CLIMATE RISK COUNTRY PROFILE

TUVALU

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ACKNOWLEDGEMENTS

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

- Tuvalu's island groups have experienced historical warming of around 0.8°C since 1980.
- Future trends in warming are obscured by the inability of climate models to accurately simulate trends at sufficiently small spatial scales. Warming is likely to take place at a rate slightly lower than the global average. On the highest emissions pathway warming of around 2.8°C is projected by the end of the century.
- Tuvalu faces a diverse set of risks from climate change but data and reliable model projections are lacking, presenting challenges for decision makers.
- Potential threats to human well-being and natural ecosystems include increased prevalence of heat wave, intensified cyclones, saline intrusion, wave-driven flooding, and permanent inundation.
- Biodiversity and the natural environment of Tuvalu face extreme pressure, and loss of some species of fish, coral, bird, and terrestrial species is likely without very effective conservation measures.
- Tuvalu faces a potential long-term threat from permanent inundation and wave-driven flooding, and some studies have suggested that many of its low-lying islands will become uninhabitable within the 21st century.
- Some migration of communities has already been documented from Tuvalu's atolls. However, other research has suggested that the risk of large-scale net loss of land may previously have been overstated and that current drivers of migration primarily relate to socioeconomic issues.
- Tuvalu's population already lives in a dynamic ecosystem, to which it has adapted, but climate change is likely to increase its variability, pose new threats, and place stress on livelihoods.
- Communities are likely to need support to adapt and manage disaster risks facing their wellbeing, livelihoods, and infrastructure. Geographic isolation and economic vulnerabilities, including dependence on remittance and foreign aid, will increase the challenges faced by communities and decision makers.

COUNTRY OVERVIEW

Tuvalu is a microstate of the Polynesian sub-region of the southern Pacific Ocean which consists of nine atolls. Tuvalu is recognized internationally as one of the most climate-vulnerable states on earth. Its islands, which have a surface area of only 26 square kilometers (km^2) and had a population of approximately 11,800 as of 2020, have an average height above sea-level of less than 3 meter (m). Not only is Tuvalu threatened by sea-level rise, it must contend with extreme exposure to tropical cyclones. Tuvalu's economy has become highly dependent on external aid and employment opportunities are limited. Issues of poverty and deprivation have persisted in Tuvalu, but detailed data is sparse (**Table 1**).

Fishing and fishing licenses provide 42% of national revenue, with other income sources including its internet domain, the national trust fund, and remittances from family members abroad. In recent years Tuvalu has seen migration from the outer islands to its capital, Funafuti. Additionally, United Nations research estimates that around 15% of the population of Tuvalu left the country between 2005–2015. A majority of the population are considering emigration but many do not have the financial resources to do so. Tuvalu is characterized by high levels of inequality as measured by consumption levels in an assessment by the World Bank.[1]

[1] World Bank (2015). Hardship and vulnerability in the Pacific island countries. Feature Story. [27 March, 2014]. URL: https://www.worldbank.org/en/news/feature/2014/03/27/hardship-and-vulnerability-in-the-pacific-island-countries

The prosperity of Tuvalu's population depends upon effective management of climate changes, variability, and disaster risk. The Tuvalu Climate Change Policy (2012–2021) sets the country's direction over the period 2012–2021. Reflecting the country's precarious position, consideration is given to issues of vulnerability, disaster preparedness, planning and impact assessment, but also to migration and relocation needs. As documented in Tuvalu's Second National Communication to the UNFCCC (2015) the country has made repeated attempts since the 1980s to construct disaster protection infrastructure, these have failed to provide sustained protection. Tuvalu has signed and ratified the Paris Agreement and its Intended Nationally Determined Contribution (2015).

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 Tuvalu. 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 Tuvalu, 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[2,3] 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 also directs the reader to other 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).[4] 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.

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[2] 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

[3] 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.

[4] 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[5]	N/A	FAO, 2020
National Poverty Rate[6]	26.3% (2010)	ADB, 2020a
Share of Wealth Held by Bottom 20%[7]	N/A	World Bank, 2021
Net Annual Migration Rate[8]	N/A	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[9]	N/A	UNDESA, 2019
Average Annual Change in Urban Population[10]	2.3% (2015–20)	UNDESA, 2019
Dependents per 100 Independent Adults[11]	N/A	UNDESA, 2019
Urban Population as % of Total Population[12]	64% (2020)	CIA, 2020
External Debt Ratio to GNI[13]	37.0% (2017)	ADB, 2020b
Government Expenditure Ratio to GDP[14]	156.7% (2016)	ADB, 2020b

CLIMATOLOGY

Climate Baseline

Overview

Tuvalu has a tropical climate, with consistently high temperatures year-round (27°C–29°C) and high mean annual precipitation (2,500–3,000 millimeters [mm]) (**Figure 1**). Precipitation variability is high, with wet years receiving twice as much rainfall as dry years. Variability is linked to regional weather patterns, with higher rates in El Niño (ENSO) years and reduced rates during La Niña years. The tropical cyclone season in Tuvalu tends to run from November to April and the dry season from May to October.

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5 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/

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

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

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

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

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

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

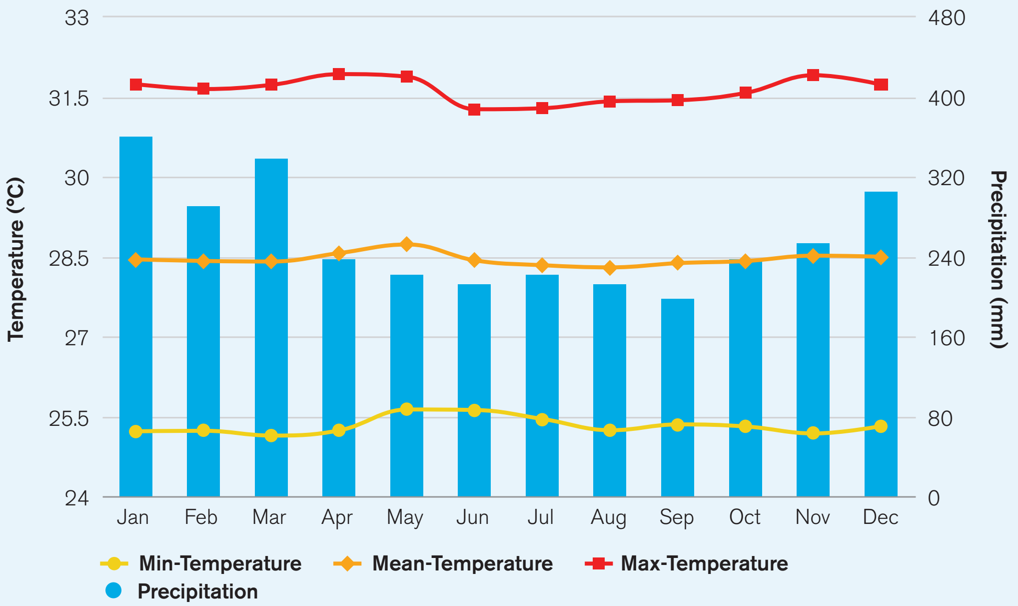
12 CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

13 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

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

Annual Cycle

FIGURE 1. Average monthly mean, max, and min temperatures and rainfall in Tuvalu (1991–2020)[15]



Key Trends

Temperature

Tuvalu's Second National Communication to the UNFCCC (2015) reports historical increases in both mean and seasonal air temperatures. Minimum air temperatures have risen 0.24°C per decade and maximums by 0.21°C per decade since 1950, while sea surface temperatures have risen 0.13°C per decade since 1970. As small island atolls Tuvalu's temperatures are strongly controlled by sea-surface temperatures in the vicinity of the islands. This provides stability in temperatures and means temperature rises in Tuvalu correlate well with sea-surface temperature rises. The Berkeley Earth Dataset on historical warming shows a significant increase in the rate of warming post-1980, suggesting that the over the subsequent 40-year period the climate in the vicinity of Tuvalu warmed by approximately 0.8°C.[16]

Precipitation

No statistically significant changes in annual and seasonal precipitation rates have been measured. Mean annual precipitation rates have tended to be around 500–600 millimeters (mm) lower in Tuvalu's northern-most atoll, Nanumea, than in the capital Funafuti. Nanumea also experiences greater interannual variability with annual rates ranging from 1,000–4,000 mm between 2000–2010. ENSO has a strong influence on inter-annual variability.

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[15] WBG Climate Change Knowledge Portal (CCKP, 2021). Tuvalu. URL:. URL: https://climateknowledgeportal.worldbank.org/country/tuvalu

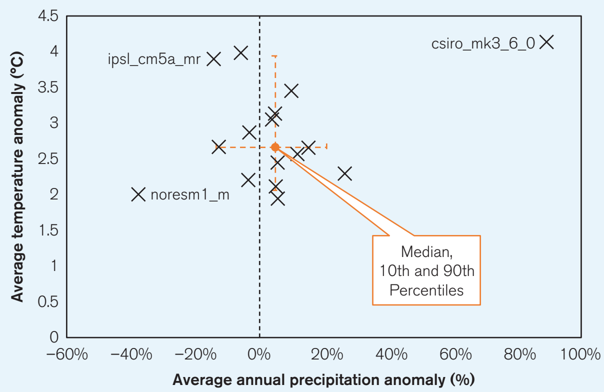
[16] Carbon Brief (2018). Mapped: How every part of the world has warmed – and could continue to warm. [26 September 2018]. URL: https://www.carbonbrief.org/mapped-how-every-part-of-the-world-has-warmed-and-could-continue-to-warm [accessed 25/10/2019]

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 Tuvalu under RCP8.5 is shown in **Figure 2**. However, it should be noted that concerns have been raised about the realism of some of the more extreme outlier models labelled in **Figure 2**.[17]

FIGURE 2. 'Projected average temperature anomaly' and 'projected annual rainfall anomaly' in Tuvalu. 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.[18] Three models are labelled.



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.

[17] 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

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

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.[19] 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 Tuvalu's temperature change projections (°C) under four emissions pathways. Projected changes over the 1986–2005 baseline are given for 20-year periods centered on 2050 and 2090, with the 5th and 95th percentiles provided in brackets.[2]

	Mean Surface Air Temp (Annual)		Max Temp (1-in-20 Year Event)		Min Temp (1-in-20 Year Event)	
Scenario	**2050**	**2090**	**2050**	**2090**	**2050**	**2090**
RCP2.6	0.8 (0.5–1.2)	0.8 (0.4–1.3)	0.7 (0.1–1.1)	0.7 (–0.1–1.1)	0.7 (0.2–1)	0.8 (0.4–0.9)
RCP4.5	1 (0.7–1.4)	1.4 (1–2.1)	0.9 (0.1–1.3)	1.3 (0.6–2)	0.9 (0.5–1.3)	1.3 (1–1.9)
RCP6.0	0.9 (0.6–1.4)	1.7 (1.1–2.6)	NA	NA	NA	NA
RCP8.5	1.4 (1–1.9)	2.8 (2–4)	1.4 (0.5–2)	2.9 (1.4–4.2)	1.5 (1–2.1)	3 (2.2–4)

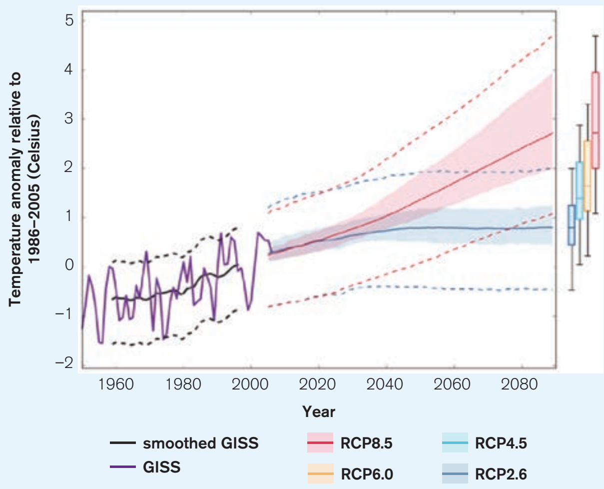
[19] Gasser, T., Kechiar, M., Ciais, P., Burke, E. J., Kleinen, T., Zhu, D., . . . Obersteiner, M. (2018). Path-dependent reductions in CO2 emission budgets caused by permafrost carbon release. Nature Geoscience, 11, 830–835. URL: https://www.nature.com/articles/s41561-018-0227-0?WT.feed_name=subjects_climate-sciences

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 2** and **3** 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.

The model ensemble's estimate of warming under the highest emissions pathway (RCP8.5) is an average temperature increase of approximately 1.4°C by the 2050s and approximately 2.9°C by the 2090s. These temperature increases are projected to occur relatively evenly throughout the year, with little variation from month to month. The model ensemble's estimate of warming under the lowest emissions pathway (RCP2.6) is an average temperature increase of approximately 0.8°C by the 2050s, then for temperatures to remain constant at 0.8°C up to the 2090s.

FIGURE 3. Historical and simulated surface air temperature time series for the region surrounding Tuvalu. 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.[2]



Precipitation

Considerable uncertainty clouds projections of local long-term future precipitation trends in Tuvalu. Models disagree on the direction of change. Issues are likely driven by climate models' inability to simulate either fine resolution changes, or future ENSO patterns. However, some global trends might be expected. The intensity of sub-daily extreme rainfall events appears to be increasing with temperature, a finding supported by evidence from different regions of Asia.[20] However,

[20] 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

as this phenomenon is highly dependent on local geographical contexts further research is required to constrain its impact in Tuvalu. Future precipitation intensity and totals will also be strongly influence by future cyclone behavior which again, is somewhat uncertain.

CLIMATE RELATED NATURAL HAZARDS

Heat Waves

Tuvalu regularly experiences high maximum temperatures, but typically has a very stable temperature regime, with an average monthly maximum of around 31°C. Further research is required to better understand the implications of climate change, and its interaction with the ENSO phenomenon, for Tuvalu's future temperature regime and potential heat waves. In statistical terms the probability of heat waves is likely to grow significantly, as the average temperature moves away from the historical baseline. However, the implications for communities, and particularly the likelihood that key thresholds of human health risk will be passed (approximately 35°C wet bulb temperature), require further study.

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.[21] 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.

Drought

The primary type of drought affecting Tuvalu is meteorological drought, usually associated with a precipitation deficit. The CMIP5 model ensemble does not provide credible information on future drought severity in Tuvalu. Analysis by the Australian Bureau of Meteorology suggests the most likely future involves fewer days being spent in drought conditions, but confidence in these projections is low.[2] Various issues affect accurate projection, including the nation's small land mass, wide distribution, sensitivity to El Niño, remote pacific location and the lack of data on historical trends. General global and regional trends towards greater climatic extremes are recognized as a cause concern. There is a significant need for model improvement and further research.

Floods, Cyclones and Storm Surge

Climate change is expected to interact with cyclone hazard in complex ways which are currently poorly understood. Known risks include the action of sea-level rise to enhance the damage caused by cyclone-induced storm surges, and the possibility of increased 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

[21] 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

but increased intensity and frequency of the most extreme events.[22,23] 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.[24] The Australian Bureau of Meteorology suggest that the frequency of genesis of cyclones affecting Tuvalu is likely to reduce.

Evaluation of the climate change implications for severe wind hazard have thus far produced inconclusive results.[25] 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.[26] One study has suggested that under future climates, cyclone generation will become more frequent during El Niño events, but less frequent during La Niña events.[27] Further research is required to better understand potential changes in cyclone seasonality and intensity. See below for further discussion of the impacts relating to wave-driven flooding and storm surge.

CLIMATE CHANGE IMPACTS

Natural Resources

Water

Tuvalu's fresh water supply depends almost entirely on rainfall. What groundwater is available is often brackish and unsuitable for consumption. Sea-level rise is likely to increase issues of salt intrusion into groundwater and soils, increased sea-levels also increase the risks of damage to water supply infrastructure from natural hazards. Model predictions on future precipitation trends are highly uncertain, global modelling suggests a general trend towards greater variability and greater extremes however, there is disagreement between models covering the Polynesia region, some predicting declining annual precipitation others suggesting increases. Future rainfall patterns are likely to be strongly influenced by the interaction between climate change and ENSO, which is currently poorly understood. The vulnerability and sustainability of groundwater resources under climate changes and potentially amplified extremes in Tuvalu are enhanced by issues with legislation and regulation enforcement.[28]

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22 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

23 Widlansky, M. J., Annamalai, H., Gingerich, S. B., Storlazzi, 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

24 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

25 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: http://datadiscoverystudio.org/geoportal/rest/metadata/item/6cfcbc32c20448579f55edcd2a8383d1/html

26 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. URL: https://www.sciencedirect.com/science/article/pii/S0921818114001957

27 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://ui.adsabs.harvard.edu/abs/2017NatCC...7..123C/abstract

28 Holding, S., Allen, D. M., Foster, S., Hsieh, A., Larocque, I., Klassen, J., & Van Pelt, S. C. (2016). Groundwater vulnerability on small islands. Nature Climate Change, 6, 1100. URL: https://ui.adsabs.harvard.edu/abs/2016NatCC...6.1100H/abstract

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 m–0.74 m by the end of the 21st century by the IPCC's Fifth Assessment Report[29] 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.[30]

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.[31] 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.[32] Studies have shown that the extent of wave-driven flooding is impacted by coral reef height and health, highlighting the importance of coral conservation as an adaptation.[33] Without successful adaptation some studies have estimated that wave-driven flooding will make many atoll islands uninhabitable by the mid 21st century.[34] However, the scientific field lacks consensus on the gravity of the threat. Other studies have shown that atoll islands have potential to sustain and even grow despite sea-level rise thanks to geomorphological processes which build land.[35] The future picture is likely one of a dynamic ecosystem which will demand adaptive lifestyles and livelihoods from inhabitants.

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).[36]

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)

29 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

30 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. URL: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2016GL069401

31 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

32 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. DOI: https://doi.org/10.1038/s41598-017-01362-7

33 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/abs/10.1002/2017EF000589

34 Storlazzi, C. D., Gingerich, S. B., van Dongeren, A., Cheriton, O. M., Swarzenski, P. W., Quataert, E., . . . McCall, R. (2018). Most atolls will be uninhabitable by the mid-21st century because of sea-level rise exacerbating wave-driven flooding. Science Advances, 4(4). URL: https://pubmed.ncbi.nlm.nih.gov/29707635/

35 Kench, P. S., Ford, M. R., & Owen, S. D. (2018). Patterns of island change and persistence offer alternate adaptation pathways for atoll nations. Nature Communications, 9(1), 605. URL: https://www.nature.com/articles/s41467-018-02954-1

36 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

Island Ecology

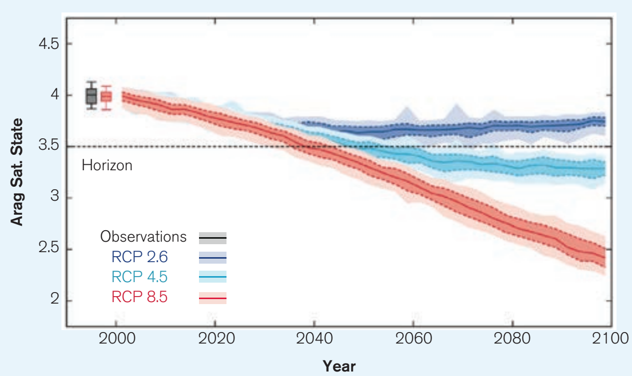
Sea-level rise not only threatens humans residing on Pacific islands, but also their unique ecosystem functions and ecology. Indeed, island biodiversity faces a variety of human pressures.[37] Research has shown that inundation of low-lying islands has the potential to remove important refuges for migrating sea birds.[38] 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.[39] 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%.[40]

Coral Reefs and Fisheries

Calcium carbonite 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 carbonite saturation on the ocean's service via an increase in ocean acidification and by decreasing carbonite ion concentrations. As a result, there are serious concerns that if carbonite minerals, such as aragonite, become under saturated, it could undermine current ocean ecosystems.[41] **Figure 4** shows the projected aragonite saturation state under three emission scenarios for Tuvalu. 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,

FIGURE 4. Projected changes in aragonite saturation state near Tuvalu's islands 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.[2]



[37] 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

[38] Reynolds, M. H., Courtot, K. N., Berkowitz, P., Storlazzi, 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

[39] Taylor, S., & Kumar, L. (2016). Global Climate Change Impacts on Pacific Islands Terrestrial Biodiversity: A Review. Tropical Conservation Science, 9(1), 203–223. URL: https://journals.sagepub.com/doi/full/10.1177/194008291600900111

[40] 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

[41] 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/

face an extinction threat.[42] As a result of changes in temperature, dissolved oxygen, and acidity, the maximum catch potential of currently resident species has been forecast to decline significantly in Tuvalu.[43] 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.[44]

Economic Sectors

Agriculture and Food Security

Climate change will influence food production via direct and indirect effects on crop growth processes. Direct effects include alterations to carbon dioxide availability, precipitation and temperatures. Indirect effects include through impacts on water resource availability and seasonality, soil organic matter transformation, soil erosion, changes in pest and disease profiles, the arrival of invasive species, and decline in arable areas due to the submergence of coastal lands and salinization. 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. 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.[45] It has been reported that as much as 80% of the food consumed on Funafuti is imported,[46] this dependence, combined with low-income levels, gives Tuvalu significant vulnerability to international price shocks.

In regard to local production, Pacific atoll islands have been identified as having particular vulnerability to degradation in agricultural systems as a consequence of climate change. FAO research suggests key issues include heat stress on plants, changes in soil moisture and temperature, loss of soil fertility due to soil erosion, and water stress due to salinization of soils and changes in the water table height.[47] Additional impacts are expected from an increased frequency and intensity of drought periods, similar to that experienced in 2011 in Tuvalu, this is particularly driven by a lack of irrigation infrastructure. Threats to the productivity and predictability of crop yields represent a threat to Tuvalu's food security, particularly in the context of widespread subsistence farming.

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[42] 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

[43] 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

[44] 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

[45] 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

[46] UNU (2012). Small islands, big food concerns. URL: https://ourworld.unu.edu/en/small-islands-big-food-concerns [accessed 28/10/2019]

[47] FAO (2012). Climate change impact on agriculture and food security. Regional Training Workshop on Adaptation for the Pacific Least Developed Countries. [28 September – 3 October 2012] Funafuti, Tuvalu. URL: https://unfccc.int/sites/default/files/leg_2012_pacific_workshop_fao_presentation.pdf

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. Work by Dunne et al. (2013) suggests that global labor productivity during peak months has already dropped by 10% as a result of warming, and that a decline of up to 20% might be expected by the 2050s under the highest emissions pathway (RCP8.5).[48] 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.

Communities

Poverty, Inequality, and Vulnerability to Climate-Related Disaster

Tuvalu faces a wide array of economic development challenges. These include limited natural resources, fragmented land areas, very small domestic economy-its remote location means imports, exports and tourism can be very costly- and weak infrastructure among other factors.[49] According to World Bank findings, in 2010, 26.6% of the Tuvaluan population was living below the national poverty line.[50] In 2010 the national Basic Needs Poverty line (BNPL) set cash income per head at $34.55 a rise of 10.5% from 2004. The BNPL line for Funafuti is higher at $40.06 due to higher cost of living, and Funafuti has seen a steady influx of migrants from outer areas. The percentage of people who are jobless and economically inactive in the public sphere (such as students, retired people and those in full-time home duties) rose from 19% in 2004/5 to 24% in 2010.[51] As such, Tuvalu relies heavily on overseas remittance, other off-shore sources of income and is heavily dependent on foreign aid.[52] Remittances alone from Tuvaluans working on short-term contracts abroad and from those living permanently outside Tuvalu make as much as 30% of GNI.[53] However, despite these constraints and rising poverty rates, Tuvalu performs relatively well on certain key human indicators such as access to health services and formal education (which is almost universal), and an adult literacy rate which reaches 99%.[54]

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[48] 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

[49] Pacific Economic Bulletin (2003). Volume 18 Number 2, November 2003. Asia Pacific Press. URL: http://devpolicy.org/PEB/sort-by/issue/2003-volume-18-number-2/

[50] World Bank (2021). Poverty headcount ratio at national poverty lines (% of population). URL: http://data.worldbank.org/indicator/SI.POV.NAHC/countries/TV?page=1&display=default [accessed 25/10/2021]

[51] Tuvalu (2016). Te Kakeega III National Strategy for Sustainable Development 2016 to 2020. Government of Tuvalu. URL: https://www.adb.org/sites/default/files/linked-documents/cobp-tuv-2017-2019-ld-02.pdf

[52] Milan, A., Oakes, R., and Campbell, J. (2016). Tuvalu: Climate change and migration –Relationships between household vulnerability, human mobility and climate change Report No.18. Bonn: United Nations University Institute for Environment and Human Security (UNU-EHS). URL: https://collections.unu.edu/eserv/UNU:5856/Online_No_18_Tuvalu_Report_161207_.pdf

[53] Tuvalu (2016). Te Kakeega III National Strategy for Sustainable Development 2016 to 2020. Government of Tuvalu. URL: https://www.adb.org/sites/default/files/linked-documents/cobp-tuv-2017-2019-ld-02.pdf

[54] Milan, A., Oakes, R., and Campbell, J. (2016). Tuvalu: Climate change and migration –Relationships between household vulnerability, human mobility and climate change Report No.18. Bonn: United Nations University Institute for Environment and Human Security (UNU-EHS). URL: https://collections.unu.edu/eserv/UNU:5856/Online_No_18_Tuvalu_Report_161207_.pdf

Tuvaluan law grants equal opportunities for men and women; however, in Tuvalu women constitute 78% of the labor force in the subsistence economy but only 37% of the formal employment sector.[55] Although, women in Funafuti tend to have achieved higher levels of education than those living on the outer islands.[56] They are still primarily perceived as care givers and responsible for domestic duties.[57]

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.[58] 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. Women can lack the capital and mobility to adapt their livelihoods.

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.[59]

Migration

Due to its low-lying atoll islands, there is a widespread belief that Tuvalu will be a typical case of forced migration induced by environmental changes. Currently, there is both a high internal migration (primarily to Funafuti) and international migration of Tuvaluans. As a result of internal migration from the outer islands, Funafuti Atoll has become increasingly urbanized over the last 25 years and is under severe population pressure. The 2012 census found that 57% of the country's population now live on Funafuti, compared to 47% in 2002.[60]

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55 UNICEF (2017). Situation analysis of children in Tuvalu. United Nations Children's Fund, Pacific Office, Suva. URL: https://www.unicef.org/pacificislands/media/1266/file/Situation-Analysis-of-Children-Tuvalu.pdf

56 United Nations Population Fund Pacific Sub-Regional Office (UNFPA) (2015). Tuvalu National Population and Housing Census 2012: Migration, Urbanisation and Youth Monograph. URL: http://countryoffice.unfpa.org/pacific/?publications=12319

57 Secretariat of the Pacific Community (SPC) (2013) Stocktake of the Gender Mainstreaming Capacity of Pacific Island Governments: Tuvalu. URL: https://pacificwomen.org/wp-content/uploads/2017/09/Tuvalu-gender-stocktake.pdf

58 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

59 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

60 Tuvalu (2016). Te Kakeega III National Strategy for Sustainable Development 2016 to 2020. Government of Tuvalu. URL: https://www.adb.org/sites/default/files/linked-documents/cobp-tuv-2017-2019-ld-02.pdf

The migration drivers include environmental change, employment, education and for improved opportunities for future generations. However, some literature suggests concerns about the impacts of climate change are not currently a significant driver of migration and do not appear to be a significant influence on those who intend to migrate in the future.[61] Similarly, in one qualitative research Tuvaluans who migrated to New Zealand did not necessarily do so for climate change reasons.[62]

Tuvaluans migrate in search of paid work, new opportunities and lifestyles.[63] Tuvaluans have got several schemes to enable them to leave their country and become seasonally employed outside Tuvalu. The Pacific Access Category (PAC) was initiated in 2002 and allows an annual quota of migrants (up to 75 for Tuvalu) from Pacific island countries to enter New Zealand and work with a residence permit. Another measure to enter New Zealand was the Recognized Seasonal Employers scheme (RSE), established in 2007. In 2013–2014, 70 Tuvaluan workers left to work under this scheme.[64] Tuvaluans are also eligible for temporary migration to Australia under the Seasonal Worker Program (SWP). Between December 2013 and May 2014, 10 workers were recruited through the SWP.[60] As a result of high migration, some of the Tuvaluan outer islands are highly depopulated, especially of working-age adults, which has had a severe impact on the islands' development.[59]

Tuvalu suffers from a severe case of brain drain, the loss of skilled labor has been particularly acute (from the medical profession, teachers, other professional ranks, experienced senior public servants), leaving gaps in the labor force that are becoming increasingly difficult to fill from within the remaining labor force.[59] Tuvaluans are likely to continue to emigrate in search of employment, greater economic opportunity and increasingly to the threat of climate change.

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[61] Mortreux, C. and Barnett, J. (2009). Climate change, migration and adaptation in Funafuti, Tuvalu, Global Environmental Change. 19(1), 105–112. URL: https://www.sciencedirect.com/science/article/abs/pii/S0959378008000903

[62] Shen, S. and Gemenne, F. (2011). Contrasted Views on Environmental Change and Migration: the Case of Tuvaluan Migration to New Zealand. International Migration, 49: e224-e242. DOI: https://doi.org/10.1111/j.1468-2435.2010.00635.x

[63] Tuvalu (2016). Te Kakeega III National Strategy for Sustainable Development 2016 to 2020. Government of Tuvalu. URL:https://www.adb.org/sites/default/files/linked-documents/cobp-tuv-2017-2019-ld-02.pdf

[64] Curtain, R., Dornan, M., Doyle, J., and Howes, S. (2015). Pacific Possible: Labour mobility: the ten billion dollar price. World Bank and Australian National University. URL: http://pubdocs.worldbank.org/en/555421468204932199/pdf/labour-mobility-pacific-possible.pdf

Human Health

The broad human health risks of climate change in Pacific island countries were assessed in a 2016 study. A large suite of issues were identified. Specifically flagged in Tuvalu 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.[65]

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.[66] 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.[67] The potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[68] Further research is required to constrain estimates of extreme heat to Tuvalu's geographical range.

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 pregnancy in the Pacific region,[69,70] and could contribute to increased levels of hypertension more generally.

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[65] 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/

[66] 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

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

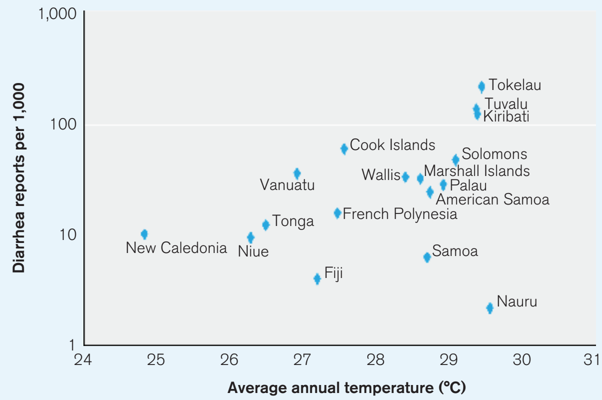
[68] Mitchell, D., Heaviside, C., Schaller, N., Allen, M., Ebi, K. L., Fischer, E. M., . . . Vardoulakis, S. (2018). Extreme heat-related mortality avoided under Paris Agreement goals. Nature Climate Change, 8(7), 551–553. URL: https://pubmed.ncbi.nlm.nih.gov/30319715/

[69] 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/

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

Multiple studies have found that increased temperatures, drought, and rainfall are correlated with increases in reported levels of diarrheal disease[71,72,73] including specifically in the Pacific island region.[74] 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.[75] **Figure 5** shows research by Singh et al. (2001),[70] which demonstrated the link between annual average temperature and average reporting rates of diarrheal disease specifically amongst Pacific island states.

FIGURE 5. Annual average temperature and average reporting rates for diarrheal disease, Pacific islands (1986–1994). $r^2 = 0.49$; $p < 0.05$[70]



POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

- Strategic Roadmap for Emergency Management 2021–2023 (2021)
- Intended Nationally Determined Contribution (INDC) (2015)
- Second National Communication (2015)
- Tuvalu National Strategic Action Plan for Climate Change and Disaster Risk Management 2012–2016 (2012)
- National Climate Change Policy 2012–2021 (2011)
- Initial National Communication (1999)
- National Disaster Management Plan (1997)

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

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

73 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. URL: https://www.sciencedirect.com/science/article/pii/S0160412015300489

74 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/

75 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/

Climate Cange Priorities of the WBG

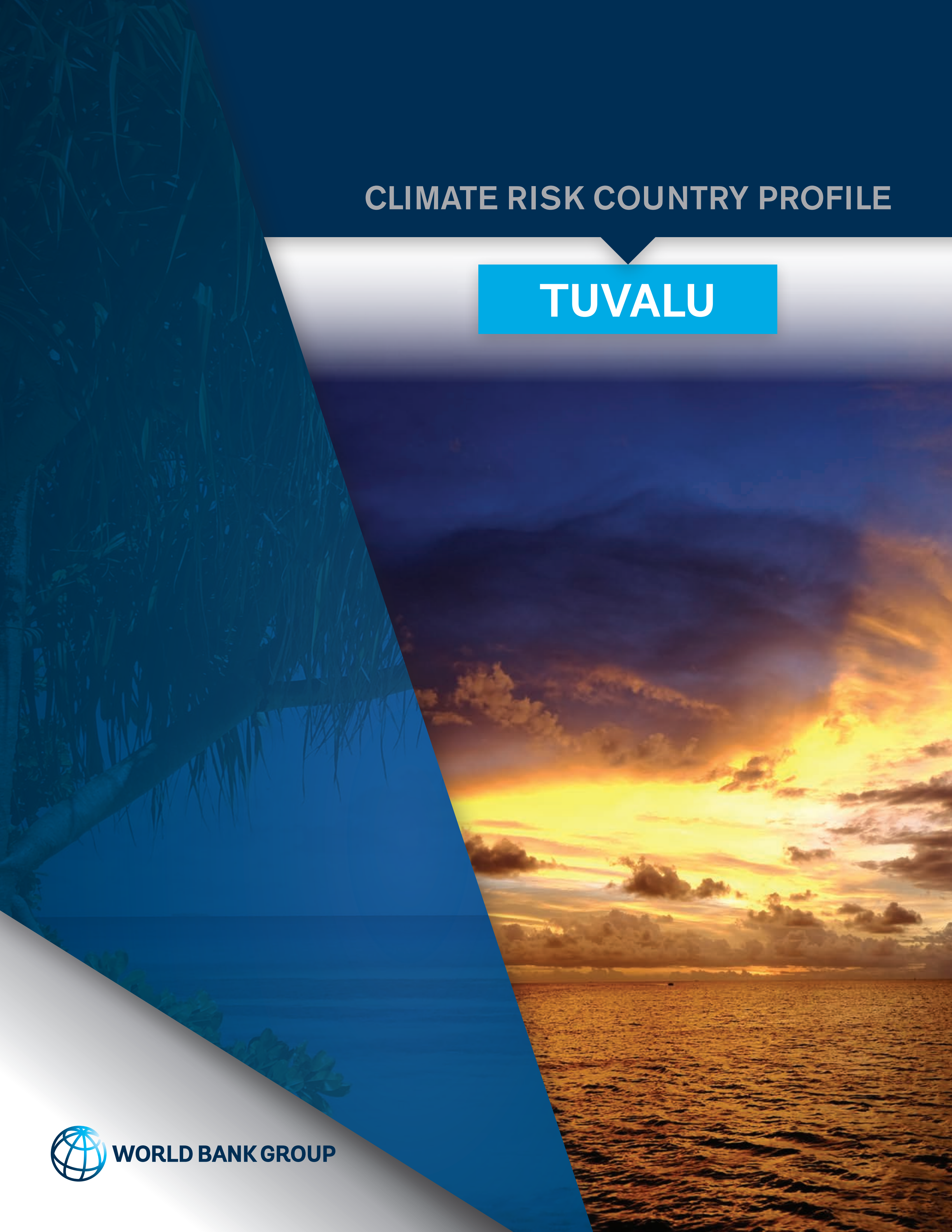
WBG — Regional Partnership Framework

The World Bank Group has agreed its 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

TUVALU



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