

CLIMATE RISK COUNTRY PROFILE

VANUATU



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

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

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FOREWORD

Climate change is a major risk to good development outcomes, and the World Bank Group is committed to playing an important role in helping countries integrate climate action into their core development agendas. The World Bank Group is 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.

The World Bank Group is investing in incorporating and systematically managing climate risks in development operations through its individual corporate commitments.

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 IDA and IBRD 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 Group's Climate Change Knowledge Portal, a comprehensive online 'one-stop shop' for global, regional, and country data related to climate change and development.

Recognizing the value of consistent, easy-to-use technical resources for client countries as well as to support respective internal climate risk assessment and adaptation planning processes, the World Bank Group's Climate Change Group has developed this content. Standardizing and pooling expertise facilitates the World Bank Group 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 developing countries, the climate risk 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.

It is my hope that these efforts will spur deepening of long-term risk management in developing countries and our engagement in supporting climate change adaptation planning at operational levels.



Bernice Van Bronkhorst

Global Director

Climate Change Group (CCG)

The World Bank Group (WBG)

KEY MESSAGES

- Vanuatu is warming and is expected to warm throughout the 21st century. Future rates of warming are clouded by current models' inability to simulate very localized changes but, warming is expected to be in the range of 0.7°C–2.9°C depending on the 21st century rate of global emissions.
- Natural variability between years, even decades, ensure short- and medium-term rainfall changes are difficult to detect and project into the future. Further research is urgently required to develop models better suited to modelling the future climate of Pacific Islands.
- The sea-level near Vanuatu is projected to increase throughout the 21st century, with models showing a very high confidence in this trend. While Vanuatu's islands have higher elevation than some Pacific Island nations', long-term sea-level rise, in combination with local tectonic movements, threatens coastal livelihoods and infrastructure.
- Coral bleaching as a result of climate change is a significant risk to the country's ecology and economy and is part of the global picture of coral loss.
- A realignment of the nation's fisheries is likely, but without careful and sustainable management the future production outlook is not necessarily negative.
- Potential intensification of the most extreme tropical cyclone events threatens significant damage and loss to Vanuatu's population. The science underpinning our understanding of future Pacific circulation patterns is weak, and likely trends are not well understood.
- Adaptation and disaster risk reduction efforts are hampered by Vanuatu's lack of economic independence, high community dependence on subsistence agriculture, and its inaccessible location. Climate change threatens to drive poverty and inequality.

COUNTRY OVERVIEW

The Republic of Vanuatu is an island nation situated in the Melanesia region of Oceania. The country consists of over 80 individual islands, over which is spread a population of over 299,800 people (2019)¹ which has been growing rapidly. The nation is culturally diverse, exemplified by its 138 distinct languages, although there are only three languages officially recognized (English, French, and Bislama). Since Vanuatu declared independence, in 1980, it has been a constitutional representative democracy.

The economy of Vanuatu, like surrounding island states, is based predominantly on the service sector (67% of GDP value added), followed by agriculture (22%) and industry (11%). However, there is significant local dependence on subsistence agriculture² and issues of poverty and undernourishment are prevalent (**Table 1**). The nation

¹ World Bank (2021). World Development Indicators. DataBank. [accessed 17 February, 2021]. URL: <https://databank.worldbank.org/source/world-development-indicators>

² PCRAFI (2015). Vanuatu Country Note. Pacific Catastrophe Risk Assessment and Financing Initiative. The World Bank. URL: https://www.gfdr.org/sites/default/files/publication/Pacific_Catastrophe_Risk_Insurance-Pilot_Report_140715%281%29.pdf

has extensive natural resources, including forests, uplands, corals, and atolls which provide habitats for unique biodiversity and supplement the livelihoods of the 80% of the population that reside in rural areas.

Disasters resulting from natural hazards are a significant contributor to issues of social deprivation and impede economic development in Vanuatu, costing on average an estimated 6% of GDP every year.¹ The nation's exposure to natural hazards, extensive low-lying coastal zone, development context, and precarious natural resource base mean it is amongst the most vulnerable nations to climate change in the world. Vanuatu published its [Third National Communication](#) in 2020 and submitted its [Updated Nationally Determined Contributions](#) in 2020 to the UNFCCC. These documents outline the country's commitment to ensuring adaptation and climate change resilience and align with the country's development goals.

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 Vanuatu. 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 Vanuatu, therefore potentially excluding some international influences and localized impacts. The core climate projections presented are sourced from the Pacific-Australia Climate Change Science and Adaptation Planning Program,^{3,4} as well as 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 staff to inform their climate actions. The document also aims to direct the reader to many useful sources of secondary data and research. For a meta-analysis of the research available on climate change adaptation in small-island developing nations please see Klöck and Nunn (2019).⁵

³ Australian Bureau of Meteorology and CSIRO (2014) Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and CSIRO, Melbourne, Australia. URL: https://www.pacificclimatechangescience.org/wp-content/uploads/2014/07/PACCSAP_CountryReports2014_WEB_140710.pdf

⁴ The NextGen projections for the Pacific region under CMIP5 are expected to be available from late 2021. These will provide an update on the PACCSAP 2014 projections referenced in this profile. The process for providing the new NextGen CMIP6 projections for the Pacific is still in the planning phase.

⁵ Klöck, C. and Nunn, P.D. (2019). Adaptation to Climate Change in Small Island Developing States: A Systematic Literature Review of Academic Research. The Journal of Environment & Development. URL: <https://journals.sagepub.com/doi/abs/10.1177/1070496519835895>

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished ⁶	9.8% (2017–19)	FAO, 2020
National Poverty Rate ⁷	12.7% (2010)	ADB, 2020a
Share of Wealth Held by Bottom 20% ⁸	Unknown	World Bank, 2021
Net Annual Migration Rate ⁹	0.04% (2015–20)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1) ¹⁰	2.2% (2015–20)	UNDESA, 2019
Average Annual Change in Urban Population ¹¹	2.6% (2015–20)	UNDESA, 2019
Dependents per 100 Independent Adults ¹²	73 (2020)	UNDESA, 2019
Urban Population as % of Total Population ¹³	25.5% (2020)	CIA, 2020
External Debt Ratio to GNI ¹⁴	45.9% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP ¹⁵	29.1% (2017)	ADB, 2020b

Due to a combination of political, geographic, and social factors, Vanuatu is recognized as extremely vulnerable to climate change impacts, ranked 132nd out of 182 countries in the 2020 ND-GAIN Index.¹⁶ The ND-GAIN Index ranks 182 countries using a score which calculates a country's vulnerability to climate change and other global challenges as well as their readiness to improve resilience. The more vulnerable a country is the lower their score, while the more ready a country is to improve its resilience the higher it will be. Norway has the highest score and is ranked 1st. **Figure 1** is a time-series plot of the ND-GAIN Index showing Vanuatu's progress.

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.



⁶ FAO, IFAD, UNICEF, WFP, WHO (2020). The state of food security and nutrition in the world. Building Resilience for peace and food security. FAO. Rome. URL: <http://www.fao.org/documents/card/en/c/ca9692en/>

⁷ ADB (2020a). Basic Statistics 2020. Asian Development Bank. Manila. URL: <https://www.adb.org/publications/basic-statistics-2020>

⁸ World Bank (2021). Income share held by lowest 20%. URL: <https://data.worldbank.org/indicator/SI.DST.FRST.20> [accessed 25/10/2021]

⁹ UNDESA (2019). World Population Prospects 2019. URL: <https://population.un.org/wpp/Download/Standard/Population/> [accessed 15/02/2021]

¹⁰ UNDESA (2019). World Population Prospects 2019. URL: <https://population.un.org/wpp/Download/Standard/Population/> [accessed 15/02/2021]

¹¹ UNDESA (2019). World Urbanization Prospects 2019. URL: <https://population.un.org/wup/Download/> [accessed 15/02/2021]

¹² UNDESA (2019). World Population Prospects 2019. URL: <https://population.un.org/wpp/Download/Standard/Population/> [accessed 15/02/2021]

¹³ CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: <https://www.cia.gov/the-world-factbook/>

¹⁴ ADB (2020b). Key Indicators for Asia and the Pacific 2020, 51st Edition. Asian Development Bank. Manila. URL: <https://www.adb.org/sites/default/files/publication/632971/ki2020.pdf>

¹⁵ ADB (2020b). Key Indicators for Asia and the Pacific 2020, 51st Edition. Asian Development Bank. Manila. URL: <https://www.adb.org/sites/default/files/publication/632971/ki2020.pdf>

¹⁶ University of Notre Dame (2020). Notre Dame Global Adaptation Initiative. URL: <https://gain.nd.edu/our-work/country-index/>

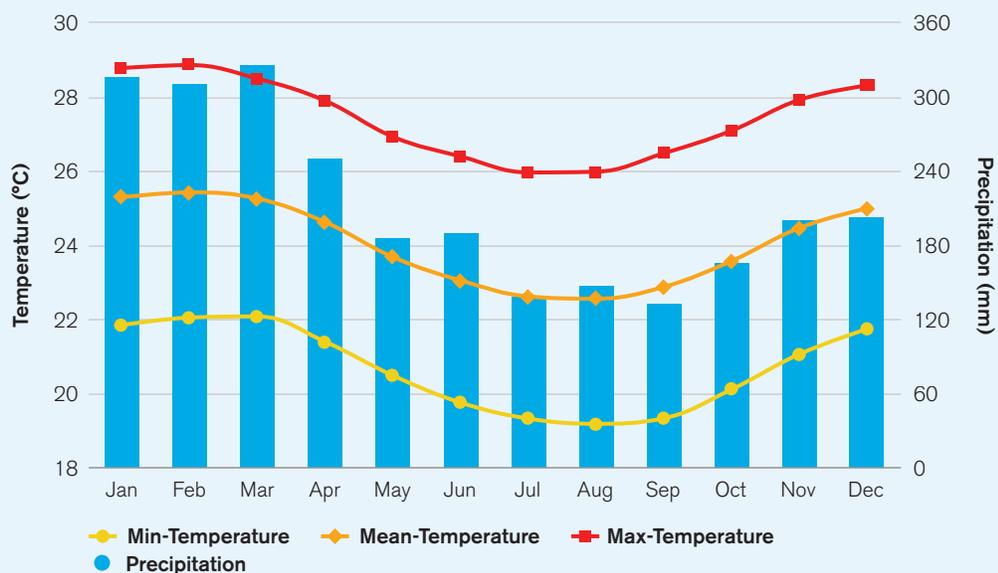
Climate Baseline

Overview

Vanuatu's climate is typical of a Pacific Island nation, with low seasonal variation in temperature (average temperatures varying just 4°C throughout the year) and relatively high precipitation totals, for the latest climatology, 1991-2020 (**Figure 2**). Climate, and particularly precipitation variation, are influenced strongly by the El Niño–Southern Oscillation (ENSO). ENSO has a complex relationship with climate but can be a driver of both drought and flood events as well as regional sea-levels.

Annual Cycle

FIGURE 2. Average monthly mean, max, and min temperatures and rainfall in Vanuatu, 1991–2020¹⁷



Key Trends

Temperature

Vanuatu's Second National Communication to the UNFCCC suggests temperatures have been rising in the region at around 0.1°C per decade since the 1970s. However, the Berkeley Earth Dataset suggests a slightly more complex picture. Up to the 1990s there was limited warming in the region, but from 1995 that warming accelerated, and temperatures between 2014 and 2018 were averaging around 0.5°C–0.6°C above the long-term average.¹⁸

¹⁷ WBG Climate Change Knowledge Portal (CCKP, 2021). Climate Data: Historical. URL: <https://climateknowledgeportalworldbank.org/country/vanuatu/climate-data-historical>

¹⁸ Carbon Brief (2018). Mapped: How every part of the world has warmed — and could continue to warm. [26 September 2018]. URL: <https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm> [accessed 25/10/2019]

Precipitation

A study has pointed to significant natural multi-decadal rainfall variability in the South Pacific Convergence Zone (which Vanuatu is situated within). Observing records over 400 years, it shows abrupt changes of ~1,800 millimeters (mm) can occur between wet seasons.¹⁹ However, no changes in rainfall patterns significantly outside the range of normal inter-annual variation have been documented and linked to human-induced climate changes.

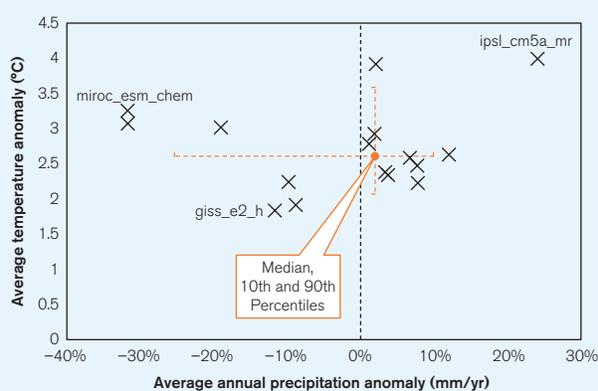
Climate Future

Model Ensemble

Due to differences in the way global circulation models (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 sub-national scales. Exploring the spread of climate model outputs can assist in understanding uncertainties associated with climate models. The range of projections from 16 GCMs on the indicators of average temperature anomaly and annual precipitation anomaly for Vanuatu under RCP8.5 is shown in **Figure 3**. However, it should be noted that concerns have been raised about the realism of some of the more extreme outlier models labelled in **Figure 3**.²⁰

The majority of the models from which outputs are presented in this report are from the CMIP5 round of standardization and quality assurance. Unfortunately, models of this generation operate at large spatial scales and are not well equipped to simulate the future climate of small islands. Typically, the changes projected will relate more to the expected changes over nearby ocean than the island itself. Caution should therefore be applied in interpreting results. This highlights a major area for future development, a research opportunity, and an urgent need from the perspective of policy makers planning for climate change.

FIGURE 3. ‘Projected average temperature change’ and ‘projected annual rainfall change’ in Vanuatu. Outputs of 16 models within the ensemble simulating RCP8.5 over the period 2080–2099. Models shown represent the subset of models within the ensemble which provide projections across all RCPs and therefore are most robust for comparison.²¹ Three models are labelled.



¹⁹ Partin, J.W., Quinn, T.M., Shen, C.C., Emile-Geay, J., Taylor, F.W., Maupin, C.R., Lin, K., Jackson, C.S., Banner, J.L., Sinclair, D.J. and Huh, C.A., 2013. Multidecadal rainfall variability in South Pacific Convergence Zone as revealed by stalagmite geochemistry. *Geology*, 41(11), pp. 1143–1146. DOI: <https://doi.org/10.1130/G34718.1>

²⁰ McSweeney, C.F., Jones, R.G., Lee, R.W. and Rowell, D.P., 2015. Selecting CMIP5 GCMs for downscaling over multiple regions. *Climate Dynamics*, 44(11–12), pp. 3237–3260. URL: <https://link.springer.com/article/10.1007/s00382-014-2418-8>

²¹ World Bank Climate Change Knowledge Portal (2021). Climate Data: Projection. URL: <https://climateknowledgeportal.worldbank.org/>

RCPs

The Representative Concentration Pathways (RCPs) represent four plausible futures, based on the rate of emissions reduction achieved at the global level. Four RCPs (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 low and high emissions pathways, are the primary focus; RCP2.6 represents a very strong mitigation scenario, whereas RCP8.5 assumes a high-emissions scenario. For reference, **Table 2** provides information on all four RCPs over two-time horizons. In subsequent analysis RCPs 2.6 and 8.5, the low and high emissions pathways, are the primary focus. RCP2.6 would require rapid and systemic global action, achieving significant emissions reduction throughout the 21st century. RCP8.5 assumes annual global emissions will continue to increase throughout the 21st century. Climate changes under each emissions pathway are presented against a reference period of 1986–2005 for all indicators. For more information, please refer to the [RCP Database](#).

A Precautionary Approach

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

TABLE 2. An overview of Vanuatu's temperature change projections (°C) under four emissions pathways. Projected changes over the 1986–2005 baseline are given for 20-year periods centred on 2050 and 2090 with the 5th and 95th percentiles provided in brackets.²³

Scenario	Mean Surface Air Temp (Annual)		Max Temp (1-in-20 Year Event)		Min Temp (1-in-20 Year Event)	
	2050	2090	2050	2090	2050	2090
RCP2.6	0.7 (0.5, 1.1)	0.7 (0.3, 1.2)	0.7 (0.2, 0.9)	0.7 (0.3, 0.9)	0.6 (0.2, 1)	0.6 (0.1, 0.9)
RCP4.5	0.9 (0.6, 1.5)	1.3 (0.8, 2)	0.9 (0.5,1.2)	1.3 (0.7, 2)	1 (0.3, 1.2)	1.3 (0.7, 1.8)
RCP6.0	0.9 (0.6, 1.3)	1.6 (1.2, 2.5)	NA	NA	NA	NA
RCP8.5	1.3 (0.8, 2)	2.7 (1.9, 4)	1.4 (0.7, 2)	2.9 (1.9, 4.2)	1.4 (0.9, 1.8)	3 (2.1, 3.9)

²² Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. *Nature Geoscience*, 11, 830–835.

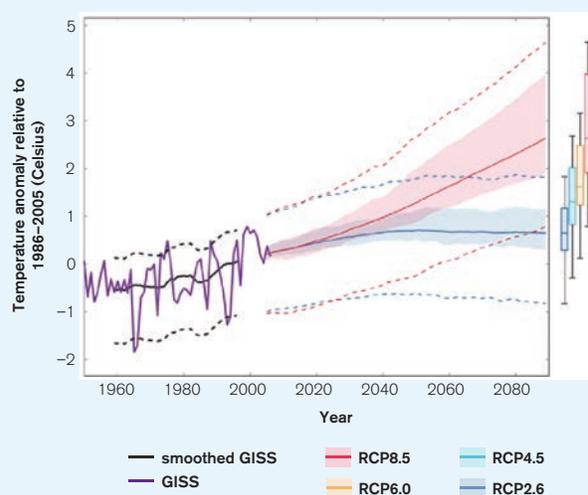
²³ Australian Bureau of Meteorology and CSIRO (2014). *Climate Variability, Extremes and Change in the Western Tropical Pacific: New Science and Updated Country Reports*. Pacific-Australia Climate Change Science and Adaptation Planning Program Technical Report, Australian Bureau of Meteorology and Commonwealth Scientific and Industrial Research Organisation, Melbourne, Australia. URL: https://www.pacificclimatechangescience.org/wp-content/uploads/2014/07/PACCSAP_CountryReports2014_WEB_140710.pdf

Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 2** are the changes (anomalies) in maximum and minimum temperatures over the given time period, as well as changes in the average temperature. **Figures 3** and **4** display only the average temperature projections. While similar, these three indicators can provide slightly different information. Monthly and 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.

There is relatively good agreement among models that future temperature rises over Vanuatu's islands will be below the global average. Under the highest emissions pathway temperatures are projected to reach around 2.8°C by the 2090s, compared to around 3.7°C globally, this reflects the moderating effect of large amounts of nearby ocean cover. However, this ocean cover can also distort model simulations, and the current iteration of global models does not have the spatial accuracy to reliably capture climate processes over small island states; as such these projections should be approached with caution.

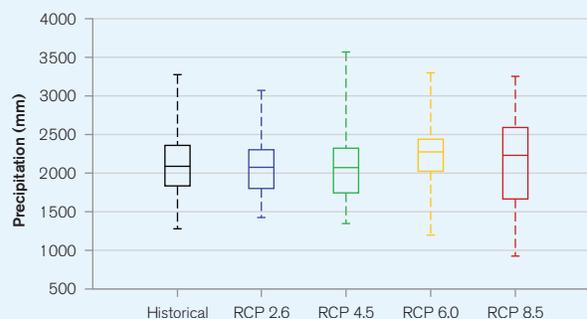
FIGURE 4. Historical and simulated surface air temperature time series for the region surrounding Vanuatu. The graph shows the anomaly (from the base period 1986–2005) in surface air temperature from observations (the GISS dataset, in purple), and for the CMIP5 models under the very high (RCP8.5, in red) and very low (RCP2.6, in blue) emissions scenarios. The solid red and blue lines show the smoothed (20-year running average) multi-model mean anomaly in surface air temperature, while shading represents the spread of model values (5–95th percentile). The dashed lines show the 5–95th percentile of the observed interannual variability for the observed period (in black) and added to the projections as a visual guide (in red and blue). This indicates that future surface air temperature could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centered on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6. (Australian Bureau of Meteorology and CSIRO, 2014).²³



Precipitation

Considerable uncertainty surrounds projections of local long-term future precipitation trends in Vanuatu, and little can be said regarding changes in average annual rainfall (**Figure 5**). However, the intensity of sub-daily extreme rainfall events appears to be increasing with temperature.²⁴ But this phenomenon is highly dependent on local geographical contexts and further research is required to constrain its impact in Vanuatu.

FIGURE 5. Projected average annual precipitation in the vicinity of Vanuatu for the period 2080–2099



CLIMATE RELATED NATURAL HAZARDS

Heat Waves

Vanuatu regularly experiences high maximum temperatures, with an average monthly maximum of around 27.2°C and an average February maximum of 28.8°C. Projected climate changes are expected to push temperatures above 30°C on a regular basis. The historic temperature regime in Vanuatu was very stable; further research is required to better understand the implications of climate change, and its interaction with the ENSO phenomenon, for its future regime and potential heat waves.

An additional factor for consideration is the potential for marine heat waves. Research has identified the Western Tropical Pacific as a global hotspot for climate change impacts on marine heat waves. Marine heat waves are projected to extend their spatial footprint and to grow in duration and intensity.²⁵ The consequences of this trend may be serious for marine ecosystems in the region (and the livelihoods dependent on them), which are adapted to survive under very stable temperature regimes.

²⁴ Westra, S., Fowler, H. J., Evans, J. P., Alexander, L. V., Berg, P., Johnson, F., Kendon, E. J., Lenderink, G., Roberts, N. (2014). Future changes to the intensity and frequency of short-duration extreme rainfall. *Reviews of Geophysics*, 52, 522–555. URL: <https://agupubs.onlinelibrary.wiley.com/doi/10.1002/2014RG000464>

²⁵ Frölicher, T. L., Fischer, E. M., & Gruber, N. (2018). Marine heatwaves under global warming. *Nature*, 560(7718), 360–364. URL: <https://www.nature.com/articles/s41586-018-0383-9>

Drought

Two types of drought may affect Vanuatu, meteorological (usually associated with a precipitation deficit) and hydrological (usually associated with a deficit in surface and subsurface water flow). Meteorological drought is expected to increase in frequency, with one study suggesting a potential doubling in the frequency of severe and extreme droughts by the 2080s under RCP8.5.²⁶ This represents a major risk as there is very high dependence on rainwater for subsistence.²⁷

Flood, Cyclones, and Storm Surge

Vanuatu has very high exposure and vulnerability to the impact of flood, tropical cyclones, and storm surge which can strike in combination or isolation. Cyclones bring coastal and flash flooding even when only passing in the vicinity of the island. According to its Second National Communication to the UNFCCC around 20–30 cyclones pass over Vanuatu every decade, around 3–5 of which will cause severe damage. In 2015 Cyclone Pam, a category 5 tropical cyclone, struck Vanuatu killing 11 people, destroying or damaging over 17,000 buildings and displacing 65,000 people. The economic damages associated with the incident were estimated to be equivalent to around 64% of GDP.²⁸

Climate change is expected to interact with cyclone hazard in complex ways which are currently poorly understood. Known risks include the action of sea-level rise to enhance the damage caused by cyclone-induced storm surges, and the possibility of increased wind speed and precipitation intensity. Modelling of climate change impacts on cyclone intensity and frequency conducted across the globe points to a general trend of reduced cyclone frequency but increased intensity and frequency of the most extreme events.^{29,30} Trends emerging from the scientific literature in regard to tropical cyclone genesis and tracks in the Pacific point towards a climate change-driven westward shift in the genesis location of cyclones.³¹ Evaluation of the climate change implications for severe wind hazard have thus far produced inconclusive results.³² Other characteristics, such as maximum wave height, have been shown to be strongly linked to El Niño-Southern Oscillation, and as such will depend upon the poorly understood relationship between climate change and ENSO.³³ One study has suggested that under future climates, cyclone generation

²⁶ Y. Li.; P. Urich. (2017). Climate Change Impact Assessment for Luganville, Vanuatu: ADB/CLIMsystems Ltd. (Unpublished.)

²⁷ Foster, T. and Willetts, J. (2018). Multiple water source use in rural Vanuatu: are households choosing the safest option for drinking? *International Journal of Environmental Health Research*, 28(6), pp. 579–589. URL: <https://doi.org/10.1080/09603123.2018.1491953>

²⁸ NABCCDRR (2015). Cyclone Pam post disaster needs assessment. National Advisory Board on Climate Change and Disaster Risk Reduction. URL: <https://www.nab.vu/cyclone-pam-post-disaster-needs-assessment> [accessed 16/05/2019]

²⁹ Walsh, K., McBride, J., Klotzbach, P., Balachandran, S., Camargo, S., Holland, G., Knutson, T., Kossin, J., Lee, T., Sobel, A., Sugi, M. (2015). Tropical cyclones and climate change. *WIREs Climate Change*: 7: 65–89. URL: <https://onlinelibrary.wiley.com/doi/abs/10.1002/wcc.371>

³⁰ Widlansky, M. J., Annamalai, H., Gingerich, S. B., Storlagzi, C. D., Marra, J. J., Hodges, K. I., . . . Kitoh, A. (2019). Tropical Cyclone Projections: Changing Climate Threats for Pacific Island Defense Installations. *Weather, Climate, and Society*, 11(1), 3–15. DOI: <https://doi.org/10.1175/WCAS-D-17-0112.1>

³¹ Wu, L., Wang, C., & Wang, B. (2015). Westward shift of western North Pacific tropical cyclogenesis. *Geophysical Research Letters*, 42(5), 1537–1542. DOI: <https://doi.org/10.1002/2015GL063450>

³² Siquera, A., Arthur, A., Woolf, M. (2014) Evaluation of severe wind hazard from tropical cyclones — current and future climate simulations. Pacific-Australia Climate Change Science and Adaptation Planning Program. URL: <https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/79681>

³³ Stephens, S. A., & Ramsay, D. L. (2014). Extreme cyclone wave climate in the Southwest Pacific Ocean: Influence of the El Niño Southern Oscillation and projected climate change. *Global and Planetary Change*, 123, 13–26. DOI: <https://doi.org/https://doi.org/10.1016/j.gloplacha.2014.10.002>

will become more frequent during El Niño events, but less frequent during La Niña events.³⁴ 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.

Vanuatu already has a significant population and asset base exposed to flooding of different types. Over 10,000 people and several thousand infrastructure assets are exposed to riverine flooding and several hundred people and infrastructure assets are exposed to storm surge. This exposure is expected to increase as climate change causes the sea-level to rise.

CLIMATE CHANGE IMPACTS

Natural Resources

Water

The low-lying small island states of the Pacific face many challenges ensuring secure access to clean water. Amongst the islands of Vanuatu, sources of water vary depending on the topography of the islands. Volcanic islands do have some small rivers and streams but these are not present on low-lying islands.³⁵ All of the larger islands, along with some smaller ones, also have access to groundwater (although smaller islands are vulnerable to ground water salinization).³⁶ Most Pacific Island states are almost entirely dependent upon rainfall to support agricultural production, and thus are highly vulnerable to rainfall variability.³⁷

A report by Water Aid in 2018 based on WHO/UNICEF monitoring³⁸ suggested only 90.5% of Vanuatu's population had access to at least a basic water supply. According to a 2009 census conducted by the Vanuatu National Statistics Office the source for water usage varies depending on the activity it is being used for and between rural and urban families. Most households in urban environments use shared or private piped water for both drinking and washing but rainfall collected in tanks is also commonly used in rural areas, especially as a source of drinking water.³⁹ However, the safety of the water within rural rainwater tanks in Vanuatu has been found to commonly be unhealthy for human consumption with relatively high levels of E. coli contamination.⁴⁰ If extended periods

³⁴ Chand, S. S., Tory, K. J., Ye, H., & Walsh, K. J. E. (2016). Projected increase in El Niño-driven tropical cyclone frequency in the Pacific. *Nature Climate Change*, 7, 123. URL: <https://doi.org/10.1038/nclimate3181>

³⁵ FAO (2016). Aquastat: Vanuatu. URL: http://www.fao.org/nr/water/aquastat/countries_regions/VUT/

³⁶ SOPAC (2007). National Integrated Water Resource Management Diagnostic Report: Vanuatu. URL: https://www.pacificwater.org/userfiles/file/GEF%20IWRM%20Final%20Docs/Vanuatu%20IWRM%20Diagnostic%20%20Report%20Vol%202%2014_04_07.pdf

³⁷ UNEP (2011). Freshwater Under Threat Pacific Islands: Vulnerability Assessment of Freshwater Resources to Environmental Change. URL: https://www.garagoga.es/contenidos/medioambiente/onu/830_eng.pdf

³⁸ Water Aid (2018). The State of the World's Water 2018. URL: <https://www.wateraidindia.in/sites/g/files/jkxooof336/files/the-water-gap-state-of-water-report.pdf>

³⁹ VNSO (2010). National Population and Housing Census, 2009. URL: <https://catalog.ihns.org/index.php/catalog/4102>

⁴⁰ Foster, T., & Willetts, J. (2018). Multiple water source use in rural Vanuatu: are households choosing the safest option for drinking? *International journal of environmental health research*, 28(6), 579–589. URL: <https://pubmed.ncbi.nlm.nih.gov/30079752/>

of drought and increased groundwater salinization occur, the need to improve rainwater storage structures will become more pressing. Aquifers used in Port Vila and Luganville have already come under increased pressure and will likely continue to do so as the population increases.³⁰

The Coastal Zone

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44 meters (m) –0.74m by the end of the 21st century by the IPCC's Fifth Assessment Report⁴¹ but some studies published more recently have highlighted the potential for more significant rises (**Table 3**). Localized sea-level rise can in fact be an extremely complex phenomenon to measure and model, notably due to the influence of large-scale climate phenomena such as ENSO. Some studies have suggested that the western Pacific has been experiencing above average rates of sea-level rise, but the extent to which this is attributable to human-driven climate change and/or likely to continue requires further research.⁴²

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.⁴³ The return period of exceptionally high sea-levels, driven by climate circulations, is expected to reduce and low-lying pacific island nations are particularly at risk.⁴⁴ Studies have shown that the extent of wave-driven flooding is impacted by coral reef height and health, highlighting the importance of coral conservation.⁴⁵

Vanuatu's Second National Communication reports sea-level rise at a rate of around 6 mm/yr between 1990 and 2010 – slightly faster than the global average over the same period. Notably, the net rate at which the sea is encroaching on Vanuatu's islands can be significantly accelerated by the simultaneous subsidence of the land driven by tectonic movements. Between 1997–2009 such movements almost doubled the rate of net sea-level rise.⁴⁶ Tectonic movements can hamper efforts to monitor sea-level rise.⁴⁷ One study has modelled the expected rates of coastal erosion under rising sea-levels.⁴⁸ In the long run, coastal infrastructure may be threatened by permanent inundation.

⁴¹ 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

⁴² Peyser, C. E., Yin, J., Landerer, F. W., & Cole, J. E. (2016). Pacific sea level rise patterns and global surface temperature variability. *Geophysical Research Letters*, 43(16), 8662–8669. DOI: <https://doi.org/10.1002/2016GL069401>

⁴³ Widlansky, M. J., Timmermann, A., & Cai, W. (2015). Future extreme sea level seesaws in the tropical Pacific. *Science Advances*, 1(8). DOI: <https://doi.org/10.1126/sciadv.1500560>

⁴⁴ Vitousek, S., Barnard, P. L., Fletcher, C. H., Frazer, N., Erikson, L., & Storlaggi, C. D. (2017). Doubling of coastal flooding frequency within decades due to sea-level rise. *Scientific Reports*, 7(1), 1399. DOI: <https://doi.org/10.1038/s41598-017-01362-7>

⁴⁵ 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. DOI: <https://doi.org/10.1002/2017EF000589>

⁴⁶ Ballu, V., Bouin, M.N., Siméoni, P., Crawford, W.C., Calmant, S., Boré, J.M., Kanas, T. and Pelletier, B., 2011. Comparing the role of absolute sea-level rise and vertical tectonic motions in coastal flooding, Torres Islands (Vanuatu). *Proceedings of the National Academy of Sciences*, 108(32), pp. 13019–13022. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3156165/>

⁴⁷ Deo, M.N., Govind, R. and El-Mowafy, A., 2013. The Stability of Tide Gauges in the South Pacific Determined from Multi Epoch Geodetic Levelling, 1992 to 2010. *Marine Geodesy*, 36(3), pp. 261–284. DOI: <https://doi.org/10.1080/01490419.2013.786003>

⁴⁸ Sahin, O., Stewart, R.A., Faivre, G., Ware, D., Tomlinson, R. and Mackey, B. (2019). Spatial Bayesian Network for predicting sea level rise induced coastal erosion in a small Pacific Island. *Journal of environmental management*, 238, pp. 341–351. URL: <https://pubmed.ncbi.nlm.nih.gov/30856594/>

TABLE 3. 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).⁴⁹

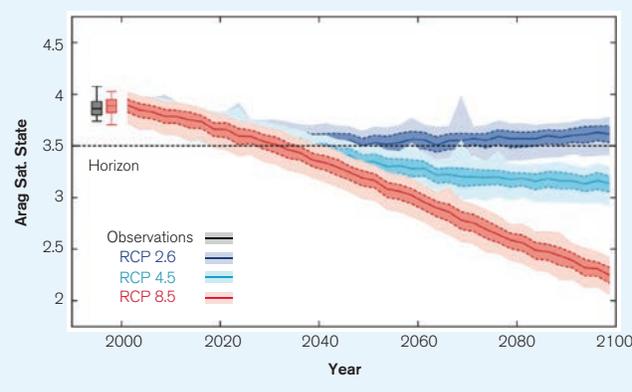
Scenario	Rate of Global Mean Sea-Level Rise in 2100	Global Mean Sea-Level Rise in 2100 Compared to 1986–2005
RCP2.6	4.4 mm/yr (2.0–6.8)	0.44 m (0.28–0.61)
RCP4.5	6.1 mm/yr (3.5–8.8)	0.53 m (0.36–0.71)
RCP6.0	7.4 mm/yr (4.7–10.3)	0.55 m (0.38–0.73)
RCP8.5	11.2 mm/yr (7.5–15.7)	0.74 m (0.52–0.98)
Estimate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

Coral Reefs and Fisheries

Calcium carbonate is used for the external skeletons of multiple marine organisms – for instance, plankton, coral reefs, and shell-fish. Increases in atmospheric carbon dioxide are understood to lead to reduced levels of calcium carbonate saturation on the ocean’s surface via an increase in ocean acidification and by decreasing carbonate ion concentrations. As a result, there are serious concerns that if carbonate minerals, such as aragonite, become under saturated, it could undermine current ocean ecosystems.⁵⁰ **Figure 6** shows the projected aragonite saturation state under three emission scenarios for Vanuatu. Worryingly under RCP4.5 and 8.5 the saturation state is expected to decrease below the threshold needed to sustain healthy coral reefs.

Climate change and human resource exploitation represent a dual threat to fisheries. Species living in and around coral reefs, either permanently or in their juvenile period, and particularly larger species, face an extinction threat.⁵¹ As a result of changes in temperature, dissolved oxygen, and acidity, the maximum catch potential of currently resident species has been

FIGURE 6. Projected changes in aragonite saturation state in Vanuatu from CMIP5 models under RCP2.6, 4.5 and 8.5. Shown are the median values (solid lines), the interquartile range (dashed lines), and 5% and 95% percentiles (light shading). The horizontal line represents the threshold at which transition to marginal conditions for coral reef health typically occurs.²³



⁴⁹ 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>

⁵⁰ Orr, J. C., Fabry, V. J., Aumont, O., Bopp, L., Doney, S. C., Feely, R. A., . . . & Key, R. M. (2005). Anthropogenic ocean acidification over the twenty-first century and its impact on calcifying organisms. *Nature*, 437(7059), 681. URL: <https://pubmed.ncbi.nlm.nih.gov/16193043/>

⁵¹ Mellin, C., Mouillot, D., Kulbicki, M., McClanahan, T. R., Vigliola, L., Bradshaw, C. J. A., . . . Caley, M. J. (2016). Humans and seasonal climate variability threaten large-bodied coral reef fish with small ranges. *Nature Communications*, 7(1), 10491. DOI: <https://doi.org/10.1038/ncomms10491>

forecast to decline significantly in Vanuatu.⁵² As a result there have been strong calls for support to communities to identify suitable responses and financing mechanisms, and to adapt to the changing marine environment.⁵³

Climate change is expected to have a far smaller impact on reducing fish stocks than the effects of fishing. In Vanuatu, around 1% of GDP is typically derived from the fisheries sector.⁵⁴ Climate change is projected to affect how tropical tuna stocks in the Pacific are distributed (such as skipjack, yellowfin, bigeye, and albacore). One study shows that the biomass of skipjack and yellowfin tuna is largely expected to shift eastwards during the 21st century with the effect being weaker for bigeye and albacore tuna.⁵⁵ If these shifts are realized it is likely that a greater proportion of tuna catch will need to be made in international waters. One study which assessed the future of the Vanuatu fishing sector under climate change has suggested that despite some potential new pressures and species range shifts Vanuatu will be able to remain a net exporter of fish up to 2050.⁵⁶ However, protecting and developing the sector is projected to come with significant adaptation costs to the national government.⁵⁷

Island Ecology

Sea-level rise not only threatens humans residing on Pacific islands, but also their unique ecosystem functions and ecology. Indeed, island biodiversity faces a variety of human pressures.⁵⁸ Research has shown that inundation of low-lying islands has the potential to remove important refuges for migrating sea birds.⁵⁹ As climate changes so the suitable range for species to inhabit shifts, typically either upslope or away from the equator. In the Island environment the capacity for species to shift is extremely limited and as such loss and extinction are becoming increasingly likely. Major concerns have been raised for the terrestrial ecology of low-lying Pacific islands, for example endemic lizards, which may become trapped in a shrinking habitat.⁶⁰ Research has also highlighted the risks to biodiversity in the Pacific through study of tree richness in New Caledonia, where the range sizes of 87%–96% of species was projected to decline, typically by 52%–84%.⁶¹

⁵² Asch, R. G., Cheung, W. W. L., & Reygondeau, G. (2018). Future marine ecosystem drivers, biodiversity, and fisheries maximum catch potential in Pacific Island countries and territories under climate change. *Marine Policy*, 88, 285–294. URL: <https://www.openchannels.org/literature/19806>

⁵³ Hanich, Q., Wabnitz, C. C. C., Ota, Y., Amos, M., Donato-Hunt, C., & Hunt, A. (2018). Small-scale fisheries under climate change in the Pacific Islands region. *Marine Policy*, 88, 279–284. DOI: <https://doi.org/https://doi.org/10.1016/j.marpol.2017.11.011>

⁵⁴ FAO (2018). *Fishery and Aquaculture Country Profiles — the Republic of Vanuatu*. URL: <http://www.fao.org/fishery/facp/VUT/en>

⁵⁵ Pacific Community (2019). *The Western and Central Pacific Tuna Fishery: 2017 Overview and Status of Stocks*. URL: https://www.researchgate.net/publication/346512257_The_western_and_central_pacific_tuna_fishery_2019_overview_and_status_of_stocks

⁵⁶ Dey, M.M., Rosegrant, M.W., Gosh, K., Chen, O.L. and Valmonte-Santos, R. (2016). Analysis of the economic impact of climate change and climate change adaptation strategies for fisheries sector in Pacific coral triangle countries: Model, estimation strategy, and baseline results. *Marine Policy*, 67, pp. 156–163. DOI: <https://doi.org/10.1016/j.marpol.2016.01.004>

⁵⁷ Rosegrant, M.W., Dey, M.M., Valmonte-Santos, R. and Chen, O.L. (2016). Economic impacts of climate change and climate change adaptation strategies in Vanuatu and Timor-Leste. *Marine Policy*, 67, pp. 179–188. URL: <https://doi.org/10.1016/j.marpol.2015.12.010>

⁵⁸ Jupiter, S., Mangubhai, S., & Kingsford, R. T. (2014). Conservation of Biodiversity in the Pacific Islands of Oceania: Challenges and Opportunities. *Pacific Conservation Biology*, 20(2), 206–220. URL: <https://www.publish.csiro.au/pc/pc140206>

⁵⁹ Reynolds, M. H., Courtot, K. N., Berkowitz, P., Storlaggi, C. D., Moore, J., & Flint, E. (2015). Will the Effects of Sea-Level Rise Create Ecological Traps for Pacific Island Seabirds? *PLOS ONE*, 10(9), 1–23. DOI: <https://doi.org/10.1371/journal.pone.0136773>

⁶⁰ Taylor, S., & Kumar, L. (2016). Global Climate Change Impacts on Pacific Islands Terrestrial Biodiversity: A Review. *Tropical Conservation Science*, 9(1), 203–223. DOI: <https://doi.org/10.1177/194008291600900111>

⁶¹ Pouteau, R., & Birnbaum, P. (2016). Island biodiversity hotspots are getting hotter: vulnerability of tree species to climate change in New Caledonia. *Biological Conservation*, 201, 111–119. URL: <https://agris.fao.org/agris-search/search.do?recordID=FR2017101025>

Economic Sectors

Agriculture and Food

Vanuatu's economy remains strongly oriented towards agriculture (particularly in rural areas). Food products constituted around 85% of exports in 2011. Simultaneously, Vanuatu has a food trade deficit and dependence on imports for food security equivalent to over \$50 per capita in 2011 giving it high vulnerability to price shocks and disaster events.⁶² Key agricultural crops include coconuts, kava, and cocoa plants. About one third of cultivable land is currently being farmed, with most being used to produce coconuts. Copra, which is the kernel inside coconuts, accounted for 35% of Vanuatu's exports in 2007, and coconuts are also used as a source of food, drink, animal feed, and as a construction material by the islands' communities.⁶³

Climate change could influence food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation and temperatures. Indirect effects include through impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest and disease profiles, the arrival of invasive species, and decline in arable areas due to the submergence of coastal lands. 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.⁶⁴ 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.

Multiple climate-linked drivers threaten the productivity of Vanuatu's agricultural sector. Given the significance of agriculture to Vanuatu's economy, saltwater intrusion poses a present danger to food production with much of the land currently cultivated situated in coastal areas.⁶⁵ Saltwater intrusion, which allows salt from seawater to be absorbed into the soil, has been observed to cause reduced crop efficiency and even lead to crop failure.^{66,67} Cyclones can also cause devastating damage to agricultural products⁶⁸ but, as mentioned previously, there is uncertainty surrounding how their intensity and frequency might change in the future.

⁶² WITS (2019). World Trade Integrated Solution. World Bank. URL: <https://wits.worldbank.org/> [accessed 24/05/2019]

⁶³ MALFFB, Vanuatu (2021). Department of Agriculture and Rural Development — Background. URL: <https://malffb.gov.vu/index.php?id=1>

⁶⁴ 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>

⁶⁵ Vanuatu (2017). National Redd+ Programme-*Malekula*. URL: <http://reddplus.vu/vanuatu-national-redd-program/redd-selected-islands/malekula/>

⁶⁶ Nhung, T. T., Le Vo, P., Van Nghi, V., & Bang, H. Q. (2019). Salt intrusion adaptation measures for sustainable agricultural development under climate change effects: A case of Ca Mau Peninsula, Vietnam. *Climate Risk Management*, 23, 88–100. URL: <https://agris.fao.org/agris-search/search.do?recordID=US201900151965>

⁶⁷ Bartels, D., & Sunkar, R. (2005). Drought and salt tolerance in plants. *Critical reviews in plant sciences*, 24(1), 23–58. DOI: <https://doi.org/10.1080/07352680590910410>

⁶⁸ McKenzie, E., Prasad, B., & Kaloumaira, A. (2005). *Economic impacts of natural disasters on development in the pacific: Volume 2: Economic assessment tools*. Pacific Islands Applied Geoscience Commission (SOPAC). URL: https://www.researchgate.net/publication/269408914_The_economic_impact_of_natural_disasters_on_development_in_the_Pacific

A further, and perhaps lesser appreciated influence of climate change on agricultural production is through its impact on the health and productivity of the labor force. Dunne et al. (2013) 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 the 2050s under the highest emissions pathway (RCP8.5).⁶⁹ Vanuatu currently operates an agricultural system highly dependent on physical labor inputs and hence is potentially vulnerable to higher temperatures without adaptation.⁷⁰ In combination, it is highly likely that the above processes will have a considerable impact on national food consumption patterns both through direct impacts on internal agricultural operations, and through impacts on the global supply chain.

Tourism

Over 40% of GDP in Vanuatu is linked to the tourism sector. In one critical review of the literature examining the dynamics between climate change and tourism, there appeared to be multiple indications that the tourism sectors of small island states, such as Vanuatu, are particularly vulnerable to climate change.⁷¹ In the long-term, the dual threats of rising sea levels and coastal erosion could reduce the quantity and quality of available beach space without significant adaptation measures and could therefore reduce the attractiveness of the country as a tourist destination. Another area of vulnerability is the valuable recreational diving sector, which is threatened by environmental degradation, loss of reefs, and coastal erosion.⁷² One study has identified an explicit need for the Government of Vanuatu to take an active and direct role in adapting the nation's tourism sector to climate change.⁷³ At present, tourism can come into conflict with other sectors and research has pointed towards a need to actively pursue greater co-ordination, sustainability and benefit sharing. Agroecological tourism additionally has the potential to support traditional practices and preserve cultural knowledge.⁷⁴

In addition to direct physical impacts, climate change may affect the tourism sector in Vanuatu through global efforts to mitigate climate change. One possible manifestation is in the increased cost of international flights. One study estimated that while the cost of achieving an emissions-target compatible tourism sector may be proportionately low (3.6%). Nonetheless the necessary increase in trip costs (estimated at \$11 when averaging across every global trip but potentially higher on a long-haul destination such as Vanuatu) may reduce Vanuatu's attractiveness as a tourist destination.⁷⁵ Further research is required to better constrain the suite of potential climate change impacts on the sector.

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

⁷⁰ Lebot, V., & Siméoni, P. (2015). Community Food Security: Resilience and Vulnerability in Vanuatu. *Human Ecology*, 43(6), 827–842. URL: <https://link.springer.com/article/10.1007/s10745-015-9796-3>

⁷¹ Scott, D., Gössling, S., & Hall, C. M. (2012). International tourism and climate change. *Wiley Interdisciplinary Reviews: Climate Change*, 3(3), 213–232. DOI: <https://doi.org/10.1002/wcc.165>

⁷² Klint, L. M., Jiang, M., Law, A., Delacy, T., Filep, S., Calgario, E., . . . Harrison, D. (2012). Dive tourism in Luganville, Vanuatu: Shocks, stressors, and vulnerability to climate change. *Tourism in Marine Environments*, 8(1–2), 91–109. URL: http://vuir.vu.edu.au/21781/1/Klint_et_al_2012.pdf

⁷³ Klint, L.M., Wong, E., Jiang, M., Delacy, T., Harrison, D. and Dominey-Howes, D., 2012. Climate change adaptation in the Pacific Island tourism sector: analysing the policy environment in Vanuatu. *Current Issues in Tourism*, 15(3), pp. 247–274. DOI: <https://doi.org/10.1080/13683500.2011.608841>

⁷⁴ Addinsall, C., Weiler, B., Scherrer, P. and Glencross, K., 2017. Agroecological tourism: bridging conservation, food security and tourism goals to enhance smallholders' livelihoods on South Pentecost, Vanuatu. *Journal of Sustainable Tourism*, 25(8), pp. 1100–1116. URL: https://researchportal.scu.edu.au/discovery/fulldisplay/alma991012820952902368/61SCU_INST:ResearchRepository

⁷⁵ Scott, D., Gössling, S., Hall, C. M., & Peeters, P. (2016). Can tourism be part of the decarbonized global economy? The costs and risks of alternate carbon reduction policy pathways. *Journal of Sustainable Tourism*, 24(1), 52–72. URL <https://doi.org/10.1080/09669582.2015.1107080>

Communities

Poverty, Inequality and Vulnerability to Climate-Related Disaster

Not only do Pacific Islands such as Vanuatu face multiple hazards but, as climate change drives hazard intensity, so does the risk of simultaneous hazard or 'compound' hazard exposure.⁷⁶ At the same time Pacific nations face very considerable uncertainty around future changes which are enhanced by deficiencies in the current suite of climate models. In this context a focus on reducing vulnerability and alleviating the underlying drivers of risk is essential. One study has attempted to develop a framework for understanding and targeting resources at such drivers in Vanuatu.⁷⁷

Vanuatu has been making progress in its disaster risk management, as evidenced by the effective advance warning systems which saved lives when Cyclone Pam struck in in 2015.⁷⁸ Preparing for disaster both in terms of risk reduction and response can be challenging for Pacific Islands with extremely limited resources. As of 2015, Vanuatu had a budget for disaster management of around \$265,000 per year, and a disaster insurance facility of around \$17 million. Analysis suggests that there is an annual probability of 91% and 22% respectively that demand will exceed these resources. A lack of state and individual resource to cope with natural hazards is a particular issue with regards to food availability and the nation's dependence on imports, leading to frequent food poverty.⁷⁹

Many of the climate changes projected are likely to disproportionately affect the poorest groups in society. For instance, heavy manual labor jobs are commonly among the lowest paid whilst also being most at risk of productivity losses due to heat stress.⁸⁰ Poorer businesses are the least able to afford air conditioning, an increasing need given the projected increase in the need for air conditioning with temperature increases. Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation. While Vanuatu's islands are typically higher above sea-level than some of its Pacific neighbors, climate displacement may still present a risk. Those communities likely to be most affected are the poorest whose homes and livelihoods could be at risk. Studies have highlighted the need to better understand the health and wellbeing risks of climate-driven migration.⁸¹

⁷⁶ Matthews, T., Wilby, R.L. and Murphy, C. (2019). An emerging tropical cyclone-deadly heat compound hazard. *Nature Climate Change*, 9, 602–606. URL: <https://www.nature.com/articles/s41558-019-0525-6>

⁷⁷ Jackson, G., McNamara, K. and Witt, B. (2017). A framework for disaster vulnerability in a small island in the Southwest Pacific: a case study of Emae island, Vanuatu. *International Journal of Disaster Risk Science*, 8(4), pp. 358–373. URL: <https://link.springer.com/article/10.1007/s13753-017-0145-6>

⁷⁸ Handmer, J. and Iveson, H. (2017). Cyclone Pam in Vanuatu: Learning from the low death toll. *Australian Journal of Emergency Management*, The, 32(2), p.60. URL: <https://ajem.infoservices.com.au/items/AJEM-32-02-22>

⁷⁹ Feeny, S., McDonald, L., Miller-Dawkins, M., Donahue, J., & Posso, A. (2013). Household vulnerability and resilience to shocks: findings from Solomon Islands and Vanuatu. Australian National University. Working Paper. URL: <http://dpa.bellschool.anu.edu.au/experts-publications/publications/1402/household-vulnerability-and-resilience-shocks-findings>

⁸⁰ Kjellstrom, T., Briggs, D., Freyberg, C., Lemke, B., Otto, M., Hyatt, O. (2016) Heat, human performance, and occupational health: A key issue for the assessment of global climate change impacts. *Annual Review of Public Health*: 37: 97–112. URL: <https://www.annualreviews.org/doi/abs/10.1146/annurev-publhealth-032315-021740>

⁸¹ Dannenberg, A.L., Frumkin, H., Hess, J.J. and Ebi, K.L., 2019. Managed retreat as a strategy for climate change adaptation in small communities: public health implications. *Climatic Change*, pp. 1–14. URL: https://ideas.repec.org/a/spr/climat/v153y2019i1d10.1007_s10584-019-02382-0.html

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.⁸²

Human Health

The broad human health risks of climate change in Pacific Island Countries were assessed in a 2016 study and a large suite of issues were identified. Specifically flagged in Vanuatu were the health impacts of extreme weather events, heat-related illness, water security and safety, food security and malnutrition, vector-borne diseases, respiratory illnesses, non-communicable diseases, and a variety of other disorders.⁸³

Heat-Related Mortality

Research has placed a threshold of 35°C (wet bulb ambient air temperature) on the human body's ability to regulate temperature, beyond which even a very short period of exposure can present risk of serious ill-health and death.⁸⁴ Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change is expected to push global temperatures closer to this temperature 'danger zone' both through slow-onset warming and intensified heat waves.

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 Australasian region, could increase by 211% by 2030 and 437% by 2050.⁸⁵ The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).⁸⁶ Further research is required to better constrain estimates to Vanuatu's geographical range.

⁸² 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>

⁸³ Lachlan, M., Rokho, K., Alistair, W., Simon, H., Jeffery, S., Dianne, K., . . . L., E. K. (2016). Health Impacts of Climate Change in Pacific Island Countries: A Regional Assessment of Vulnerabilities and Adaptation Priorities. *Environmental Health Perspectives*, 124(11), 1707-1714. URL: <https://pubmed.ncbi.nlm.nih.gov/26645102/>

⁸⁴ 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>

⁸⁵ 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. DOI: [10.1007/s12199-013-0354-6](https://doi.org/10.1007/s12199-013-0354-6)

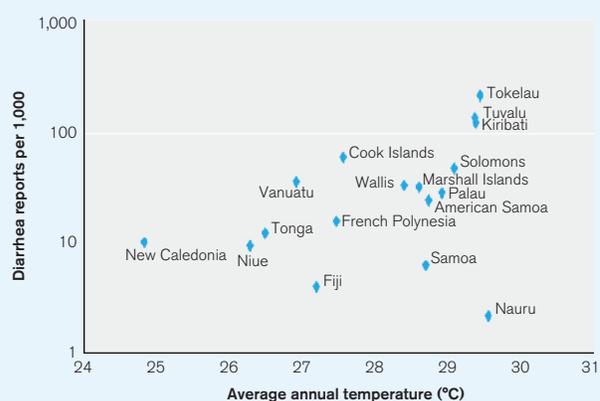
⁸⁶ Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. *Nature Climate Change*, 8(7), 551-553. URL: <https://pubmed.ncbi.nlm.nih.gov/30319715/>

Disease and General Health

Sea-level rises pose a serious threat to the water security of Pacific nations due to potential salinization of potable water sources. Saline intrusion to drinking water sources has been linked to the increased prevalence of hypertension during pregnancy⁸⁷ and, as 57% of the adult population in Vanuatu is overweight,⁸⁸ could contribute to increased levels of hypertension more generally.

Multiple studies have found that increased temperatures, drought, and rainfall are correlated with increases in reported levels of diarrheal disease^{89,90,91} including specifically in the Pacific Island region.⁹² While the interaction between temperature and diarrheal disease is still unclear, one explanation of the association is that rotavirus and other bacteria that cause diarrhea are able to proliferate in warm marine water. Another possible explanation is that higher temperatures can cause food to spoil more rapidly, and thus cause food poisoning.⁹³ **Figure 7** shows research by Singh et al. (2001),⁹² which demonstrated the link between annual average temperature and average reporting rates of diarrheal disease specifically amongst Pacific island states.

FIGURE 7. Annual average temperature and average reporting rates for diarrheal disease, Pacific Islands (1986–1994). $r^2 = 0.49$; $p < 0.05$ ⁸⁵



⁸⁷ Khan, A. E., Ireson, A., Kovats, S., Mojumder, S. K., Khusru, A., Rahman, A., & Vineis, P. (2011). Drinking water salinity and maternal health in coastal Bangladesh: implications of climate change. *Environmental health perspectives*, 119(9), 1328–1332. URL: <https://pubmed.ncbi.nlm.nih.gov/21486720/>

⁸⁸ WHO (2021). Global Health Observatory Repository. URL: https://www.who.int/gho/ncd/risk_factors/overweight/en/ [accessed 01/03/2019]

⁸⁹ Chou, W. C., Wu, J. L., Wang, Y. C., Huang, H., Sung, F. C., & Chuang, C. Y. (2010). Modelling the impact of climate variability on diarrhea-associated diseases in Taiwan (1996–2007). *Science of the Total Environment*, 409(1), 43–51. URL: <https://pubmed.ncbi.nlm.nih.gov/20947136/>

⁹⁰ Zhou, X., Zhou, Y., Chen, R., Ma, W., Deng, H., & Kan, H. (2013). High temperature as a risk factor for infectious diarrhoea in Shanghai, China. *Journal of epidemiology*, JE20130012. URL: <https://pubmed.ncbi.nlm.nih.gov/23994865/>

⁹¹ Wu, X., Lu, Y., Zhou, S., Chen, L., & Xu, B. (2016). Impact of climate change on human infectious diseases: Empirical evidence and human adaptation. *Environment International*, 86, 14–23. DOI: <https://doi.org/10.1016/j.envint.2015.09.007>

⁹² Singh, R. B., Hales, S., De Wet, N., Raj, R., Hearnden, M., & Weinstein, P. (2001). The influence of climate variation and change on diarrheal disease in the Pacific Islands. *Environmental health perspectives*, 109(2), 155–159. URL: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1240636/>

⁹³ Bentham, G., & Langford, I. H. (2001). Environmental temperatures and the incidence of food poisoning in England and Wales. *International journal of biometeorology*, 45(1), 22–26. URL: <https://pubmed.ncbi.nlm.nih.gov/11411411/>

National adaptation Policies and Strategies

- First Nationally Determined Contribution (NDC) (2020)
- Intended Nationally Determined Contribution (INDC) (2016)
- Climate Change and Disaster Risk Reduction Policy 2016–2030 (2015)
- National Adaptation Programme for Action (NAPA) (2007)

Climate Change Priorities of the WBG

WBG — Regional Partnership Framework

The World Bank Group has agreed a [Regional Partnership Framework: Kiribati, Republic of Nauru, Republic of The Marshall Islands, Federated States of Micronesia, Republic of Palau, Independent State of Samoa, Kingdom of Tonga, Tuvalu, and Vanuatu](#) which covers the period 2017–2021. Climate change is one of four key focus areas of the agreement, which states: “Protecting incomes and livelihoods. A key focus will be on strengthened preparedness and resilience to natural disasters and climate change. Interventions will also help countries strengthen health systems and address NCDs.”

Under the heading of strengthening resilience to natural disasters and climate change, the RPF aims to continue to support regional and single-country activities that help the PIC9 strengthen their resilience against natural disasters and climate change. PICs combine high exposure to frequent and damaging natural hazards with low capacity to manage the resulting risks. Vulnerability is exacerbated by poor planning, which has increased losses and exposure to natural disasters, and by climate change, which is predicted to amplify the magnitude of cyclones, droughts, and flooding. Sea level rise will worsen coastal erosion and salinization of freshwater resources and increase the severity of storm surges, which will be particularly damaging in atoll islands and low-lying areas. All these impacts adversely affect agriculture, fisheries, coastal zones, water resources, health and ecosystems and the communities that rely upon them. The cost of inaction is substantial. Investments in disaster proofing and climate resilience cost substantially less than rebuilding after a disaster. The WBG will ensure that at least 35% of the total portfolio will directly or indirectly support climate-related co-benefits. The RPF further identifies a range of regional and country-specific interventions including vulnerability assessment and disaster risk planning, financing and insurance initiatives for climate risks and natural hazards, as well as support to resilience building interventions in areas such as transport, agriculture and water supply.

CLIMATE RISK COUNTRY PROFILE

VANUATU



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