CLIMATE RISK COUNTRY PROFILE

MALAYSIA

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

- Between 1970 and 2013, Peninsular Malaysia, Sabah and Sarawak regions experienced surface mean temperature increase of 0.14°C–0.25°C per decade.
- Under RCP8.5, the highest emissions pathway, average temperatures are projected to increase by 3.11°C by the 2090s (0.6°C less than the global average) and 0.8°C by the 2090s under RCP2.6, the lowest emissions pathway, approximately 0.2°C less than the global average.
- An increase in rainfall is also projected and is expected to be larger in Sabah and Sarawak than in Peninsular Malaysia, although there is generally large uncertainty around precipitation projections.
- Malaysia is particularly vulnerable to flooding, with this natural hazard contributing more damage than any other the country experiences. The frequency and extremity of flood events have increased in recent decades with projections showing they will continue to increase with continued global warming.
- The frequency and intensity of heat waves experienced in Malaysia is projected to increase significantly due to a warming climate.
- Coastal adaptation and disaster risk reduction issues have risen up the national agenda in Malaysia. Vulnerability assessments identify risks to agricultural production in coastal areas from sea-level rise in the range projected under the RCP emission pathways (approximately 0.4–0.7m by 2100, with greater sea level rise in Sabah-Sarawak).
- Modelling suggests that occurrence of droughts and floods early in the rice-growing season could reduce yields by up to 60%. Furthermore, drought conditions may impact the cultivation of rubber, palm oil and cocoa.
- In Malaysia, climate change threatens to exacerbate poverty and inequality, with low-income earners economically dependent on activities where climatic conditions play a prominent role, such as agriculture, fishing and informal sectors in the urban economy, and typically living in more exposed areas.

COUNTRY OVERVIEW

Malaysia is a tropical nation in Southeast Asia, comprised of Peninsular Malaysia (West Malaysia) and East Malaysia. Malaysia features diverse land cover and topography, with a coastline of over 4,800 km, mountain ranges, and more than 50% forest cover. As of 2019, Malaysia had a population of around 32 million, and remains one of the most developed economies in the region. Around 22% of the population live in the greater area of the capital city, Kuala Lumpur. While poverty levels are comparatively low for the region, Malaysia has historically been characterized by high levels of income inequality, particularly evident in urban areas. In 2009 the World Bank estimated GINI in Malaysia at 46.3, indicating very high levels of income inequality. However, since then the Government of Malaysia has focused efforts to decline its GINI, suggesting movement towards a more equal society. As of 2018 Malaysia's economy was service sector dominated (54.5% of national GDP), underpinned by manufacturing (23% of GDP). These sectors also dominate national employment and, in contrast to other Southeast Asian nations, agriculture employs only around 11% of the labor force (**Table 1**).

While Malaysia remains one of the most biodiverse countries on Earth, the country battles with degradation of ecosystems, both in its wetland and forest habitats. Peninsular Malaysia has suffered significant deforestation since 1960s, but the has slowed down since the 1980s. The drivers of deforestation are complex, but agricultural expansion for crops like palm oil play a considerable role.[1] Concerns have been raised that climate changes could accelerate the processes threating Malaysia's natural resources. Malaysia's Tenth (2011–2015) and Eleventh (2016–2020) National Plans have targeted significant investment at climate resilience enhancements. In 2018 the Ministry of Natural Resources and the Environment submitted Malaysia's Third National Communication and Second Biennial Update to the UNFCCC. Malaysia ratified the Paris Climate Agreement and its Nationally Determined Contribution in November 2016.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[2]	3.0% (2017–2019)	FAO, 2020
National Poverty Rate[3]	5.6% (2018)	World Bank, 2019
Share of Income Held by Bottom 20%[4]	5.8% (2015)	World Bank, 2019
Net Annual Migration Rate[5]	0.16% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[6]	0.6% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[7]	2.13% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[8]	44.2 (2020)	UNDESA, 2019
Urban Population as % of Total Population[9]	77.2% (2020)	CIA, 2020
External Debt Ratio to GNI[10]	64% (2019)	World Bank, 2020
Government Expenditure Ratio to GDP[11]	19.7% (2018)	ADB, 2020b

1 Miyamoto, Motoe & Mohd Parid, Mamat & Noor Aini, Zakaria & Michinaka, Tetsuya. (2014). Proximate and underlying causes of forest cover change in Peninsular Malaysia. Forest Policy and Economics. 44. 10.1016/j.forpol.2014.05.007. URL: https://www.sciencedirect.com/science/article/pii/S1389934114000768

2 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/

3 World Bank (2019). Poverty headcount ratio at national poverty lines (% of population). URL: https://data.worldbank.org/ [accessed 17/12/20]

4 World Bank (2019). Income share held by lowest 20%. URL: https://data.worldbank.org/ [accessed 17/12/20]

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

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

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

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

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

10 World Bank (2020). QEDS: Quarterly External Debt Statistics. World Bank. URL: https://datatopics.worldbank.org/debt/qeds

11 ADB (2020b). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/publications/key-indicators-asia-and-pacific-2020

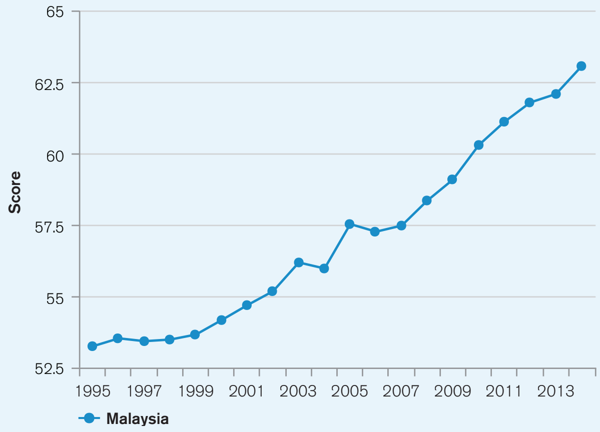
Green, Inclusive and Resilient Recovery

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 Malaysia. 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 Malaysia, 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 ADB staff to inform their climate actions and to direct them to many useful sources of secondary data and research.

Due to a combination of political, geographic, and social factors, Malaysia is recognized as vulnerable to climate change impacts, ranked 42nd out of 181 countries in the 2020 ND-GAIN Index[12] 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 Malaysia'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.



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

Climate Baseline

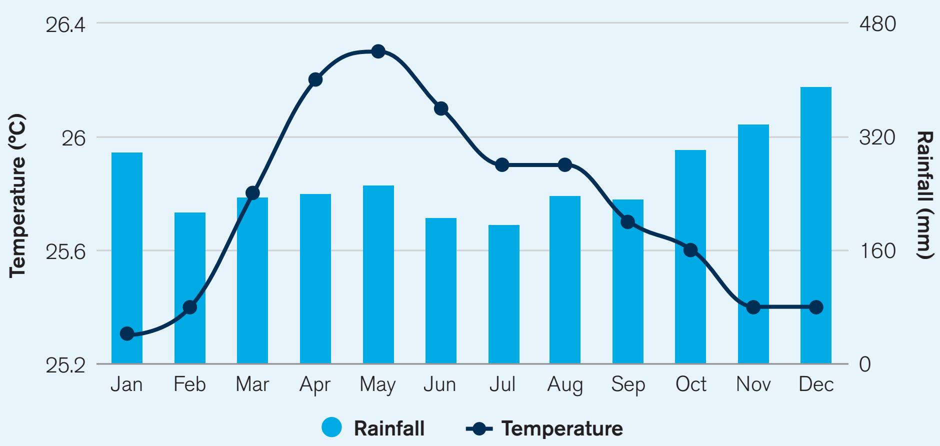
Overview

Malaysia equatorial location means the climate is hot and humid throughout the year. Climatic conditions vary across the country, with different climates found in Peninsular Malaysia to that in the East (where maritime weather has more effect). Mountain ranges influence local climate conditions, which can be categorized as highlands (cooler and wetter, with high cloud cover), lowlands (temperatures between 23°C and 32°C and high humidity) and coastal (similar temperatures to lowlands, sunny and less rainfall). There are two monsoon seasons: the Southwest Monsoon (April–September) and the Northeast Monsoon (October–March). Malaysia receives about six hours of direct sunlight per day, with cloud cover most likely during the afternoon/evening.[13]

Annual Cycle

Malaysia's mean annual temperature is 25.4°C and mean annual precipitation is 3,085.5 mm. As **Figure 2** shows, there is relatively little seasonal variability in average monthly temperature, ranging one degree Celsius between a minimum of 24.9°C in January and maximum of 25.9°C in May. April, May and June are the hottest months of the year, for the latest climatology, 1991–2020. Average monthly precipitation is also relatively constant throughout the year, ranging between approximately 200 millimeters (mm) during June and July and 350 mm in November and December. **Figure 3** shows the spatial variation of the average annual precipitation and temperature across Malaysia.

FIGURE 2. Average monthly temperature and rainfall in Malaysia (1991–2020)[14]

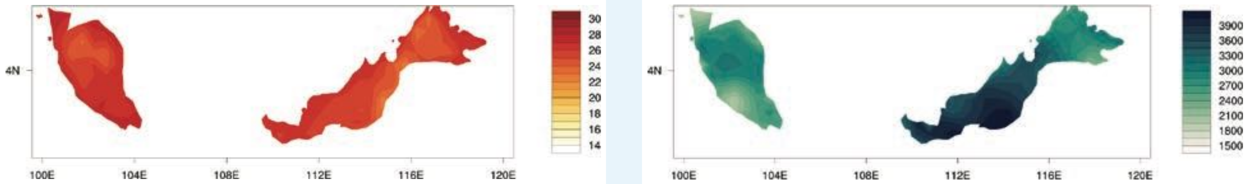


[13] Malaysia (2015). First Biennial Update Report to the UNFCC. Ministry of Natural Resources and Environment Malaysia. URL: https://unfccc.int/sites/default/files/resource/MALBUR1.pdf

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

Spatial Variation

FIGURE 3. (Left) annual mean temperature (°C), and (right) annual mean rainfall (mm) in Malaysia over the period 1991–2020[15]



Key Trends

Temperature

Interannual temperature variation in Malaysia is dominated by the influence of El Niño-Southern Oscillation (ENSO), with ENSO periods associated with warmed weather across all of Malaysia's regions.[16] Malaysia's Second Biennial Update Report describes the historical trends in temperature associated with climate change.[17] Between 1970–2013, Peninsular Malaysia, Sabah and Sarawak regions experienced surface mean temperature increase of 0.14°C–0.25°C per decade. Surface maximum temperatures increased by 0.17°C–0.22°C per decade during the same period, while surface minimum temperatures increased by 0.20°C–0.32°C per decade.[13]

The First Biennial Update Report (2016) presents highest and lowest daily maximum temperatures from 19 meteorological stations across the Peninsular, Sabah and Sarawak regions. These show an increase in daily maximum temperatures across the three regions and an increase in daily minimum temperatures in Peninsular Malaysia and Sarawak but a decreasing trend in Sabah.[13]

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

[16] Tangang, F.T., Juneng, L. and Ahmad, S., 2007. Trend and interannual variability of temperature in Malaysia: 1961–2002. Theoretical and Applied Climatology, 89(3–4), pp. 127–141. URL: https://link.springer.com/article/10.1007/s00704-006-0263-3

[17] Malaysia (2018). Third National Communication and Second Biennial Update Report to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Malaysia%20NC3%20BUR2_final%20high%20res.pdf

Precipitation

The ENSO climate phenomenon has a lesser impact on precipitation variability in Malaysia, when compared with temperature variation.[18] Malaysia's historical record shows mixed trends in the country's annual rainfall between 1951 and 2013. For Peninsular Malaysia and Sabah there is a slight decrease, and for Sarawak there is a slight increase in rainfall.[13] However, from 1990 onwards, increased rainfall trends were observed across all three regions. Mayowa et al. (2015) studied rainfall trends on the east coast of Peninsular Malaysia between 1970–2010. From 54 stations situated along this coastline, they observed a significant increase in annual rainfall and during the monsoon period as well as an increase in the number of days classified as heavy rainfall (days with rainfall >20mm).[19]

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.[20] 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 Banks' 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 RCP2.6 represents a very strong mitigation scenario, whereas RCP8.5 assumes business-as-usual scenario. For more information, please refer to the RCP Database.

For Malaysia, these models show a trend of consistent warming that varies by emissions scenario. Projections for precipitation, while highly variable, shows rainfall likely to increase overall, as well as experience an increase in intensity for extreme rainfall events. **Tables 2** and **3** below, provide information on projected temperature anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

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[18] Wong, C.L., Venneker, R., Uhlenbrook, S., Jamil, A.B.M. and Zhou, Y., 2009. Variability of rainfall in Peninsular Malaysia. Hydrology and Earth System Sciences Discussions, 6(4), pp. 5471–5503. URL: https://hess.copernicus.org/preprints/6/5471/2009/hessd-6-5471-2009.pdf

[19] Mayowa, O. O., Pour, S. H., Shahid, S., Mohsenipour, M., Harun, S. B. I. N., Heryansyah, A., & Ismail, T. (2015). Trends in rainfall and rainfall-related extremes in the east coast of Peninsular Malaysia. Journal of Earth System Science, 124(8), 1609–1622. URL: https://www.ias.ac.in/public/Volumes/jess/124/08/1609-1622.pdf

[20] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience, 11, 830–835. URL: https://www.nature.com/articles/s41561-018-0227-0?WT.feed_name=subjects_carbon-cycle

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Malaysia 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 bracket[21]

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	0.9 (0.1, 1.7)	0.8 (0.1, 1.9)	0.9 (0.3, 1.5)	0.9 (0.3, 1.6)	0.9 (0.4, 1.5)	0.9 (0.3, 1.6)
RCP4.5	1.2 (0.3, 2.1)	1.6 (0.7, 2.6)	1.2 (0.6, 1.8)	1.7 (1.0, 2.4)	1.2 (0.7, 1.8)	1.7 (1.0, 2.5)
RCP6.0	1.0 (0.2, 1.9)	2.0 (1.0, 3.1)	1.0 (0.5, 1.7)	2.1 (1.3, 3.0)	1.1 (0.6, 1.6)	2.1 (1.3, 3.0)
RCP8.5	1.6 (0.7, 2.6)	3.5 (2.3, 4.9)	1.6 (1.0, 2.3)	3.4 (2.6, 4.7)	1.7 (1.1, 2.3)	3.6 (2.6, 4.6)

TABLE 3. Projections of average temperature anomaly (°C) in Malaysia 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[21]

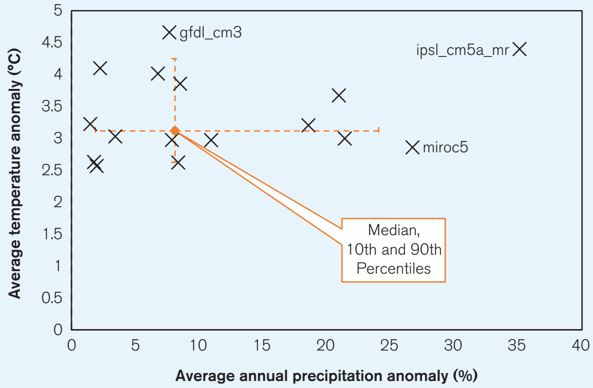
Scenario	2040–2059		2080–2099	
	Jun–Aug	Dec–Feb	Jun–Aug	Dec–Feb
RCP2.6	1.0 (0.5, 1.6)	0.9 (0.1, 1.4)	0.9 (0.5, 1.7)	0.9 (0.1, 1.5)
RCP4.5	1.2 (0.7, 1.8)	1.2 (0.1, 1.4)	1.7 (1.1, 2.4)	1.6 (0.8, 2.4)
RCP6.0	1.1 (0.6, 1.7)	1.0 (0.3, 1.6)	2.2 (1.5, 2.9)	2.0 (1.0, 2.8)
RCP8.5	1.7 (1.1, 2.3)	1.6 (1.0, 2.3)	3.6 (2.7, 4.6)	3.4 (2.3, 4.4)

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

Model Ensemble

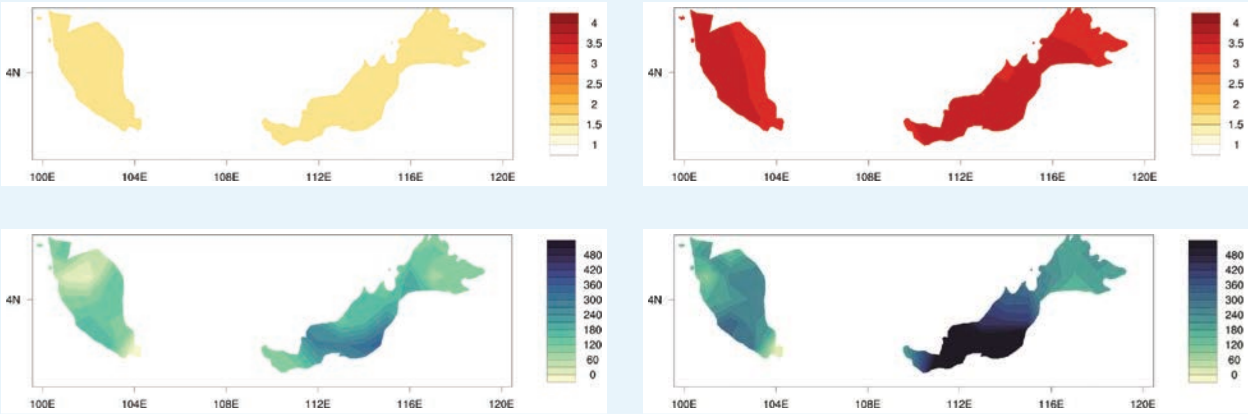
Climate projections presented in this document are derived from datasets available through the CCKP, unless otherwise stated. These datasets are processed outputs of simulations performed by multiple General Circulation Models (GCM) (for further information see Flato et al., 2013).[22] Collectively, 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 Bhutan under RCP8.5 is shown in **Figure 4**. Spatial representation of future projections of annual temperature and precipitation for mid and late century under RCP8.5 are presented in **Figure 5**.

FIGURE 4. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Malaysia. 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.[21] Three models are labelled.



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.[23]



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[22] 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

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

Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes (anomalies) in daily maximum and daily minimum temperatures over the given time period, as well as changes in the average temperature. **Figures 6** and **7** display the monthly and annual 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 impacted by temperature extremes.

FIGURE 6. Historic and projected average annual temperature in Malaysia under RCP2.6 (blue) and RCP8.5 (red) estimated by the model ensemble. Shading represents the standard deviation of the model ensemble.[24]

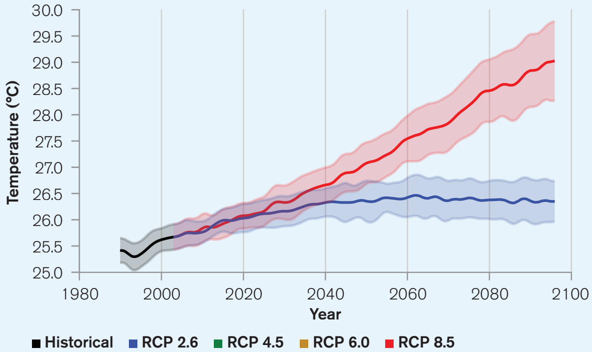
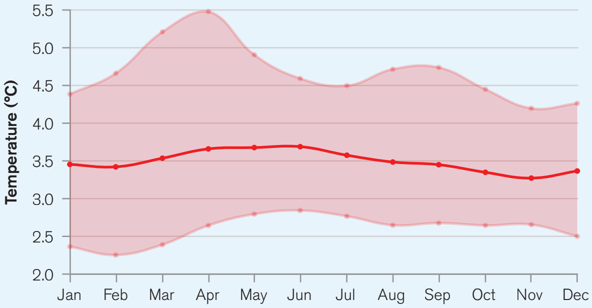


FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Malaysia for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentiles.[24]



Under the RCP8.5 emissions pathway, average temperatures are projected to increase by 3.4°C by the 2090s and by 0.9°C by the 2090s under the RCP2.6 emissions pathway. Under all emissions scenarios, projected maximum temperature increases are similar to projected minimum temperature increases. Both monthly maximum and minimum temperature rise notably faster than the average temperature.

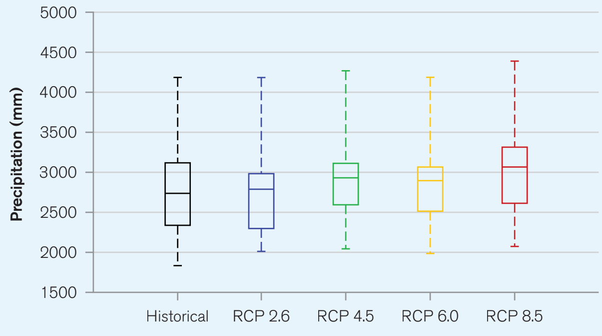
As shown in **Table 3** and **Figure 7**, there is relatively little seasonal variation in projected temperature rises, across all emissions pathways. What is evident in **Figure 7** is the high uncertainty surrounding these projections, especially around the March/April period.

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

Precipitation

As the scatter plot in **Figure 4** shows, despite high uncertainty surrounding precipitation projections, the majority of models project an increase in precipitation. The boxplots presented in **Figure 8** point to only a slight increase in average annual precipitation under all emissions pathways by the 2090s: the RCP6.0 median 2,890.8 mm, and RCP8.5 median 3,061.4 mm compared to the historical median of 2,732.3 mm, showing a 6% and 12% increase, respectively.

FIGURE 8. Projected average annual precipitation for Malaysia in the period 2080–2099.[24]



While considerable uncertainty surrounds projections of local long-term future precipitation trends, 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.[25] However, as this phenomenon is highly dependent on local geographical contexts further research is required to constrain its impact in Malaysia.

CLIMATE RELATED NATURAL HAZARDS

The INFORM 2019 Risk Index[26] **(Table 4)** ranks Malaysia 42nd, 50th and 86th out of 191 countries for flood, tropical cyclone and drought risk. For flooding and tropical cyclones, this places Malaysia in the top third of countries at risk. In contrast to its relatively high levels of exposure, Malaysia ranks low in terms of vulnerability (ranked joint 106th with Sweden). However, it is important to note that the INFORM Index does not include other climate-related hazards relevant to Malaysia such as landslides. The section that follows analyses climate change influences on the exposure component of risk in Malaysia. 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.

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

[26] European Commission (2019). INFORM Index for Risk Management. Bhutan Country Profile. URL: https://drmkc.jrc.ec.europa.eu/inform-index/Countries/Country-Profile-Map

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

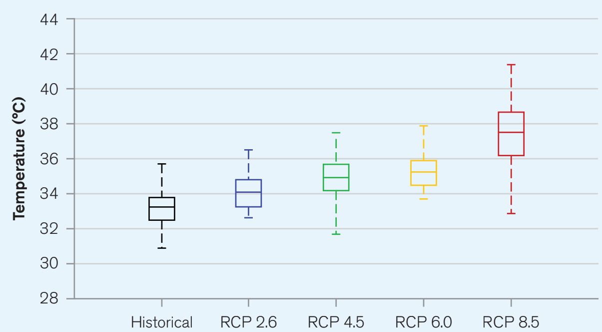
Flood (0–10)	Tropical Cyclone (0–10)	Drought (0–10)	Vulnerability (0–10)	Lack of Coping Capacity (0–10)	Overall Inform Risk Level (0–10)	Rank (1–191)
6.6 [4.5]	2.9 [1.7]	3.3 [3.2]	3.0 [3.6]	3.2 [4.5]	3.2 [3.8]	111

Heatwaves

Malaysia regularly experiences high maximum temperatures, on average experiencing an annual maximum of daily maximums of around 33°C. In general, Malaysia experiences a very stable temperature regime. The current median probability of a heat wave (defined as a period of three or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) is very low, around 2%.[14]

Under RCP8.5 emissions pathway, by the 2090s this number increases dramatically to 93%. The reason for this dramatic increase relates to primarily to the general warming trend, which moves ambient temperatures away from the historical baseline (1986–2005) against which heatwave is measured. Heatwave is defined as anomalous high temperatures and as such this shift in dynamics leads to high frequency of what would be considered heatwave conditions. Simultaneously Malaysia is also projected to experience a transition to considered chronic heat stress. Under RCP8.5 average daily maximum temperatures surpass 33°C by the end of the century. In addition, as shown in **Figure 9**, the annual maximum of daily maximums climbs to 34–37°C by the 2090s across the different emissions pathway.

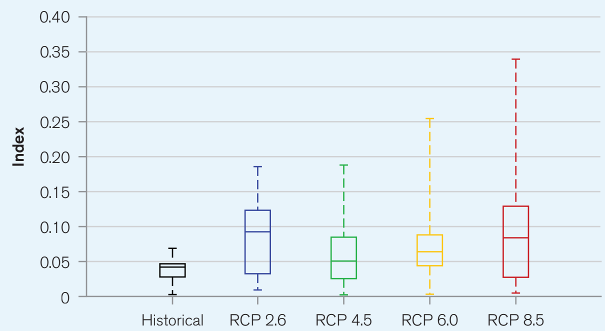
FIGURE 9. Historical (1986–2005) and projected (2080–2099) annual maximum of daily maximum temperatures in Malaysia.[24]



Drought

Two primary types of drought may affect Malaysia, 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). Depending on factors such as crop choice and land management practices, agricultural drought may also result. At present, Malaysia 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. Areas such as the Kelantan River Basin are affected by severe droughts, often during El Niño events. Impacts of severe drought include reduction in agricultural and aquaculture productivity and negative effects on freshwater supply and industrial sectors.[27] For example, in 2014, severe drought affected 8,000 paddy farmers and causing $22 million USD in crop losses.[28]

FIGURE 10. Annual probability of experiencing a 'severe drought' in Malaysia (–2 SPEI Index) in 2080–2099 under four emissions pathways.[24]



Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[29] In comparison to West and Central Asia, South East Asia is less likely to experience extreme increases in drought intensity. Nonetheless increases are expected. As **Figure 10** shows, projections under all emissions pathways show different likelihoods of experiencing a year with a severe drought by the 2090s, with the probability roughly doubling from 4% to 9% and 8% for RCP2.6 and RCP8.5 emissions pathways, respectively. The projected change is less under RCP4.5 and RCP6.0. Of Malaysia's three regions, Sabah in the northeast, is expected to be most vulnerable to increased drought from climate change.[30] In their drought forecasting study of the Langat River Basin, Huang et al. (2016) find that under the RCP8.5 emissions pathway there is a low probability of frequent, severe agricultural droughts between 2016–2100.[31] Research suggests a consequence of increased drought incidence and temperature rises may be increased prevalence of wild fires.[32]

Flood

Malaysia is particularly vulnerable to flooding, with this natural hazard contributing more damage than any other the country experiences. Frequency and extremity of flood events have increased in recent decades with projections they could increase with continued global warming.[33,34] 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

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27 Al-Amin, Abul & Filho, Walter & Maria De la Trinxeria, Josep & Hamid Jaafar, Abdul & Abdul Ghani, Zabawi. (2011). Assessing the Impacts of Climate Change in the Malaysian Agriculture Sector and its Influences in Investment Decision. URL: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=1934054

28 Tan, M.L., Ibrahim, A.B., Yusop, Z., Chua, V., and Chan, N.W. (2017). Climate change impacts under CMIP5 RCP scenarios on water resources of the Kelantan River Basin, Malaysia. Atmospheric Research. 189. 1–10. 10.1016/j.atmosres.2017.01.008. URL: http://eprints.utm.my/id/eprint/75423/

29 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

30 Yusuf, A.A. and Francisco, H. (2009) Climate Change Vulnerability Mapping for Southeast Asia. Economy and Environment Program for Southeast Asia. URL: https://www.idrc.ca/sites/default/files/sp/Documents%20EN/climate-change-vulnerability-mapping-sa.pdf

31 Huang, Yuk & Tat Ang, Jong & Jie Tiong, Yong & Mirzaei, Majid & Zaki Mat Amin, Mohd. (2016). Drought Forecasting using SPI and EDI under RCP-8.5 Climate Change Scenarios for Langat River Basin, Malaysia. Procedia Engineering. 154. 710–717. URL: https://www.sciencedirect.com/science/article/pii/S1877705816319622

32 Van der Werf, G.R., Dempewolf, J., Trigg, S.N., Randerson, J.T., Kasibhatla, P.S., Giglio, L., Murdiyarso, D., Peters, W., Morton, D.C., Collatz, G.J. and Dolman, A.J., 2008. Climate regulation of fire emissions and deforestation in equatorial Asia. Proceedings of the National Academy of Sciences, 105(51), pp. 20350–20355. URL: https://pubmed.ncbi.nlm.nih.gov/19075224/

33 Kuok Ho, Daniel Tang. (2018). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. Science of the Total Environment. 10.1016/j.scitotenv.2018.09.316. URL: https://pubmed.ncbi.nlm.nih.gov/30290336/

34 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. 10.1016/j.gsf.2014.02.009. URL: https://www.sciencedirect.com/science/article/pii/S167498711400036X

up to a 1 in 25-year event, the population annually affected by flooding in Malaysia is estimated at 130,000 and the expected annual damages at $1.8 billion. Socio-economic 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 70,000 people, and the damages by $1.8 billion under the RCP8.5 emissions pathway (AQUEDUCT Scenario B).[35] Paltan et al. (2018) show that even under lower emissions pathways coherent with the Paris Climate Agreement almost all Asian countries could face an increase in the frequency of extreme river flows.[36] 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. There is good agreement among models on this outlook. The CCKP model ensemble also projects an increase in the intensity of extreme rainfall events, with potential increases in the volume of water deposited over 5 days in the range of 8–32% by the 2090s. This projection suggests an increased likelihood of flash flooding, and associated hazards such as landslide. These impacts are not well studied, but some authors have suggested their maybe serious implications for Malaysia's infrastructure systems.[37] Willner et al. (2014) suggests the median increase in the population affected by an extreme (90th percentile) river flood by 2035–2044 as a result of climate change is approximately 102,290 people (see **Table 5**).[38] This represents an increase of 140% from the population exposed to extreme flooding in 1971–2004.

TABLE 5. Estimated number of people in Malaysia 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.[38]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	16,727	94,660	77,933
Median	73,212	175,502	102,290
83.3 Percentile	245,505	433,042	187,537

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

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

36 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. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aad985/meta

37 Sa'adin, S. L. B., Kaewunruen, S., & Jaroszweski, D. (2016). Heavy rainfall and flood vulnerability of Singapore-Malaysia high speed rail system. Australian Journal of Civil Engineering, 14(2), 123–131. URL: https://www.tandfonline.com/doi/abs/10.1080/14488353.2017.1336895

38 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

frequency but increased intensity and frequency of the most extreme events.[39] 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.

Despite its proximity to the Northwestern Pacific tropical cyclone basin, Malaysia rarely experiences tropical cyclones (due to its location near the equator), although like other coastal regions in the northwestern Pacific, some areas of the country are threatened by storm surges.[40] Intensity of tropical storms in the Southeast Asia region is projected to increase due to climate change. This is likely to impact the frequency and intensity of storm surge events Malaysia experiences.[41] Work by Dasgupta et al. (2009) assesses the potential increase in a 1 in 100-year storm surge zone under one meter of sea-level rise (the upper end of projected rises by the end of the 21st century), suggesting an increase in the impact area of around 24% and an increase in the population affected of around 34%.[42]

CLIMATE CHANGE IMPACTS

Natural Resources

Water

97% of the water supply in Malaysia is drawn from surface water flows, and storage depends almost entirely on reservoirs. This context leaves Malaysia vulnerable to extremes and unpredictability in precipitation rates. Uncertainty in downscaled climate modelling presents a major challenge to Malaysia's water planning. Regional modeling of Peninsular Malaysia for climate change impacts on its water resources indicate how mean monthly streamflow could be similar between 2025–2050 as it was in 1984–1993, except for the Kelantan and Pahang regions where projections point to a significant increase.[43] One study of the Klang watershed (encompassing Kuala Lumpur) suggested that whether runoff increases or decreases may depend on the emissions pathway which unfolds over

39 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/abs/10.1002/wcc.371

40 Zhang, H. and Sheng, J. (2015). Examination of extreme sea levels due to storm surges and tides over the northwest Pacific Ocean. Continental Shelf Research. 93. 10.1016/j.csr.2014.12.001. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2013JC009160

41 Anuar, Mohd & , Norzana & Awang, Nor & Abdul Hamid, Mohd. Radzi. (2018). Historical Storm Surges: Consequences on Coastal Resources and Shoreline Protection in East Coast of Peninsular Malaysia. 15–18. 10.15142/T33H1T. URL: https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1116&context=ishs

42 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. URL: http://documents1.worldbank.org/curated/en/657521468157195342/pdf/WPS4901.pdf

43 Jamalluddin bin Shaaban, Ahmad & Amin, M & Chen, Z.-Q & Ohara, Noriaki. (2010). Regional Modeling of Climate Change Impact on Peninsular Malaysia Water Resources. Journal of Hydrologic Engineering - J HYDROL ENG. 16. URL: https://www.researchgate.net/publication/245287710_Regional_Modeling_of_Climate_Change_Impact_on_Peninsular_Malaysia_Water_Resources

the 21st century.[44] Another study conducting downscaled modelling in the west of Peninsular Malaysia suggested moderate (5%) future increases in runoff.[45] Nonetheless, new challenges to water management may present. Concurrent with future hydrological changes will be changes to the plant and crop water demands. Water management will need to account for potential increases in crop water demand associated with increased temperatures.

Malaysia's Second National Communication places an increased emphasis on the importance of integrated water resource management and basin management, including nature-based solutions.[13] However, the threat climate change represents to natural ecosystems in Malaysia has implications for its water management. Degraded basin ecosystems increase drainage rates, exacerbating downstream flooding. An additional challenge reported by regional governments in Malaysia is the encroachment of urban sprawl onto flood prone areas, areas which might otherwise have acted to buffer flood water.

Forests and Ecosystems

Malaysia holds rare and rich biodiversity but recent decades have been characterized by conflicts between human development and wildlife, notably in the expansion of palm oil agriculture.[46] Studies have suggested ways in which climate change may drive further land and natural resource conflict as drivers such as sea-level rise cause relocation of communities.[47] As climate zones shift so species will shift or, if they are unable to move due to physiological or physical barriers, may be lost. Studies suggest that climate change processes will also drive losses in the maximum potential catch of fish species.[48] With the growing urgency to decarbonize the global economy opportunities for conservation and restoration of ecosystems lie in the positive feedbacks between forest carbon stocks and forest species richness in Malaysia.[49]

Coastal Zones

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44–0.74 m by the end of the 21st century by the IPCC's Fifth Assessment Report but some studies published more recently have highlighted the potential for more significant rises (**Table 6**). Sea-level rise rates can vary locally; study assessing historical sea-level rise in Malaysia puts the rate of rise over the period 1993–2015 at around 3.3 mm per year east of Malaysia, and around 5.0 mm per year west of Malaysia.[50]

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[44] Kabiri, R., Ramani Bai, V., & Chan, A. (2015). Assessment of hydrologic impacts of climate change on the runoff trend in Klang Watershed, Malaysia. Environmental Earth Sciences, 73(1), 27–37. URL: https://link.springer.com/article/10.1007%2Fs12665-014-3392-5

[45] Tukimat, N.N.A. and Harun, S. (2014). Optimization of water supply reservoir in the framework of climate variation. International Journal of Software Engineering and Its Applications, 8, 361–378. URL: https://www.academia.edu/24975364/Optimization_of_Water_Supply_Reservoir_in_the_Framework_of_Climate_Variation

[46] Koh, L. P., & Wilcove, D. S. (2008). Is oil palm agriculture really destroying tropical biodiversity? Conservation Letters, 1(2), 60–64. URL: https://conbio.onlinelibrary.wiley.com/doi/full/10.1111/j.1755-263X.2008.00011.x

[47] Wetzel, F. T., Kissling, W. D., Beissmann, H., & Penn, D. J. (2012). Future climate change driven sea-level rise: secondary consequences from human displacement for island biodiversity. Global Change Biology, 18(9), 2707–2719. URL: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1365-2486.2012.02736.x

[48] Asch, R. G., Cheung, W. W. L., & Reygondeau, G. (2018). Future marine ecosystem drivers, biodiversity, and fisheries maximum catch potential in Pacific Island countries and territories under climate change. Marine Policy, 88, 285–294. URL: https://www.openchannels.org/literature/19806

[49] Deere, N. J., Guillera-Arroita, G., Baking, E. L., Bernard, H., Pfeifer, M., Reynolds, G., . . . Struebig, M. J. (2018). High Carbon Stock forests provide co-benefits for tropical biodiversity. Journal of Applied Ecology, 55(2), 997–1008. https://doi.org/10.1111/1365-2664.13023. URL: https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.13023

[50] Hamid, A.I.A., Din, A.H.M., Hwang, C., Khalid, N.F., Tugi, A. and Omar, K.M. (2018). Contemporary sea level rise rates around Malaysia: Altimeter data optimization for assessing coastal impact. Journal of Asian Earth Sciences, 166, pp. 247–259. URL: https://ui.adsabs.harvard.edu/abs/2018JAESc.166..247H/abstract

Coastal adaptation and disaster risk reduction issues have risen up the national agenda in Malaysia. Vulnerability assessments following the country's Third National Communication to the UNFCCC identified risks to agricultural production in coastal areas from sea-level rise in the range predicted under the RCP emission pathways (projected approximately 0.4–0.7 m by 2100)[51] with greater sea level rise in Sabah-Sarawak.[52] Rising sea levels are predicted to have significant negative impacts for Malaysia's coastal zone, with the most impact felt in the east coast.[53] Some suggest by 2040, potentially all of Malaysia's mangrove zone could become submerged and by 2060, sea-level rise might impact the country's industrial zones (ibid). Under one meter of sea-level rise, around 7,000 km^2 of coastal land would be at risk.[54] Approximately six percent of palm oil production and four percent of rubber production is currently at risk from sea-level rise. The First Biennial Update Report identifies measurement of the socioeconomic impacts of sea-level rise at the local level as key knowledge gap.[13]

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[55] 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		1.84m (0.98–2.47)

51 Malaysia (2018). Third National Communication and Second Biennial Update Report to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/Malaysia%20NC3%20BUR2_final%20high%20res.pdf
52 Ercan, Ali & Fauzi, Mohd & Kavvas, M. (2013). The impact of climate change on sea level rise at Peninsular Malaysia and Sabah-Sarawak. Hydrological Processes. 27. 367–377. 10.1002/hyp.9232. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/hyp.9232
53 Abdul Hamid, Amalina Izzati & Md Din, Ami Hassan & Hwang, Cheinway & Khalid, Nur & Tugi, Astina & Omar, Kamaludin. (2018). Contemporary Sea Level Rise Rates around Malaysia: Altimeter Data Optimization for Assessing Coastal Impact. Journal of Asian Earth Sciences. 166. URL: https://www.sciencedirect.com/science/article/abs/pii/S136791201830302X
54 Sarkar, M., Kabir, S., Begum, R.A., Pereira, J.J., Jaafar, A.H. and Saari, M.Y. (2014). Impacts of and adaptations to sea level rise in Malaysia. Asian Journal of Water, Environment and Pollution, 11(2), pp. 29–36. URL: https://link.springer.com/article/10.1007/s11356-020-07601-1
55 Church, J. a., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, S., Levermann, A., . . . Unnikrishnan, A. S. (2013). Sea level change. In Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (pp. 1137–1216). Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press. URL: https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter13_FINAL.pdf
56 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

As shown in **Table 7**, under the RCP8.5 emissions pathway, by 2070–2100, up to 234,500 within Malaysia are potentially exposed to flooding from sea-level rise. However, with investment in adaptation, it is projected this number might potentially reduce to as little as 550.[57]

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 Malaysia.[57]

Scenario	Without Adaptation	With Adaptation
RCP2.6	27,080	270
RCP8.5	234,540	550

Economic Sectors

Tourism

Tourism represents a major sector of the Malaysian economy. The UNWTO estimate there were around 27 million inbound overnight visitors to Malaysia in 2017[58] and The World Travel and Tourism Council (WTTC) claim that tourism directly employs 4.6% of the labor force and indirectly contributes to 11.8% of jobs.[59] Government data suggests that the nation's coastal states are its most visited tourist destinations outside of the capital.[60] Multiple studies have shown the vulnerability of Malaysia's coastal areas and particularly its valuable mangrove ecosystems to inundation. Areas facing enhanced inundation risk include tourism infrastructure.[61] Additional risks to tourism arise from the potential for extreme heats which lead to personal discomfort and potential health issues. Some studies have suggested that the relative attractiveness of higher latitude destinations is growing as a result of temperature shifts.[62] Flood risk and coral bleaching represent additional climate-risks which may impact on attractiveness.[63]

57 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
58 UNWTO (2018). Malaysia: Country-specific: Basic indicators (Compendium) 2013–2017 (11.2018). URL: https://www.e-unwto.org/toc/unwtotfb/current [accessed 05/02/2019]
59 WTTC (2018). Travel and Tourism Economic Impact 2018: Malaysia. World Travel and Tourism Council. URL: https://wttc.org/Research/Economic-Impact
60 Tourism Malaysia (2019). My Tourism Data. URL: http://mytourismdata.tourism.gov.my/ [accessed 05/03/2019]
61 Awang, N. A., Shah, A. M., Ahmad, A., Anak Benson, Y., & Hamid, M. R. A. (2014). Sea Level Rise Impacts and Adaption Measures for Sandakan, Sabah. In Proceedings of the 11th International Conference on Hydroscience & Engineering. URL: https://izw.baw.de/e-medien/iche-2014/PDF/15%20Mini-Symposium%20Impacts%20of%20Climate%20Change/15_01.pdf
62 Scott, D., Gössling, S., & Hall, C. M. (2012). International tourism and climate change. Wiley Interdisciplinary Reviews: Climate Change, 3(3), 213–232. URL: https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.165
63 Farahani, B.M. (2010). Tourism as a Victim of Climate Change, Adaptation and Mitigation: Case of Malaysia as a Vulnerable Destination. ASEAN Journal on Hospitality and Tourism, 9(2), pp. 77–86. URL: http://journals.itb.ac.id/index.php/ajht/article/view/3448

In addition to direct physical impacts, climate change may affect the tourism sector in Malaysia through global efforts to mitigate climate change. One possible manifestation is in the increased cost of international flights. One study estimated that while the cost of achieving an emissions-target compatible tourism sector may be proportionately low (3.6%) the necessary increase in trip costs (estimated at $11 when averaging across every global trip but potentially higher on a long-haul destinations) may reduce Malaysia's attractiveness as a tourist destination.[64] Further research is required to better constrain the suite of potential climate change impacts on the sector.

Agriculture

Climate change could 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.[65] 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. It is highly likely that national food consumption patterns will be affected by climate change through direct impacts on internal national agricultural operations, and through impacts on the global supply chain.

Malaysia reports on climate change risks to agriculture in its Second National Communication to the UNFCCC (2011). Vulnerability assessments of the sector show that Malaysia' major crops face stronger sensitivity to rainfall and precipitation limitations than to temperature. In this regard the uncertainty in climate models on future precipitation changes presents challenges for adaptation decision making. Modelling suggests that occurrence of droughts and floods early in the rice growing season could reduce yields by up to 60%.[66] Drought conditions may result in an inability to cultivate rubber, palm oil and cocoa. Palm oil represents a particularly important commodity to the Malaysian economy and studies suggest it has very significant vulnerability to climate change, with large areas of the country likely to become unsuitable for cultivation.[67]

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[64] Scott, D., Gössling, S., Hall, C. M., & Peeters, P. (2016). Can tourism be part of the decarbonized global economy? The costs and risks of alternate carbon reduction policy pathways. Journal of Sustainable Tourism, 24(1), 52–72. URL: https://pure.buas.nl/en/publications/can-tourism-be-part-of-the-decarbonized-global-economy-the-costs-

[65] 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

[66] Alam, Md. Mahmudul & Chamhuri, Siwar & Murad, Md & Toriman, Mohd. (2011). Farm Level Assessment of Climate Change, Agriculture and Food Security Issues in Malaysia. World Applied Sciences Journal. 14. 431–442. URL: https://www.idosi.org/wasj/wasj14(3)11/12.pdf

[67] Paterson, R. R. M., Kumar, L., Taylor, S., & Lima, N. (2015). Future climate effects on suitability for growth of oil palms in Malaysia and Indonesia. Scientific Reports, 5, 14457. URL: https://www.nature.com/articles/srep14457

Malaysia's food security is related to agricultural productivity, with the country outlining the threat climate change poses on its independence from imports.[13] Some studies have shown a direct or indirect relationship between climate change and the food security of Malaysian households living in poverty in east coast Peninsular Malaysia.[68] 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. Dunne et al. (2013) suggests that global labor productivity during peak months has already dropped by 10% as a result of warming, and that a decline of up to 20% might be expected by 2050 under the highest emissions pathway (RCP8.5).[69] In combination, it is highly likely that the above processes could 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.

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.[70] 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 it is certain that temperature rises in Malaysia will move them away from optimal conditions for human life and livelihoods. Indeed, projected temperature increases under all of the RCP emissions pathways represent major risks to human and ecosystem health, as well as economic productivity.

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[71] can push temperatures higher than those of the rural surroundings, commonly anywhere in the range of 0.1–3°C in global mega-cities.[72] UHI in the range of 4–6°C has been recorded in Kuala Lumpur, typically peaking at night time.[73] As well as impacting on human health (see Communities) the temperature peaks that will result from combined UHI and climate change, as well as future urban expansion, are likely to damage the productivity of the service sector economy, both through direct impacts on labor productivity, but also through the additional costs of adaptation. UHI contributes to the formation of haze pollution events. Haze damage can have considerable economic effect, for example it was estimated the aggregate value of haze damage in Kuala Lumpur throughout 1997 was $321 million.[73]

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68 Kuok Ho, Daniel Tang. (2018). Climate change in Malaysia: Trends, contributors, impacts, mitigation and adaptations. Science of The Total Environment. 10.1016/j.scitotenv.2018.09.316. URL: https://pubmed.ncbi.nlm.nih.gov/30290336/

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

70 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/handle/10986/28723

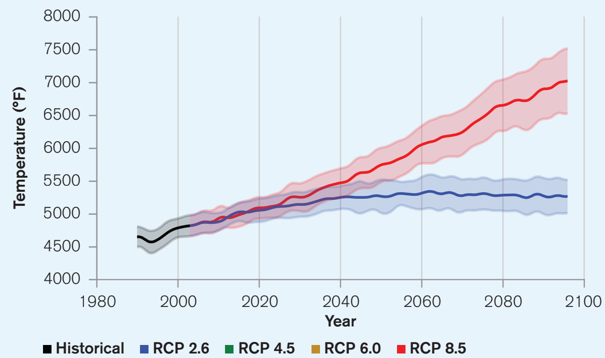
71 Cao, C., Lee, X., Liu, S., Schultz, N., Xiao, W., Zhang, M., & Zhao, L. (2016). Urban heat islands in China enhanced by haze pollution. Nature Communications, 7, 1–7. URL: https://www.nature.com/articles/ncomms12509

72 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://europepmc.org/article/agr/ind605450314

73 Elsayed, Ilham. (2012). Mitigation of the Urban Heat Island of the City of Kuala Lumpur, Malaysia. International Digital Organization for Scientific Information (IDOSI), Middle East Journal of Scientific Research. 11. 1602–1613. 10.5829/idosi.mejsr.2012.11.11.1590. URL: https://eko-yol.com/ru/wp-content/uploads/sites/4/2019/03/Kuala-Lumpur-Mitigation_of_the_Urban_Heat_Island_Inte.pdf

Research suggests that on average a one degree increase in ambient temperature can result in a 0.5–8.5% increase in electricity demand.[74] 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. As shown in **Figure 11**, 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. In Malaysia, Yau and Hasbi (2017) project an increase in cooling load by 11.7% by 2080, an increase of 330,000 KJ/h.[75]

FIGURE 11. Historic and projected annual cooling degree days in Malaysia (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[24].



Communities

Poverty, Inequality and Vulnerability to Climate-Related Disasters

Malaysia's geographic location and low poverty rates mean both its risk and vulnerability to natural hazards are lower than some of its Southeast Asian neighbors. Nonetheless, Malaysia suffers high average annual losses; in 2014 UNISDR estimated these at around $1.3 billion.[76] While Malaysia can experience drought, landslides, and storm surges, the large majority of its losses are attributable to flooding. Floods have caused considerable infrastructural, economic damage and human loss. For example, floods in Keningau in Sabah killed 241 people and caused approximately USD$100 million in damage, with thousands of houses and building destroyed.[77] Similarly, floods in the Johor state in 2008 claimed 28 lives and resulted in USD 21.9 million in damages (ibid). The east coast of Peninsular Malaysia is considered more vulnerable to flooding than elsewhere, experiencing flooding from heavy rainfall almost annually.[19] Parts of Malaysia are also vulnerable to drought events which can have considerable impact, for example a drought in Kelantan in 2014 impacted more than 8,000 paddy farmers and led to USD$ 22 million crop losses.[28] Vulnerability to flooding has been significantly increased by land-use and natural resource management practices, notably deforestation to make way for rubber and palm oil has led to increased risk.[78]

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74 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

75 Yau, Y.H. & Hasbi, Syafawati. (2017). A Comprehensive Case Study of Climate Change Impacts on the Cooling Load in an Air-Conditioned Office Building in Malaysia. Energy Procedia. 143. 295–300. URL: https://www.sciencedirect.com/science/article/pii/S1876610217364512

76 UNISDR (2014). PreventionWeb: Basic country statistics and indicators. URL: https://www.preventionweb.net/countries

77 Chan, Ngai Weng. (2015). Impacts of Disasters and Disaster Risk Management in Malaysia: The Case of Floods. In book: Resilience and Recovery in Asian Disasters: Community Ties, Market Mechanisms and Governance., Edition: 1,., Publisher: Springer, Editors: Aldrich, D.P., Oum, S. And Sawada, Y, pp. 239–266. URL: https://www.eria.org/ERIA-DP-2013-14.pdf

78 Tan-Soo, J.-S., Adnan, N., Ahmad, I., Pattanayak, S. K., & Vincent, J. R. (2016). Econometric Evidence on Forest Ecosystem Services: Deforestation and Flooding in Malaysia. Environmental and Resource Economics, 63(1), 25–44. https://doi.org/10.1007/s10640-014-9834-4.

Many of the climate changes projected are likely to disproportionately affect the poorest groups in society. For instance, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.[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.

In Malaysia, climate change threatens to exacerbate poverty, with low-income earners economically dependent on activities where climatic conditions play a prominent role, such as agriculture, fishing and informal sectors in the urban economy.[80] As Salleh and Ghaffar (2015) observe, there is a risk that 'climate change would make the poor poorer and that low-income groups which are hovering just above the poverty threshold value to fall below the poverty line'.

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.[81]

Human Health

Nutrition

The World Food Programme (2015) estimate that without adaptation action the risk of hunger and child malnutrition on a global scale could increase by 20% respectively by 2050. Further research is required to constrain the impacts of local and global food supply chain impacts on nutrition in Malaysia.

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.[82] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change may push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves.

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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://www.annualreviews.org/doi/abs/10.1146/annurev-publhealth-032315-021740

80 Salleh, K.O. & Ghaffar G.F. & Ar, G. (2009). Climate Change and its Implications on Poverty in Malaysia. p. 64. University of Malaysia. URL: https://ejournal.um.edu.my/index.php/SARJANA/article/view/10351

81 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

82 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

Honda et al. (2014) found that under the A1B emissions scenario from CMIP3 (most comparable to RCP6.0), and without adaptation, annual heat-related deaths in the South-East Asian region, could increase 295% by 2030 and 691% by 2050.[83] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[84] Under the RCP8.5 emissions pathway, heat-related deaths for 65+ year-olds in Malaysia are projected to increase dramatically by 2080, from a baseline of <1 per 100,000 in 1961–1990 to 45 per 100,000.[85]

Disease

Malaysia' climate also makes the country particularly vulnerable to vector-borne diseases. Recognizing these threats Malaysia's Nationally Determined Contribution reports that the government have made a sustained investment in the health sector, with a particular focus on adapting to climate change. Climate change projections suggest a rise in infectious and vector-borne diseases: under low or high RCP emissions pathways. As a result of temperature rises 43 million people in Malaysia will be at risk of malaria by 2070, from a 1961–2000 baseline of 17.6 million (an increase of 144%) (WHO, 2015). Similarly, the vectorial capacity of dengue fever is expected to increase by 2070 (ibid). A very significant rise in the number of cases of dengue fever was reported between 2000–2010, with climate parameters believed to be one of the driving factors.[86] There is potential for water-borne disease also to increase in prevalence. Notably diarrheal disease has been associated with drought events, which may increase in frequency.[87]

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 8. Key national adaptation policies, plans and agreements

Policy/Strategy/Plan	Status	Document Access
National Communications to the UNFCCC	Three submitted	Latest: September, 2018
Nationally Determined Contribution to Paris Climate Agreement	Submitted	November, 2016
Technology Needs Assessment	Under development (Phase II)	TBC
Third Biennial Update Report	Submitted	December, 2020
National Renewable Energy Policy	Enacted	2019
National Policy on Climate Change	Enacted	2009

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

84 Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://pubmed.ncbi.nlm.nih.gov/30319715/

85 World Health Organisation (2015). Climate and Health Country Profile – 2015, Malaysia. URL: http://www.who.int/globalchange/resources/PHE-country-profile-Malaysia.pdf?ua=1

86 Mohd-Zaki, A.H., Brett, J., Ismail, E. and L'Azou, M. (2014). Epidemiology of dengue disease in Malaysia (2000–2012): a systematic literature review. PLoS neglected tropical diseases, 8(11), p. e3159. URL: https://journals.plos.org/plosntds/article?id=10.1371/journal.pntd.0003159

87 Alhoot, M.A., Tong, W.T., Low, W.Y. and Sekaran, S.D. (2016). Climate Change and Health: The Malaysia Scenario. In Climate Change and Human Health Scenario in South and Southeast Asia (pp. 243–268). Springer, Cham. URL: https://www.springer.com/gp/book/9783319236834

CLIMATE RISK COUNTRY PROFILE

MALAYSIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK