CLIMATE RISK COUNTRY PROFILE

VIETNAM

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

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Graphic Design: Circle Graphics, Reisterstown, MD.

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 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.

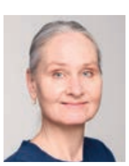
For the World Bank Group: a key aspect of the World Bank Group's Action Plan on Adaptation and Resilience (2019) is to help countries shift from addressing adaptation as an incremental cost and isolated investment to systematically incorporating climate risks and opportunities at every phase of policy 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: 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

- Projected temperature increases in Vietnam are similar to the global average, ranging between 1.0°C and 3.4°C by 2080–2099 when compared with the 1986–2005 baseline. The range in possible temperature rises highlights the significant differences between 21st century emissions pathways.
- Rises in annual maximum and minimum temperatures are expected to be stronger than the rise in average temperature, likely amplifying the impacts on human health, livelihoods, and ecosystems.
- There is considerable uncertainty around future precipitation trends and the intensity of extreme events, in particular due to the current generation of climate models' poor performance simulating the El Niño Southern Oscillation (ENSO).
- Vietnam's low-lying coastal and river delta regions have very high vulnerability to rising sea-levels. Depending on the emissions pathway 6–12 million people will potentially be affected by coastal flooding by 2070–2100 without effective adaptation action.
- Climate change is likely to increase the population affected by fluvial flooding, projected to be in the range of 3–9 million people by 2035–2044 depending on the emissions pathway.
- Losses of agricultural productivity are projected for key food and cash crops, multiple drivers have been proposed, including saline intrusion and shifts in the viable geographical range of plant species.
- As temperatures rise the increase in heat stress on the Vietnamese population will lead to negative health outcomes, particularly for poorer communities and outdoor laborers.
- Vietnam faces potentially significant social and economic impacts across multiple regions and sectors. Without effective adaptation and disaster risk reduction efforts multidimensional poverty and inequality are likely to increase.

COUNTRY OVERVIEW

Vietnam is a Southeast Asian nation with an extensive coastline and diverse but generally warm climate including temperate and tropical regions. In 2019 Vietnam's population was estimated at 96.4 million, approximately one third of whom live in the metropolitan areas of its two mega-cities, Hanoi and Ho Chi Minh City. The relative contribution of agriculture, forestry, and fishing to the country's economy has declined in recent years due to the rapid growth of the industry and service sectors; as of 2017 the agricultural sector contributed 15.3% of gross domestic product, this is somewhat mismatched against an employment contribution of around 40.3% of the country's labor force (see key country indicators in **Table 1**). Rice production has a particularly vital role for the country in terms of food security, rural employment and foreign exchange, employing two-thirds of the rural labor force and positioning Vietnam as consistently one of the world's largest rice exporters. Vietnam's long coastline, geographic location, and diverse topography and climates contribute to its being one of the most hazard-prone countries of Asia and the Pacific Region. Given that a high proportion of the country's population and economic assets (including irrigated agriculture) are located in coastal lowlands and deltas and rural areas face issues of poverty and deprivation, Vietnam has been ranked among the five countries likely to be most affected by climate change. It has been estimated that climate change will reduce national income by up to 3.5% by 2050.[1]

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[1] Arndt, C., Tarp, F., & Thurlow, J. (2015). The economic costs of climate change: A multi-sector impact assessment for Vietnam. Sustainability: 7: 4131–4145.

Vietnam demonstrates dedication to combating climate change through a range of national policies and concrete adaptation measures. In 2011, the National Climate Change Strategy was issued, outlining the objectives for 2016–2050. In 2012, the National Green Growth Strategy was approved, which includes mitigation targets and measures. In 2013, the Law on Natural Disaster Prevention and Control was enacted, aiming to address diverse natural hazards that affect the country, which are primarily climate related. Additionally, the 2014 Law on Environment includes a full chapter on climate change. Vietnam ratified the Paris Agreement on November 3, 2016 and the associated Nationally Determined Contribution.

This document aims to succinctly summarize the climate risks faced by Vietnam. 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 Vietnam, 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 and to direct them to many useful sources of secondary data and research.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished	10.7% (2014–2016)	FAO, 2017
National Poverty Rate	7.0% (2015)	ADB, 2018
Share of Wealth Held by Bottom 20%	7.1% (2014)	WB, 2018
Net Migration Rate	–0.04% (2010–2015)	UNDESA, 2017
Infant Mortality Rate (Between Age 0 and 1)	1.9% (2010–2015)	UNDESA, 2017
Average Annual Change in Urban Population	2.1% (2010–2015)	UNDESA, 2018
Dependents per 100 Independent Adults	59.5 (2015)	UNDESA, 2017
Urban Population as % of Total Population	35.9% (2018)	CIA, 2018
External Debt Ratio to GNI	42.5% (2015)	ADB, 2017a
Government Expenditure Ratio to GDP	28.7% (2016)	ADB, 2017a

Notre-Dame GAIN Index Ranking (2018)	
98th	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 readier a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st (University of Notre-Dame, 2019).

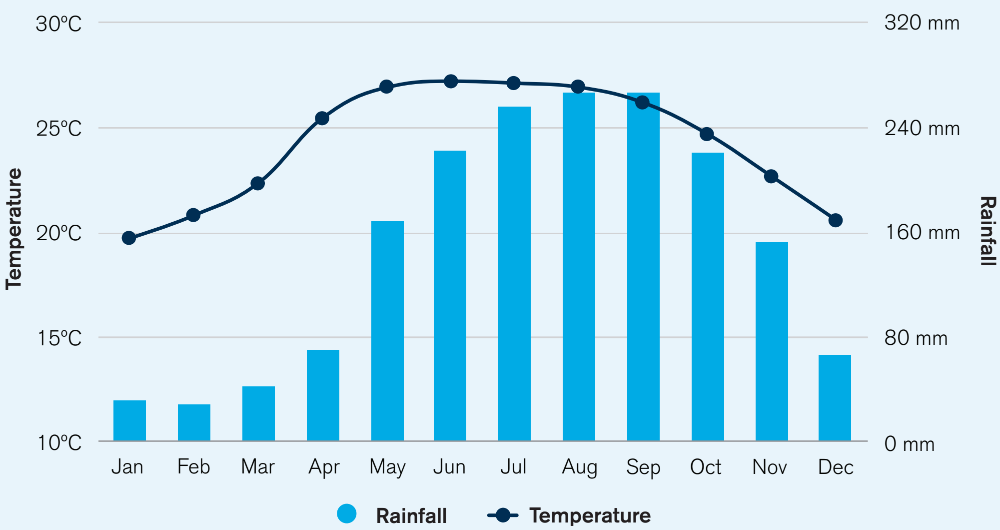
Climate Baseline

Overview

Vietnam has both a tropical climate zone and a temperate climate zone, with all of the country experiencing the effects of the annual monsoon (see the country's annual climate cycle in **Figure 1**). Rainy seasons correspond to monsoon circulations, which bring heavy rainfall in the north and south from May to October, and in the central regions from September to January. In the northern regions, average temperatures range from 22°C–27.5°C in summer to 15°C–20°C in winter, while the southern areas have a narrower range of 28°C–29°C in summer to 26°C–27°C in winter (see regional changes in **Figures 2** and **3**). Vietnam's climate is also impacted by the El Niño Southern Oscillation (ENSO), which influences monsoonal circulation, and drives complex shifts in rainfall and temperature patterns which vary spatially at a sub-national level. El Niño has also been shown to influence sea-level,[2] drought incidence[3] and even disease incidence.[4]

Annual Cycle

FIGURE 1. Average monthly temperature and rainfall in Vietnam (1901–2016)[5]



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[2] Muis, S., Haigh, I. D., Guimarães Nobre, G., Aerts, J. C. J. H., & Ward, P. J. (n.d.). Influence of El Niño-Southern Oscillation on Global Coastal Flooding. Earth's Future, 6(9), 1311–1322.

[3] Sano, M., Buckley, B.M. and Sweda, T. (2009). Tree-ring based hydroclimate reconstruction over northern Vietnam from Fokienia hodginsii: eighteenth century mega-drought and tropical Pacific influence. Climate Dynamics, 33, 331–340.

[4] Thai, K.T., Cazelles, B., Van Nguyen, N., Vo, L.T., Boni, M.F., Farrar, J., Simmons, C.P., van Doorn, H.R. and de Vries, P.J. (2010). Dengue dynamics in Binh Thuan province, southern Vietnam: periodicity, synchronicity and climate variability. PLoS Neglected Tropical Diseases, 4, pp. 747.

[5] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-historical

Spatial Variations

FIGURE 2. Annual mean temperature (°C) in Vietnam over the period 1901–2019[6]

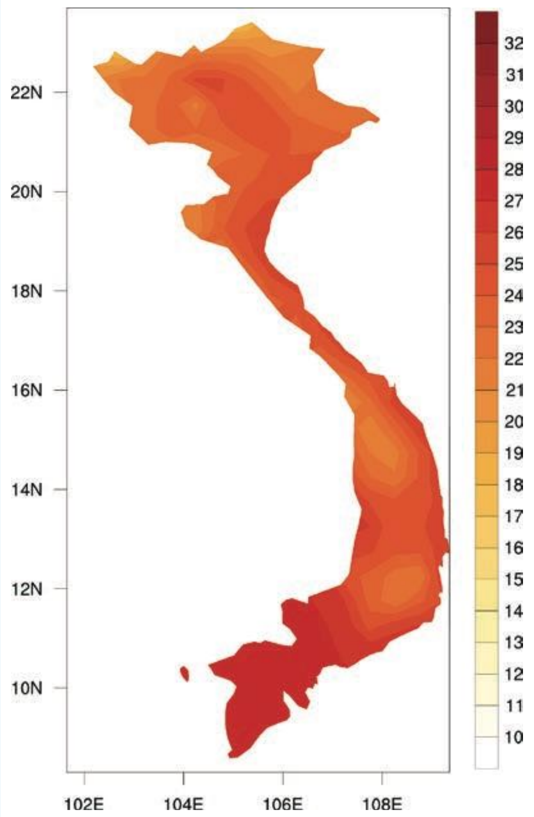
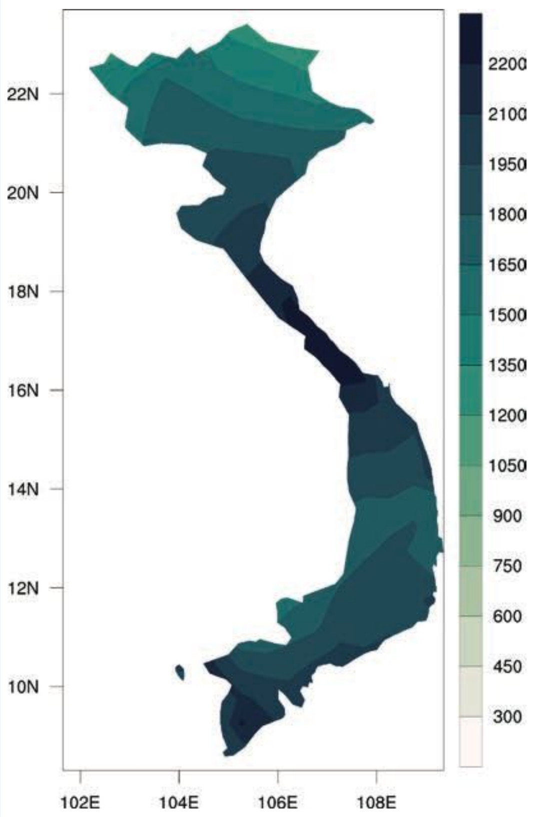


FIGURE 3. Annual mean rainfall (mm) in Vietnam over the period 1901–2019



Key Trends

Temperature

Mean annual temperature has increased by 0.5°C–0.7°C since 1960, with the rate of increase most rapid in southern Vietnam and the Central Highlands. In the period 1971–2010 the rate of warming is estimated at 0.26°C per decade, this is reported as being almost twice the rate of global warming over the same period.[7] Greater warming has been identified in winter months than in summer months. The frequency of 'hot' days and nights has increased significantly since 1960 in every season, and the annual frequency of 'cold' days and nights has decreased significantly.

[6] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data: Historical. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-historical

[7] Nguyen, D. Q., Renwick, J., & Mcgregor, J. (2014). Variations of surface temperature and rainfall in Vietnam from 1971 to 2010. International Journal of Climatology: 34: 249–264.

Precipitation

Mean rainfall over Vietnam does not show any significant increase or decrease on a national level since 1960. The proportion of rainfall falling in heavy events has not changed significantly since 1960, nor has the maximum amount falling in 1-day or 5-day events. However, on a sub-national level some changes are significant, the general trend has been towards increased rainfall in central regions, and reduced rainfall in northern and southern regions.[8] El Niño remains a major influencer of trends in precipitation.[9]

Climate Future

Overview

The Representative Concentration Pathways (RCPs) represent four plausible futures, based on the rate of emissions reduction achieved at the global level. For more background please refer to the World Bank's Climate Change Knowledge Portal (CCKP) metadata. For reference, **Tables 2** and **3** provide information on all four RCPs over two time periods. In subsequent analysis RCP 2.6 and 8.5, the extremes of low and high emissions pathways, are the primary focus. RCP2.6 would require rapid and systemic global action, achieving emissions reduction throughout the 21st century sufficient to reach net zero global emissions by around 2080. RCP8.5 assumes annual global emissions will continue to increase throughout the 21st century. Climate changes under each emissions pathway are presented against a reference period of 1986–2005 for all indicators.

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. 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 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).[10] 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

8 Katzfey, J., McGregor, J., Suppiah, R. (2014). High-resolution climate projections for Vietnam: Technical Report. CSIRO, Australia.
9 Nguyen, D. Q., Renwick, J., & Mcgregor, J. (2014). Variations of surface temperature and rainfall in Vietnam from 1971 to 2010. International Journal of Climatology: 34: 249–264.
10 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.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Vietnam for 2040–2059 and 2080–2099, from the reference period of 1986–2005 for all RCPs. The table shows the median of the CCKP model ensemble and the 10th–90th percentiles in brackets.[11]

Scenario	Average Daily Maximum Temperature		Average Daily Temperature		Average Daily Minimum Temperature	
	2040–2059	2080–2099	2040–2059	2080–2099	2040–2059	2080–2099
RCP2.6	1.1 (−0.4, 2.7)	1.2 (−0.1, 2.8)	1.1 (−0.1, 2.3)	1.1 (−0.1, 2.4)	1.1 (−0.1, 2.1)	1.1 (−0.1, 2.2)
RCP4.5	1.3 (−0.1, 3.1)	1.9 (0.3, 3.8)	1.4 (0.1, 2.7)	1.9 (0.7, 3.4)	1.4 (0.1, 2.5)	1.9 (0.5, 3.2)
RCP6.0	1.1 (−0.3, 2.6)	2.2 (0.6, 4.2)	1.2 (−0.1, 2.3)	2.3 (0.7, 3.8)	1.1 (0.0, 2.2)	2.2 (0.7, 3.6)
RCP8.5	1.8 (0.2, 3.5)	3.7 (1.8, 6.1)	1.8 (0.4, 3.1)	3.7 (2.1, 5.6)	1.8 (0.4, 3.0)	3.7 (2.1, 5.4)

TABLE 3. Projections of average temperature anomaly (°C) in Vietnam 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

Scenario	2040–2059		2080–2099	
	Jun–Aug	Dec–Feb	Jun–Aug	Dec–Feb
RCP2.6	1.0 (0.1, 2.1)	1.1 (−0.1, 2.4)	1.0 (0.1, 2.1)	1.2 (0.0, 2.5)
RCP4.5	1.4 (0.4, 2.4)	1.4 (0.1, 2.6)	1.9 (0.8, 3.0)	1.9 (0.6, 3.3)
RCP6.0	1.2 (0.2, 2.3)	0.9 (−0.1, 2.1)	2.4 (1.1, 3.7)	2.1 (0.6, 3.6)
RCP8.5	1.7 (0.5, 2.8)	1.9 (0.5, 3.2)	3.5 (2.4, 5.4)	3.7 (1.8, 5.6)

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 Vietnam under RCP8.5 is shown in **Figure 4**.

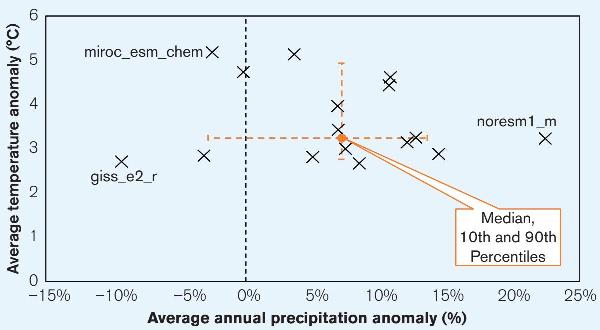
Key Trends

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 5** and **6** 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

[11] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data: Projections. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-projections

FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Vietnam. 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.



Global Temperature Projections

Unless otherwise stated projections shown here represent changes against the 1986–2005 baseline. An additional 0.61°C of global warming is estimated to have taken place between the periods 1850–1900 and 1986–2005.[12] The global average temperature changes projected between 1986–2005 and 2081–2100 in the IPCC's Fifth Assessment Report are:

- RCP2.6: 1.0°C
- RCP4.5: 1.8°C
- RCP6.0: 2.2°C
- RCP8.5: 3.7°C

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 labour, and the yield of crops, which are often disproportionately influenced by temperature extremes.

Vietnam is projected to experience an average temperature increase of 3.4°C by 2080–2100 under the highest emission pathway (RCP8.5). This warming is slightly less than the global average projected by the IPCC AR5 report of 3.7°C. By the end of the century Vietnam is projected to experience three times greater warming under RCP8.5 when compared to RCP2.6, the lowest emissions pathway. Notably, across all emissions scenarios and future time periods, changes in annual maximum temperatures are greater than changes in average temperature. Study suggests that temperature increases will be strongest in southern Vietnam, but uncertainty is high in sub-national comparisons.[13]

Precipitation

Considerable uncertainty clouds projections of future precipitation change, as shown in **Figure 7**, none of the end-of-century changes across the four emissions pathways are statistically significant. However, as shown in **Figure 4**, out of 16 models analyzed, 12 show an increase in average annual precipitation in the WBG's model ensemble. Comprehensive analysis of climate projections on a regional level by Katzfey et al. (2014) suggests that there is no strong consensus around either significant increases or decreases in

[12] Kirtman, B., Power, S. B., Adedoyin, A. J., Boer, G. J., Bojariu, R., Camilloni, I., . . . Wang, H.-J. (2013). Near-term Climate Change: Projections and Predictability. 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. 953–1028). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press.

[13] Katzfey, J., McGregor, J., Suppiah, R. (2014). High-resolution climate projections for Vietnam: Technical Report. CSIRO, Australia.

FIGURE 5. Historic and projected average annual temperature in Vietnam under RCP2.6 (blue) and RCP8.5 (red). The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10th–90th percentiles.[14]

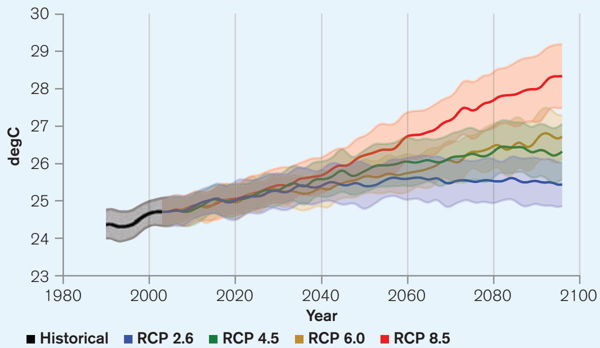
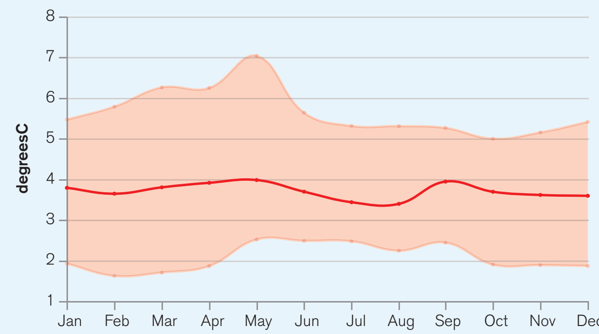
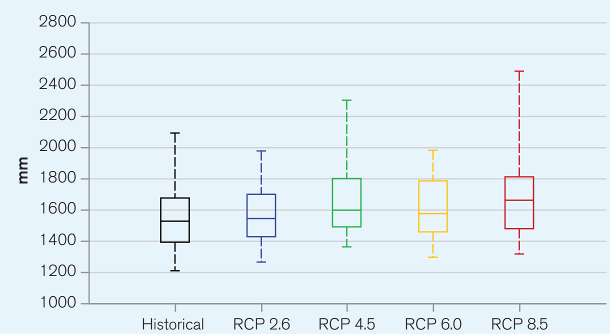


FIGURE 6. Projected change in monthly temperature for Vietnam for the period 2080–2099 under RCP8.5. The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10th–90th percentiles.



annual rainfall.[15] By contrast, modeling conducted by the Vietnam Ministry of Natural Resources and Environment shows more confidence in projections of annual precipitation increases across all mainland regions of Vietnam. Changes projected are typically in the range of 10% to 20% by 2045–2065 under both the RCP4.5 and RCP8.5 emissions scenarios.[16] Some variation in extreme rainfall amounts is reported, with some increases in extreme rainfall projected in southern and central Vietnam, and slight reductions projected elsewhere. These projections are broadly in line with global 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.[17] The poor performance of global climate models in consistently projecting precipitation trends has been linked to their poor simulation of the El Niño phenomenon,[18,19] an important area for future development.

FIGURE 7. Boxplots showing the projected average annual precipitation for Vietnam in the period 2080–2099[20]



[14] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate by Sector. URL: https://climateknowledgeportal.worldbank.org/country/vietnam
[15] Katzfey, J., McGregor, J., Suppiah, R. (2014). High-resolution climate projections for Vietnam: Technical Report. CSIRO, Australia.
[16] MONRE (2016). Climate change and sea level rise scenarios for Vietnam. Vietnam Ministry of Natural Resources and Environment (MONRE).
[17] 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.
[18] 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.
[19] 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.
[20] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate by Sector. URL: https://climateknowledgeportal.worldbank.org/country/vietnam

CLIMATE-RELATED NATURAL HAZARDS

Vietnam faces high disaster risk levels, ranked 91 out of 191 countries by the 2019 INFORM Risk Index (**Table 4**), driven particularly by its exposure to hazards. Vietnam has extremely high exposure to flooding (ranked joint 1st with Bangladesh), including, riverine, flash, and coastal flooding. Vietnam also has high exposure to tropical cyclones and their associated hazards (ranked 8th). Drought exposure is slightly lower (ranked 82nd) but is still significant as highlighted by the severe drought of 2015–2017. Vietnam's overall ranking on the INFORM Risk Index is somewhat mitigated by its better scores in terms of vulnerability and coping capacity. **Table 5** provides an overview of the social and economic losses associated with natural disasters in Vietnam from 1900 to 2018. The sections below highlight potential impacts of climate change on the key natural hazards in the country.

TABLE 4. Selected indicators from the INFORM 2019 Index for Risk Management for Vietnam. For the sub-categories of risk (e.g., "Flood") higher scores represent greater risks. Conversely the most at-risk country is ranked 1st.

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)
10.0	7.9	3.5	2.4	4.2	3.8	91

TABLE 5. Summary of natural hazards in Vietnam from 1900 to 2018[21]

Disaster Type	Disaster Subtype	Events Count	Total Deaths	Total Affected	Total damage ('000 US$)
Drought	Drought	6	0	7,860,000	7,399,120
Epidemic	Others	1	16	83	0
	Bacterial disease	1	598	10,848	0
	Parasitic disease	1	200	0	0
	Viral disease	8	395	97,027	0
Flood	Others	16	1,012	2,011,287	160,055
	Coastal flood	6	804	4,353,316	749,000
	Flash flood	13	481	912,607	516,700
	Riverine flood	52	3,644	25,637,158	2,896,407
Landslide	Avalanche	1	200	38,000	0
	Landslide	4	109	40	0
	Mudslide	1	21	1,034	2,300
Storm	Others	10	323	219,280	145,035
	Convective storm	8	160	4,513	10,100
	Tropical cyclone	92	18,869	53,272,568	9,967,657

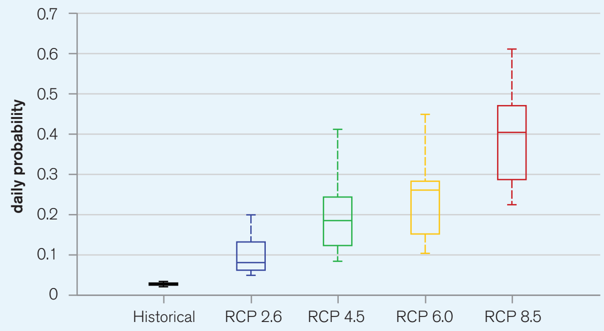
[21] Emergency Events Database (EM-DAT) of the Centre for Research on the Epidemiology of Disasters (CRED). Assessed on Nov 26, 2018. URL: https://www.emdat.be/

Heat Waves

Vietnam regularly experiences high maximum temperatures, with an average monthly maximum of around 28°C and an average May maximum of 31°C. The current daily probability of a heat wave is around 3%.[22] Temperature rises in Vietnam, a country already experiencing high average temperatures, are expected to lead to what might be considered chronic heat stress in some areas, even under lower emissions pathways. Study highlights both Hanoi and Ho Chi Minh City among the urban areas most threatened by deadly heat globally.[23]

Multi-model ensemble suggests an increase in the daily probability of heatwave under all emissions pathways. Changes are significantly greater under higher emissions pathways, with probability increasing to 40% by 2080–2099 under RCP8.5, versus around 8% under RCP2.6 (**Figure 8**). These values reflect a transition to a less stable temperature regime. Heatwaves and temperature extremes are likely to remain correlated with ENSO events, and ENSO can be treated as an early warning of potential disaster-level events when the two drivers combine. Analysis suggests climate change made a 29% contribution to the extreme temperatures experienced across Southeast Asia in April 2016, while ENSO contributed 49%. The contribution of general global warming is likely to grow, the contribution of climate change through its likely impact on the ENSO process is poorly understood.[24]

FIGURE 8. Projected changes in daily probability of observing a heat wave in Vietnam under all RCPs. 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.[25]



Drought

Two primary types of drought may affect Vietnam, 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 larger river basins). At present Vietnam faces an annual median probability of severe meteorological drought of around 4%, as defined by a standardized precipitation evaporation index (SPEI) of less than –2.[26]

Recent analysis provides a global overview of changes in drought conditions under different warming scenarios. Projections for Southeast Asia suggest that the return periods of droughts will reduce. This trend is less significant

[22] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data-Projections. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-projections

[23] Matthews, T., Wilby, R.L. and Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. Proceedings of the National Academy of Sciences, 114, 3861–3866.

[24] 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.

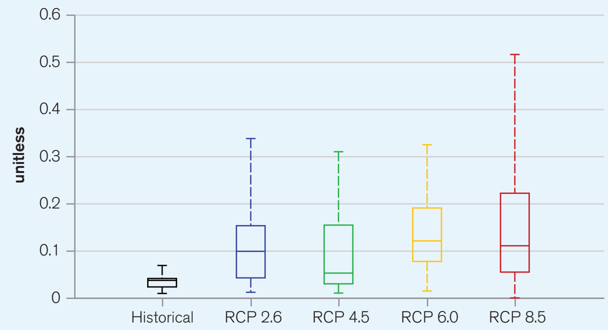
[25] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data-Projections. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-projections

[26] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data-Projections. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-projections

under lower levels of global warming, but once warming reaches 2°C–3°C events that presently occur only once in every hundred years may return at frequencies greater than once in every fifty years in Southeast Asia.[27]

Broadly in line with this estimate, the multi-model ensemble projects an increase in the annual probability of drought in Vietnam of around 10% under all emissions pathways (**Figure 9**), and this increase remains relatively constant over the period from 2020–2100. Analysis suggests these changes apply across all of Vietnam's regions, with droughts projected to take place more often and for longer periods. However, there is some variation between climate models and downscaling approaches and caution should be applied to the application of these projections.[28]

FIGURE 9. Annual probability of Vietnam experiencing a year with severe drought conditions in the period 2080–2099[29]



Flood

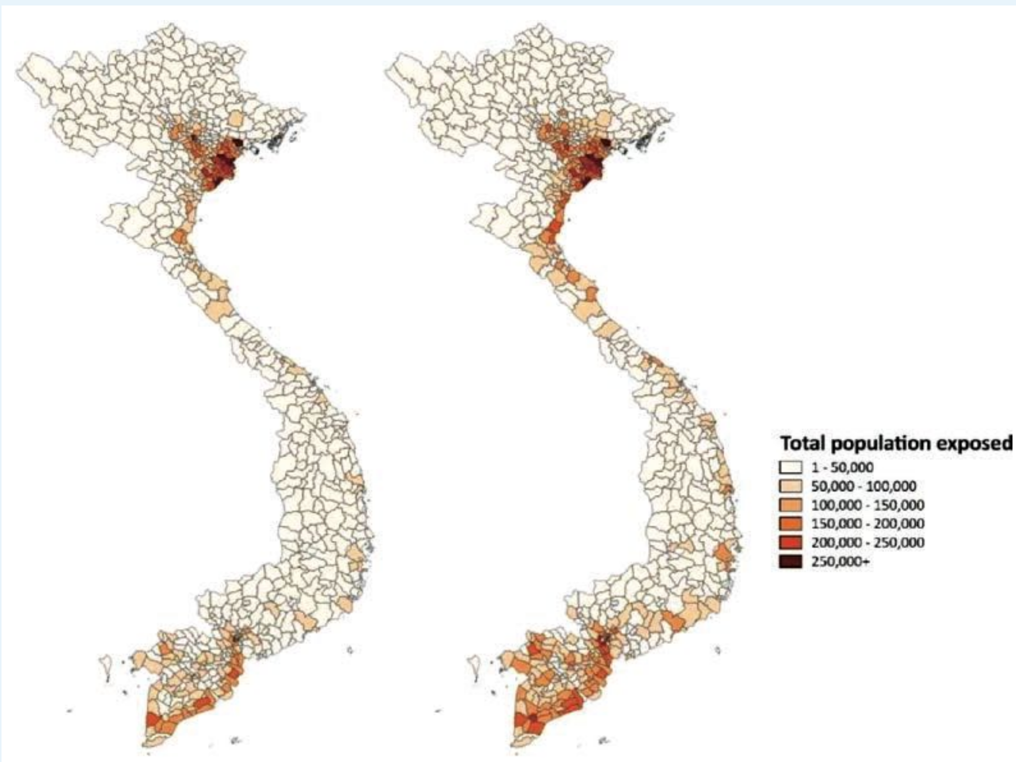
Flood represents the largest risk by economic impact in Vietnam, accounting for an estimated 97% of average annual losses from hazards. The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of river flood exposure. As of 2010, assuming protection for up to a 1-in-25 year event, the population annually affected by flooding in Vietnam is estimated at 930,000 people and expected annual impact on GDP at $2.6 billion.[30] This is slightly higher than the UNISDR estimate of annual losses from all flood types of approximately $2.3 billion.[31]

Development and climate change are both likely to increase these figures. A study by the World Bank suggests that around 33% of the national population are vulnerable to flooding at a return level of 1-in-25 years, but this will increase to 38% under RCP2.6 and 46% under RC8.5 by 2100.[32] AQUEDUCT makes a similar projection, but reported in annualized terms. The climate change component, when isolated, is projected to increase the annually affected population by 433,000 people, and the impact on GDP by $3.6 billion by 2030 under the RCP8.5 emissions pathway.

[27] 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.
[28] Katzfey, J., McGregor, J., Suppiah, R. (2014). High-resolution climate projections for Vietnam: Technical Report. CSIRO, Australia.
[29] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate by Sector. URL: https://climateknowledgeportal.worldbank.org/country/vietnam
[30] WRI (2018). AQUEDUCT Global Flood Analyzer. Available at: https://floods.wri.org/# [accessed: 22/11/2018]
[31] UNISDR (2014). PreventionWeb: Basic country statistics and indicators. Available at: https://www.preventionweb.net/countries [accessed 14/08/2018].
[32] Bangalore, M., Smith, A., & Veldkamp, T. (2016). Exposure to Floods, Climate Change, and Poverty in Vietnam. Policy Research Working Paper 7765, The World Bank. URL: http://documents.worldbank.org/curated/en/928051469466398905/pdf/WPS7765.pdf

Impacts are heavily concentrated in Vietnam's two mega-river deltas, of the Red River and Mekong River, and urban areas in their vicinity including the nation's two largest conurbations, Hanoi and Ho Chi Minh City (**Figure 10**). The deltas receive floods annually with the monsoon season, and over decades many households have learned to live with, and exploit the benefits provided by the flood. Intensification of extreme events, as projected by most global models, as well as rising sea-levels, will exacerbate the risks posed by river floods. Research projects an increase in the population affected by an extreme river flood in the order of 3–10 million by 2035–2044 as a result of climate change (**Table 6**).[33]

FIGURE 10. Absolute exposure at the district level (total number of people in a district exposed), for a 25-year historical flood (left) and a 25-year historical flood under RCP8.5 (right)[34]



[33] 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.

[34] Bangalore, M., Smith, A., & Veldkamp, T. (2016). Exposure to Floods, Climate Change, and Poverty in Vietnam. Policy Research Working Paper 7765, The World Bank.

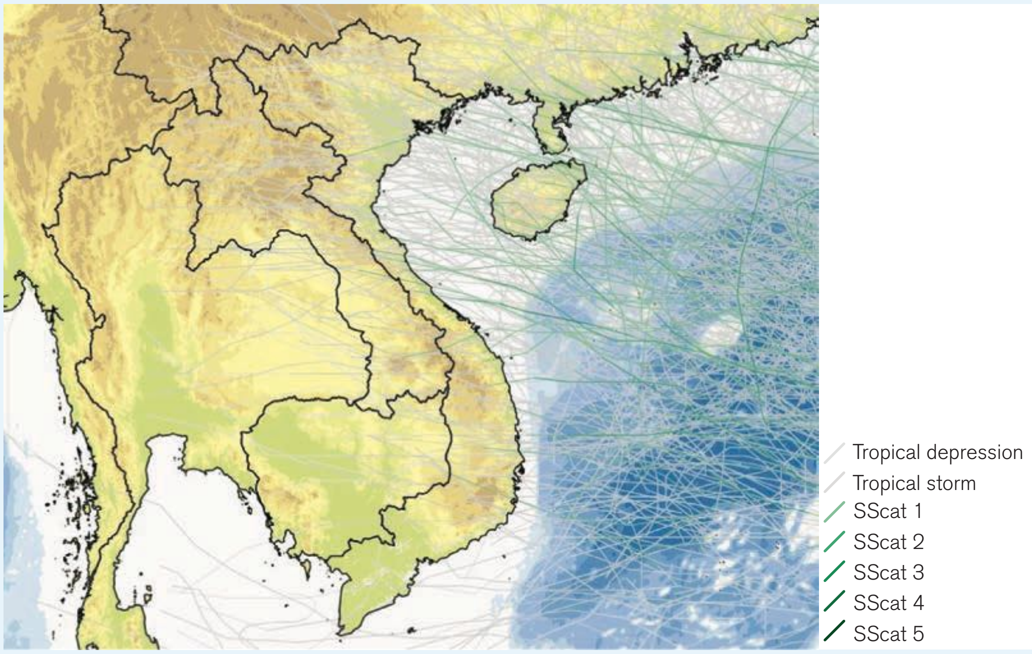
TABLE 6. Estimated number of people affected by an extreme river flood (extreme river flood is defined as being in the 90th percentile in terms of numbers of people affected) in the historic period 1971–2004 and the future period 2035–2044. Figures represent an average of all four RCPs and assume present day population distributions.[35]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	4,714,238	14,500,863	9,786,625
Median	10,009,842	17,870,746	7,860,904
83.3 Percentile	18,246,015	21,576,580	3,330,565

Tropical Cyclones and Storm Surge

Vietnam has very high exposure to tropical cyclones, with a particularly high rate of landfall along its northern coast (**Figure 11**). 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 wind speed and precipitation intensity. Previous work by the World Bank, albeit based on older climate projections, has highlighted the potentially significant growth in the area of Vietnam that would be exposed to storm surge under increased sea-levels and storm intensities.[36]

FIGURE 11. Historical cyclone tracks over Vietnam (1970–2015)[37]



[35] 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.
[36] Dasgupta, S., Laplante, B., Murray, S. and Wheeler, D. (2009). Sea-level Rise and Storm Surges: A Comparative Analysis of Impacts in Developing Countries. The World Bank.
[37] The Global Risk Data Platform. Assessed on Nov 26, 2018. URL: https://preview.grid.unep.ch/index.php?preview=map&lang=eng

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.[38] 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 there has been a general trend involving an eastward shift of cyclone activity in the Western North Pacific. Studies suggest this shift may be enhanced by climate change under higher emissions pathways.[39] While studies are limited to subsets of models and many utilize older emissions scenarios and/or the AR3 model ensemble, existing data suggests this has already begun reducing the frequency of tropical cyclone landfall over Vietnam and Southeast Asia.[40] Studies (albeit with similar limitations) have also suggested a small potential shift of cyclone activity away from summer months and towards the winter.[41]

Climate change induced sea-level rise is likely to increase the potential risk associated with storm surges driven by tropical cyclones. Studies estimate that without adaptation 9% of national GDP will be at risk from the impact of a 1-in-100-year storm surge impacting the Red River Delta region in 2050.[42] Storm surge is found to be a major contributor to the economic costs of climate change on a national level in the period beyond 2050.[43]

CLIMATE CHANGE IMPACTS

Climate Change Impacts on Natural Resources

Water

Vietnam's water resources already experience significant pressures from human development processes. Key issues include over-utilization of groundwater, land-use changes (notably to aquaculture) and rapid, sometimes unplanned, urban development.[44] These processes also include transboundary issues in the case of the Mekong River, the basin of which spans four other nations. Considerable uncertainty clouds projections of change in future precipitation and cyclone activity. Most studies suggest such changes will have a markedly lesser impact in comparison with

[38] 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.
[39] Kossin, J., Emmanuel, K., Camargo, S. (2016). Past and projected changes in Western North Pacific tropical cyclone exposure. Journal of Climate: 29: 5725–5739.
[40] Redmond, G., Hodges, K. I., Mcsweeney, C., Jones, R., & Hein, D. (2015). Climate Dynamics: 45: 1983–2000.
[41] Wang, C., Liang, J., & Hodges, K. I. (2017). Projections of tropical cyclones affecting Vietnam under climate change: downscaled HadGEM2-ES using PRECIS 2.1. Quarterly Journal of the Royal Meteorological Society: 143: 1844–1859.
[42] Neumann, J., Emanuel, K., Ravela, S., Ludwig, L., & Verly, C. (2015). Risks of Coastal Storm Surge and the Effect of Sea Level Rise in the Red River Delta, Vietnam. Sustainability: 7: 6553–6572.
[43] Arndt, C., Tarp, F., & Thurlow, J. (2015). The economic costs of climate change: A multi-sector impact assessment for Vietnam. Sustainability: 7: 4131–4145.
[44] Erban, L. E., Gorelick, S. M., & Zebker, H. a. (2014). Groundwater extraction, land subsidence, and sea-level rise in the Mekong Delta, Vietnam. Environmental Research Letters, 9(8), 084010.

human development impacts. In the context of uncertainty research has focused on the development of systems for more efficient water management, and ensuring water security. These include wastewater reuse, managing saline intrusion, and soft measures for improving water and irrigation use efficiency.[45,46,47] Dam construction is having a significant impact on the hydrology of the Mekong Delta, but overexploitation of groundwater resources also represents a major pressure.[48]

A potential shift in tropical cyclone activity associated with climate change may have noticeable impacts on flow dynamics.[49] Peak flows associated with tropical cyclones *have historically delivered* the majority of the sediment which ultimately deposits in the Mekong Delta and determines its capacity to build land height against sea-level rise. Through this mechanism climate change can also influence nutrient fluxes to the Delta, with knock-on effects for agricultural productivity.[50] Any changes in the frequency and severity of extreme events are likely to have major social and economic consequences, as shown by the drought event of 2015–2017 and the flooding regularly experienced in the Mekong Delta throughout the 1990's and 2000's. In the case of the Mekong Delta, where water resources management is a particular challenge, the Mekong Delta Plan, ratified in 2013, aims to set a future course balancing competing development objectives and managing climate change risks.

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 meters (m) by the end of the 21st century by the IPCC's Fifth Assessment Report[51] but some studies published more recently have highlighted the potential for more significant rises (**Table 7**).

Vietnam is one of the world's most vulnerable countries to sea-level rise. Without adaptation an estimated 12 million people face permanent inundation on higher emissions pathways, primarily concentrated in the nation's two low-lying mega-river deltas (**Table 8**). An estimated 2.4% of Vietnam's GDP is at risk from permanent inundation in the Red River Delta region.[52] The national and provincial governments of Vietnam are already working to protect their coastline, primarily through hard infrastructure, and in some cases through mangrove restoration. The protection of the Mekong Delta has been the subject of debate through the development of the Mekong Delta Plan and its vision to 2050. In 2016, the Ministry of Natural Resources and the Environment published an extensive assessment

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[45] Trinh, L. T., Duong, C. C., Van Der Steen, P., & Lens, P. N. L. (2013). Exploring the potential for wastewater reuse in agriculture as a climate change adaptation measure for Can Tho City, Vietnam. Agricultural Water Management, 128, 43–54.

[46] Toan, T. Q. (2014). Climate Change and Sea Level Rise in the Mekong Delta: Flood, Tidal Inundation, Salinity Intrusion, and Irrigation Adaptation Methods. In N. D. Thao, H. Takagi, & M. B. T.-C. D. and C. C. in V. Esteban (Eds.) (pp. 199–218). Oxford: Elsevier.

[47] Hong, N. B., & Yabe, M. (2017). Improvement in irrigation water use efficiency: a strategy for climate change adaptation and sustainable development of Vietnamese tea production. Environment, Development and Sustainability, 19(4), 1247–1263.

[48] Erban, L. E., Gorelick, S. M., & Zebker, H. a. (2014). Groundwater extraction, land subsidence, and sea-level rise in the Mekong Delta, Vietnam. Environmental Research Letters, 9(8), 084010.

[49] 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.

[50] Whitehead, P. G., Jin, L., Bussi, G., Voepel, H. E., Darby, S. E., Vasilopoulos, G., … Hung, N. N. (2019). Water quality modelling of the Mekong River basin: Climate change and socioeconomics drive flow and nutrient flux changes to the Mekong Delta. Science of The Total Environment, 673, 218–229.

[51] 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.

[52] Neumann, J., Emanuel, K., Ravela, S., Ludwig, L., & Verly, C. (2015). Risks of Coastal Storm Surge and the Effect of Sea Level Rise in the Red River Delta, Vietnam. Sustainability: 7: 6553–6572.

TABLE 7. 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

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)

of national vulnerability to sea-level rise. The report identifies vulnerable areas in the Red and Mekong deltas, with 50 centimeter (cm) of sea-level rise potentially inundating 6.9% and 4.5% respectively, as well as some vulnerable central provinces, such as Quang Binh Province where 50cm would inundate 1.7% of the surface area.

In addition to the threat of permanent inundation, livelihoods in Vietnam's low-lying areas face major challenges from saline intrusion, which has already forced land-use changes, abandonment, and reduced yields in many provinces. During particularly severe dry seasons, such as in 2016, salt has intruded up to 50km inland from the coast and estuary, resulting in major crop damage. Coastal erosion exacerbated by climate change is also an increasing threat to Vietnam's extensive coastline.[53]

TABLE 8. 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 Vietnam (UK Met Office, 2014)[54]

Scenario	Without Adaptation	With Adaptation
RCP2.6	6,335,260	47,920
RCP8.5	12,759,460	65,740

Fisheries and aquaculture represent major components of the Vietnamese economy, typically contributing around 6-7% of GDP and a similar proportion of employment. While other human drivers, such as overfishing and intensification of aquaculture, represent the most significant threats to the sustainability of the sector, climate change may have relevant impacts. Potential climate change impacts include rapid onset events such as river and coastal flooding, as well as saline intrusion, which are known to reduce the productivity of aquaculture operations. Coastal flooding may also impact on coastal infrastructure needed to access ocean fisheries. However, the most significant climate impact is expected to be the change in the maximum catch potential in ocean fisheries

[53] Duc, D.M., Yasuhara, K., Hieu, N.M. and Lan, N.C. (2017). Climate change impacts on a large-scale erosion coast of Hai Hau district, Vietnam and the adaptation. Journal of Coastal Conservation, 21, 47–62.
[54] UK Met Office (2014). Human dynamics of climate change: Technical Report. Met Office, UK Government.

resulting from drivers such as raised sea-surface temperatures and acidification. Modelling by the FAO points to changes in the range of –6% and –11% by 2050, with the variation influenced by the different potential emissions pathway.[55,56]

Climate Change Impacts on 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. Analysis estimates 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.[57] 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.

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. Study suggests that 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 2050 under the highest emissions pathway (RCP8.5).[58] Research focused on laborers in Da Nang has shown the high likelihood that by 2050 temperatures will regularly exceed thermal comfort levels set by the Vietnamese Ministry of Health,[59] an issue which will likely impact several million laborers in agriculture and other industries around Vietnam. 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.

Rice is perhaps the most important crop in Vietnam's agricultural sector. About 52% of paddy rice production is from the Mekong River Delta: 82% of the summer autumn rice is produced in the Mekong River Delta, and another 18% in the Red River Delta. Other important rice-growing regions are the North-East and the

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55 Nguyen, L. A., Pham, T. B. V, Bosma, R., Verreth, J., Leemans, R., De Silva, S., & Lansink, A. O. (2018). Impact of Climate Change on the Technical Efficiency of Striped Catfish, Pangasianodon hypophthalmus, Farming in the Mekong Delta, Vietnam. Journal of the World Aquaculture Society, 49(3), 570–581. URL: http://dro.deakin.edu.au/eserv/DU:30105231/nguyen-impactof-2018.pdf

56 FAO (2018). Impacts of climate change on fisheries and aquaculture: Synthesis of current knowledge, adaptation and mitigation options. Food and Agriculture Organization of the United Nations. URL: http://www.fao.org/3/i9705en/i9705en.pdf

57 Tebaldi, C., & Lobell, D. (2018). Differences, or lack thereof, in wheat and maize yields under three low-warming scenarios. Environmental Research Letters: 13: 065001.

58 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.

59 Opitz-Stapleton, S., Sabbag, L., Hawley, K., Tran, P., Hoang, L., & Nguyen, P. H. (2016). Heat index trends and climate change implications for occupational heat exposure in Da Nang, Vietnam. Climate Services, 2–3, 41–51.

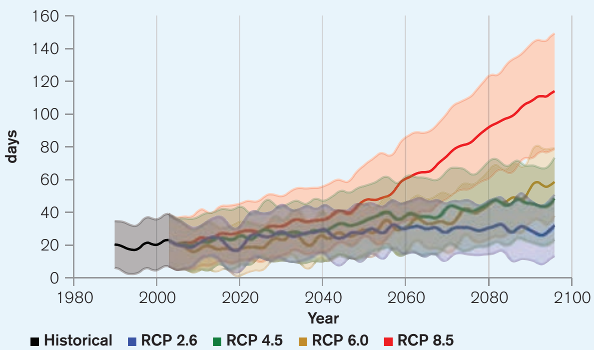
North-Central Coast. In most zones, irrigated rice is cultivated in two to three crops per year. The continued rise in rice production is largely due to improved irrigation, new rice varieties, new rice technologies, and increased triple cropping in the Mekong River Delta. Development has involved increasing control over natural hydrological processes and has involved water and land management trade-offs which have at times disadvantaged poorer groups.[60] Notably, the average size of farms remains very small, even in Vietnam's most productive regions, at around 1 hectare.[61]

Climate change threatens multiple stressors on rice production, including high temperatures (particularly during development stages), saline intrusion, drought, and flood (crop submergence). However, some of these negative impacts may be partially offset by the benefits of increased atmospheric CO_2 concentrations. Study[62] suggests that climate change may damage rice yields in the Mekong River Delta in the long term. The outlook reported for rain-fed rice is particularly poor across all time horizons with yield declines potentially over 50% on higher emissions pathways by 2040. Irrigated rice fares better in the shorter-term showing some yield improvements up to 2030. By the 2040s irrigated rice could also be facing yield reductions of up to 23% under higher emissions pathways. Another analysis[63] estimates the net impact of climate change on rice yields (including CO_2 gains) across all of Vietnam and also suggests losses can be expected, at 5%–10% by 2040, with similar values under both RCPs 4.5 and 8.5. It suggests there is a possibility that adaptations, such as changes to planting dates, may be sufficient to mitigate these losses. Further research and analysis is required to better understand the impact this would have on the viability of growing three rice crops in a year, a development that has dramatically increased Vietnam's rice production in recent years.

Maize is the second most important food crop substituting as a staple good in periods of rice shortage, especially for people in rural areas and mountainous regions. Maize is also the primary source of feed for Vietnam's poultry and livestock industry and is therefore an important source of income for many farmers. The outlook for maize production is also poor due to its sensitivity to high temperatures (**Figure 12**). Concerns have also been raised regarding potential future climate stressors affecting cash crops grown in Vietnam's Central Highlands region, notably tea, coffee, pepper and rubber. In 2016, USAID and UNDP particularly identify the risk that runoff will decline negatively affecting yields.[64] Another key crop also projected to experience production declines resulting from climate change is coffee. A study in 2015 projects that many key coffees growing areas of Vietnam's central highlands will become unsuitable for coffee under the RCP6.0 emissions pathway.[65]

[60] Chapman, A., & Darby, S. (2016). Evaluating sustainable adaptation strategies for vulnerable mega-deltas using system dynamics modelling: Rice agriculture in the Mekong Delta's An Giang Province, Vietnam. Science of the Total Environment. 559: 326–338.
[61] USAID/UNDP (2016). Economics of climate change adaptation: Agriculture sector analysis for Viet Nam. USAID Climate Change Adaptation Project Preparation Facility for Asia and the Pacific/United Nations Development Programme.
[62] Jiang, Z., Raghavan, S. V., Hur, J., Sun, Y., Liong, S.-Y., Nguyen, V. Q., & Van Pham Dang, T. (2018). Future changes in rice yields over the Mekong River Delta due to climate change—Alarming or alerting? Theoretical and Applied Climatology.
[63] 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.
[64] USAID/UNDP (2016). Economics of climate change adaptation: Agriculture sector analysis for Viet Nam. USAID Climate Change Adaptation Project Preparation Facility for Asia and the Pacific/United Nations Development Programme.
[65] Bunn, C., Läderach, P., Ovalle Rivera, O., & Kirschke, D. (2015). A bitter cup: climate change profile of global production of Arabica and Robusta coffee. Climatic Change, 129(1), 89–101.

FIGURE 12. Annual average number of hot days (T>35°C) under RCP2.6 (Blue) and RCP8.5 (Red). The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10th–90th percentiles.[66]



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.[67] 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 but with a monthly average maximum temperature of 28°C it is inevitable that increases in temperature will have a negative influence on outdoor thermal comfort and hence labor productivity and health in Vietnam. The Vietnam Ministry of Health sets a threshold of 28°C as a maximum for safe heavy labor.[68]

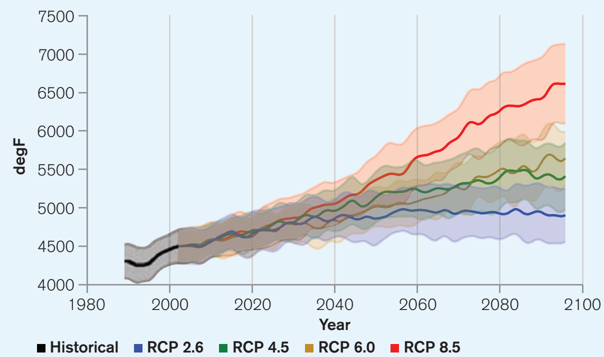
The effects of temperature rise and heat stress in urban areas are increasingly compounded by the phenomenon of the Urban Heat Island (UHI), which has been documented in urban conurbations around the world. Hard surfaces, residential and industrial sources of heat, and air pollution[69] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1°C–3°C in global mega-cities.[70] Studies suggest Ho Chi Minh City experiences around 0.5°C–0.8°C of UHI.[71] As well as impacting on human health (see Impacts on 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, 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.[72] 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.[73]

[66] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate by Sector. URL: https://climateknowledgeportal.worldbank.org/country/vietnam
[67] 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.
[68] Opitz-Stapleton, S., Sabbag, L., Hawley, K., Tran, P., Hoang, L., & Nguyen, P. H. (2016). Heat index trends and climate change implications for occupational heat exposure in Da Nang, Vietnam. Climate Services, 2-3, 41–51.
[69] 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.
[70] 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.
[71] Doan, V.Q. and Kusaka, H. (2018). Projections of urban climate in the 2050s in a fast-growing city in Southeast Asia: The greater Ho Chi Minh City metropolitan area, Vietnam. International Journal of Climatology, 38, 4155–4171.
[72] 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.
[73] ADB (2017). Climate Change Profile of Pakistan. Asian Development Bank.

Projections show a potential increase in average monthly maximum temperatures under high emissions pathways to over 40°C in Vietnam. Such increases will place extreme pressure on densely urbanized areas, amplified by the urban heat island affect. As shown in **Figure 13** the cooling necessary to maintain buildings at a suitable temperature for safe and productive living and working will increase considerably under higher emissions pathways. Secondary consequences of this are first to place pressure on energy supply, and second to penalize poorer and marginalized groups unable to access energy for cooling.

FIGURE 13. Annual cooling degree days (cumulative degrees above 65°F) in Vietnam under RCP2.6 (Blue) and RCP8.5 (Red). The values shown represents the median of 30+ GCM model ensemble with the shaded areas showing the 10th–90th percentiles.[75]



In Vietnam flooding also represents a major threat to urban areas, particularly to urban infrastructure critical to national productivity, but also to exposed communities, often the poorest and marginalized. Research suggests that average annual losses in Ho Chi Minh City associated with 40cm of sea-level rise reach 1%–5% of the city's GDP dependent on the success of adaptation, while Hai Phòng has the potential to lose 0.5%–20% of its GDP also dependent on the success of adaptation.[74]

Climate Change Impacts on Communities

Vulnerability to Climate-Related Disaster

Vietnam faces diverse hazards, including tropical cyclones and storm surges, droughts, and floods. In terms of people killed, affected and total damage tropical cyclones represent the most significant threat, with over 80 different storm events, around 45 million people affected and nearly 19,000 killed from 1953–2010. The second most threatening natural hazard in Vietnam is flooding, with around 60 major events, 5,000 killed, and 25 million affected in the past half century. Given its high exposure to floods and storms, and the fact that two of its most important economic sectors – industry and agriculture – are located in coastal lowlands and deltas – Vietnam has been listed by the World Bank as one of the five countries that will be worst-affected by climate change. UNISDR estimate Vietnam's average annual losses to disaster at around $2.4 billion, or almost 1.5% of GDP.[76] However, the absolute value of losses is projected to rise dramatically over coming years as the value of both the exposed assets and the climate-related hazard increase.[77]

[74] Hallegatte, S., Green, C., Nicholls, R. J., & Corfee-Morlot, J. (2013). Future flood losses in major coastal cities. Nature Climate Change: 3: 802–806.

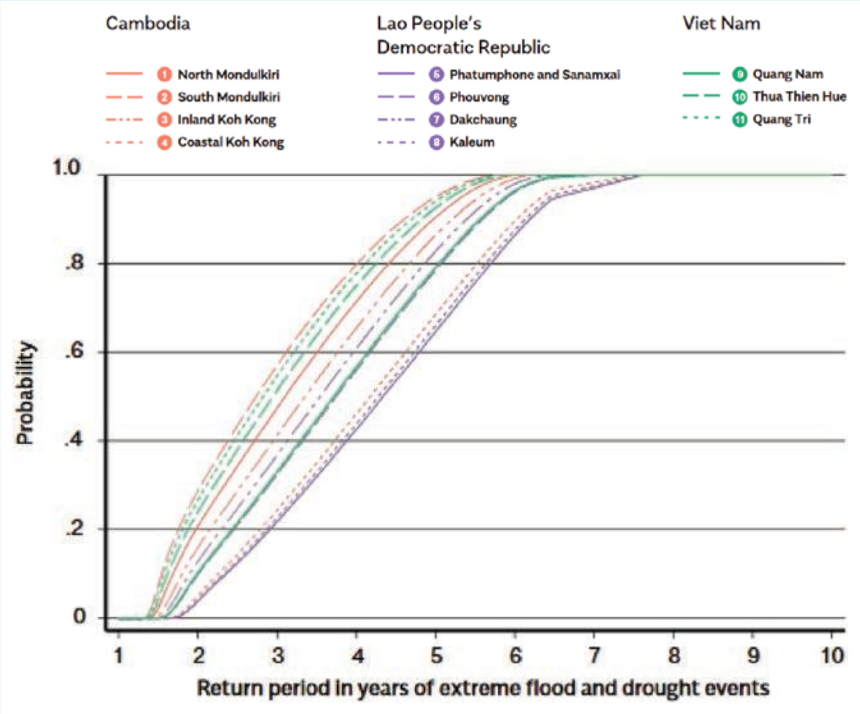
[75] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate by Sector. URL: https://climateknowledgeportal.worldbank.org/country/vietnam

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

[77] Government of Vietnam (2016). Vietnam 2016: Rapid flood damage assessment.

Vietnam's vulnerability to climate change is enhanced by its levels of poverty and deprivation, with around 10% of the population undernourished.[78] Work by ADB highlights that many further households in Vietnam have a high probability of falling into extreme poverty even when exposed to relatively high frequency flood and drought events. For example, an event at a frequency of once in every four years impacting in the three highly exposed communities that were analyzed (**Figure 14**) has approximately a 50% chance of pushing a household into extreme poverty. This highlights the precarious nature of life in Vietnam for many households 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.[79]

FIGURE 14. Probability of falling into extreme poverty by return period of combined flood and drought events[80]



Human Health

Nutrition

The World Food Programme estimates that without adaptation action the risk of hunger and child malnutrition on a global scale will increase by 20% respectively by 2050.[81] Work by Springmann et al. (2016)[82] has assessed the

78 FAO, IFAD, UNICEF, WFP, WHO (2017). The state of food security and nutrition in the world. Building Resilience for peace and food security. FAO. Rome.

79 ADB (2017). Risk financing for rural climate resilience in the Greater Mekong Subregion. Greater Mekong Subregion Core Environment Program. Asian Development Bank (ADB).

80 ADB (2017). Risk financing for rural climate resilience in the Greater Mekong Subregion. Greater Mekong Subregion Core Environment Program. Asian Development Bank (ADB).

81 WFP (2015). Two minutes on climate change and hunger: A zero hunger world needs climate resilience. The World Food Programme.

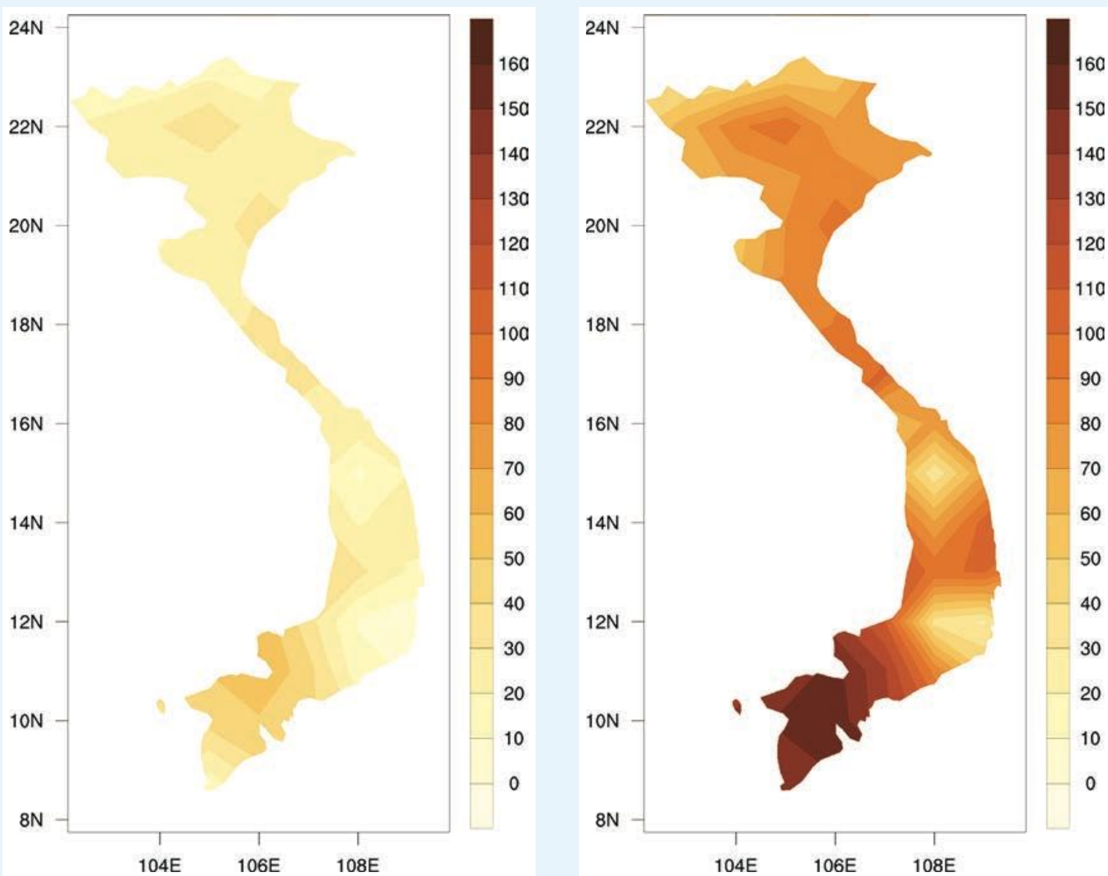
82 Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., . . . Scarborough, P. (2016). Global and regional health effects of future food production under climate change: a modelling study. The Lancet: 387: 1937–1946.

potential for excess, climate-related deaths associated with malnutrition. They identify two key risk factors which are expected to be the primary drivers: a lack of fruit and vegetables in diets and health complications caused by increasing prevalence of people underweight. Vietnam is among the three countries projected to be worst affected in absolute terms by deaths caused by such food shortage. The authors project that there will be approximately 125 climate-related deaths per million population linked to lack of food availability in Vietnam in the year 2050 under RCP8.5. This estimate does not include the impact of potential climate-related changes to the nutritional content of food.

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.[83] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human

FIGURE 15. CMIP5 ensemble projected change (32 GCMs) in very hot days (T>35°C) by 2040–2059 (left) and by 2080–2099 (right), relative to 1986–2005 baseline under RCP8.5.[84]



[83] 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.

[84] WBG Climate Change Knowledge Portal (CCKP, 2019). Climate Data- Projections. URL: https://climateknowledgeportal.worldbank.org/country/vietnam/climate-data-projections

health. Climate change will push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves. Matthews et al. (2017)[85] identify both Ho Chi Minh City and Hanoi as among the world's most vulnerable to deadly temperatures. Work by Honda et al. (2014),[86] which utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0), estimates that without adaptation, annual heat-related deaths in Southeastern Asia will increase 294% by 2030 and 691% by 2050.

Disease

Studies suggest climate changes are likely to delay the eradication of infectious diseases, an area in which Vietnam has made significant recent progress. For instance, the WHO estimates that a temperature increase in the region of 2°C–3°C will increase the incidence of malaria by around 3%–5%. Similar trends are also suggested for dengue fever and diarrhoeal disease, but actual changes will be highly context dependent and further research is required.

Poverty and Inequality

Many of the changes projected are likely to disproportionately affect the poorest groups in society. Heavy manual labour jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[87] Poorer businesses are least able to afford air conditioning, an increasing need given the projected increase in cooling days, and poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and farming technologies which assist in adaptation.

In the case of Vietnam, work by Bangalore et al. (2016)[88] suggests that flooding in urban areas will affect the poorest communities most strongly due to the common occurrence of more deprived households adopting residence on land with high hazard exposure and/or low levels of protection. Gender is also linked into this issue, as Tu and Nitivattananon (2011)[89] show that women tend to be most exposed to the risks of living in this precarious environment. Similar issues have been identified in flood-prone rural areas, notably Vietnam's major river deltas, where poorer and particularly landless households hold lowest resilience. Common causes include a lack of access to credit to see households through difficult periods, poorer transport connections, and lesser food reserves.[90] The households with most sensitivity to climate pressures also often include ethnic minorities who face additional challenges to their coping capacity.[91]

Poorer households are often the most dependent on ecosystem functions to sustain their livelihoods. These functions can be disrupted by climate change, and also by adaptation measures. This has been demonstrated in the Mekong Delta context where poorer farming livelihoods have previously benefited from nutrients in sediments deposited by annual

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[85] Matthews, T., Wilby, R.L. and Murphy, C. (2017). Communicating the deadly consequences of global warming for human heat stress. Proceedings of the National Academy of Sciences, 114, 3861–3866.

[86] 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.

[87] 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.

[88] Bangalore, M., Smith, A., & Veldkamp, T. (2016). Exposure to Floods, Climate Change, and Poverty in Vietnam. Policy Research Working Paper 7765, The World Bank.

[89] Tu, T.T. and Nitivattananon, V. (2011). Adaptation to flood risks in Ho Chi Minh City, Vietnam. International Journal of Climate Change Strategies and Management, 3, 61–73.

[90] Nguyen, K. V., & James, H. (2013). Measuring Household Resilience to Floods: a Case Study in the Vietnamese Mekong River Delta. Ecology and Society: 18.

[91] Nguyen, T. T. X., & Woodroffe, C. D. (2016). Assessing relative vulnerability to sea-level rise in the western part of the Mekong River Delta in Vietnam. Sustainability Science, 11(4), 645–659.

flooding which boost agricultural productivity.[92] Both sediment fluxes and flooding patterns are now being disrupted by the complex dynamics of combined climate change and human development interventions.[93] This includes adaptations such as dike construction which provide flood protection, but also drive inequality by reducing poorer farmers' access to ecosystem services.[94] Early signs have been identified of accelerated internal migration away from rural areas.[95]

POLICIES AND PROGRAMMES

National Adaptation Policies and Plans

TABLE 9. Key national adaptation policies, strategies, and plans

Policy, Strategy, Plan	Status	Document Access
Nationally Determined Contribution to UNFCCC	Submitted	November, 2016
Financing Vietnam's Response to Climate Change (The Vietnam's Climate Public Expenditure and Investment Review)	Completed	April, 2015
Law on Natural Disaster Prevention and Control	Enacted	June, 2013
Technology Needs Assessment for Climate Change Adaptation	Completed	June, 2012
National Strategy on Climate Change	Enacted	December, 2011
National Communications to the UNFCCC	Three submitted	Latest: February, 2019

Climate Change Priorities of ADB and the WBG

ADB – Country Partnership Strategy

ADB's Country Partnership Strategy with Vietnam (2016–2020)[96] has three strategic priorities, the third of these focuses on improving environmental sustainability and climate change response. Under the third pillar are three focal areas, resource management, climate change adaptation, and climate change mitigation. The actions in these three areas are summarized in **Table 10**.

[92] Chapman, A. D., Darby, S. E., Hông, H. M., Tompkins, E. L., & Van, T. P. D. (2016). Adaptation and development trade-offs: fluvial sediment deposition and the sustainability of rice-cropping in An Giang Province, Mekong Delta. Climatic Change: 137: 3–4.

[93] 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.

[94] Chapman, A., & Darby, S. (2016). Evaluating sustainable adaptation strategies for vulnerable mega-deltas using system dynamics modelling: Rice agriculture in the Mekong Delta's An Giang Province, Vietnam. Science of the Total Environment. 559: 326–338.

[95] Chapman, A. D., & Darby, S. E. (2018). Dams and the economic value of sediment in the Vietnamese Mekong Delta. Ecosystem Services: 32: 110–111.

[96] Asian Development Bank (2016). Vietnam - Country partnership strategy for 2016–2020: Fostering More Inclusive and Environmentally Sustainable Growth. https://www.adb.org/sites/default/files/institutional-document/199661/cps-vie-2016-2020.pdf

TABLE 10. Priority areas of ADB's Country Partnership Strategy with Vietnam

Priority Areas	
Resource management	ADB Biodiversity Conservation Corridors Initiative will support efforts to maintain and improve the cover, condition, and biodiversity of forestlands and associated ecosystems in rural areas where communities depend heavily on the surrounding natural resources for their livelihoods. In parallel, ADB will support water resource management initiatives to improve the efficiency of agricultural water use and improve water resource planning. Wastewater and solid waste management initiatives supported through inclusive urban development projects will contribute to improved water quality and reduced air pollution
Climate Change Adaptation	ADB will support climate change adaptation by mainstreaming climate-proofing measures into infrastructure investments and supporting the introduction of new climate technologies. ADB will partner with available climate funds to meet the incremental costs of these interventions, including the Green Climate Fund, Urban Climate Change Resilience Trust Fund, and bilateral climate funds. ADB support for climate change adaptation will be strengthened by synergies with the urban services and other municipal infrastructure sector, where ADB will support improved urban planning and sustainable urban development. In agriculture, ADB will improve disaster risk management capacity by supporting water resource planning and efficient water use in drought-affected provinces. Biodiversity conservation will further support ecosystem-based adaptation strategies, including watershed protection. Initial screening and detailed climate resilience and vulnerability assessments will be undertaken at the project design stage to determine climate financing needs.
Climate change mitigation	ADB will support the attainment of Vietnam's COP21 intended nationally determined contribution targets through (a) technical advice and capacity building of responsible agencies, and (b) direct investments. In the energy sector, ADB will support government efforts to increase renewable energy investment while promoting initiatives that improve energy efficiency and reduce transmission and distribution losses. ADB will support regulatory policy and institutional reforms, including cross-border energy trade agreements to curtail coal-fired energy generation. In transport, ADB will use Clean Technology Fund resources to support investment in mass transit projects that reduce vehicular emissions. Urban development projects will promote more efficient energy and water use. In the agriculture and natural resources sector, ADB will pilot climate-friendly agricultural practices, including agricultural waste management and carbon sequestration. ADB supports efforts to reduce emissions stemming from deforestation and forest degradation.

WBG – Country Partnership Framework

The WBG's Country Partnership Framework with Vietnam (2018–2022)[97] has three strategic priorities, the third of these focuses on ensuring environmental sustainability and resilience. Under the third focus area are three objectives: promote low carbon energy generation, including renewables and energy efficiency, and reduce GHG emission; increase climate resilience and strengthen disaster risk management; strengthen natural resource management and improve water security.

[97] World Bank (2017). Vietnam - Country partnership framework for the period FY18-FY22 (English). Washington, D.C. : World Bank Group. http://documents.worldbank.org/curated/en/173771496368868576/Vietnam-Country-partnership-framework-for-the-period-FY18-FY22

TABLE 11. Priority areas of the World Bank's Country Partnership Framework with Vietnam

Priority Areas	
Promote low carbon energy generation including renewables and energy efficiency, and reduce GHG emission	WBG energy sector program seeks to help the country transition in its energy mix: (i) increase energy efficiency (demand and 33 supply sides), including targeting enterprises to upgrade inefficient production systems and introduce new and clean technologies; (ii) scale up non-hydropower renewable energy, with particular focus on solar and wind, and gas-to-power; (iii) promote the financial viability of EVN and the power sector; (iv) introduce competition in gas and electricity markets; and (v) improve sector governance
Increase climate resilience	With growing climate threats, the World Bank will support the government in integrating climate change issues into key policies, planning, and legislation. Building on ongoing work, it will provide financing, operational support, and analytical work to implement a transformative multisector program in the Mekong Delta—a multisector and spatial engagement model that can be replicated (e.g. Central Highlands; Northern Mountains regions). Interventions will support regional planning and decision-making and climate-resilient livelihoods and infrastructure. The World Bank will provide specific and spatially targeted support for climate-smart practices in key rice- and coffee-growing districts and for fisheries co-management efforts in coastal communities. Upstream, the WBG will provide strategic support for policy reforms relating to climate resilience (e.g. water and forests).
Strengthen disaster risk management	The WBG's engagement in disaster risk management (DRM) seeks to strengthen resilience to the impacts of natural hazards, climate change, and pandemics, with particular emphasis on building capacity of government and communities and focusing on ex-ante risk reduction. The WBG will engage through an integrated DRM framework across ASA, lending, and TA, in six thematic areas aimed to: (i) strengthen institutional DRM policy and planning capacity; (ii) strengthen core DRM technical capacity and investments; (iii) support development of hydro-meteorological services and an early warning system; (iv) mainstream DRM in key sectors; (v) increase household level resilience to disasters; (vi) support stronger DRM financial protection and post-disaster resilience; and (vii) ensure pandemic preparedness.
Strengthen natural resource management and improve water security	During the CPF period, the WBG will provide financing and conduct analytical work to assist Vietnam to leapfrog some of the environmental and natural resource degradation challenges often faced by fast-growing economies. The World Bank will bring cutting-edge information technology and systems to assist Vietnam to better monitor land and natural resources and improve their governance, to ensure their more efficient and sustainable use. The World Bank will also provide tools and support to build capacity of relevant stakeholders to improve management of environmental and social risks. World Bank support will promote productive and sustainable use of land, forests, fisheries, and ecosystem services, while tapping related carbon benefits and financing, while paying due consideration to livelihood impacts. The WBG will also support the government developing and implementing an integrated approach to water resources management, to improve water security and productivity, and ensure sustainability of the sector. This will include strong engagement in agriculture (irrigation and climate-smart agriculture), as well as in energy (hydropower) and urban water supply and sanitation. The World Bank will engage to strengthen institutional governance in the water sector, to clarify roles and responsibilities, and promote integrated management of water resources. The WBG will also seek to strengthen private sector participation in the sector—both as a provider of water services and as an investor. WBG support will be provided through an integrated program of lending, analytical and advisory work, TA, and policy work. IFC will take an opportunistic approach in the water and sanitation sector, engaging if appropriate. Where appropriate, the WBG will seek to adopt a spatial approach to its engagement.

CLIMATE RISK COUNTRY PROFILE

VIETNAM

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK