CLIMATE RISK COUNTRY PROFILE

THAILAND

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

- Observations show temperature increases across Thailand since the mid-20th century and an increase in annual precipitation. Most of this increase occurs during the wet season.
- By the 2090s, the average temperature is projected to increase by 0.95°C–3.23°C above the 1986–2005 baseline, with the rate of warming dependent on the emissions pathway.
- Projected temperature increases are strongest in the south, and in daily maximum and minimum temperatures.
- Floods are by far the greatest natural hazard facing Thailand in terms of economic and human impacts. Thailand is cited as one of the ten most flood-affected countries in the world. Drought and cyclone impacts also represent major hazards. All may intensify in future climate scenarios.
- The number of people affected by an extreme river flood could grow by over 2 million by 2035–2044, and coastal flooding could affect a further 2.4 million people by 2070–2100.
- Projections suggest that Thailand's agriculture sector could be significantly affected by a changing climate, due to its location in the tropics where agricultural productivity is particularly vulnerable to temperature rises.
- The combination of rising seas and sinking land, as well as potential cyclone-induced storm surge resulted from the climate change impact, place the country's capital Bangkok in a precarious position when the net, or relative, rate of sea-level rise. Large amounts of critical public and private infrastructure are in areas which are likely to be exposed under future climate change situation.
- The aftermath of devastating floods in 2011 provides an example of how climate change can adversely affect poorer people in Thailand, with studies showing that post-flood, higher income groups received more government compensation than lower income groups.
- The human impacts of climate change in Thailand remain dependent on the approach to adaptation adopted, but there is a significant risk that the poorest and marginalized groups will experience disproportionately greater loss and damage.

COUNTRY OVERVIEW

Thailand is the 20th most populous country in the world, located at the center of Southeast Asia with a land area of 513,120 km^2. Thailand is categorized into key areas: the northern region is hilly and mountainous, the northeast region is a high plain, with the central region as a large, low plain, the eastern region has valleys and small hills, with the western region being hilly and mountainous. The southern end of the country is a peninsula with the Andaman Sea to the west and Gulf of Thailand. Located in the tropical region, Thailand's climate is relatively warm all year round.[1]

By 2030, Thailand's population is projected to reach about 71–77 million, with an increasing proportion living in urban areas. Thailand's economy is 90% based on the industrial and service sector, with the agricultural sector accounting for only 10% (but 33% of the workforce).[2] The latter half of the 20th century witnessed significant economic growth

[1] Thailand (2018). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf

[2] CIA (2018). The World Factbook: Thailand. URL: https://www.cia.gov/library/publications/the-world-factbook/geos/th.html

of 7.5% a year between 1960 and 1996, such that Thailand is now considered a newly industrialized country. As a result, Thailand has reduced poverty significantly, improving the education and health circumstances for millions of its population. Economic growth has slowed in recent decades due to a number of national and global economic and political instabilities, and multidimensional poverty and undernourishment persist (**Table 1**).[3] The country has experienced slower average growth after the 1997 Asian financial crisis and 2008 global sub-prime crisis. Thailand has experienced negative growth due to the impacts form the COIVD-19 pandemic, which has adversely affected Thailand's small, open economy, its export and the country's tourism sector. To counter this, Thailand has placed emphasis on self-reliance and resilience to external factors in its economic planning.[1]

Thailand submitted its Third National Communication to the UNFCCC in 2018, its Initial Nationally Determined Contribution in 2016 and its Updated Nationally Determined Contribution in 2020. Thailand is recognized as highly vulnerable to climate variability and change due to increasing natural hazards, such as heavy rainfall, floods, and droughts, as well as sea level rise impacts the country's coasts. Thailand is focusing its adaptation efforts key sectors such as energy, water, transportation, agriculture, human settlements and public health.[4]

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[5]	9.3% (2017–2019)	FAO, 2020
National Poverty Rate[6]	9.9% (2018)	ADB, 2020
Share of Income Held by Bottom 20%[7]	7.2% (2018)	World Bank, 2019
Net Annual Migration Rate[8]	0.03% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[9]	0.8% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[10]	1.7% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[11]	42 (2020)	UNDESA, 2019
Urban Population as % of Total Population[12]	51.4% (2020)	CIA, 2020
External Debt Ratio to GNI[13]	35.1% (2018)	ADB, 2020
Government Expenditure Ratio to GDP[14]	20.5% (2019)	ADB, 2020

3 World Bank (2018). The World Bank in Thailand URL: https://www.worldbank.org/en/country/thailand/overview [accessed 12/12/2018]
4 Thailand (2018). Thailand's Third National Communication. Ministry of Natural Resources and Environment. URL: https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf
5 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/
6 ADB (2020). Basic Statistics 2020. URL: https://www.adb.org/publications/basic-statistics-2020 [accessed 27/01/21]
7 World Bank (2019). Income share held by lowest 20%. URL: https://data.worldbank.org/ [accessed 17/12/20]
8 UNDESA (2019). World Population Prospects 2019: MIGR/1URL: 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 (2020). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020
14 ADB (2020). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020

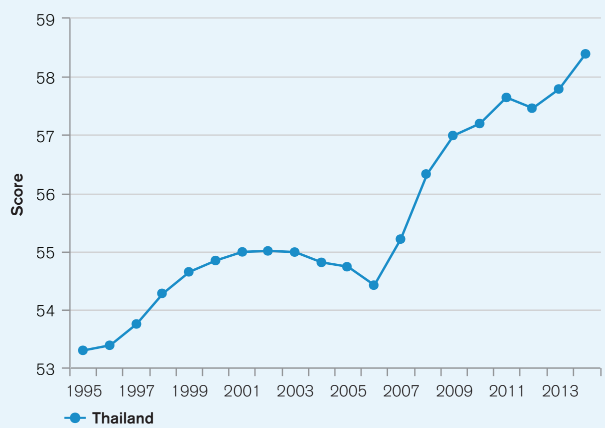
Green, Inclusive and Resilient Recovery

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 Thailand. 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 Thailand, 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.

Due to a combination of political, geographic, and social factors, Thailand is recognized as vulnerable to climate change impacts, ranked 62nd 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 Thailand'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.



[15] University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/

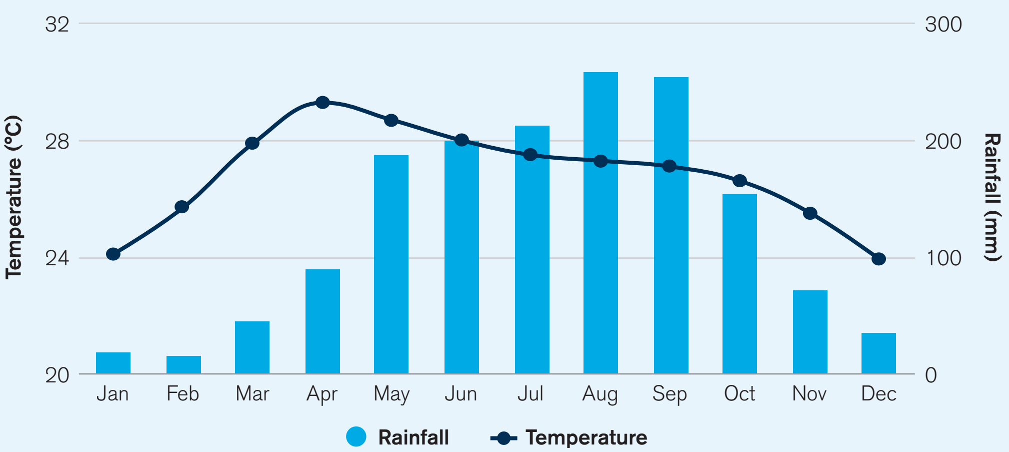
Climate Baseline

Overview

Thailand has a tropical climate influenced by seasonal monsoon winds. The southwest monsoon (May) brings a stream of warm moist air from the Indian Ocean towards Thailand, causing abundant rain over the country, especially the mountainous regions. This phenomenon is intensified by the Inter-Tropical Convergence Zone (ITCZ) in the months of May to October and tropical cyclones which produce large amounts of rainfall. The northeast monsoon, starting in October, brings cold and dry air from the anticyclone in China over major parts of Thailand, especially the northern and northeastern parts which are located at higher latitude areas. In the south, the monsoon causes mild weather and abundant rain along the eastern coast.[16] **Figure 2** provides an overview of Thailand's seasonal climate cycle, but hides sub-national variations, across the latest climatology, 1991–2020. Thailand's hottest months are April and May, with the coldest months experienced during December and January. The mean annual temperature is 26.3°C, with a seasonal temperature variation of 5.7°C (between lows of 23.2°C and highs of 28.9°C). The months with the highest rainfall are August and September, with approximately 255 mm recorded during these months. The months with the highest rainfall coincide with Thailand's monsoon season, May to October. Mean annual rainfall is 1,542 mm. **Figure 3** shows the spatial differences of observed historical temperature and rainfall in Thailand.

Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Thailand (1991–2020)[17]

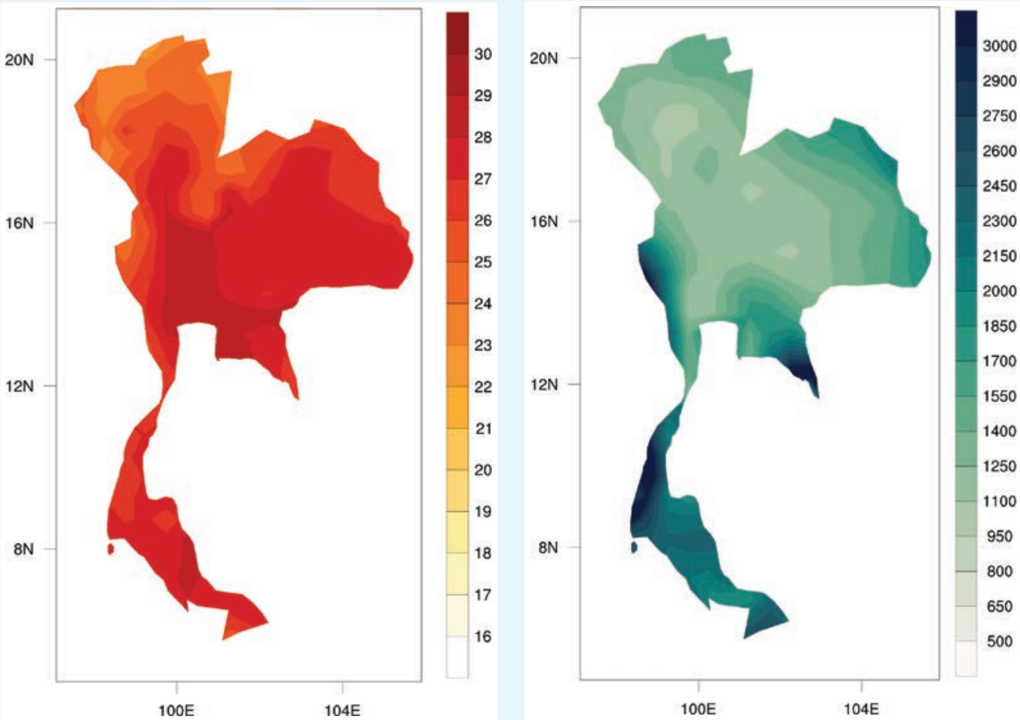


[16] Thailand (2018). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf

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

Spatial Variation

FIGURE 3. (Left) annual mean temperature (°C), and (right) annual mean rainfall (mm) in Thailand over the period 1991–2020.[18]



Key Trends

Temperature

Various studies report temperature increases across Thailand since mid-20th century. Manton et al. (2001) report a significant increase in minimum temperatures at meteorological stations located in Thailand between 1961–1998, as well as an increase in the number of warm nights.[19] Atsamon (2011) observed increases in daily maximum, mean and minimum temperatures at 65 meteorological stations between 1970–2006 (0.12–0.59°C, 0.10–0.40°C and 0.11–0.55°C per decade, respectively).[20]

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

[19] Manton, M.J. & Della-Marta, Paul & Haylock, M.R. & Hennessy, K & Nicholls, Neville & Chambers, Lynda & Collins, D.A. & Daw, G & Finet, A & Gunawan, Dodo & Inape, Kasis & Isobe, H & Kestin, T.S. & Lefale, Penehuro & Leyu, C.H. & Lwin, T & Maitrepierre, Luc & Ouprasitwong, N & Page, C.M. & Yee, D. (2001). Trends in extreme daily rainfall and temperature in Southeast Asia and The South Pacific: 1961–1998. International Journal of Climatology. 21. 269 - 284. URL: https://rmets.onlinelibrary.wiley.com/doi/10.1002/joc.610

[20] Limsakul, Atsamon & Limjirakan, Sangchan & Sriburi, Thavivongse & Boochub Suttamanuswong, and. (2011). Trends in Temperature and Its Extremes in Thailand. Thai Environmental Engineering Journal. 25. 9–16. URL: https://www.researchgate.net/publication/230692853_Trends_in_Temperature_and_Its_Extremes_in_Thailand

The Berkeley Earth dataset[21] provides historical temperature change estimates for 1° × 1° grid cells, and can be used to estimate warming over the 20th century. In general, it should be noted that estimates of warming over grid cells with larger proportions of ocean cover are less reliable, but also generally show less warming. Estimated warming around Bangkok between 1851 and 2017 (average) is 1°C. Observations show a warming of 1.4°C over the same period in the southern town of Nakhon Si Thammarat, while there was an observed increase of 1.2°C in the northern town of Lampang.

Precipitation

Studies observe an increase in annual precipitation, with an increase in precipitation during the wet season contributing most to this increase.[22] Variability of precipitation in Thailand over the 20th century was driven particularly by El Niño Southern Oscillation, with years of strong El Niño correlated with moderate and severe drought.[23] A 2016 study found that while precipitation events have been less frequent across the country, they have intensified.[24]

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.[25] Climate change projections associated with the highest emissions pathway (RCP8.5) are presented here to facilitate decision making which is robust to these risks.

Climate Future

Overview

The main data source for the World Bank Group's Climate Change Knowledge Portal (CCKP) is the Coupled Model Inter-comparison 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 where RCP2.6 represents a very strong mitigation scenario and RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database.

21 Carbon Brief (2018). Mapped: How every part of the world has warmed – and could continue to. Infographics, Berkeley Dataset. [26 September 2018]. URL: https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm

22 Lacombe, Guillaume & Hoanh, Chu & Smakhtin, Vladimir. (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. URL: https://wle.cgiar.org/multi-year-variability-or-unidirectional-trends-mapping-long-term-precipitation-and-temperature-0

23 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

24 Limsakul, A. and Singhruck, P. (2016). Long-term trends and variability of total and extreme precipitation in Thailand. *Atmospheric Research, 169*, pp. 301–317. URL: https://tdri.or.th/wp-content/uploads/2015/11/1-long-term-trends-main.pdf

25 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. URL: http://pure.iiasa.ac.at/id/eprint/15453/

For Thailand, these models show a trend of consistent warming, which will increase towards the end of the century. While rainfall projections are less certain and vary by both RCP scenario as well as models, projected precipitation trends show a likely slight increase in rainfall. **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 Thailand 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[26]

	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	1.0 (–0.6, 2.9)	1.1 (–0.6, 3.0)	1.0 (–0.3, 2.4)	1.1 (–0.2, 2.5)	1.0 (–0.1, 2.2)	1.1 (–0.2, 2.4)
RCP4.5	1.3 (–0.5, 3.3)	1.8 (0.0, 3.9)	1.4 (0.0, 2.8)	1.9 (0.4, 3.5)	1.4 (0.0, 2.7)	2.0 (0.6, 3.5)
RCP6.0	1.2 (–0.7, 3.0)	2.2 (0.4, 4.5)	1.2 (–0.4, 2.5)	2.3 (0.6, 4.1)	1.2 (–0.2, 2.4)	2.4 (0.7, 4.0)
RCP8.5	1.7 (0.0, 3.6)	3.6 (1.6, 6.1)	1.8 (0.4, 3.2)	3.8 (2.0, 5.8)	1.9 (0.5, 3.2)	3.9 (2.2, 5.9)

TABLE 3. Projections of average temperature change (°C) in Thailand 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 bracket[20]

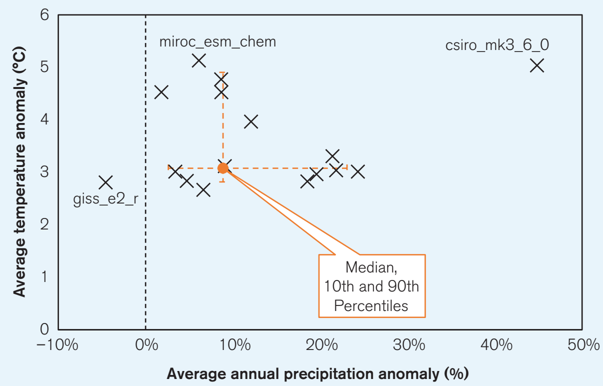
	2040–2059		2080–2099	
Scenario	**Jun–Aug**	**Dec–Feb**	**Jun–Aug**	**Dec–Feb**
RCP2.6	1.0 (0.2, 2.0)	1.0 (–0.6, 2.6)	1.0 (0.1, 2.0)	1.1 (–0.4, 2.6)
RCP4.5	1.4 (0.5, 2.5)	1.4 (–0.4, 2.8)	1.8 (0.9, 3.0)	1.9 (0.2, 3.7)
RCP6.0	1.2 (0.3, 2.3)	1.0 (–0.8, 2.2)	2.3 (1.2, 3.7)	2.1 (0.2, 4.0)
RCP8.5	1.6 (0.6, 2.8)	1.9 (0.1, 3.4)	3.5 (2.4, 5.4)	3.8 (1.4, 6.1)

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

Model Ensemble

Climate projections presented in this document are derived from datasets available through the CCKP, unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) (for further information see Flato et al., 2013).[27] 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. The range of projections from 16 GCMs for annual average temperature change and annual precipitation change in Thailand under RCP8.5 is shown in **Figure 4**. Spatial variation of future projections of annual temperature and precipitation for mid and late century under RCP8.5 are presented in **Figure 5**.

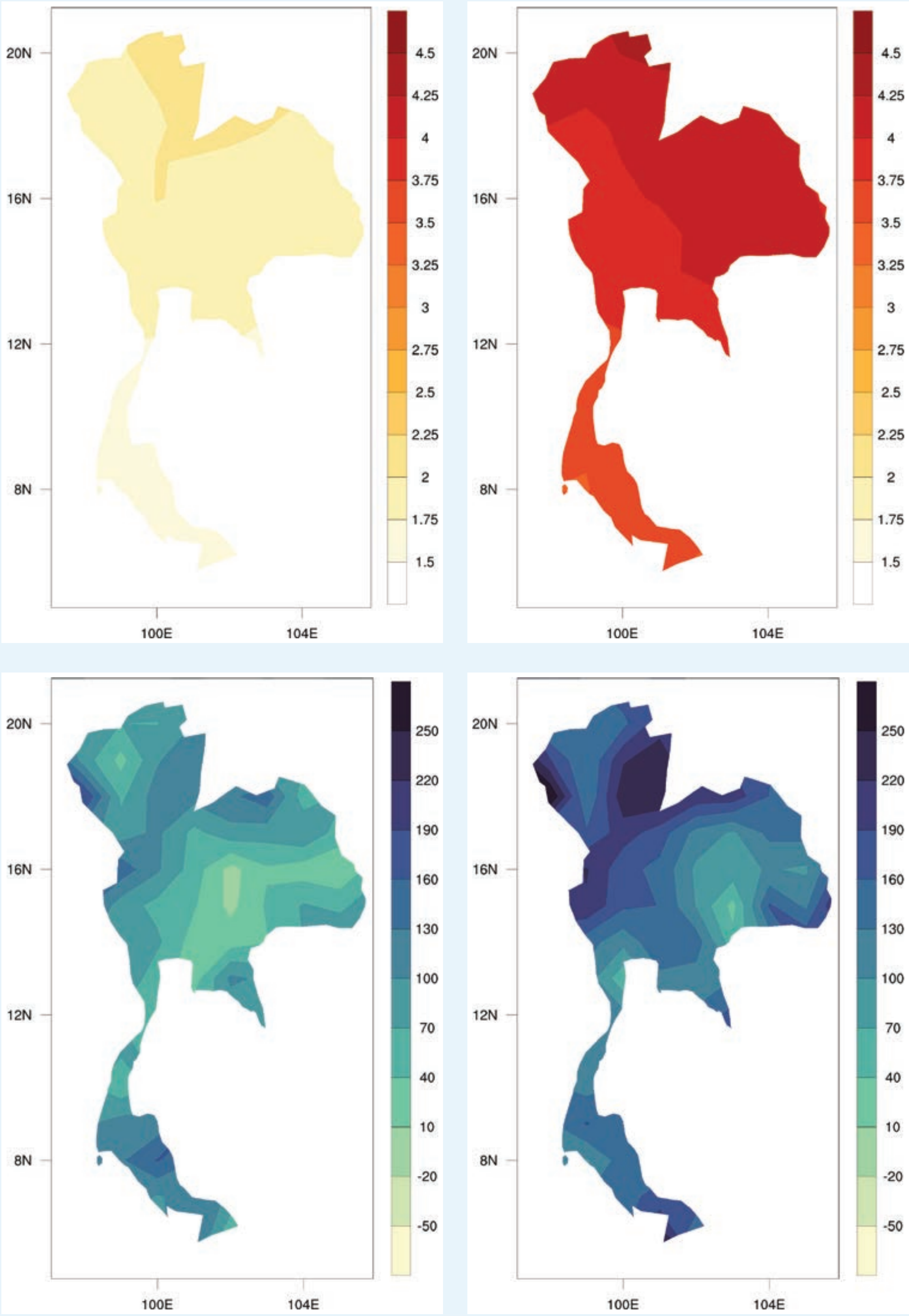
FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Thailand. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and therefore are most robust for comparison.[20] Three outlier models are labelled.



[27] 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: http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

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.[28]



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

Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes 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 as the viability of ecosystems, health impacts, productivity of labor, and the yield of crops, which are often disproportionately influenced by temperature extremes.

FIGURE 6. Historic and projected average annual temperature in Thailand under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble[29].

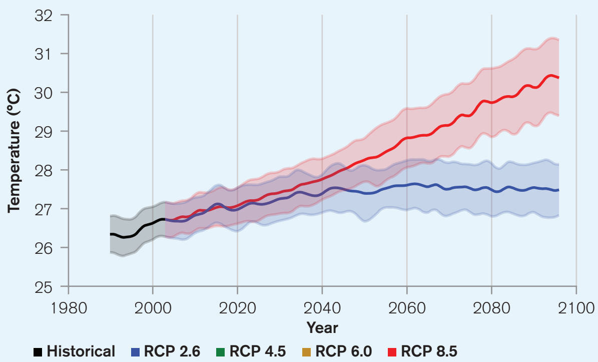
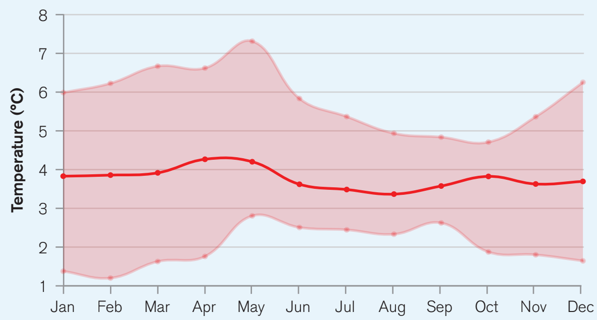


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Thailand for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles[23].



Under the RCP8.5 emissions pathway, average temperatures are projected to increase by 3.8°C by the 2080s, approximately 0.5°C less than the global average, and 1.1°C by the 2080s under the RCP2.6 emissions pathway, similar to the projected global average. Under all emissions scenarios, annual average of monthly maximum and monthly minimum temperatures are projected to increase considerably greater than projected increases in the average temperature (**Table 2**). For example, under RCP8.5 emissions pathway, by the 2090s annual average monthly maximum is projected at 3.8°C, minimum at 3.9°C compared to the annual average of 3.2°C.

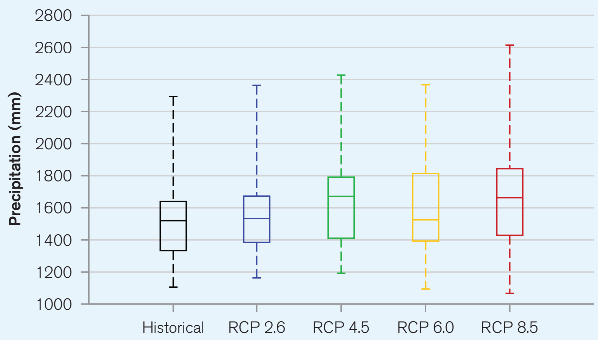
As shown in **Table 3** and **Figure 7**, there is relatively little seasonal variation in projected temperature rises, across all emissions pathways. What is evident in **Figure 7** is the high degree of uncertainty surrounding these projections.

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

Precipitation

A majority of the ensemble models project increases in annual precipitation rates (**Figure 4** and 8). However, uncertainty remains high as reflected in the range of model estimates, and in and between emissions pathways (**Figure 8**). This uncertainty is also seen in studies applying downscaling techniques to assess precipitation changes.[30] Downscaling studies in the upper Ping River Basin in the north of the country project rainfall extent and frequency to vary across the catchment, with wet days increasing in frequency and extent during the wet season for some areas, and in the dry season for the central areas of the catchment.[31] For the Bangkok region, one study suggests an increase in precipitation during the rainy season by 2100.[32] Downscaling studies in the upper Ping River Basin in the north of the country project rainfall extent and frequency to vary across the catchment, with wet days increasing in frequency and extent during the wet season for some areas, and in the dry season for the central areas of the catchment.

FIGURE 8. Boxplots showing the projected average annual precipitation for Thailand in the period 2080–2099[23].



The poor performance of global climate models in consistently projecting precipitation trends has been linked to their poor simulation of the El Niño phenomenon,[33,34] an important area for future development. While considerable uncertainty surrounds projections of local long-term future precipitation trends (see **Figure 8**) some global trends are evident. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature, a finding supported by evidence from different regions of Asia.[35]

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30 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: http://publications.cirad.fr/une_notice.php?dk=593587

31 Saengsawang, S., Pankhao, P., Kaprom, C. and Sriwongsitanon, N., 2017. Projections of future rainfall for the upper Ping River Basin using regression-based downscaling. *Advances in Climate Change Research, 8*(4), pp. 256–267. URL: https://www.sciencedirect.com/science/article/pii/S1674927817300084

32 Vu, M.T., Aribarg, T., Supratid, S., Raghavan, S.V. and Liong, S.Y., 2016. Statistical downscaling rainfall using artificial neural network: significantly wetter Bangkok?. *Theoretical and applied climatology, 126*(3–4), pp. 453–467. URL: https://www.tib.eu/en/search/id/BLSE%3ARN379732731/Statistical-downscaling-rainfall-using-artificial/

33 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: https://ui.adsabs.harvard.edu/abs/2016JGRD..121.3894Y/abstract

34 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/jcli/article/30/2/775/96236/ENSO-in-the-CMIP5-Simulations-Life-Cycles

35 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/full/10.1002/2014RG000464

Thailand faces high exposure to natural hazard risks and is ranked 81st out of 191 countries by the 2019 Inform Risk Index[36] (**Table 4**). Thailand has extremely high exposure to flooding (ranked 9th), including, riverine, flash, and coastal flooding. Thailand also has exposure to tropical cyclones and their associated hazards (ranked 27th). Drought exposure is also significant (ranked 29th). Thailand's overall ranking on the INFORM risk index is somewhat mitigated by its coping capacity and the levels of social vulnerability in its population, both of which are scored higher than most other countries in the region. The section which follows analyses climate change influences on the exposure component of risk in Thailand. The following section focuses on the climate change implications for the natural hazard exposure component of risk in Thailand. 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.

TABLE 4. Selected indicators from the INFORM 2019 index for risk management for Thailand. 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.

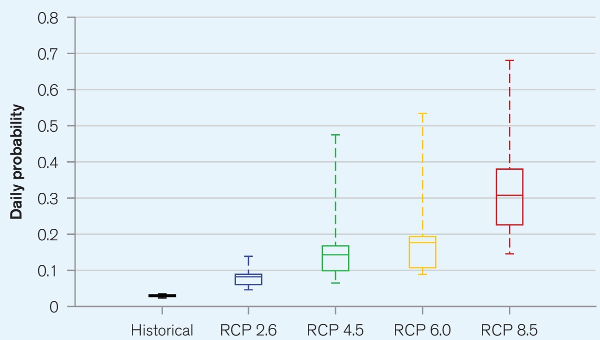
Flood (0–10)	Tropical Cyclone (0–10)	Drought (0–10)	Vulnerability (0–10)	Lack of Coping Capacity (0–10)	Overall Inform Risk Level (0–10)	Rank (1–191)
8.8 [4.5]	4.9 [1.7]	5.7 [3.2]	3.1 [3.6]	3.9 [4.5]	4.1 [3.8]	81

Heatwaves

Thailand regularly experiences high maximum temperatures, with an average monthly maximum of around 31.6°C and an average April maximum of 35.1°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%[23]. Under all emissions pathways, the likelihood of experiencing a heat wave increases considerably by 2080–2099, up to 18% under the RCP6.0 pathway and 31% under the RCP8.5 pathway (see **Figure 9**).

There is considerable spatial variation in projected likelihood of experiencing heatwave: in the southern areas of the country, the probability of heat wave per annum is as high as 73% by the 2090s (under RCP8.5

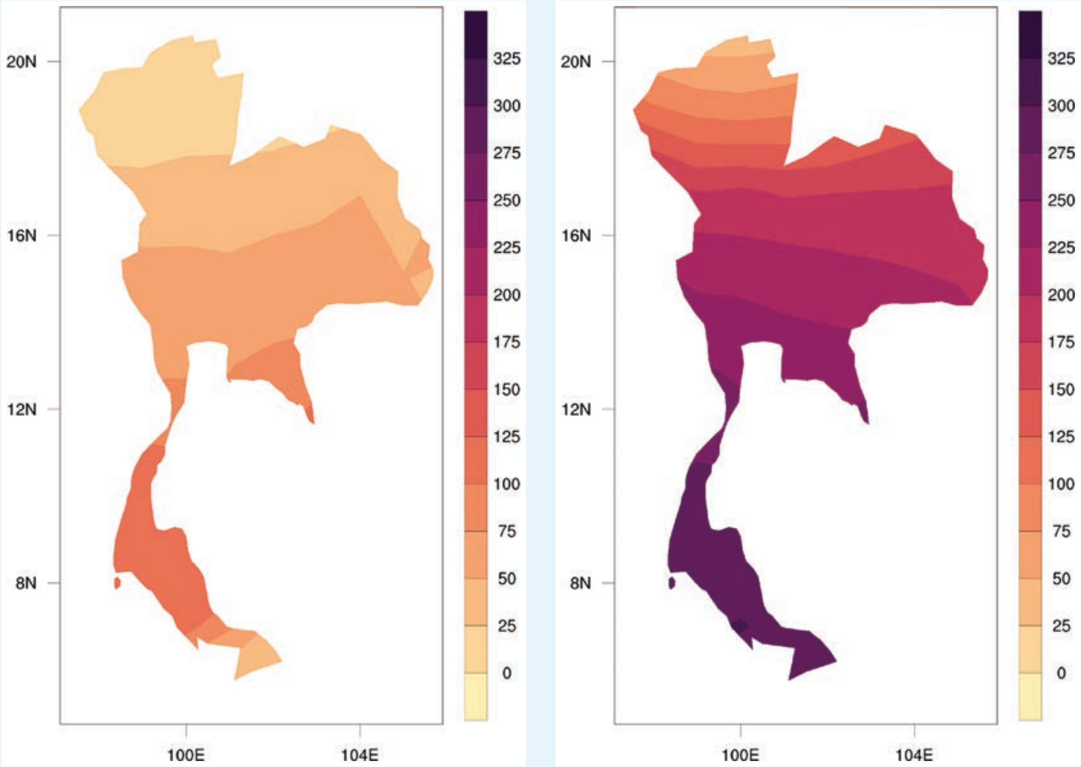
FIGURE 9. Projected changes in the probability of observing a heat wave in Thailand for the period 2080–2099. A 'Heat Wave' is defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature[23].



[36] European Commission (2019). INFORM Index for Risk Management. Thailand Country Profile. URL: https://drmkc.jrc.ec.europa.eu/inform-index/INFORM-Risk/Country-Profile/moduleId/1767/id/386/controller/Admin/action/CountryProfile

emissions pathway) but as low as 17% in the northern regions under the same scenario (**Figure 9**). However, these changes need to be interpreted with regard to the baseline (1986–2005) against which changes are measured. Historically stable environments, as found in many tropical regions (particularly Southern Thailand), will see more significant increases in heatwave simply due to long-term warming which moves ambient temperatures away from the baseline. Another measure of future heat-hazard risk is the number of days each year in which temperatures reach levels dangerous to human life. By the 2080s, Thailand is projected to experience very significant increases in the number of days in which Heat Index exceeds 35°C, particularly under higher emissions pathways (RCP6.0 and 8.5) (**Figure 10**).

FIGURE 10. Projected changes in the number of days with a Heat Index above 35°C by 2080–2099 under RCP8.5 emissions pathways.[20]



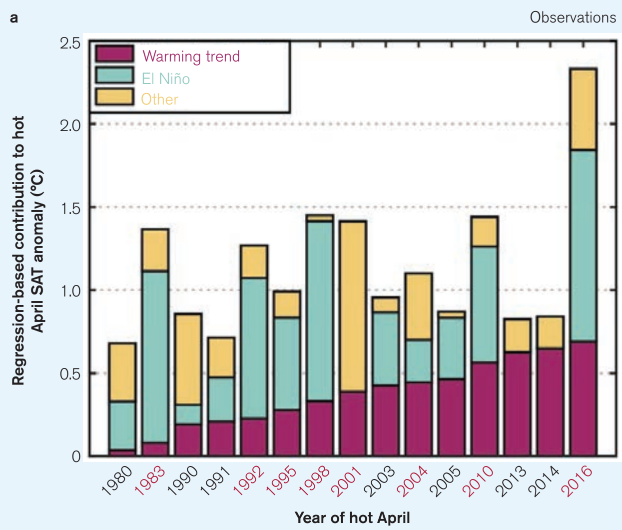
One study suggests climate change made a 29% contribution to the extreme temperatures experienced across Southeast Asia in April 2016, while ENSO contributed 49%.[37] The contribution of general global warming to extreme temperatures has been growing (**Figure 11**), while the contribution of climate change through its impact on the ENSO process is poorly understood.

[37] 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://www.nature.com/articles/ncomms15531

Drought

Two primary types of drought may affect Thailand, 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). Local soil and land management practices can also interact with the hydrological conditions to result in agricultural drought. At present Thailand faces an annual median probability of severe meteorological drought of around 4%[23], as defined by a standardized precipitation evaporation index (SPEI) of less than –2. This is projected to double by 2080–2099 under RCP6.0 and RCP8.5 emissions pathways, but uncertainty in the model estimates is high (see **Figure 12**).

FIGURE 11. Observations: The relative contribution of El Niño (green bars) versus the long-term warming trend (red bars) towards the 15 hottest April SATs (>80th percentile) in the GISTEMP record of Southeast Asia (MSA; 1940–2016) using a regression model. The residual of the observed anomaly and the regression fit is termed as 'other' variability (yellow bars). The years in red on the x-axis indicate the eight hottest extreme April events (>90th percentile), from Thirumalai et al. (2017)[30]



Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios. In comparison to West and Central Asia, South East Asia is less likely to experience extreme increases in drought intensity.[38] Nevertheless, it is likely to experience more prolonged periods of drought.[39] In Western Thailand, El Niño-related droughts have become more frequent and severe concurrently with increasing CO_2 levels and as such likely to increase under all RCP emissions pathways.[40] With increased drought conditions, as well as increases in temperature, Thailand is at risk from heightened air pollution, particularly for major urban areas. These conditions are also likely to increase the country's risk for forest fires, which will impact air quality, particularly for harmful particulate matter (PM2.5), population health and can impact revenue from the tourism sector.

[38] 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/10.1002/2017GL076521

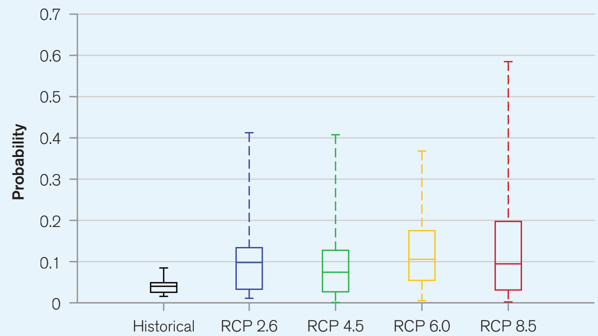
[39] Nock, Charles & Baker, Patrick & Wanek, Wolfgang & Leis, Albrecht & Grabner, Michael & Bunyavejchewin, Sarayudh & Hietz, Peter. (2011). Long-term increases in intrinsic water-use efficiency do not lead to increased stem growth in a tropical monsoon forest in Thailand. Global Change Biology. 17(2). pp1049-1063. URL: https://onlinelibrary.wiley.com/doi/full/10.1111/j.1365-2486.2010.02222.x

[40] Thailand (2018). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf

Flood

The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of flood exposure to large-scale river flooding. As of 2010, assuming protection for up to a 1 in 25-year event, the population annually affected by river flooding in Thailand is estimated at 1.1 million people and expected annual urban damage is estimated at $1.6 billion. Development and climate change are both likely to increase these figures. The climate change component can be isolated and by 2030 is expected to increase the annually affected population by 500,000 people, and urban damage by $6.9 billion under the RCP8.5 emissions pathway (AQUEDUCT Scenario B).[41]

FIGURE 12. Annual probability of experiencing a 'severe drought' in Thailand (–2 SPEI Index) in 2080–2099 under four emissions pathways[23].



Paltan et al. (2018) demonstrate that even under lower emissions pathways coherent with the Paris Climate Agreement almost all Asian countries face an increase in the frequency of extreme river flows. What would historically have been a 1 in 100-year flow, could become a 1 in 50-year or 1 in 25-year event in most of South, Southeast, and East Asia.[42] There is good agreement among models on this trend.

Floods are by far the major natural hazard facing Thailand in terms of frequency and damage – the country is cited as one of the ten most flood-affected in the world.[43] According to the UNISDR,[44] the average annual loss associated with flooding in Thailand is approximately US$2.6 billion, which represents almost 100% of losses associated with hazards. Studies suggest flooding incidence across the country are likely to increase as a result of climate change, with higher frequency of intense rainfall events contributing to irregular riverbank overflow, flash floods in urban areas and landslides and flash floods in mountain areas. Coastal areas are also likely to experience more flooding from sea-level rise (see The Coastal Zone section).[45,46]

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

42 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, 094003. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aad985/meta

43 Loo, Yen Yi & Billa, Lawal & Singh, Ajit. (2014). Effect of climate change on seasonal monsoon in Asia and its impact on the variability of monsoon rainfall in Southeast Asia. Geoscience Frontiers. 36 (6), 817–823. URL: https://www.sciencedirect.com/science/article/pii/S167498711400036X

44 UNISDR (2014). PreventionWeb: Basic country statistics and indicators. Available at: https://www.preventionweb.net/countries

45 Lebel, Louis & Manuta, Jesse & Garden, Po. (2010). Institutional traps and vulnerability to changes in climate and flood regimes in Thailand. Regional Environmental Change. 11. 45–58. URL: https://link.springer.com/article/10.1007/s10113-010-0118-4

46 Promchote, Parichart & Wang, Shih-Yu & Johnson, Paul. (2015). The 2011 Great Flood in Thailand: Climate Diagnostics and Implications from Climate Change. Journal of Climate. 29 (1) 367–379. URL: https://pdfs.semanticscholar.org/a47b/2acca30c2039169a040e4583a6cc7467078f.pdf

Willner et al. (2014)[47] suggest that the median increase in the population affected by an extreme (90th percentile) flood by 2035–2044 is approximately 2.3 million people (this estimation based on fixed present-day distribution of population) (see **Table 5**). This represents an increase of 258% from the population exposed to extreme flooding in 1971–2004.

TABLE 5. Estimated number of people in Thailand affected by an extreme river flood (extreme 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.[40]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	312,568	1,194,555	881,987
Median	886,335	3,177,190	2,290,855
83.3 Percentile	2,184,124	4,941,744	2,757,620

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 and increased intensity and frequency of the most extreme events.[48] 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.

Studies suggest that the frequency of extreme rainfall events (greater than 100mm in one day) are likely to become more commonplace as result of climate warming.[49] Thailand's Second National Communication to the UNFCC expects an increase in typhoons reaching Thailand between 2013 and 2043, while the number of monsoon storms are projected to stay relatively stable during the same time-period. Higher sea levels and wetter pre-monsoon conditions increase the risk of large-scale flooding, as experienced in 2011.[50]

[47] 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

[48] 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

[49] USAID (2014). Thailand Climate Change Vulnerability Profile. URL: http://cmsdata.iucn.org/downloads/thailand_country_profile___june2014_press.pdf

[50] Promchote, P., Wang, S.Y.S. and Johnson, P.G. (2016). The 2011 great flood in Thailand: Climate diagnostics and implications from climate change. *Journal of Climate, 29*(1), pp. 367–379. URL: https://journals.ametsoc.org/jcli/article/29/1/367/35049/The-2011-Great-Flood-in-Thailand-Climate

Natural Resources

Water

Thailand's NC2 describes the country's water resources: 25 watershed areas, 6.4 million hectares irrigated, 14.6 million hectares rain-fed, with approximately a quarter of its 800 billion m^3/year rainfall becoming utilizable surface water and a total water storage capability of 74 billion cum., of which 90% is made of large and medium-sized reservoirs. It is predicted water demand could rise to 120 billion m^3/year as a result of population and economic growth, threatening socio-economic development.[1]

Two river systems account for most water flows over Thailand's land surface: namely the Mekong River in the east, and Chao Phraya in the north and central regions. Both systems have been significantly influenced by human development impacts on land cover. Issues such as deforestation and agricultural intensification have reduced water retention and increased flood potential. Under climate change, most studies suggest flow volumes are likely to increase under most emissions pathways and time horizons. One study showed a particularly large increase (>20%) in runoff in the central province of Nakhon Sawan.[51] The net change in runoff from the northeastern region of Thailand which feeds the Mekong River is less clear, with models disagreeing on the direction of change. However, there is convincing evidence that peak flows could increase, by 5–10% by 2036–2065.[52] Future flows in the Mekong River are also likely to be affected by the operation of hydropower dams.[53]

While overall annual precipitation is projected to increase, rainfall during some periods may decrease, such as between September and October. This, alongside a less stable runoff regime, may have consequences for rice agriculture, increasing water stress and requiring greater irrigated water requirements[54] (see Agriculture section).

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 0.44–0.74m by the end of the 21st century by the IPCC's Fifth Assessment Report but some studies published more recently have highlighted the potential for greater rises (**Table 6**).[55]

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51 Kotsuki, S., Tanaka, K., & Watanabe, S. (2014). Projected hydrological changes and their consistency under future climate in the Chao Phraya River Basin using multi-model and multi-scenario of CMIP5 dataset. Hydrological Research Letters, 8(1), 27–32. URL: https://www.jstage.jst.go.jp/article/hrl/8/1/8_27/_article

52 Hoang, L. P., Lauri, H., Kummu, M., Koponen, J., Vliet, M. T. H. Van, Supit, I., . . . Ludwig, F. (2016). Mekong River flow and hydrological extremes under climate change. Hydrology and Earth System Sciences, 20, 3027–3041. URL: https://hess.copernicus.org/articles/20/3027/2016/

53 Räsänen, T.A., Someth, P., Lauri, H., Koponen, J., Sarkkula, J. and Kummu, M. (2017). Observed river discharge changes due to hydropower operations in the Upper Mekong Basin. *Journal of hydrology, 545*, pp. 28–41. URL: https://research.aalto.fi/en/publications/observed-river-discharge-changes-due-to-hydropower-operations-in-

54 Boonwichai, Siriwat & Shrestha, Sangam & Babel, Mukand & Weesakul, Sutat & Datta, Avishek. (2018). Climate change impacts on irrigation water requirement, crop water productivity and rice yield in the Songkhram River Basin, Thailand. Journal of Cleaner Production. 198, 1–1652. URL: https://www.x-mol.com/paper/744044?recommend

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

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 Le Bars et al. 2017.[56]

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)

Thailand's First Biennial Update Report describes how coastal inundation and seawater intrusion are likely to increase as a result of climate change, however specific studies are limited.[57] Studies have explored the impacts of extreme land subsidence on sea levels along Thailand's coast.[58] A 2013 study found relative sea level rise in the Gulf of Thailand ranging from 1.4–12.7mm/year between 1985 and 2009 and that the largest contribution to this rise was land subsidence at the river mouths.[59] A combination of rising seas and sinking land, as well as potential cyclone-induced storm surge, place the country's capital Bangkok in a precarious position when the net, or relative, rate of sea-level rise is considered.[60] Land loss from sea-level rise will also affect sustainable land use for economic activities in the tourism, import and export sectors and industrial zones. Large amounts of critical public infrastructure is located in areas which are likely to be exposed under future climate change scenarios.[61]

As shown in **Table 7**, under the RCP8.5 emissions pathway, by 2070–2100, up to 2.5 million people in Thailand are potentially exposed to flooding from sea-level rise. However, with investment in effective adaptation, including balancing of trade-offs between hard infrastructural approaches (e.g. dykes and sea-walls) and nature-based approaches (e.g. habitat restoration), this number may be very significantly reduced.

56 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

57 Thailand (2018). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Thailand%20TNC.pdf

58 Saramul, S. and Ezer, T., 2014. Spatial variations of sea level along the coast of Thailand: Impacts of extreme land subsidence, earthquakes and the seasonal monsoon. *Global and Planetary Change, 122*, pp. 70–81. URL: http://www.ccpo.odu.edu/~tezer/PAPERS/2014_GPC_GOT_SeaLev.pdf

59 Sojisuporn, Pramot & Sangmanee, Charmrat & Wattayakorn, Gullaya. (2013). Recent estimate of sea-level rise in the Gulf of Thailand. Maejo International Journal of Science and Technology. 7. 106–113. URL: https://www.researchgate.net/publication/260166201_Recent_estimate_of_sea-level_rise_in_the_Gulf_of_Thailand

60 Fuchs, Roland & Mostafanezhad, Mary & Louis, Elizabeth. (2011). Climate Change and Asia's Coastal Urban Cities. Environment and Urbanization Asia. 2. 13–28. https://doi.org/10.1177%2F097542531000200103

61 Duangyiwa, C., Yu, D., Wilby, R., Aobpaet, A. (2015) Coastal Flood Risks in the Bangkok Metropolitan Region, Thailand: Combined Impacts of Land Subsidence, Sea Level Rise and Storm Surge. AGU Fall Meeting, San Francisco, 14th–18th December 2015. URL: https://ui.adsabs.harvard.edu/abs/2015AGUFMNH33C1927D/abstract

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 Thailand.[62]

Scenario	Without Adaptation	With Adaptation
RCP2.6	491,270	570
RCP8.5	2,451,250	1,370

Land and Soil

Thailand's NC2 describes 'problematic land' which impacts land designated as agricultural, with over half of this land possessing saline, sandy, shallow or acidic soils (see **Table 8**). Having low productivity, these soils have reduced ecological resilience to climate change, and limit options when looking to adapt to a changing climate[1]. Increasing temperatures and possible (though uncertain) increases in drought incidence, may drive desertification, but land-use and land management practices, particularly agricultural intensification,[63] remain the dominant process contributing to land degradation in Thailand.[64] Historical deforestation[65] has also exposed Thailand's soils to erosion and degradation and ultimately impacted negatively on biodiversity.[66]

TABLE 8. Land with problematic soils in Thailand, 2004. Source: Thailand's second national communication

Problematic Land	Area (HA)
1. Saline Soils	721,920
2. Sandy Soils	2,043,173
3. Shallow Soils	6,938,499
4. Acid Sulfate Soils	881,623
5. Organic Soils	42,456
6. Slope Complex	15,361,117
7. Acid Soils	15,749,199

[62] 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

[63] Bruun, T. B., de Neergaard, A., Burup, M. L., Hepp, C. M., Larsen, M. N., Abel, C., . . . Mertz, O. (2017). Intensification of Upland Agriculture in Thailand: Development or Degradation? Land Degradation & Development, 28(1), 83–94. URL: https://onlinelibrary.wiley.com/doi/full/10.1002/ldr.2596

[64] Wijitkosum, S. (2016). The impact of land use and spatial changes on desertification risk in degraded areas in Thailand. Sustainable Environment Research, 26(2), 84–92. URL: https://www.sciencedirect.com/science/article/pii/S246820391630019X

[65] Leinenkugel, P., Wolters, M. L., Oppelt, N., & Kuenzer, C. (2015). Tree cover and forest cover dynamics in the Mekong Basin from 2001 to 2011. Remote Sensing of Environment, 158, 376–392. URL: https://www.sciencedirect.com/science/article/pii/S0034425714004313

[66] Akber, M. A., & Shrestha, R. P. (2015). Land use change and its effect on biodiversity in Chiang Rai province of Thailand. Journal of Land Use Science, 10(1), 108–128. URL: https://www.tandfonline.com/doi/abs/10.1080/1747423x.2013.807315

Economic Sectors

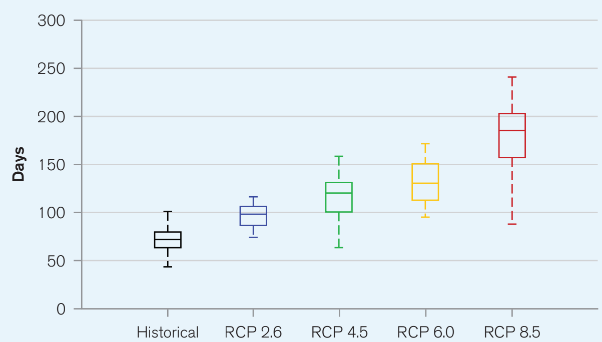
Agriculture

Climate change may 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.[67] 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.

Projections suggest that Thailand's agriculture sector could be significantly affected from a changing climate, due to its location in the tropics where agricultural productivity is particularly vulnerable.[68] Boonwichai (2018) found that decreases in rainfall during rice productive phase (September and October) and increases in temperature could influence rice yield. Their study projects rain-fed rice yields to reduce 10% by 2080 under RCP 8.5 emissions pathway and crop water productivity reducing 29% by 2080 under the same emissions pathway.[47] Other work suggests that Thailand could experience a 5.3% decrease in rice yield by 2041–2050 compared to the 1991–2000 baseline under the RCP 4.5 emissions pathway and a 6.1% decrease for the same time period under the RCP 8.5 emissions pathway.[69]

Increased temperatures, which result in more very hot (>35°C) days, indeed a potential 160% rise in the number of very hot days by 2080–2099 under the highest emissions pathways (**Figure 13**), are projected to have detrimental impacts on agricultural productivity. Increasing temperatures could affect other key agricultural products, such as lychee in the north, which is vulnerable to temperature change as witnessed in December 2009, where above average temperatures saw lychee crop productivity fall by more than half.[42] The impacts on agriculture are projected to have regional variation: western, north-central and north-western areas are likely to suffer less negative impacts compared to eastern, south-central

FIGURE 13. Climate model ensemble estimate of the annual number of very hot (Tmax >35°C) days in 2080–2099 under four emissions pathways in Thailand[23]



[67] 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

[68] Hughes, J. (2007). The Impact of Climate Change on Tropical Agriculture. ICRISAT, 4(1). URL: https://www.omicsonline.org/open-access/review-on-impacts-of-climate-change-on-vegetable-production-and-its-management-practices-2329-8863-1000330-99188.html

[69] 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

and north-eastern areas.[70] When placed in a global context, aggregate agriculture production in Southeast Asian countries are projected to suffer a greater decline than most other regions.[71]

Urban and Energy

Research has established a reasonably well constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[72] 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 Urban Heat Island (UHI). Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[73] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C–3°C in global mega-cities.[74] As well as impacting human health, the temperature peaks that result from combined UHI and climate change, as well as future urban expansion, are likely to damage the productivity of the service sector economy, both through direct impacts on labor productivity, but also through the additional costs of adaptation. Studies have shown the presence of an UHI in Bangkok and how it is intensifying. Indeed, the UHI severity is higher compared to other cities considered to have UHI problems such as Shanghai and San Diego, with average annual temperatures 0.8°C higher than surrounding areas between 2008–2012.[75]

Research suggests that on average a one degree rise in ambient temperature can result in a 0.5%–8.5% increase in electricity demand.[76] 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.[77]

[70] Attavanich, Witsanu (2013): The Effect of Climate Change on Thailand's Agriculture. Published in: 7th International Academic Conference Proceedings No. ISBN: 978-80-905241-7-0: pp. 23–40. URL: https://mpra.ub.uni-muenchen.de/84005/

[71] Kurukulasuriya, Pradeep & Rosenthal, Shane. (2003). Climate Change and Agriculture: A Review of Impacts and Adaptations. Climate Change Series 91. Environment Department Papers, World Bank, Washington, D.C. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/16616/787390WP0Clima0ure0377348B00PUBLIC0.pdf?sequence=1&isAllowed=y

[72] 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

[73] 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.nature.com/articles/ncomms12509

[74] Zhou, D., Zhao, S., Liu, S., Zhang, L., & Zhu, C. (2014). Surface urban heat island in China's 32 major cities: Spatial patterns and drivers. Remote Sensing of Environment, 152, 51–61. URL: https://chunxxu.github.io/zhaolab/assets/paper/201405.pdf

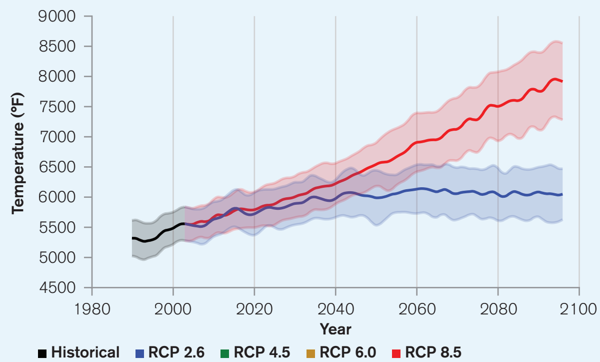
[75] Arifwidodo, Sigit & Tanaka, Takahiro. (2015). The Characteristics of Urban Heat Island in Bangkok, Thailand. Procedia – Social and Behavioral Sciences, 195, 423–428. URL: https://www.sciencedirect.com/science/article/pii/S1877042815039634

[76] 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://www.sciencedirect.com/science/article/abs/pii/S0378778814007907

[77] ADB (2017). Climate Change Profile of Pakistan. Asian Development Bank. URL: https://www.adb.org/publications/climate-change-profile-pakistan

With average summer temperatures projected to rise throughout Thailand's urban areas, particularly at the levels projected by higher emissions pathways, there is a major risk to human and ecosystem health, as well as economic productivity. As shown in **Figure 14** a substantial increase in the amount of building cooling required is projected, placing demands either on energy systems or on health systems depending on the efficacy of the response. Infrastructure will likely come under pressure, both from temperatures and the increased risk of riverine (fluvial) and surface water (pluvial) flooding.

FIGURE 14. Historic and projected annual cooling degree days in Thailand (cumulative degrees above 65°F) under RCP2.6 (blue) and RCP8.5 (red). The values shown represent the median of 30+ GCM model ensemble with the shaded areas showing the 10–90th percentiles[23].



Communities

Poverty, Inequality, and Disaster Vulnerability

Many of the climate changes projected are likely to disproportionately affect the poorest groups in society. Vulnerability to climate change is differentiated across social groups, the result of embedded inequalities and uneven power structures.[78] 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.[79] 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.[80] Poor people are less able to invest in prevention and mitigation against adverse effects of environment change and natural hazards.[81] Studies have also shown that Thailand's richer households are more likely to engage in adaptation activities in advance of disaster than poorer counterparts.[82] The aftermath of 2011's devastating flood provides an example of how climate change can adversely affect poorer people in Thailand. Post-flood, higher income groups received more government compensation than lower income groups, 500 Bahts compared to 200 Bahts.

[78] Plan International. (2018). Climate change, young women and girls: vulnerability, impacts and adaptations in northern Thailand. URL: https://plan-international.org/publication/climate-change-girls-thailand

[79] 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://pubmed.ncbi.nlm.nih.gov/26989826/

[80] Hallegatte, Stéphane & Fay, Marianne & Barbier, Edward. (2018). Poverty and climate change: Introduction. Environment and Development Economics. 23. 217–233. URL: https://agris.fao.org/agris-search/search.do?recordID=US202000034159

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[82] Hallegatte, Stéphane & Bangalore, Mook & Bonzanigo, Laura & Fay, Marianne & kane, tamaro & narloch, ulf & Rozenberg, Julie & Treguer, David & Vogt-Schilb, Adrien. (2015). Shock Waves: Managing the Impacts of Climate Change on Poverty. URL: https://openknowledge.worldbank.org/handle/10986/22787

Thailand is one of the most flood-prone countries in the world. As mentioned above, flooding accounts for nearly 100% of average annual loss associated with hazards. However, according to the UNISDR, in terms of mortality and loss of life, earthquakes pose a more significant (non-climate related) risk.[83] In 2011, a record-breaking flood caused widespread destruction and served as example of the country's vulnerability to climate-related disaster. The flood, the result of an exceptionally heavy monsoon season and the landfall of Tropical Storm Nock-ten, caused 815 deaths, affected 13.6 million people and damaged 20,000 km^2 of farmland. Economically, the flood led to $45 billion of damages and resulted in the most expensive insurance loss ever recorded in global history from a flood at $15 billion.[36,84] This flood also had significant impacts on global supply chains.[85] Disasters are made more likely by the persistence of multidimensional poverty and malnourishment (**Table 1**). As is often the case, marginalized groups, including ethnic minorities, remote communities, and the disabled, are typically the most vulnerable to natural hazards in Thailand[86], and key determinants of resilience are assets, and diversified income sources.[87]

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.[88]

Human Health

Nutrition

The World Food Programme estimate that without adaptation the risk of hunger and child malnutrition on a global scale could increase by 20% by 2050[89]. Springmann et al. (2016) assessed the potential for excess, climate-related deaths associated with malnutrition[90]. The authors identify two key risk factors that are expected to be the

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83 UNISDR (2014). PreventionWeb: Basic country statistics and indicators. URL: https://www.preventionweb.net/countries [accessed 14/08/2018]

84 Zbigniew W. Kundzewicz, Shinjiro Kanae, Sonia I. Seneviratne, John Handmer, Neville Nicholls, Pascal Peduzzi, Reinhard Mechler, Laurens M. Bouwer, Nigel Arnell, Katharine Mach, Robert Muir-Wood, G. Robert Brakenridge, Wolfgang Kron, Gerardo Benito, Yasushi Honda, Kiyoshi Takahashi & Boris Sherstyukov (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

85 Haraguchi, M. and Lall, U. 2015. Flood risks and impacts: A case study of Thailand's floods in 2011 and research questions for supply chain decision making. *International Journal of Disaster Risk Reduction*, 14, 256–272. URL: https://trid.trb.org/view/1377177

86 Lebel, L., Manuta, J. B., & Garden, P. (2011). Institutional traps and vulnerability to changes in climate and flood regimes in Thailand. Regional Environmental Change, 11(1), 45–58. URL: https://link.springer.com/article/10.1007/s10113-010-0118-4

87 Willroth, P., Revilla Diez, J., & Arunotai, N. (2011). Modelling the economic vulnerability of households in the Phang-Nga Province (Thailand) to natural disasters. Natural Hazards, 58(2), 753–769. URL: https://link.springer.com/article/10.1007/s11069-010-9635-1

88 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

89 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/

90 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://pubmed.ncbi.nlm.nih.gov/26947322/

primary 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 44.68 climate-related deaths per million population linked to lack of food availability in Thailand by the year 2050 under RCP8.5.

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.[91] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change will push global temperatures more towards the temperature 'danger zone' both through slow-onset warming and intensified heat waves. Bangkok already faces potentially lethal combinations of high temperatures and humidity on approximately 8 days per year.[92]

Honda et al. (2014), which utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0), estimates that without adaptation, annual heat-related deaths in the South-Eastern Asian region, could increase 295% by 2030 and 691% by 2050.[93] Under the RCP8.5 emissions pathway, heat-related deaths for 65+ year-olds are projected to increase considerably by 2080, from a baseline of 3 per 100,000 in 1961–1990 to 58 per 100,000.[94] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[95]

Disease

Climate change projections suggest a rise in infectious and vector-borne diseases in Thailand.[81] Thailand's Initial National Communication conducted the first study on climate change impacts on health in Thailand, exploring the relationship between temperature and mosquito growth rate. It found that increased temperatures could contribute to the greater spread of malaria by 2050. However, further research on the relationship of malaria and dengue diseases with climate factors has not established clear relationships and requires further study.[1] Hydrological changes may also enhance disease transmission in Thailand. Relationships between flood, drought and diarrheal disease have been established,[96] as has a relationship between flood and leptospirosis[97].

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[91] 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

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[94] World Health Organisation (2015) Climate And Health Country Profile – 2015, Thailand. URL: http://www.searo.who.int/thailand/areas/phe-country-profile-thailand.pdf

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[97] Lau, C. L., Smythe, L. D., Craig, S. B., & Weinstein, P. (2010). Climate change, flooding, urbanisation and leptospirosis: Fuelling the fire? Transactions of the Royal Society of Tropical Medicine and Hygiene, 104(10), 631–638. URL: https://pubmed.ncbi.nlm.nih.gov/20813388/

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 9. Key national adaptation policies, plans and agreements

Policy/Strategy/Plan	Status	Document Access
National Communications to the UNFCCC	Three submitted	Latest: August, 2018
Nationally Determined Contribution (NDC) to Paris Climate Agreement	Submitted	September, 2016
National Disaster Risk Management Plan	Enacted	March, 2015
Technology Needs Assessments (TNA) Report for Climate Change	Completed	July, 2012
12th National Economic and Social Development Plan (NESDP)	Enacted	2017
National Adaptation Plan (2018–2037)	Under Development	
Climate Change Master Plan (2015–2050)	Approved	July, 2016
Energy Efficiency Plan 2015		2011
Power Development Plan 2015	Enacted	2015
Alternative Energy Development Plan 2015	Enacted	2015
Natural Water Resources Management Strategies (2015–2026)	Enacted	2015
Master Plan for Integrated Biodiversity Management B.E. 2558–2564 (2015–2021	Enacted	2015
Transport Infrastructure Development Plan (2015–2022)	Enacted	2015
4th National Strategic Plan on Chemical Management (2012–2021)	Enacted	March, 2012
Bangkok Climate Change Master Plan 2013–2023	Enacted	2012

Climate Change Priorities of ADB and the WBG

ADB – Country Partnership Strategy

ADB's most recent Country Partnership Strategy (CPS) with Thailand ran between 2013–2016. The strategy included issues of environmental sustainability as a core focus, stating that ADB will support the government's environmentally sustainable development and green economy agenda by (i) helping to strengthen community-based integrated water and flood risk management projects; (ii) providing non sovereign investments in renewable energy and energy efficiency projects; (iii) conducting a study on green city development in the southern city of Songkhla; (iv) strengthening management of biodiversity conservation corridors; (v) pilot testing energy-saving technologies and the reduction of carbon emissions; and (vi) assisting in drawing on climate change funds and other financing modalities.[98]

ADB and the Government of Thailand implements a Country Operations Business Plan (2019–2021) to serve as a bridge between the current CPS and the forthcoming CPS planned for 2020–2024.

[98] ADB (2013). Country Partnership Strategy, Thailand 2013–2016. URL: https://www.adb.org/sites/default/files/institutional-document/33990/files/cps-tha-2013-2016.pdf

WBG – Country Partnership Framework

The World Bank Group have agreed a Country Partnership Framework (CPF) with Thailand covering the period 2019–2022. The Framework contains two focus areas, the first of which 'promoting resilient and sustainable growth' includes six objectives. Objective 4 aims to address climate change and improve water resource management. Specifically, under this objective. the WBG will partner with Thailand to develop resilience against floods and droughts in the face of climate change, and promote sustainable and equitable economic development.[99]

[99] WBG (2019). Thailand – World Bank Group Country Partnership Framework 2019–2022. URL: https://elibrary.worldbank.org/doi/abs/10.1596/30977

CLIMATE RISK COUNTRY PROFILE

THAILAND

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK