriculture and strengthen sustainable use of natural resources. The CPF identifies a number of priority areas for the country's environmental challenges, including:

- Improved management and restoration of degraded land and water-based assets,
- Addressing emerging challenges in urban areas such as drainage and sewage systems, wastewater treatment, and solid waste management, and
- Investing in supporting infrastructure to maximize the sustainable economic contribution of natural wealth assets.

Building on Cambodia's NDC, Climate Change Strategic Plan (2014–23) and its National Adaptation Plan, the WBG support includes efforts encompassing both adaptation and mitigation, including exploring areas related to green climate funds. During the CPF period, the IFC will seek to expand successful regional green buildings and manufacturing resource efficiency efforts to Cambodia.

CLIMATE RISK COUNTRY PROFILE

CAMBODIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK