CLIMATE RISK COUNTRY PROFILE

INDONESIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK

ACKNOWLEDGEMENTS

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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

- Projections of temperature rise for Indonesia are hindered by the lack of fine resolution modelling. Most projections suggest that overall warming could be less than the global average. Warming in the range of 0.8°C−1.4°C is expected by the 2050s in Indonesia. Projections should be approached with caution as higher warming rates could be experienced inland.
- While precipitation projections suggest an increase in average annual rainfall, there is considerable variability and uncertainty regarding spatial and temporal distribution. For example, western Indonesia is projected to experience a significantly increased number of dry days by the second half of the 21st century, under the RCP8.5 emissions pathway.
- Indonesia is ranked in the top-third of countries in terms of climate risk, with high exposure to all types of flooding, and extreme heat. The intensity of these hazards is expected to grow as the climate changes. Without effective adaptation, population exposure will also rise. For example, the population exposed to an extreme river flood could grow by 1.4 million by 2035−2044.
- Indonesia is particularly vulnerable to sea-level rise, with the country ranked fifth highest in the world terms of the size of the population inhabiting lower elevation coastal zones. Without adaptation, the total population likely to be exposed to permanent flooding by the period 2070−2100 could reach over 4.2 million people.
- Rice production is particularly vulnerable to climate change as global changes in El Niño patterns are likely to impact the onset and length of the wet season. Higher temperatures are also projected to reduce rice crop yields. Alongside other impacts on agricultural production, Indonesia faces multiple threats to its food security.
- Climate change is also likely to have impacts on water availability, disaster risk management, urban development, particularly in the coastal zones, and health and nutrition, with implications for poverty and inequality.
- While national-level vulnerability indexes, such as the ND-GAIN Country Index, suggest a reduction in overall national-level climate vulnerability in Indonesia, there is high variation in the potential impacts of climate change at the regional and local levels. Without well planned adaptation and disaster risk reduction efforts at these levels, the poorest and most marginalized communities are likely to experience significant loss and damage as a result of climate change impacts.

COUNTRY OVERVIEW

The Republic of Indonesia, herein Indonesia, is the world's largest archipelagic state, consisting of more than 17,500 islands with over 81,000 kilometres (km) of coastline, a population of 270.6 million as of 2019 and the largest economy in Southeast Asia.[1] The country's islands are home to an extremely varied geography, topography, and climate, ranging from sea and coastal systems to peat swamps and montane forests.[2]

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[1] World Bank (2020). Indonesia – Overview. URL: https://www.worldbank.org/en/country/indonesia/overview
[2] Naylor, R., Battisti, D., Vimont, D., Falcon, W., Burke, M. (2007). Assessing Risks of Climate Variability and Climate Change for Indonesian Rice Agriculture. Proceedings of the National Academy of Sciences of the United States of America. 104. 7752–7. URL: https://www.pnas.org/content/pnas/104/19/7752.full.pdf

Indonesia is highly vulnerable to climate change impacts, including extreme events such as floods and droughts, and long-term changes from sea level rise, shifts in rainfall patterns and increasing temperature. While rapid economic growth has led to a reduction in poverty in recent decades, with the poverty rate halving from 24% in 1999 to 9.78% in 2020,[3] high population density in hazard prone areas, coupled with strong dependence on the country's natural resource base, make Indonesia vulnerable to the projected climate variability and climate change (**Table 1**). These impacts of climate change will be felt across multiple sectors and regions. The Asian Development Bank (ADB) estimates that by 2100, the impacts of climate change could cost between 2.5–7% of the country's gross domestic product (GDP), with the poorest bearing the brunt of this burden.[4]

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[5]	9.0% (2017–2019)	FAO, 2020
National Poverty Rate[6]	9.8% (2018)	World Bank, 2019
Share of Income Held by Bottom 20%[7]	6.9% (2018)	World Bank, 2019
Net Annual Migration Rate[8]	−0.04% (2015–2020)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[9]	1.9% (2015–2020)	UNDESA, 2019
Average Annual Change in Urban Population[10]	2.27% (2015–2020)	UNDESA, 2018
Dependents per 100 Independent Adults[11]	47.5 (2020)	UNDESA, 2019
Urban Population as % of Total Population[12]	56.6% (2020)	CIA, 2020
External Debt Ratio to GNI[13]	37.6% (2018)	ADB, 2020
Government Expenditure Ratio to GDP[14]	16.3% (2019)	ADB, 2020

[3] World Bank (2020). Indonesia – Overview. URL: https://www.worldbank.org/en/country/indonesia/overview
[4] Orecchia, C., Raitzer, D., Bosello, F., Tavoni, M., Marangoni, G., Nuella, J. (2016). Southeast Asia and the Economics of Global Climate Stabilization. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/178615/sea-economics-global-climate-stabilization.pdf
[5] FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Transforming food systems for affordable healthy diets. FAO. Rome. URL: http://www.fao.org/documents/card/en/c/ca9692en/
[6] World Bank (2019). Poverty headcount ratio at national poverty lines (% of population). URL: https://data.worldbank.org/ [accessed 17/12/20]
[7] World Bank (2019). Income share held by lowest 20%. URL: https://data.worldbank.org/ [accessed 17/12/20]
[8] UNDESA (2019). World Population Prospects 2019: MIGR/1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
[9] UNDESA (2019). World Population Prospects 2019: MORT/1-1. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
[10] UNDESA (2019). World Urbanization Prospects 2018: File 6. URL: https://population.un.org/wup/Download/ [accessed 17/12/20]
[11] UNDESA (2019). World Population Prospects 2019: POP/11-A. URL: https://population.un.org/wpp/Download/Standard/Population/ [accessed 17/12/20]
[12] CIA (2020). The World Factbook. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/
[13] ADB (2020). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/443671/ki2018.pdf
[14] ADB (2020). Key Indicators for Asia and the Pacific 2020. Asian Development Bank. URL: https://www.adb.org/sites/default/files/publication/443671/ki2018.pdf

Due to a combination of political, geographic, and social factors, Indonesia is recognized as vulnerable to climate change impacts, ranked 97nd out of 181 countries in the 2020 ND-GAIN Country Index.[15] The ND-GAIN Country Index ranks 181 countries using a composite score which is calculated based on a country's vulnerability to climate change and other global challenges (vulnerability index) as well as their readiness to improve resilience (readiness index). The more vulnerable a country is the lower their overall country index 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 Indonesia's progress in reducing its overall vulnerability and increasing its readiness to climate change in over the past two decades.

A significant proportion of the county's greenhouse gas (GHG) emissions stem from land use change, particularly conversion of peatlands into agricultural plantations as well as from the country's energy sector.[16] Emissions from land use and land use changes represented 52.3% of total GHG emissions in Indonesia between 2000 to 2017,[17] significantly contributing to the country's position as a top emitter of GHG emissions. Emissions from energy constitute approximately one-quarter of the country's emissions, and are growing.[18]

FIGURE 1. The ND-GAIN Index score (out of 100) 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.

The Government of Indonesia is committed to reducing the country's GHG emissions. Through Presidential Regulation No. 61/2011, concerning the National Action Plan for Greenhouse Gas Emission Reduction (RAN-GRK), Indonesia set an emission reduction target of 26%, compared to business-as-usual, with domestic efforts, or up to 41% with international support under the reference emission level, by 2020. Post-2020 emission reduction targets have been set at 29% of the reference emission level by 2030, with an unconditional target and up to 41% with international support (conditional target). In support of these efforts, the Indonesian Government has promulgated relevant legal and policy instruments, including the national action plan on GHG emissions reduction as stipulated in Presidential Regulation (PERPRES) No. 61/2011 and GHG inventory through Presidential

[15] University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: https://gain.nd.edu/our-work/country-index/
[16] Republic of Indonesia (2017). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/8360571_Indonesia-NC3-2-Third%20National%20Communication%20-%20Indonesia%20-%20editorial%20refinement%2013022018.pdf
[17] Kementerian PPN/Bappenas (2019). Low Carbon Development: A Paradigm Shift Towards a Green Economy in Indonesia. URL: https://www.wavespartnership.org/sites/waves/files/kc/09_LCDI_2019.pdf
[18] Dunne, Daisy (2019). The Carbon Brief Profile: Indonesia. Carbon Brief. URL: https://www.carbonbrief.org/the-carbon-brief-profile-indonesia

Regulation (PERPRES) No. 71/2011.[19] Land use, land-use change and forestry (LULUCF) and energy measures will play a major role in Indonesia's climate change mitigation strategies to achieve emission reduction targets. For climate change adaptation, the country's medium-term strategy is to reduce risks from climate change on all development sectors — agriculture, water, energy security, forestry, maritime and fisheries, health, public service, infrastructure, and urban system by 2030.[20]

Indonesia's first national strategy on climate change was developed by the Ministry of Environment in 2007. Indonesia ratified the Paris Agreement on October 31, 2016 and established its commitment through its Nationally-Determined Contribution (2016). Indonesia completed its Third National Communication (NC3) in 2017 and its Second Biennial Update Report (2018).

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 Indonesia. 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 Indonesia, therefore potentially excluding some international influences and localized impacts. The core data presented is sourced from the database sitting behind the World Bank Group's Climate Change Knowledge Portal (CCKP), incorporating climate projections from the Coupled Model Inter-comparison Project Phase 5 (CMIP5). This document is primarily meant for WBG and ADB staff to inform their climate actions. The document also aims and to direct the reader to many useful sources of secondary data and research.

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[19] Republic of Indonesia (2017). Third National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/8360571_Indonesia-NC3-2-Third%20National%20Communication%20-%20Indonesia%20-%20editorial%20refinement%2013022018.pdf

[20] Ministry of Environment and Forestry (2017). Indonesia Second Biennial Update Report (BUR) Under the United Nations Framework Convention on Climate Change. URL: https://unfccc.int/sites/default/files/resource/Indonesia-2nd_BUR.pdf

Climate Baseline

Overview

Indonesia's climate is tropical, with the highest rainfall occurring in its low-lying areas. The mountainous regions experience cooler temperatures. The wet season occurs between November and April, leaving May through October typically dry. There is little season-by-season variation in temperature and relatively little variation by elevation (averaging 23°C in the mountainous areas and 28°C in the coastal areas). There is more variability in precipitation by elevation: the average annual rainfall in the lowlands around 1,800 millimeters (mm) to 3,200 mm compared with the mountainous regions, where it can reach up to 6,000 mm.[21] The climate of Indonesia is primarily influenced by the El Niño Southern Oscillation (ENSO), where drier conditions are experienced during El Niño events and wetter conditions during La Nina events.[22]

Average monthly temperatures in Indonesia remain constant throughout the year, at approximately 25°C–26°C. In contrast, there is considerable variation in average monthly rainfall, as shown in **Figure 2**, which presents the latest climatology, 1991–2020. The lowest rainfall is found during the dry season, June to September, when average monthly rainfall in June and July is around 160 mm-180 mm. The months with the highest rainfall, associated with monsoons, occur between October to May. On average there is 300 mm of rainfall during the May and November months, approximately twice that of the driest months. **Figure 3** shows the spatial variation of observed temperature and rainfall in Indonesia.

Annual Cycle

FIGURE 2. Average monthly temperature and rainfall in Indonesia (1991–2020)[23]

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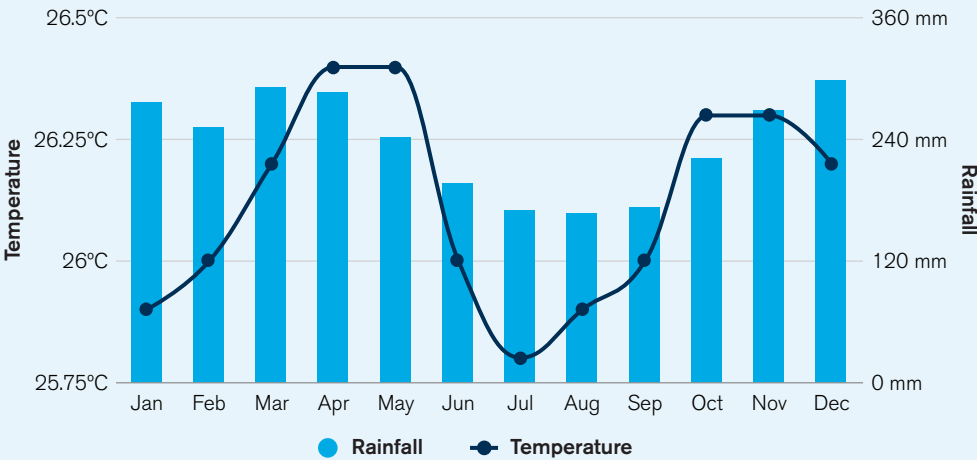
[21] USAID (2015). Climate Risk Profile: Indonesia Fact Sheet. URL: https://www.climatelinks.org/resources/climate-risk-profile-indonesia [accessed 20/12/2018].

[22] Polade, Suraj & W Pierce, David & Cayan, Daniel & Gershunov, Alexander & Dettinger, Michael (2014). The key role of dry days in changing regional climate and precipitation regimes. Scientific reports. 4. 4364. 10.1038/srep04364. URL: https://www.nature.com/articles/srep04364.pdf

[23] WBG Climate Change Knowledge Portal (CCKP, 2021). Indonesia URL: https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-historical.

FIGURE 3. (Left) Annual mean temperature(°C), and (right) annual mean rainfall (mm) in Indonesia over the period 1991–2020[24]
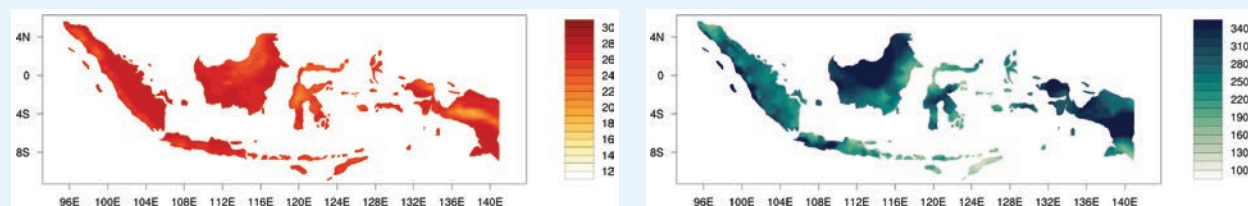
Key Trends

Temperature

Estimates from the Berkeley Earth dataset suggest Indonesia's mean annual temperature was typically around 0.8°C above the 1951–1980 baseline in the period 2010–2017. Since 1960, hot days and nights have increased by 88 days and 95 nights per annum, respectively, especially during the summer months of July–September.[21] However, observational climate data generally relates to Sumatra and Borneo, with limited data availability for the country's archipelago.[25]

Precipitation

Studies point to an overall decrease in average annual precipitation.[26] Precipitation trends vary across the country. One study for Kalimantan, Jawa, Sumatra and Papua observed increased rainfall between 1998 and 2010, whereas along the western and southern coast of Sumatra, eastern Jawa, southern Sulawesi, the Maluku Islands, western Papua, and Bali Island saw a decrease in rainfall.[27] Whilst this study highlights differences across the country, the short time period means it is not possible to infer reliable trend estimates. USAID's climate risk profile for Indonesia describes a decreased average annual precipitation of 3% during 1901–2013, but a 12% increase between 1985 and

> **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.[28] Climate change projections associated with the highest emissions pathway (RCP8.5) are presented here to facilitate decision making which is robust to these risks.

[24] WBG Climate Change Knowledge Portal (CCKP, 2021). Indonesia URL: https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-historical.

[25] UK Met Office et al. (2011). Climate: observations, projections and impacts. University of Nottingham. URL: http://eprints.nottingham.ac.uk/2040/13/Indonesia.pdf.

[26] Aldrian, E. (2007). Decreasing trends in annual rainfalls over Indonesia: A threat for the national water resource? Geophysics and Meteorology Agency, Jakarta, Indonesia. URL: https://www.researchgate.net/publication/284944836_Decreasing_trends_in_annual_rainfalls_over_Indonesia_A_threat_for_the_national_water_resource.

[27] As-Saykur, A., Tanaka, T., Osawa, T., Mahendra, M. (2013). Indonesian rainfall variability observation using TRMM multi-satellite data. International Journal of Remote Sensing. 34(21). DOI: https://doi.org/10.1080/01431161.2013.826837

[28] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO_2 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_climate-sciences

2015. The greatest decreases in rainfall have occurred during the dry season, while the greatest increases in rainfall have occurred in the north of the country.[21]

Climate Future

Overview

The main data source for the World Bank Group's Climate Change Knowledge Portal 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 Indonesia, these models show a consistent warming trend for all emissions scenarios. However, the projections in rainfall are less certain and vary by both RCP scenarios as well as models. Projected precipitation trends do show a likely increase in rainfall for western and southern areas and a reduction in rainfall for the southern islands; an increase in intensity for extreme rainfall events. **Tables 2** and **3** below, provide information on temperature projections and anomalies for the four RCPs over two distinct time horizons; presented against the reference period of 1986–2005.

TABLE 2. Projected anomaly (changes °C) for maximum, minimum, and average daily temperatures in Indonesia 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 10th–90th percentiles in brackets[29]

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 (0.2, 1.5)	0.9 (0.2, 1.8)	0.9 (0.4, 1.5)	0.9 (0.3, 1.6)	0.9 (0.4, 1.5)	0.9 (0.3, 1.5)
RCP4.5	1.2 (0.5, 2.0)	1.6 (0.8, 2.6)	1.2 (0.7, 1.8)	1.6 (1.0, 2.5)	1.2 (0.7, 1.8)	1.7 (1.1, 2.5)
RCP6.0	1.0 (0.3, 1.9)	2.0 (1.2, 3.0)	1.1 (0.6, 1.7)	2.0 (1.4, 2.9)	1.1 (0.6, 1.7)	2.0 (1.4, 3.0)
RCP8.5	1.6 (0.8, 2.5)	3.4 (2.4, 4.9)	1.6 (1.1, 2.3)	3.4 (2.6, 4.6)	1.6 (1.1, 2.3)	3.4 (2.6, 4.6)

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[29] WBG Climate Change Knowledge Portal (CCKP, 2021). Indonesia Climate Data: Projection. URL: https://climateknowledgeportal.worldbank.org/country/indonesia/climate-data-projections

TABLE 3. Projections of average temperature anomaly (°C) in Indonesia 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.[29]

Scenario	2040–2059		2080–2099	
	Jun–Aug	Dec–Feb	Jun–Aug	Dec–Feb
RCP2.6	0.9 (0.3, 1.6)	0.9 (0.4, 1.4)	0.9 (0.3, 1.6)	0.8 (0.3, 1.5)
RCP4.5	1.2 (0.6, 1.8)	1.2 (0.6, 1.7)	1.7 (1.0, 2.4)	1.6 (1.0, 2.4)
RCP6.0	1.1 (0.5, 1.6)	1.0 (0.5, 1.6)	2.1 (1.3, 2.8)	1.9 (1.3, 2.8)
RCP8.5	1.7 (1.0, 2.3)	1.6 (1.0, 2.2)	3.5 (2.6, 4.6)	3.3 (2.5, 4.4)

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).[30] 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 Indonesia 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 Indonesia. 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 that provide projections across all RCPs and therefore are most robust for comparison.[29] Three models are labelled.

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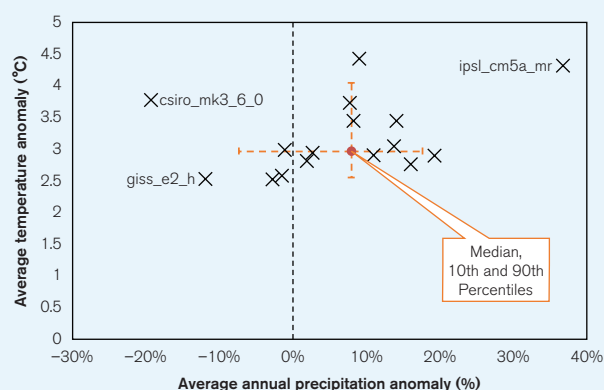
[30] Flato, G., Marotzke, J., Abiodun, B., Braconnot, P., Chou, S. C., Collins, W., . . . Rummukainen, M. (2013). Evaluation of Climate Models. Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, 741–866. URL: http://www.climatechange2013.org/images/report/WG1AR5_ALL_FINAL.pdf

FIGURE 5. CMIP5 ensemble projected change (32 GCMs) in annual temperature (bottom) and precipitation (top) by 2040–2059 (left) and by 2080–2090 (right) relative to 1986–2005 baseline under RCP8.5[31]
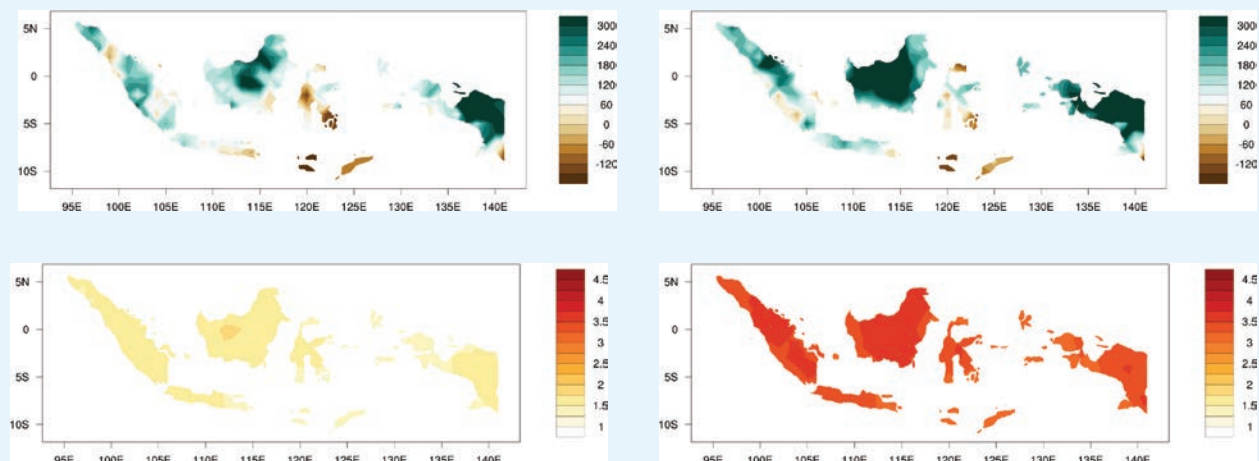
Temperature Changes

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

Projections for annual average temperature rise for Indonesia from the CCKP model ensemble are less than the global average: 3.4°C compared to 3.7°C under the RCP8.5 emissions pathway by the 2080s through the end of the century. Under the same pathway and time-period, the annual averages of maximum and minimum temperatures are projected to increase at a similar rate average temperature 3.4°C. Warming projections suggest a rise of ambient temperatures from approximately 26.5°C towards 29°C–30°C, significantly increasing the frequency of days with temperatures >30°C. However, all these projections are distorted by the inability of current global climate models to distinguish between ocean and land cover over Indonesia's smaller islands. The KNMI Climate Explorer, which can interpolate to finer spatial scales, suggests that significantly higher rates of warming may be experienced in Indonesia's inland regions.[32] For example, warming by the end of the century under RCP8.5 approaches 4°C over central regions of Kalimantan and Sumatra. As such, adaptation planning should take account of potential

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[31] WBG Climate Change Knowledge Portal (CCKP 2021). Indonesia. Climate Data. Projections. URL: https://climatedata.worldbank.org/CRMePortal/web/agriculture/crops-and-land-management?country=IDN&period=2080-2099

[32] KNMI (2019). Climate Explorer: CMIP5 projections. URL: https://climexp.knmi.nl/start.cgi

FIGURE 6. Historic and projected average annual temperature in Indonesia under two emissions pathways estimated by the model ensemble. Shading represents the standard deviation of the model ensemble. Red depicts RCP8.5 and Blue depicts RCP2.6. The solid line represents the median of the model ensemble with the shaded areas showing the 10th–90th percentile.[33]
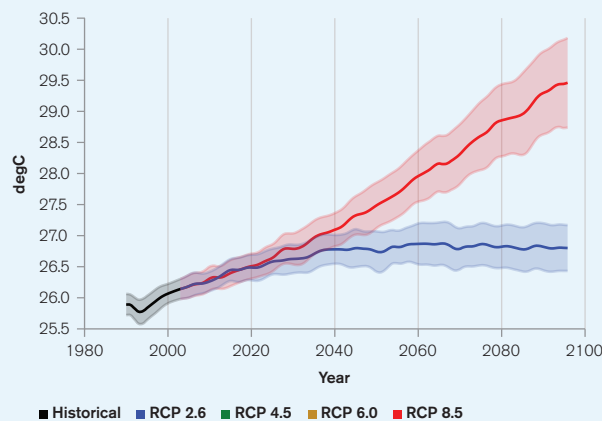
FIGURE 7. Projected change (anomaly) in monthly temperature, shown by month, for Indonesia for the period 2080–2099 under RCP8.5. The value shown represents the median of the model ensemble with the shaded areas showing the 10th–90th percentile.[33]
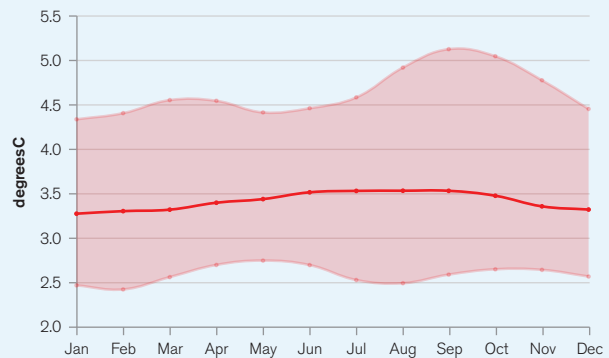
temperatures rises higher than those shown in **Tables 2** and **3**. As **Table 3** and **Figure 7** show, there is very little seasonal variation in temperature changes projected by the CMIP5 ensemble of models under any emissions pathway and over any time period.

Precipitation Changes

Projections of future rainfall are more uncertain than temperature. The CCKP model ensemble suggests increases in median annual rainfall under all emissions pathways. However, there is large uncertainty in this estimate (as seen in the interquartile range shown in **Figure 8**). This shows a slight increase in precipitation levels under all emissions pathways by the 2080s and 2090s. For example, median annual precipitation is projected to increase by 7% under RCP6.0 pathway and 11% under RCP8.5 pathway, from the historical baseline median of 2,884 mm.

FIGURE 8. Boxplots showing the projected average annual precipitation for Indonesia in the period 2080–2099.[33]

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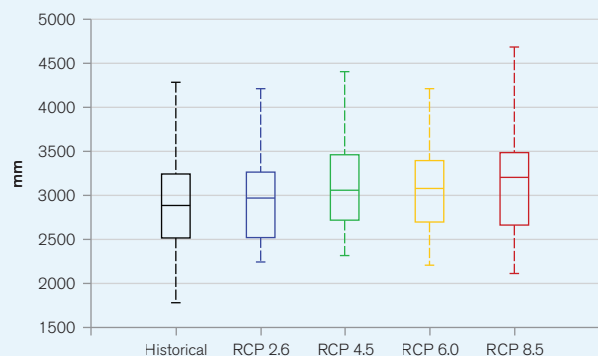
[33] WBG Climate Change Knowledge Portal (CCKP, 2021). Indonesia. Interactive Dashboard. URL: https://climatedata.worldbank.org/CRMePortal/web/energy/oil-gas-and-coal-mining?country=IDN&period=2080-2099

While considerable uncertainty clouds projections of local future precipitation changes, some global trends are still 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.[34] However, this phenomenon is highly dependent on local geographical contexts and more research focusing on Indonesia is required to understand impacts to the country. Downscaling studies for Indonesia suggest considerable variability and uncertainty regarding spatial and temporal distribution. For example, one study points to western Indonesia experiencing a significantly increased number of dry days by the 2060s through end of the century, under RCP8.5 emissions pathway.[35] Another study finds rainfall trajectories in the 2060s in Lombok and Sumbawa islands to be uncertain between December and February; decreasing up to 10% between March and May; with little change for other seasons.[36]

CLIMATE RELATED NATURAL HAZARDS

Indonesia is ranked in the top-third of countries in terms of natural hazard risk (59th out of 191) by the 2019 INFORM Risk Index[37] (**Table 4**). In particular, Indonesia has high exposure to flooding, (ranked 17th most at risk from this natural hazard). Indonesia is similarly highly exposed to tropical cyclones (ranked the 23rd). Despite this high exposure to natural hazards, Indonesia ranks moderately in terms of its coping capacity and vulnerability, where it is ranked in the top half (104th and 81st respectively). The section that follows analyses climate change influences on the exposure component of risk in Indonesia. As seen in **Figure 1**, the ND-GAIN Country Index presents an overall picture of a country's climate vulnerability and capacity to improve its resilience. In addition, the INFORM Risk Index identifies specific risks across a country to support decisions on prevention, preparedness, response and a country's overall risk management.

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

Flood (0–10)	Tropical Cyclone (0–10)	Drought (0–10)	Vulnerability (0–10)	Lack of Coping Capacity (0–10)	Overall Inform Risk Level (0–10)	Rank (1–191)
8.1 [4.5]	6.1 [1.7]	3.4 [3.2]	3.2 [3.6]	4.5 [4.5]	4.7 [3.8]	59

34 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/epdf/10.1002/2014RG000464

35 Polade, S., Pierce, D., Cayan, D., Gershunov, A., Dettinger, M. (2014). The key role of dry days in changing regional climate and precipitation regimes. Scientific reports. 4. 4364. 10.1038/srep04364. URL: https://www.nature.com/articles/srep04364.pdf

36 McGregor, J.L., Nguyen, K.C., Kirono, D.G. and Katzfey, J.J. (2016). High-resolution climate projections for the islands of Lombok and Sumbawa, Nusa Tenggara Barat Province, Indonesia: Challenges and implications. Climate Risk Management, 12, 32–44. URL: https://www.sciencedirect.com/science/article/pii/S2212096315000340

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

Heatwaves

Indonesia regularly experiences high maximum temperatures, with an average monthly maximum of around 30.6°C. Indonesia has a very stable temperature regime, with the hottest month, October, experiencing a maximum temperature of 31.1°C. The current median probability of a heat wave (defined as a period of 3 or more days where the daily temperature is above the long-term 95th percentile of daily mean temperature) is around 2%.

Indonesia is positioned as one of the most vulnerable countries to extreme heatwaves according to climate model projections.[38,39] Under all emissions pathways, the likelihood of experiencing conditions that would historically (as based against the baseline period: 1986–2005) class as a heatwave increases dramatically by the 2080s through the end of the century: approximately 71% under the RCP6.0 pathway and 96% under the RCP8.5 pathway. In their study introducing a new Heat Wave Magnitude Index, Russo et al. (2014) suggest Indonesia might experience an extreme heatwave as often as once every two years by the end of the 21st century under the RCP8.5 emissions pathways.[40] However, as these indices are in part a reflection of Indonesia's historically stable baseline climate, and the continual rise in temperatures away from these conditions, extreme heat should also be explored through other indicators.

Heat Index is another measure of climate condition, which better captures the effective temperature experienced by the human body by factoring in relative humidity. A Heat Index of 35°C is often highlighted as a threshold beyond which conditions become extremely dangerous for human health. **Figure 9** shows projections of the number of days with Heat Index >35°C. Under RCP8.5, Indonesia experiences extremely dangerous conditions almost every day of the year.

An additional factor for consideration is the potential for marine heatwaves. Research has identified the Western Tropical Pacific and Indonesia seas as global hotspots for climate change impacts on marine heatwaves. Marine heatwaves are projected to extend their spatial footprint and to grow in duration and intensity.[41] Even under lower emissions pathways (RCP4.5) increases in heatwave duration and intensity are likely to exceed anything experienced by marine ecology

FIGURE 9. Boxplots showing historical (1986–2005) and projected (2080–2099) annual number of days with Heat Index > 35°C under four emissions pathways.[33]
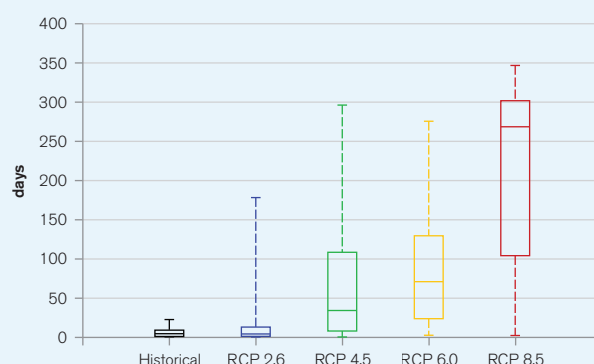
[38] Mora, C., Dousset, B., Caldwell, I.R., Powell, F.E., Geronimo, R.C., Bielecki, C.R., Counsell, C.W., Dietrich, B.S., Johnston, E.T., Louis, L.V. and Lucas, M.P. (2017). Global risk of deadly heat. Nature Climate Change, 7, 501–507. URL: https://tools.niehs.nih.gov/cchhl/index.cfm/main/detail?reference_id=15041

[39] 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. URL: https://www.pnas.org/content/pnas/114/15/3861.full.pdf

[40] Russo, S., Dosio, A., Graversen, R., Sillmann, J., Carrao, H., Dunbar, M., Singleton, A., Montagna, P., Barbosa, P., Vogt, J., (2014). Magnitude of extreme heat waves in present climate and their projection in a warming world. Journal of Geophysical Research Atmospheres. 19. 12500–12512. URL: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/2014JD022098

[41] Frölicher, T. L., Fischer, E. M., & Gruber, N. (2018). Marine heatwaves under global warming. Nature, 560(7718), 360–364. URL: https://www.ncbi.nlm.nih.gov/pubmed/30111788

within the recent historical record.[42] The consequences of this trend may be serious for marine ecosystems in the region (and for dependent livelihoods), which are adapted very stable temperature regimes.

Drought and Fire Risk

Two primary types of drought may affect Indonesia, meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow, potentially originating in the region's wider river basins). At present, Indonesia 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.

Naumann et al. (2018) provide a global overview of changes in drought conditions under different warming scenarios.[43] In comparison to West and Central Asia, South East Asia is less likely to experience extreme increases in drought intensity. As **Figure 10** shows, changes in the annual probability of experiencing a year with a severe drought by the 2090s roughly doubles from 4% to 9% under RCP2.6 and RCP8.5 emissions pathways, respectively. At a national scale, there exists few studies on climate change impacts on water stress and drought in Indonesia.[25] However, droughts are expected to increase in frequency and intensity given the association of accentuated drought with El Niño events, which are expected to increase in frequency and intensity through warmer global temperatures.[44,45]

FIGURE 10. Annual probability of experiencing a 'severe drought' in Indonesia (−2 SPEI index) in 2080–2099 under four emissions pathways.[33]
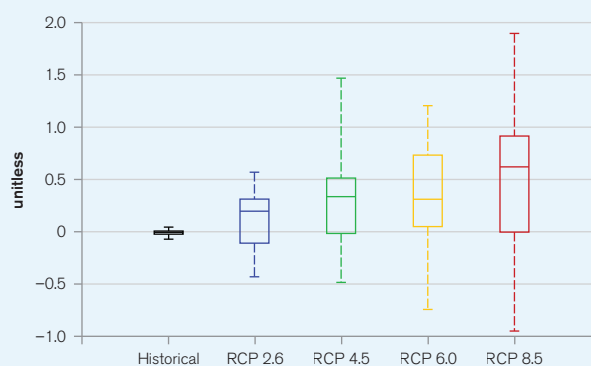
Droughts are strongly associated with El Niño Southern Oscillation, which contributes to severe escalation and extension of manmade fire events in Indonesia, such as those that took place in 1997 and 2015.[46] Following persistent droughts in the dry season from June to November 2019, an increase in forest fires has been observed

[42] Oliver, E. C. J., Burrows, M. T., Donat, M. G., Sen Gupta, A., Alexander, L. V, Perkins-Kirkpatrick, S. E., . . . Smale, D. A. (2019). Projected Marine Heatwaves in the 21st Century and the Potential for Ecological Impact. Frontiers in Marine Science, 6, 734. URL: https://doi.org/10.3389/fmars.2019.00734.

[43] 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/epdf/10.1002/2017GL076521

[44] Naylor, R., Battisti, D., Vimont, D., Falcon, W., Burke, M. (2007). Assessing Risks of Climate Variability and Climate Change for Indonesian Rice Agriculture. Proceedings of the National Academy of Sciences of the United States of America. 104. 7752–7. 10.1073/pnas.0701825104. URL: https://www.pnas.org/content/pnas/104/19/7752.full.pdf

[45] King, A., Karoly, D., Van Oldenborgh, G.J. (2016). Climate Change and El Niño Increase Likelihood of Indonesian Heat and Drought. Bulletin of the American Meteorological Society. 97. S113–S117. URL: https://journals.ametsoc.org/doi/pdf/10.1175/BAMS-D-16-0164.1

[46] Field, R.D., Van Der Werf, G.R., Fanin, T., Fetzer, E.J., Fuller, R., Jethva, H., Levy, R., Livesey, N.J., Luo, M., Torres, O. and Worden, H.M. (2016). Indonesian fire activity and smoke pollution in 2015 show persistent nonlinear sensitivity to El Niño-induced drought. Proceedings of the National Academy of Sciences, 113(33), pp. 9204–9209. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4995960/

in the Sumatra region during October.[47] Climate change projections point to more frequent and severe droughts and subsequently more forest fires.[48] Furthermore, some studies show that increased fire risk is not only associated with drought years, but also temperature rise in non-drought years: during the summer months of July to October, anomalously warmer months increased the probability of fires considerably more than anomalously dry months during this period.[49,50,51] The risks of fire and associated air quality impacts (haze) were underscored by the severe forest and peatland fires of 2015, which cost the national economy an estimated $16 billion in lost productivity, and resulted in an estimated 90,600 excess deaths (smoke-related mortality).[52] Such events also make very significant contributions to global greenhouse gas emissions.

Flood

The World Resources Institute's AQUEDUCT Global Flood Analyzer can be used to establish a baseline level of exposure to large-scale river flooding.[53] As of 2010, assuming protection for up to a 1 in 25-year event, the population annually affected by flooding in Indonesia is estimated at 1.5 million people and expected annual urban damage is estimated at $1.4 billion. Development and climate change are both likely to increase these figures. By the 2030s, climate change is expected to increase the annually affected population by 400,000 people and increase urban damage by $6.1 billion under the RCP8.5 emissions pathway (AQUEDUCT Scenario B).

Paltan et al. (2018) demonstrate that even under lower emissions pathways consistent with the Paris Climate Agreement, almost all Asian countries face an increase in the frequency of extreme river flows.[54] 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.[54] There is good agreement among models about this trend. Wilner et al. (2018) suggest this increase in flows could lead to an increase in the population affected by an extreme flood by 817,000–2,537,000 people (**Table 5**).

Muis et al. (2015) explored flood risk and adaptation strategies in Indonesia under increased climate change and urban expansion. They found high uncertainty around climate change impacts on increased river flood risk but estimated that climate change could amplify coastal flood risk by 19–37% by 2030 (measured by Expected Annual

47 World Bank (2019). Indonesia Economic Quarterly (December 2019): Investing in People. World Bank Jakarta. URL: https://www.worldbank.org/en/country/indonesia/publication/december-2019-indonesia-economic-quarterly-investing-in-people

48 Lestari, R.K., Watanabe, M., Imada, Y., Shiogama, H., Field, R.D., Takemura, T. and Kimoto, M. (2014). Increasing potential of biomass burning over Sumatra, Indonesia induced by anthropogenic tropical warming. Environmental Research Letters, 9(10), p. 104010. URL: https://iopscience.iop.org/article/10.1088/1748-9326/9/10/104010/pdf

49 Fernandes, K., Verchot, L., Baethgen, W., Gutierrez-Velez, V., Pinedo-Vasquez, M. and Martius, C. (2017). Heightened fire probability in Indonesia in non-drought conditions: the effect of increasing temperatures. Environmental Research Letters, 12(5), p. 054002. URL: https://iopscience.iop.org/article/10.1088/1748-9326/aa6884/pdf

50 Risk of Wildfire in Indonesia is shown as high in ThinkHazard! (2019). Think Hazard Risk Analysis, Wildfire. URL: http://thinkhazard.org/en/report/116-indonesia/WF

51 ThinkHazard! (2019). Think Hazard Risk Analysis, Wildfire. URL: http://thinkhazard.org/en/report/116-indonesia/DG

52 Koplitz, S. N., Mickley, L. J., Marlier, M. E., Buonocore, J. J., Kim, P. S., Liu, T., . . . Myers, S. S. (2016). Public health impacts of the severe haze in Equatorial Asia in September-October 2015: demonstration of a new framework for informing fire management strategies to reduce downwind smoke exposure. Environmental Research Letters, 11(9), 94023. URL: http://acmg.seas.harvard.edu/publications/2016/koplitz_fires_2016.pdf

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

54 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://doi.org/10.1088/1748-9326/aad985.

Damage).[55] Indonesia has one of the largest global populations inhabiting low elevation coastal zones, ranked 5th in the world with around 18% of its population inhabiting such areas. Population growth and development trends could increase the absolute size of this population to around 62 million people by 2030.[56]

Table 5. Estimated number of people in Indonesia 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.[57]

Estimate	Population Exposed to Extreme Flood (1971–2004)	Population Exposed to Extreme Flood (2035–2044)	Increase in Affected Population
16.7 Percentile	12,622	829,739	817,117
Median	56,806	1,480,701	1,423,895
83.3 Percentile	378,358	2,916,021	2,537,663

Sea Level Rise

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[58] but some studies published more recently have highlighted the potential for more significant rises (**Table 6**). Indonesia's NC3 describes how rising sea levels and strong wave action contribute to significant coastal erosion — a situation exacerbated by climate change. Coastal areas are exposed to permanent inundation, high tides and land subsidence, affecting settlements, rice fields, ponds and harbors/airports. Water resources are also put at risk, through the potential salinization of coastal surface and ground water resources. Indonesia is particularly exposed to sea-level rise, with the country ranked fifth highest in terms of population inhabiting the lower elevation coastal zone.[59] The total population likely to be exposed to permanent flooding by the 2070s through the end of the century is high, at 4,215,690 without adaptation (**Table 7**). It is estimated that by the 2030s approximately 5.5 million to 8 million people could reside in a 100-year floodplain (an area exposed to 1 in 100-year coastal floods resulting from storm surges), growing to 9.5 million to 14 million people by the 2060s. These estimates assume a modest sea-level rise of 10 centimeters (cm) by 2030 and 21 cm by 2060.[59]

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[55] Muis, S., Aerts, J., and Ward, P. (2018). Flood risk and adaptation strategies under climate change and urban expansion: A probabilistic analysis using global data. URL: https://www.sciencedirect.com/science/article/pii/S0048969715305714?via%3Dihub

[56] Neumann, B., Vafeidis, A.T., Zimmermann, J. and Nicholls, R.J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding-a global assessment. PloS one, 10(3), p. e0118571. URL: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0118571&type=printable

[57] 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/tab-pdf

[58] 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

[59] Neumann, B., Vafeidis, A. T., Zimmermann, J., & Nicholls, R. J. (2015). Future coastal population growth and exposure to sea-level rise and coastal flooding - A global assessment. PLoS ONE, 10(3). URL: https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0118571&type=printable

More analysis of Indonesia's coastal flood risk is needed which also takes into account land subsidence rates. Apart from the length of coastlines, Indonesia is disproportionally impacted by coastal flooding due to high level of subsidence due to ecosystem degradation in lowlands (i.e. peat and mineral soils).[60] Sea level rise is not just a threat due to long-term encroachment on coastal areas, but also due to the projected increase in the frequency of extreme sea-level events.[61] The return period of exceptionally high sea levels, potentially driven by cyclones, is expected to reduce and low-lying Indonesian islands are particularly at risk.[62] Wave heights which historically occurred only once every ten years could occur every 4 to 10 years by 2070–2100, even under lower emissions scenarios (RCP4.5).[63] Significant variation is projected across the Indian Ocean and Pacific and there is lesser confidence in changes projected at finer spatial scales. Studies have also shown that the extent to which elevated wave-heights translate into wave-driven flooding is impacted by coral reef height and health, highlighting the importance of coral conservation.[64]

TABLE 6. Estimates of global mean sea-level rise by rate and total rise compared to 1986–2005 including likely range shown in brackets, data from Chapter 13 of the IPCC's Fifth Assessment Report with upper-end estimates based on higher levels of Antarctic ice-sheet loss from Le Bars et al. (2017).[65]

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

TABLE 7. The average number of people in Indonesia 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 Indonesia.[66]

Scenario	Without Adaptation	With Adaptation
RCP2.6	1,377,530	2,850
RCP8.5	4,215,690	5,930

[60] Husnayaen, Rimba, A. B., Osawa, T., Parwata, I. N. S., As-syakur, A. R., Kasim, F., & Astarini, I. A. (2018). Physical assessment of coastal vulnerability under enhanced land subsidence in Semarang, Indonesia, using multi-sensor satellite data. Advances in Space Research, 61(8), 2159–2179. URL: https://ui.adsabs.harvard.edu/abs/2018AdSpR..61.2159H/abstract

[61] Widlansky, M. J., Timmermann, A., & Cai, W. (2015). Future extreme sea level seesaws in the tropical Pacific. Science Advances, 1(8). URL: https://doi.org/10.1126/sciadv.1500560.

[62] Vitousek, S., Barnard, P. L., Fletcher, C. H., Frazer, N., Erikson, L., & Storlazzi, C. D. (2017). Doubling of coastal flooding frequency within decades due to sea-level rise. Scientific Reports, 7(1), 1399. URL: https://doi.org/10.1038/s41598-017-01362-7.

[63] Wang, X. L., Feng, Y., & Swail, V. R. (2014). Changes in global ocean wave heights as projected using multimodel CMIP5 simulations. Geophysical Research Letters, 41(3), 1026–1034. URL: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2013GL058650

[64] Beetham, E., Kench, P. S., & Popinet, S. (2017). Future Reef Growth Can Mitigate Physical Impacts of Sea-Level Rise on Atoll Islands. Earth's Future, 5(10), 1002–1014. URL: https://agupubs.onlinelibrary.wiley.com/doi/pdf/10.1002/2017EF000589

[65] 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/pdf

[66] UK Met Office (2014). Human dynamics of climate change: Technical Report. Met Office, UK Government. URL: https://www.metoffice.gov.uk/weather/learn-about/climate-and-climate-change/climate-change/impacts/human-dynamics/index

Cyclones

Climate change is expected to interact with cyclone hazards in complex ways that 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. Alongside China, Vietnam, India, and Bangladesh, Indonesia is estimated to have one of the largest coastal populations exposed to flooding from 1 in 100-year storm surges.[56] Modelling of climate change impacts on cyclone intensity and frequency conducted across the globe point to a general trend of reduced cyclone frequency, but increased intensity and frequency of the most extreme events.[67] 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.

Indonesia is impacted from the movement of tropical cyclones in the south eastern Indian Ocean between January and April and the eastern Pacific between May and December, with the country usually impacted by strong winds and heavy rainfall (although due to Indonesia's equatorial location, the country is not directly in the path of cyclones). Increased sea-surface temperatures associated with climate change are projected to increase tropical cyclone intensity.

CLIMATE CHANGE IMPACTS

Natural Resources

Water

Despite having over 21% of the freshwater reserves of Asia, Indonesia has great difficulty in providing potable water as well as freshwater supplies to meet the demands of society, industry, and agricultural producers. In particular, areas such as Java, Bali, East Nusa Tenggara, and parts of Sulawesi experience water deficits, heightened in part by water pollution. Indonesia's NDC outlines how total water demand to support irrigation, domestic consumption, and municipal and industrial uses can exceed water availability in years of low climate-driven supply. Modelling, for example, from Nusa Tenggara Barat Province highlights potential future agricultural water deficits in the first rice growing season (November–March) that could also impact high value cash crops in the second season (March–June).[68]

Climate modelling points to increased water scarcity in Indonesia over the next decades. Indonesia reported in its Second National Communication to the UNFCCC (2010) that 14% of its 453 districts record no months of surplus water. By 2025, this is projected as increase to 20% by 2025, and by 31% by 2050. A study modelling future seasonal rainfall variability in Nusa Tenggara Barat province found significant implications for the water sector. Crop water demand estimates suggest projected changes will impact the rice growing period between November and March and that there will likely be insufficient water for the second growing period, March to

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[67] 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/epdf/10.1002/wcc.371

[68] Kirono, D.G., Butler, J.R., McGregor, J.L., Ripaldi, A., Katzfey, J. and Nguyen, K. (2016). Historical and future seasonal rainfall variability in Nusa Tenggara Barat Province, Indonesia: Implications for the agriculture and water sectors. Climate Risk Management, 12, pp. 45–58. URL: http://agris.fao.org/agris-search/search.do?recordID=US201700077263

June, when chilies and tobacco are grown.[69] In additional to water scarcity, saltwater intrusion is an issue facing Indonesia's water resources. This is currently experienced along Indonesia's coastline and is exacerbated by factors including land subsidence, sea level rise and groundwater exploitation. Sea level rise driven by climate change will likely result in greater saltwater intrusion over the next century.[70]

Fisheries and Coral

Fisheries represent a key component of the Indonesia economy, a major employer, and a significant contributor to national and global food security. By tonnage, in 2017 Indonesia represented the world's second largest capture fish producer, and its third largest fish farming (aquaculture) producer.[71] The impacts of climate change on Indonesia's fisheries remain uncertain. Some models suggest climate change could lead to around a 13% (RCP2.6) to 29% (RCP8.5) decrease in total fisheries catch potential in Indonesian waters by 2050, depending on the emissions scenario. These rise to 18% and 63% respectively by the end of the century.[72] Indeed at the national level, Indonesia's fisheries sector is believed to be one of the most vulnerable in the world.[73] However there is sub-national variation, in some areas like the south coast of Java, which includes the Bali Strait, some models suggest an increase in productivity. This increased productivity seen in modelling is the consequence of climate change intensifying wind stress on the ocean surface, contributing to coastal upwelling.[74]

Multiple other stressors threaten net fishery productivity and ocean biodiversity. Coral reefs provide key spawning grounds for many fish species, as well as harboring significant biodiversity, and generating tourism income (estimated at $3.1 billion per year).[75] High water temperatures and ocean acidification are both already impacting on the health of Indonesian coral reefs. Coral bleaching events are often associated with El Ninō, which brings elevated water temperatures, as seen in 2010 and 2016. The 2016 event was estimated to have created thermal conditions which would have placed corals under stress across around 39% of Indonesia's waters, up from 31% in 2010.[76] The lost income resulting from coral bleaching events is already impacting local artisanal fishing households, and in some cases driving food and income poverty.[77] Long range climate modelling suggests by 2100 Indonesia could lose between 25% (RCP4.5) and 82% (RCP8.5) of its coral cover and, under both scenarios, the majority of coral reef-based tourism could be lost.[75]

[69] Kirono, D.G., Butler, J.R., McGregor, J.L., Ripaldi, A., Katzfey, J. and Nguyen, K. (2016). Historical and future seasonal rainfall variability in Nusa Tenggara Barat Province, Indonesia: Implications for the agriculture and water sectors. Climate Risk Management, 12, pp. 45–58. URL: http://agris.fao.org/agris-search/search.do?recordID=US201700077263

[70] Rahmawati, N., Vuillaume, J.F. and Purnama, I.L.S. (2013). Salt intrusion in Coastal and Lowland areas of Semarang City. Journal of hydrology, 494, pp. 146–159. URL: https://www.sciencedirect.com/science/article/pii/S0022169413003259?via%3Dihub

[71] FAO (2019). FAO yearbook. Fishery and Aquaculture Statistics 2017/FAO annuaire. Statistiques des pêches et de l'aquaculture 2017/FAO anuario. Estadísticas de pesca y acuicultura 2017. Rome/Roma. URL: http://www.fao.org/3/ca5495t/CA5495T.pdf

[72] Barange, M., Bahri, T., Beveridge, M., Cochrane, K., Funge-Smith, S., Poulain, F. (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 (FAO) Technical Paper No. 627. URL: http://www.fao.org/3/i9705en/i9705en.pdf

[73] Blasiak, R., Spijkers, J., Tokunaga, K., Pittman, J., Yagi, N., & Österblom, H. (2017). Climate change and marine fisheries: Least developed countries top global index of vulnerability. PLOS ONE, 12(6), 1–15. URL: https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0179632

[74] Lumban-Gaol, J., Nababan, B., Amri, K., Hanggono, A., Roswintiarti, O. (2012). Climate change impact on Indonesian Fisheries. In Climate ExChange, World Meteorological Organization. URL: http://www.fao.org/3/i9705en/i9705en.pdf

[75] Gaines, S., R. Cabral, C. Free, Y. Golbuu, et al. (2019). The Expected Impacts of Climate Change on the Ocean Economy. Washington, DC: World Resources Institute. URL: https://www.oceanpanel.org/sites/default/files/2019-12/expected-impacts-climate-change-on-the-ocean-economy.pdf

[76] Wouthuyzen, S., Abrar, M., & Lorwens, J. (2018). A comparison between the 2010 and 2016 El-Nino induced coral bleaching in the Indonesian waters. {IOP} Conference Series: Earth and Environmental Science, 118, 12051. URL: https://iopscience.iop.org/article/10.1088/1755-1315/118/1/012051

[77] Chaijaroen, P. (2019). Long-lasting income shocks and adaptations: Evidence from coral bleaching in Indonesia. Journal of Development Economics, 136, 119–136. URL: https://ideas.repec.org/a/eee/deveco/v136y2019icp119-136.html

Forests and Biodiversity

Indonesia harbors some of the world's richest terrestrial biodiversity but over the past two decades its species, many which are endemic to its islands, have come under increasing pressure from human development. Between 2000 and 2012 an estimated 6 million hectares of primary forest cover was lost (equivalent to just over 3% of national land area), around 40% of which took place within areas with designated protections.[78] Studies in different settings show primary forest degradation and conversion (often into palm oil plantations) resulting in declines in species richness up to or above 50%.[79,80] Species loss is not restricted to Indonesia's terrestrial space, rare species in the coastal zone, such mangroves and seagrasses are also under threat, as well as many other marine species.[81,82]

While human development pressure is likely to remain the dominant threat to species richness and diversity in Indonesia, climate change presents new challenges. A key threat is the potential shift in suitable habitat ranges, as rising temperatures shift ranges away from the equator, and upslope. In island environments, where many species have limited mobility and land area can be very limited, there can be an amplified extinction risk as species become trapped. One study looking at bird communities in Sulawesi highlighted a particular climate-risk to species occupying high elevation areas — reporting potential bird population declines as high as 60% by 2050.[83] Another study, based in Borneo, suggested 11%-36% of mammal species could lose over 30% of their suitable habitat by 2080 as a result of climate changes, likely driving significant population declines.[84]

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 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 a decline in arable areas due to the submergence of coastal lands

[78] Margono, B. A., Potapov, P. V, Turubanova, S., Stolle, F., & Hansen, M. C. (2014). Primary forest cover loss in Indonesia over 2000–2012. Nature Climate Change, 4(8), 730–735. URL: https://media.nature.com/original/nature-assets/nclimate/journal/v4/n8/extref/nclimate2277-s1.pdf

[79] Astiani, D. (2016). Tropical peatland tree-species diversity altered by forest degradation. Biodiversitas, 17(1), 102–109. URL: https://biodiversitas.mipa.uns.ac.id/D/D1701/D170115.pdf

[80] Mumme, S., Jochum, M., Brose, U., Haneda, N. F., & Barnes, A. D. (2015). Functional diversity and stability of litter-invertebrate communities following land-use change in Sumatra, Indonesia. Biological Conservation, 191, 750–758. URL: https://www.academia.edu/25267746/Functional_diversity_and_stability_of_litter_invertebrate_communities_following_land_use_change_in_Sumatra_Indonesia

[81] Unsworth, R. K. F., Ambo-Rappe, R., Jones, B. L., Nafie], Y. A. [La, Irawan, A., Hernawan, U. E., . . . Cullen-Unsworth, L. C. (2018). Indonesia's globally significant seagrass meadows are under widespread threat. Science of The Total Environment, 634, 279–286. URL: https://pubmed.ncbi.nlm.nih.gov/29627551/

[82] Ilman, M., Dargusch, P., Dart, P., & Onriẓal. (2016). A historical analysis of the drivers of loss and degradation of Indonesia's mangroves. Land Use Policy, 54, 448–459. URL: https://www.researchgate.net/publication/298787483_A_historical_analysis_of_the_drivers_of_loss_and_degradation_of_Indonesia's_mangroves

[83] Harris, J. B. C., Dwi Putra, D., Gregory, S. D., Brook, B. W., Prawiradilaga, D. M., Sodhi, N. S., . . . Fordham, D. A. (2014). Rapid deforestation threatens mid-elevational endemic birds but climate change is most important at higher elevations. Diversity and Distributions, 20(7), 773–785. URL: https://onlinelibrary.wiley.com/doi/10.1111/ddi.12180

[84] Struebig, M. J., Wilting, A., Gaveau, D. L. A., Meijaard, E., Smith, R. J., Abdullah, T., . . . Kramer-Schadt, S. (2015). Targeted Conservation to Safeguard a Biodiversity Hotspot from Climate and Land-Cover Change. Current Biology, 25(3), 372–378. URL: https://www.sciencedirect.com/science/article/pii/S0960982214015656

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.[85] 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.

FAO describes Indonesia as a leading producer of palm oil and a major global producer of rubber, copra, cocoa and coffee, and the world's second largest marine fisheries producer. 15% of agricultural land is made up of larger plantations cultivating export crops, however, the majority are smallholders with less than a hectare of land.[86] Past trends indicate a low capacity for the agriculture sector to adapt to changes in climate. For example, harvest failure reached 100,000 tons per district between 1981 and 1990; this increased to 300,000 tons per district in the period between 1991 and 2000.[87]

Rice is a major staple in Indonesia, its production is vulnerable to changes in the onset and length of the wet season. El Niño events influence rice production, delaying rainfall and increasing the risk of annual rice deficits, with such events projected to increase from climate change. Estimates project an increase in the probability of 30-day delay in the wet season from 9%–18% today to 30%–40% by mid-century (for the main rice-producing areas of Java and Bali).[88] Rice is particularly sensitive to temperature changes, with some estimates suggesting that an increase of 1°C could reduce national production by 10%–25%.[21] Furthermore, the value of Indonesia's agricultural sector could be reduced by 10% by mid-century.[20] Climate change is also projected to impact palm oil, a significant crop for Indonesia, with the climatic suitability of growing oil palm in the region gradually decreasing by the 2030s and becoming more pronounced up to 2100.[89]

Studies exploring climate change impacts on Indonesia' coffee growing sector highlight potential conflicts which may arise.[90] Optimal coffee growing ranges are likely to shift location as a result of temperature and rainfall shifts. Coffee production losses might be mitigated through adaptive responses in local farming operations but in some areas, crop choices may need to change. At the same time, there is also likely to be increased pressure for highland deforestation in areas where coffee-growing suitability improves. Decision makers may face trade-offs, familiar in Indonesia's palm oil sector, between biodiversity, ecosystem services, and national coffee production levels.

[85] 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

[86] FAO (2017). Country fact sheet on food and agriculture policy trends: Indonesia. URL: http://www.fao.org/3/a-i7696e.pdf

[87] Ministry of Environment (2007). National Action Plan Addressing Climate Change. URL: https://theredddesk.org/sites/default/files/indonesia_national_action_plan_addressing_climate_change.pdf

[88] Naylor, R., Battisti, D., Vimont, D., Falcon, W., Burke, M. (2007). Assessing Risks of Climate Variability and Climate Change for Indonesian Rice Agriculture. Proceedings of the National Academy of Sciences of the United States of America. 104. 7752–7. 10.1073/pnas.0701825104. URL: https://www.pnas.org/content/pnas/104/19/7752.full.pdf

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

[90] Schroth, G., Läderach, P., Blackburn Cuero, D. S., Neilson, J., & Bunn, C. (2015). Winner or loser of climate change? A modeling study of current and future climatic suitability of Arabica coffee in Indonesia. Regional Environmental Change, 15(7), 1473–1482. URL: https://link.springer.com/article/10.1007/s10113-014-0713-x

Urban

Research has established a reasonably well-constrained relationship between heat stress and labor productivity, household consumption patterns, and (by proxy) household living standards.[91] 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 varies depending on local conditions and adaptations. The effects of temperature rise and heat stress in urban areas are increasingly compounded by the phenomenon of the Urban Heat Island (UHI) effect. Dark surfaces, residential and industrial sources of heat, an absence of vegetation, and air pollution[92] 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.[93] Numerous studies have shown how land-use changes associated with urbanization in Indonesia have resulted in UHIs, especially in the capital Jakarta.[94,95]

As well as impacting on human health, the temperature peaks that will result from combined UHI and climate change effects, 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.[96] Notably this serves business and residential air-cooling systems, which will be required to meet the increased cooling demand projected (**Figure 11**). 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 further reduce efficiency.[97]

FIGURE 11. Historic and projected annual cooling degree days in Indonesia (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.[33]
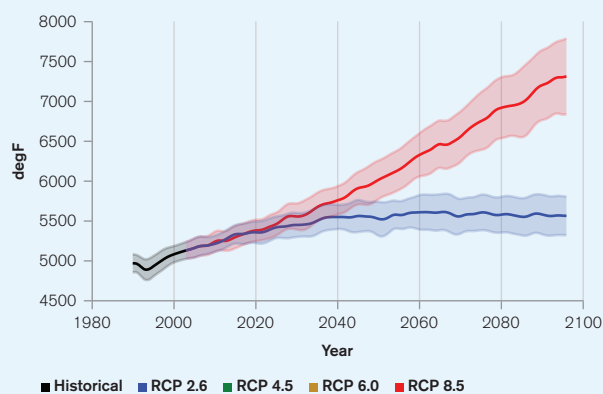
91 Mani, M., Bandyopadhyay, S., Chonabayashi, S., Markandya, A., Mosier, T. (2018). South Asia's Hotspots: The Impact of Temperature and Precipitation changes on living standards. South Asian Development Matters. World Bank, Washington DC. URL: http://documents.worldbank.org/curated/en/201031531468051189/pdf/128323-PUB-PUBLIC-DOC-DATE-7-9-18.pdf

92 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.pdf

93 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://www.sciencedirect.com/science/article/pii/S0034425714002053

94 Manik, TK and Syaukat, S. (2015). The impact of urban heat islands: assessing vulnerability in Indonesia. IIED. URL: http://pubs.iied.org/10721IIED/. [Accessed 4th January 2019.

95 Tursilowati, L., Tetuko, J., Sri Sumantyo, J., Kuze, H., Adiningsih, E. (2012). Relationship between Urban Heat Island Phenomenon and Land Use/Land Cover Changes in Jakarta – Indonesia. 3. 645–653. URL: https://journals.co.za/content/sl_jeteas/3/4/EJC126643

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

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

Cities in Indonesia face unique challenges in the context of climate change because of the country's geographic characteristics, coupled with its rapid rate of urbanization. As an archipelagic nation, whereby 75% of the country's cities are in coastal areas,[98] Indonesia is vulnerable to the impacts of sea-level rise. It is estimated that up to 95 percent of Jakarta's coastal areas could be submerged by 2050.[99] Indonesia also experience frequent natural disasters, totaling 3,622 in 2019[100] alone (**Figure 12**). Of these, approximately 90% are hydrometeorological phenomena, including tornadoes, flooding and landslides,[100] all of which are expected to worsen as a result of climate change.

Over 110 million people in approximately 60 Indonesian cities are exposed to the above negative impacts of climate change,[101] with the country's urban poor being most vulnerable. This is largely due to the concentration of urban poor in city peripheries where infrastructure supply is limited and of low-quality. This situation reflects Indonesia's 'infrastructure gap' including in urban areas, resulting from limited infrastructure investments. The last decade has seen little increase in infrastructure investment with combined total investments by the central government, subnational governments, state-owned enterprises and private sector remaining consistently at only 3%-4% of GDP.[102] As a point of comparison, China and India invested 10% and 7.5% of GDP respectively.[102]

FIGURE 12. Number of natural disasters recorded in Indonesia (2019) by the National Disaster Mitigation Agency (BNPB).

Others 177
Landslides 685
Tornadoes 1282
Floods 734
Land and forest fires 744
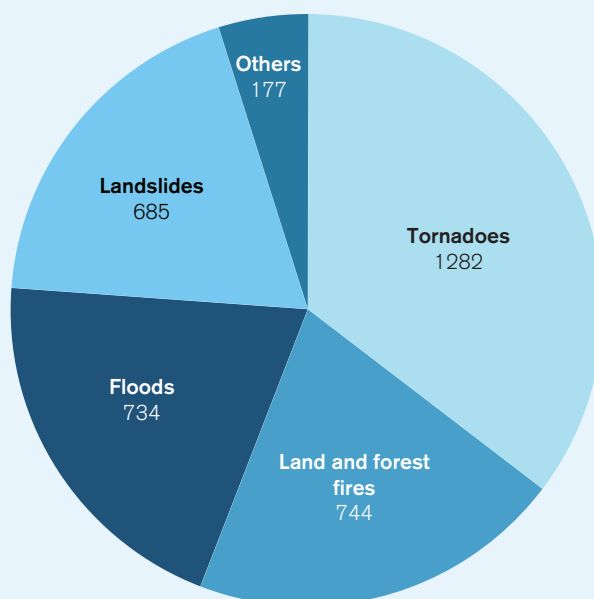
[98] Dahuri, Rokhmin. (2008). Pre-and post-tsunami coastal planning and land-use policies and issues in Indonesia. FAO. URL: http://www.fao.org/3/AG124E07.htm

[99] Aljazeera (2020). Most of Jakarta's coastal areas could be submerged by 2050. Al Jazeera America. URL: https://www.aljazeera.com/news/2020/01/jakarta-submerged-2050-200111104332173.html

[100] The Jakarta Post (2019). 3,622 natural disasters occurred in 2019: BNPB. TheJakartaPost. URL: https://www.thejakartapost.com/news/2019/12/18/3622-natural-disasters-occurred-in-2019-bnpb.html

[101] World Bank (2019). strengthening the disaster resilience of Indonesian cities – a policy note. The World Bank. URL: http://documents.worldbank.org/curated/en/748581569515561529/pdf/Strengthening-the-Disaster-Resilience-of-Indonesian-Cities-A-Policy-Note.pdf

[102] World Bank (2019). National Urban Development Project. The World Bank. URL: http://documents.worldbank.org/curated/en/385841559235504323/pdf/Indonesia-National-Urban-Development-Project.pdf

Communities

Poverty and Inequality

Climate change will 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.[103] Poorer businesses are least able to afford air conditioning, yet there could be 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, but they often cultivate lands most vulnerable to drought and anomalous weather events.

Many regions of Indonesia face very significant adaptation challenges, indeed Eastern Java, Jawa Timur, has been identified as a global hotspot, where adaptation to river flooding is a particular priority.[104] A growing research body documents the vulnerability of different sectors and regions of Indonesia to climate and disaster risk.[105] In many cases fundamental aspects of multidimensional deprivation remain at the heart of community climate and disaster vulnerability. As well as familiar issues such as lacking sources of diversified income, drivers of vulnerability commonly include low access to education and healthcare facilities.[106] Left unaddressed, climate change has potential to exacerbate poverty and inequality issues but also to drive migration challenges. Analysis by ADB has highlighted the high potential of climate-driven increases in flood and drought frequency to increase the incidence of poverty in Indonesia.[107] Migration could arise both due to short-term hazards such as flooding and cyclones, but also due to long-term declining inhabitability of low-lying areas exposed to sea-level rise, and shifts in natural resource availability — particularly the viable range of different species of crop and fish. Indonesia is expected to be one of the first countries to experience 'climate departure', which is likely to start as early as 2020 in Manokwari and by 2029 in Jakarta; substantially earlier than the world average of 2047.[108]

Future climate scenarios are expected to have adverse impacts on agricultural production and are also likely to impact food prices. For example, food prices could increase if there is widespread harvest failure resulting from unusual, extreme climate conditions. The poor in Indonesia are particularly vulnerable to food price rises, theoretical modelling shows a 100% increase in food prices would increase the number of Indonesians in extreme poverty

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[103] 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/pdf/10.1146/annurev-publhealth-032315-021740

[104] Willner, S. N., 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://doi.org/10.1126/sciadv.aao1914

[105] Djalante, R. (2018). Review article: A systematic literature review of research trends and authorships on natural hazards, disasters, risk reduction and climate change in Indonesia. Nat. Hazards Earth Syst. Sci., 18(6), 1785–1810. URL: https://www.nat-hazards-earth-syst-sci.net/18/1785/2018/

[106] Boer, R., Rakhman, A., Pulhin, J., & Schuster, S. (2019). Methodology for assessing vulnerability and climate risk of villages in Citarum River Basin, West Java, Indonesia. {IOP} Conference Series: Earth and Environmental Science, 363, 12007. URL: https://ui.adsabs.harvard.edu/abs/2019E%26ES..363a2007B/abstract

[107] Fujii, T. (2016). Climate Change and Vulnerability to Poverty: An Empirical Investigation in Rural Indonesia. ADBI Working Paper 622. Tokyo: Asian Development Bank Institute. URL: https://www.adb.org/publications/climate-change-vulnerability-poverty-indonesia

[108] Fujii, T. (2016). Climate Change and Vulnerability to Poverty: An Empirical Investigation in Rural Indonesia. Asian Development Bank. Report No. 622. URL: https://www.adb.org/sites/default/files/publication/215986/adbi-wp622.pdf

by more than 25% (**Figure 13**).[109] Climate change can amplify existing challenges in the food production system, thus contributing to food price increases, but the magnitude of such contribution under different climate, market and policy scenarios needs further research. Furthermore, poorer households in Indonesia are much less likely to take adaptive measures and plan for longer-term horizons than wealthier households, making them more exposed to environmental shocks and disasters.[109] Finally, climate impacts are likely to be strongly regionalized. Work by USAID breaks down the potential financial impacts of climate change by province and by driver, suggesting that losses in terms of income per-capita by 2050 typically vary by around 1%–5%.[110] Losses in urban provinces are dominated by climate-health impacts, coastal provinces by sea-level rise issues, and rural provinces by agricultural impacts (**Figure 14**). Many of Indonesia's most economically productive regions are also among the most climate vulnerable.

FIGURE 13. Modelled change in extreme poverty rate in different countries based on food price rises of 10%, 50%, and 100%.[111]
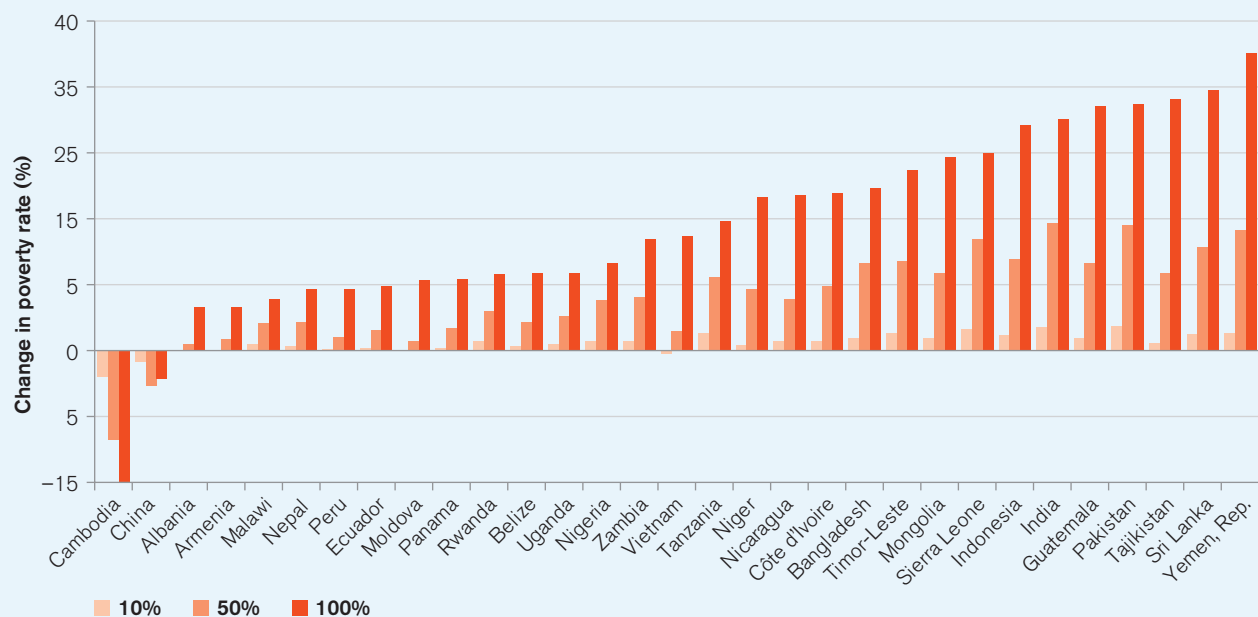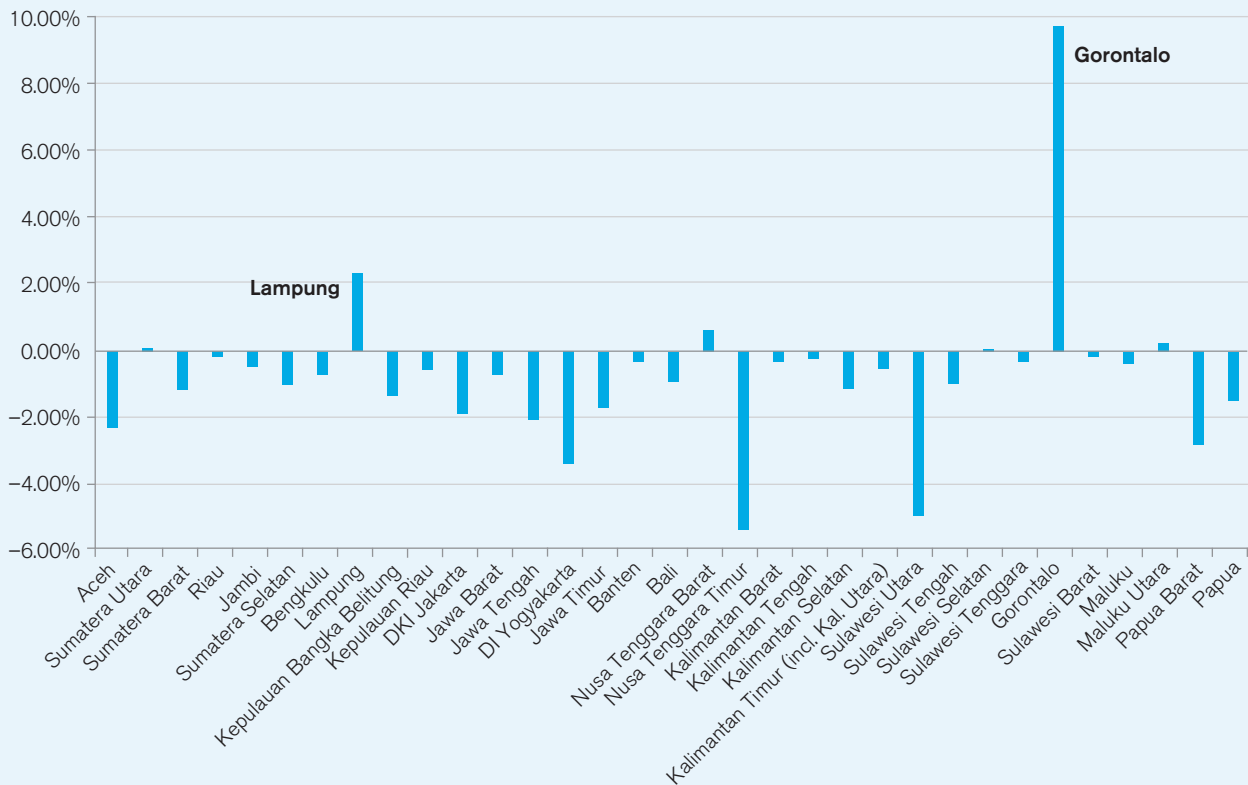
[109] Ivanic, M. and Martin, W. (2014). Short- and Long-Run Impacts of Food Price Changes on Poverty. The World Bank Group.
URL: http://documents.worldbank.org/curated/en/106581468325435880/pdf/WPS7011.pdf [accessed 14/01/2019].
[110] USAID (2016) Indonesia: Costs of Climate Change 2050. United States Agency for International Development Technical Report May 2016. URL: https://www.climatelinks.org/sites/default/files/asset/document/Indonesia%20Costs%20of%20CC%202050%20Tech%20Report.pdf
[111] Hallegatte, S., Mook Bangalore, Bonzanigo, L., Fay, M., Kane, T., Narloch, U., Rozenberg, J., Treguer, D., and Vogt-Schilb, A. (2016). Shock Waves: Managing the Impacts of Climate Change on Poverty. Climate Change and Development Series. World Bank. p. 58. URL: https://openknowledge.worldbank.org/bitstream/handle/10986/22787/9781464806735.pdf?sequence=13&isAllowed=y

FIGURE 14. Percent gains and losses in income per capita by province (percent in 2050).[110]

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.[112]

[112] 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

Human Health

Nutrition

The World Food Program estimates that without adaptation, the risk of global hunger and child malnutrition could increase by 20% by mid-century.[113] Springmann et al. (2016) assessed the potential for excess, climate-related deaths associated with malnutrition globally and regionally. The authors identify two key risk factors that are expected to be the primary drivers: a lack of fruit and vegetables in diets, and health complications caused by increasing prevalence of people undernourished and underweight. In the case of Indonesia, the projections suggest there could be approximately 35.1 climate-related deaths per million population linked to lack of food availability in Indonesia by mid-century under RCP8.5, which is the most extreme projected scenario.[114]

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 this level even a very short period of exposure can present risk of ill-health and death.[115] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change is expected to push global temperatures closer to this 'danger zone' through slow onset warming and intensified heat waves. Furthermore, the links between increased droughts, fires, and heat associated with climate change will have implications on regional air quality and public health in Indonesia.[116]

Honda et al. (2014) utilized the A1B emissions scenario from CMIP3 (most comparable to RCP6.0) to estimate that without adaptation, annual heat-related deaths in the Southeast Asian region could increase 295% by the 2030s and 691% by the 2050s.[117] Under the RCP8.5 emissions pathway, heat-related deaths for 65+ year-olds are projected to increase dramatically by the 2080s, from a baseline of <1 per 100,000 in 1961–1990 to 53 per 100,000.[118] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant).[119] Heat is also projected to influence the health and productivity of Indonesia's, particularly within the agriculture sector. Dunne et al. (2013) suggest 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 mid-century

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

[114] Springmann, M., Mason-D'Croz, D., Robinson, S., Garnett, T., Godfray, H. C. J., Gollin, D., . . . Scarborough, P. (2016). Global and regional health effects of future food production under climate change: a modelling study. The Lancet: 387: 1937–1946. URL: https://www.sciencedirect.com/science/article/pii/S0140673615011563?via%3Dihub

[115] 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

[116] Marlier, M. E., DeFries, P., Kim, S., Gaveau, D., Koplitz, S., Jacob, D., Mickley, L., Margono, B., and Myers, S. (2015). Regional air quality impacts of future fire emissions in Sumatra and Kalimantan. Environmental Research Letters 10, no. 5 (2015): 054010. URL: https://iopscience.iop.org/article/10.1088/1748-9326/10/5/054010/pdf

[117] Honda, Y., Kondo, M., McGregor, G., Kim, H., Guo, Y-L, Hijioka, Y., Yoshikawa, M., Oka, K., Takano, S., Hales, S., Sari Kovats, R. (2014). Heat-related mortality risk model for climate change impact projection. Environmental Health and Preventive Medicine 19: 56–63. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3890078/

[118] World Health Organization (2015). Climate and Health Country Profile – 2015, Indonesia. URL: https://www.who.int/globalchange/resources/country-profiles/PHE-country-profile-Indonesia.pdf [accessed: 26/02/2019].

[119] Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6181199/pdf/emss-79959.pdf

under the highest emissions pathway (RCP8.5).[120] In combination, the global and regional impacts reported above suggest it is likely that warming and heat waves will have a considerable impact on national food consumption patterns and internal agricultural operations in Indonesia, but more in-depth research is required at the country and local levels is required.

Disease

Climate change projections suggest a rise in infectious and vector-borne diseases: under low and high RCP emissions pathways, at least 308 million people (out of a projected population of 340 million) in Indonesia could be at risk of malaria by the 2070s, from a 1961–2000 baseline of approximately 160 million.[121] Similarly, the vectoral capacity of dengue fever is expected to increase by the 2070s.[118] ENSO events, projected to increase from climate change, can contribute to favorable dengue fever outbreak conditions in Indonesia.[122]

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

TABLE 8. Key national adaptation policies, strategies, and plans

Policy/Strategy/Plan	Status	Document Access
National Medium-Term Development Plan 2020–2024	Enacted	January, 2020
National Communications to the UNFCCC	Three submitted	Latest: February, 2018
Biennial Update Report	Two submitted	Latest: 2018
Managing Peatlands Report	Submitted	2018
State of Indonesia's Forests Report	Submitted	2018
Renewable Energy Regulations	Enacted	2017 (Indonesian)
Implementing Redd+ And Sustainable Management of Forests No. 70/2017	Submitted	2017 (Indonesian)
Nationally Determined Contribution (NDC) To Paris Climate Agreement	Submitted	November, 2016
National Medium Term Development Plan 2015–2019 (RPJMN 2015–2019)	Passed	2015
National Adaptation Plan	Enacted	February, 2014
Technology Needs Assessment (TNA) for Climate Change Adaptation 2012	Completed	February, 2012
National Disaster Management Plan 2010–2014	Enacted	2012
National Redd+ Strategy	Submitted	2012

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[120] 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

[121] WHO (2015). Climate and health country profile – 2015 Indonesia. World Health Organization. URL: https://apps.who.int/iris/bitstream/handle/10665/249519/WHO-FWC-PHE-EPE-15.37-eng.pdf?sequence=1&isAllowed=y

[122] Corwin, A. et al. (2001). Epidemic dengue transmission in southern Sumatra, Indonesia. Transactions of the Royal Society of Tropical Medicine and Hygiene. 95. 257–65. DOI:10.1016/S0035-9203(01)90229-9. URL: https://academic.oup.com/trstmh/article-abstract/95/3/257/1903948?redirectedFrom=fulltext

Climate Change Priorities of ADB and the WBG

ADB Country Partnership Strategy

The Asian Development Bank, with the Ministry of Environment and Forestry's Directorate General for Climate Change as the National Focal Point for the UNFCCC, developed Indonesia's Country Partnership Strategy (CPS) for period 2020–2024. This strategy identifies three strategic pathways: (i) improving well-being — by strengthening the health care system, expanding social protection, advancing educational quality in an equitable manner, and developing workforce skills; (ii) accelerating economic recovery — by supporting economic policy and structural reforms, domestic resource mobilization, financial market deepening and inclusion, and the development of high-quality infrastructure; and (iii) strengthening resilience — by supporting climate change mitigation and adaptation measures, environmental sustainability and green recovery, disaster risk management and finance, and water and food security.

ADB will embed climate change mitigation and adaptation measures in its infrastructure investments and support Indonesia's nationally determined contribution goal of 23% of energy supply coming from renewable sources by 2025. ADB will help Indonesia realize its geothermal potential, the large-scale use of its considerable solar photovoltaic and wind resources, and support gas-fired power generation infrastructure to provide backup capacity for intermittent use of renewable energy and the replacement of diesel in Indonesia. It will promote private sector investment in low-carbon initiatives, including technologies that enable the efficient use of renewable energy, and provide knowledge and capacity support to the newly established Environmental Trust Agency. It will help mobilize domestic and international climate finance and establish market-based carbon mechanisms. It will explore partnership opportunities to help Indonesia address land use, land use change, and forestry emissions. ADB's climate adaptation support will include enhancing resilience-building measures in urban and rural areas, promotion of climate-smart livelihoods, adaptive social protection, and improved forecasting systems to strengthen the resilience and capacity of women and men in vulnerable communities.

ADB will provide knowledge support and help catalyze investments for projects that foster environmental sustainability and a green recovery from COVID-19. As part of its Action Plan for Healthy Oceans and Sustainable Blue Economies, ADB will seek to mobilize public and private sector investments to help improve ocean health.[123]

WBG Country Partnership Framework

The WBG, with the Ministry of Environment and Forestry's Directorate General for Climate Change as the National Focal Point for the UNFCCC, developed Indonesia's Country Partnership Framework (CPF) for period 2016–2020. Climate change issues are integrated into all the key pillars of the CPF, which include Infrastructure Platforms at the National Level, Sustainable Energy and Universal Access, Maritime Economy and Connectivity, Delivery of Local Services and Infrastructure, Sustainable Landscape Management, and Collecting More and Spending Better. Guided by the CPF, the World Bank has been supporting the Government of Indonesia to address challenges from climate change through an active portfolio of climate-relevant lending, technical assistance (TA) and analytical activities

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[123] ADB (2020). Country Partnership Strategy, Indonesia, 2020–2024 – Emerging Stronger. URL: https://www.adb.org/sites/default/files/institutional-document/640096/cps-ino-2020-2024.pdf

across sectors. These activities cover topics ranging from green urban development, climate-resilient housing, low-carbon and climate-resilient mass transit system, renewable energy, climate and disaster risk management in water infrastructure development, reduction of the nutritional impacts of climate change, sustainable landscape management to climate-smart agricultural production. These activities are financed through lending and trust fund resources. The WBG and the Government of Indonesia are developing a new Country Partnership Framework (CPF) which will outline the WBG's support for Indonesia's development over the next five years (fiscal years 2021 through 2025).[124]

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[124] WBG (2021). Consultations – Indonesia Country Partnership Framework 2021–2025. URL: https://consultations.worldbank.org/consultation/indonesia-country-partnership-framework-2021-2025#:~:text=The%20World%20Bank%20Group%20(WBG,fiscal%20years%202021%20through%202025).

CLIMATE RISK COUNTRY PROFILE

INDONESIA

WORLD BANK GROUP

ADB ASIAN DEVELOPMENT BANK