CLIMATE RISK COUNTRY PROFILE

MICRONESIA

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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

- The Federated States of Micronesia (FSM) have experienced warming of around 0.7°C between 1980 and 2017.
- 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 3.0°C is projected by the end of the century.
- FSM 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 natural hazards such as extreme heat, intensified cyclones and extreme rainfall.
- In particular, the relative rate of sea-level rise threatens low-lying areas, increasing the risks associated with saline intrusion, tsunami and cyclone-induced storm surge, and wave-driven flooding, and coastal erosion.
- Biodiversity and the natural environment of FSM face extreme pressure, and loss of some species of fish, coral, bird, and terrestrial species is likely without very effective conservation measures.
- FSM's population already lives in a volatile environment, 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 will increase the challenges faced by communities and decision makers.
- Research is urgently needed to better understand issues of migration and displacement across FSM's islands, and to understand the potentially unequal and dual impacts of climate change and development on poorer communities.

COUNTRY OVERVIEW

The Federated States of Micronesia (FSM) is a widely dispersed archipelago located in the western part of the North Pacific Ocean. Comprised of what was generally known as Eastern and Western Caroline Islands, FSM is formed of four states (Yap, Chuuk, Pohnpei, and Kosrae, from west to east) over 607 islands, of which 74 are inhabited, covering the largest and most diverse part of the greater Micronesian region.[1] There is a wide spread across the islands of FSM — there are 1,700 miles (2,700 kilometres [km]) between islands in the western-most state of Yap and islands in the eastern-most state of Kosrae. The capital of FSM, Palikir, is located in the eastern state of Pohnpei. The total land area of FSM is only 271 square miles (702 km^2) but its exclusive economic zone (EEZ) covers an area of over one million square miles (2.5 million km^2).[1] There is also a range of island types within FSM — many of the islands are extinct volcanic shields with elevations up to about 2,500 feet (760 meters [m]) and dense vegetation interiors, but some islands are "flat, small and swampy, with low-lying, forested atoll islets, typically one to five meters above mean sea level flat".[1]

1 Federated States of Micronesia (2015). Second National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/fsmnc2.pdf

Due to its location in the western area of the Pacific and the strong influence of the northeast trade winds (which generally prevail December through April), the FSM experiences a tropical climate. Rainfall is high on the volcanic islands of Kosrae, Pohnpei and Chuuk primarily from May to November, with annual totals exceeding 400 inches (1,016 centimeters [cm]) and up to 22 inches (559 millimetres [mm]) in a given day.[1] The islands, especially within the western states, are generally affected by storms and typhoons, as well as excessive rainfall and drought as associated with the warm and cold phases of the El Niño- Southern Oscillation (ENSO); the most western state of Yap is in an area affected by a monsoon climatic pattern and can tend to experience more frequent periods of drought.[1]

As of July 2017, FSM's estimated population is 104,196, with a GDP of $329 million and a GDP per capita of $3,400 (current US dollars).[2] The majority of the country's population live in the coastal regions of the high islands, with more than half the population living in rural areas. As of 2019, the economy is predominantly service-based (66.8% of GDP), with 22.5% made up of agriculture, forestry and fishing, and 4.9% from industry, including construction.[3] The government employs two-thirds of the working population, with 58% of the government's funding from US grants and aid in the form of the Compact of Free Association agreement.[2] Signed by the United States of America and FSM in 1986, the Compact has also granted FSM's access to US federal programmes and provisions for FSM's nationals travelling to and working in the USA.[1] This Compact is set to end in 2023, and raises challenges for FSM's economic future. Current demographic challenges include population decrease, due in part to a declining fertility rate as well as out-migration to the USA and other parts of Micronesia. FSM has one of the youngest populations in the Pacific region with about 56% of the total population between 0–24 years.[1] There is also increasing urbanisation in FSM, with 22.7% of the population living in urban areas in 2017.[3] Poverty rates are also quite high in FSM **(Table 1)**, and in 2013 the poverty headcount ratio at national poverty lines was 41.2% of the population.[3]

FSM adopted its Climate Change Act in 2013 which outlined the importance of integrating climate change into all development activities. FSM submitted its Second National Communication to the UNFCCC in 2015 and its Nationally Determined Contributions in 2016 and ratified the Paris Agreement in 2016. Climate change poses significant threats for FSM development especially from accelerated sea-level rise, with its immediate coastal areas the most heavily-developed and little scope to move in-land. Like other Pacific islands, climate change has contributed towards a significant increase in extreme weather events experienced by FSM, with number, intensity and impact of these events forecasted to rise. ADB estimates climate change to have considerable economic costs for FSM, adversely affecting crop productivity, fisheries, tourism, coral reefs and human health.

[2] Federated States of Micronesia (2015). Second National Communication to the UNFCCC. URL: https://unfccc.int/sites/default/files/resource/fsmnc2.pdf

[3] World Bank (2021). World Development Indicators – DataBank: Micronesia. URL: https://databank.worldbank.org/reports.aspx?source=2&country=FSM [accessed 01/11/2021]

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 Micronesia. 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 Micronesia, 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,[4,5] as well as the World Bank Group's Climate Change Knowledge Portal.[2] 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.

[4] 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

[5] 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.

TABLE 1. Key indicators

Indicator	Value	Source
Population Undernourished[6]	N/A	FAO, 2020
National Poverty Rate[7]	41.2% (2013)	ADB, 2020a
Share of Wealth Held by Bottom 20%[8]	5.5% (2013)	World Bank, 2021
Net Annual Migration Rate[9]	–0.5% (2015–20)	UNDESA, 2019
Infant Mortality Rate (Between Age 0 and 1)[10]	2.3% (2015–20)	UNDESA, 2019
Average Annual Change in Urban Population[11]	1.1% (2015–20)	UNDESA, 2019
Dependents per 100 Independent Adults[12]	55 (2020)	UNDESA, 2019
Urban Population as % of Total Population[13]	22.9% (2020)	CIA, 2020
External Debt Ratio to GNI[14]	21.8% (2018)	ADB, 2020b
Government Expenditure Ratio to GDP[15]	55.5% (2018)	ADB, 2020b

CLIMATOLOGY

Climate Baseline

Overview

Due to its location in the western area of the Pacific, and the strong influence of the northeast trade winds (which generally prevail December through April), FSM experiences a tropical climate. As shown in **Figure 1**, FSM experiences little seasonal variation in mean air temperatures across the year (less than 1.5°C between the average hottest and coolest months) which is driven mainly by sea surface temperatures around the islands.[1] In general, across the island group, the mean annual temperature averages 27.1°C over the period 1901–2020.[16]

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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. 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 11/2021]

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]

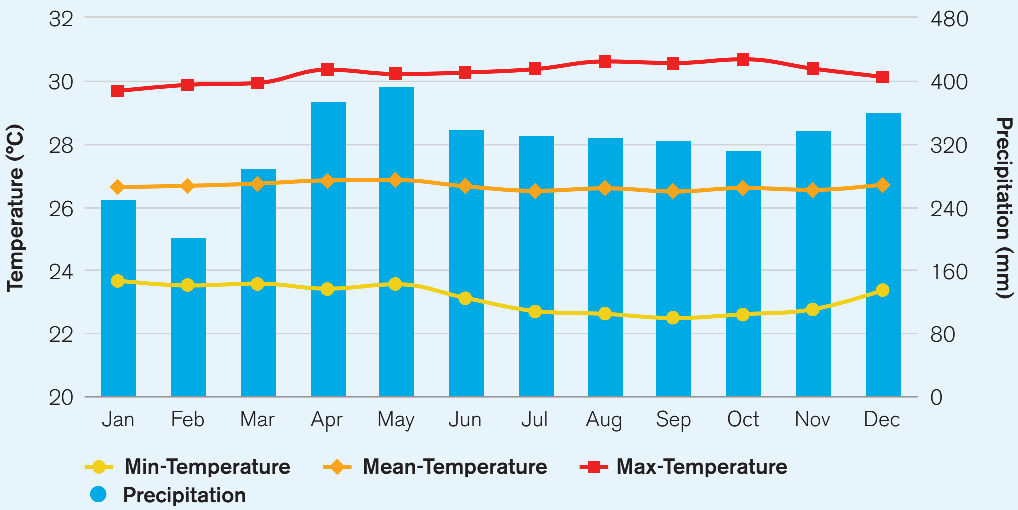
13 CIA (2020). *The World Factbook*. Central Intelligence Agency. Washington DC. URL: https://www.cia.gov/the-world-factbook/

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 WBG Climate Change Knowledge Portal (CCKP, 2021). FSM. Climate Data. URL: https://climateknowledgeportal.worldbank.org/country/federated-states-micronesia/

FIGURE 1. Average monthly mean, max, and min temperatures and rainfall in FSM, 1991–2020[16]



Rainfall is high on the volcanic islands of Kosrae, Pohnpei and Chuuk primarily during the wet season from May to November when the Intertropical Convergence Zone (ITCZ) is strongest and furthest north, with annual totals exceeding 400 inches (1,016 cm) and up to 22 inches (559 mm) in a given day.[1] Western islands receive additional rain due to the West Pacific Monsoon.[1] The islands, especially within the western states, are generally affected by storms and typhoons, as well as excessive rainfall and drought as associated with the warm and cold phases of the El Niño- Southern Oscillation (ENSO). The most western state of Yap is in an area affected by a monsoon climatic pattern and can tend to experience more frequent periods of drought.[1]

As shown in **Table 2**, relative to the other states, Yap receives the least rainfall, with annual averages of around 122 inches (3,100 mm); Chuuk receives about 140 inches (3,556 mm), Pohnpei receives just under 190 inches (4,826 mm), and Kosrae receives around 203 inches (5,156 mm).[1] However, it is noted that the mountainous interior of Kosrae may receive as high as 300 inches (7,500 mm).[1]

TABLE 2. Monthly and annual average and maximum daily rainfall in FSM (in inches)[1]

	J	F	M	A	M	J	J	A	S	O	N	D	Yr
Annual Average													
Yap	7.6	5.7	5.8	6.2	9.4	12.5	14.7	15.1	13.6	12.4	9.5	9.7	**122.2**
Chuuk	9.1	7.0	8.9	12.3	13.6	12.5	13.8	13.8	13.1	13.0	11.6	11.8	**140.8**
Pohnpei	12.1	10.6	14.4	18.0	193	16.6	16.8	16.0	15.4	15.6	16.0	15.8	**187.0**
Kosrae	15.9	15.2	174	20.2	18.4	16.2	16.5	15.2	14.9	124	14.7	19.5	**203.3**
Maximum Daily													
Yap	9.0	5.8	5.1	6.0	9.1	13.2	8.8	6.7	6.9	5.5	8.9	6.4	**13.2**
Chuuk	6.7	6.5	8.2	6.9	8.7	6.3	19.7	4.9	6.1	5.3	8.1	14.9	**19.7**
Pohnpei	9.6	8.9	9.7	12.6	7.2	4.7	7.1	10.0	9.2	7.8	22.0	7.2	**22.0**
Kosrae	7.1	11.0	9.6	6.4	7.6	6.7	9.5	6.6	6.3	6.2	9.9	11.9	**11.9**

Key Trends

Temperature

Temperature data since the 1950s highlight a general warming trend for FSM. Annual maximum air temperatures at three sites across FSM (Pohnpei, Yap and Chuuk) have risen between 0.10°C–0.14°C per decade since the 1950s.[2] However, there is variation in air temperature trends within FSM. For the state of Pohnpei, the greatest trends involve minimum air temperature, whereas for Yap, the greater trends are observed in maximum air temperature. In terms of trends for seasonal and annual mean air temperatures, increases have been evident at both Pohnpei (1950–2009) and Yap (1951–2009), with Pohnpei's wet season (May–October) mean temperature increase being quite high at 0.24°C per decade. For the state of Pohnpei, the number of warm days and warm nights have also been increasing consistent with global warming trends, although such extremes and trends in minimum temperatures at Yap are "not consistent with Pohnpei or global warming trends and may be due to unresolved inhomogeneities in the record".[4] According to the Berkeley Earth Dataset warming over FSM has accelerated since approximately 1980, with temperatures around 0.7°C above the long-term historical average by 2017.

Precipitation

According to FSM's Second National Communication to the UNFCCC, there have been declining trends in annual rainfall since the 1950s at Yap (declines of 0.31 inches (7.9mm) per decade), Pohnpei (–3.46 inches (–88mm) per decade), and Chuuk (–1.93in (–48.9mm) per decade).[1] However, it is noted that annual and seasonal rainfall trends measured over the period 1950–2009 are not statistically significant.[4] Analysis by the Australian Bureau of Meteorology and CSIRO (2014) highlights that there has been a statistically significant (at 5%) declining trend in May–October rainfall at Pohnpei, which may imply "either a shift in the mean location of the ITCZ away from Pohnpei and/or a change in the intensity of rainfall associated with the ITCZ. As well, ENSO-associated interannual rainfall variability was observed for Pohnpei since 1950 and Yap since 1952[4] – it is noted that 1998 was the driest year on record for much of FSM, and a likely consequence of that year's El Niño.[2] Statistically significant negative trends have been observed in annual Very Wet Day rainfall at Pohnpei, and annual Consecutive Dry Days at Yap (which does not coincide with an increase in the number of rain days).[4]

Climate Future

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

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

[17] 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

strong mitigation scenario, whereas RCP8.5 assumes a high-emissions scenario. For reference, **Table 3** 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 emissions reduction throughout the 21st century enough to reach net zero global emissions by around 2080. RCP8.5 assumes annual global emissions will continue to increase throughout the 21st century. Climate changes under each emissions pathway are presented against a reference period of 1986–2005 for all indicators. For more information, please refer to the RCP Database.

TABLE 3. An overview of temperature change projections (°C) in eastern FSM (top) and western FSM (bottom) 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.[4]

	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 (0.6, 1.2)	0.8 (0.5, 1.2)	0.7 (0.3, 1.2)	0.8 (0.3, 1.1)	0.8 (0.5, 1.3)	0.8 (0.3, 1.1)
RCP4.5	1.1 (0.8, 1.4)	1.5 (1, 2.1)	0.9 (0.5, 1.4)	1.3 (0.9, 2.1)	1 (0.7, 1.3)	1.4 (1, 1.8)
RCP6.0	1 (0.7, 1.4)	1.8 (1.3, 2.6)	NA	NA	NA	NA
RCP8.5	1.4 (1–1.9)	3 (2.1, 4.1)	1.4 (0.8, 2.2)	3.1 (2, 4.3)	1.5 (1, 2.1)	3.2 (2.3, 4.3)

	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 (0.6, 1.1)	0.8 (0.4, 1.2)	0.8 (0.4, 1.1)	0.8 (0.3, 1.1)	0.8 (0.5, 1.1)	0.8 (0.4, 1)
RCP4.5	1 (0.8, 1.4)	1.5 (1, 2.1)	1 (0.5, 1.3)	1.3 (0.8, 2)	1 (0.7, 1.2)	1.4 (1, 1.7)
RCP6.0	1 (0.7, 1.4)	1.8 (1.4, 2.6)	NA	NA	NA	NA
RCP8.5	1.4 (1.1, 1.9)	3 (2.1, 4)	1.5 (0.9, 2.1)	3.2 (2, 4.3)	1.5 (1, 2)	3.2 (2.2, 4.1)

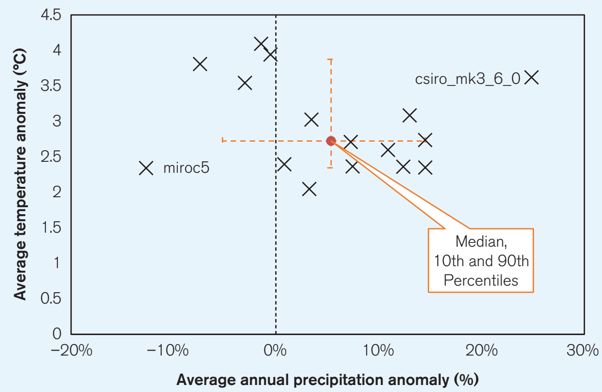
Model Ensemble

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 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. The range of projections from 16 GCMs on the indicators of average temperature anomaly and annual precipitation anomaly for FSM under RCP8.5 is shown in **Figure 2**.

Temperature

Projections of future temperature change are presented in three primary formats. Shown in **Table 3** 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.

FIGURE 2. 'Projected average temperature change' and 'projected annual rainfall change' in FSM. 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.[4] Two models are labelled.

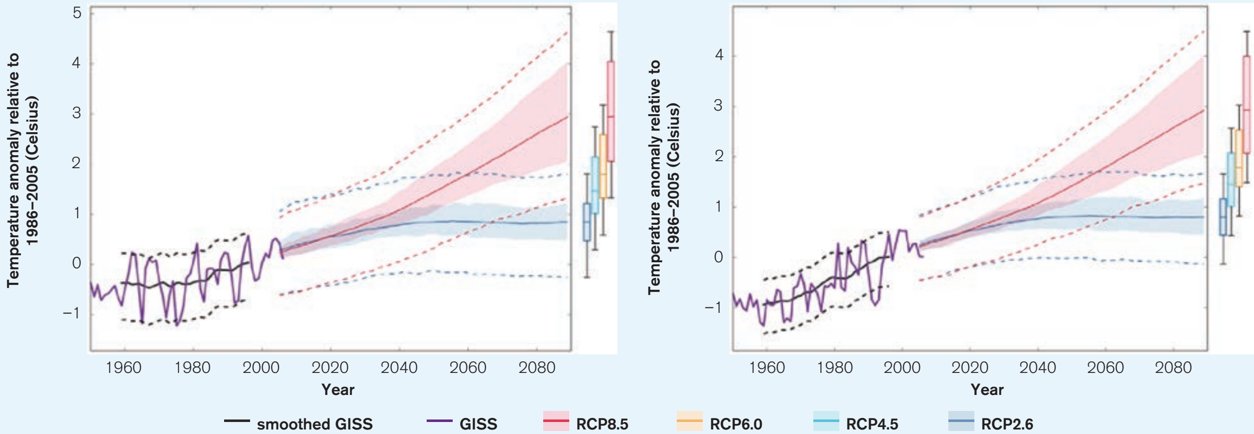


Across the Pacific, temperatures are projected to increase between 1.4°C and 3.1°C.[2] As shown in **Figure 3**, local temperature increases are expected across FSM, with warming differences varying widely across RCPs, especially after 2030. For instance, as indicated in **Table 3**, relative to the 1986–2005 baseline, a warming of 0.5°C–1.2°C for RCP2.6, and 2.1°C–4.1°C for RCP8.5 is projected for the eastern FSM by 2090. The model ensemble's estimate of warming under the highest emission pathway (RCP8.5) is an average temperature increase of 1.4°C by the 2050s and 3.0°C by the 2090s. The model ensemble's estimate of warming under the lowest emission pathway (RCP2.6) is an average temperature increase of around 0.78°C by the 2050s and a marginal reduction of this temperature increase by the 2090s to 0.76°C.

While there is *very high confidence* that temperatures in FSM will rise, based on theory and observational evidence, there is *high confidence* in the model average temperature changes.[4] As explained in Australian BOM & CSIRO (2014), this is possibly since models offer generally good simulations of past temperature changes, and as well, there are "no large model biases in sea-surface temperatures in the region."[4] It is also noted that because of natural climate variability there will still be relatively warm and cool years and decades, although likely projections indicate a warmer climate to influence more warm years and decades on average.[4]

Future temperature rises in FSM may likely be below the global average — the mean annual surface air temperature under the highest emissions pathway is projected to reach around 3°C by the 2090s, compared to around 3.7°C globally. This difference may reflect the moderating effect of large amounts of nearby ocean cover, but considering

FIGURE 3. Historical and simulated surface air temperature time series for the region surrounding the eastern (left) and western (right) FSM. 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 centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.[4]



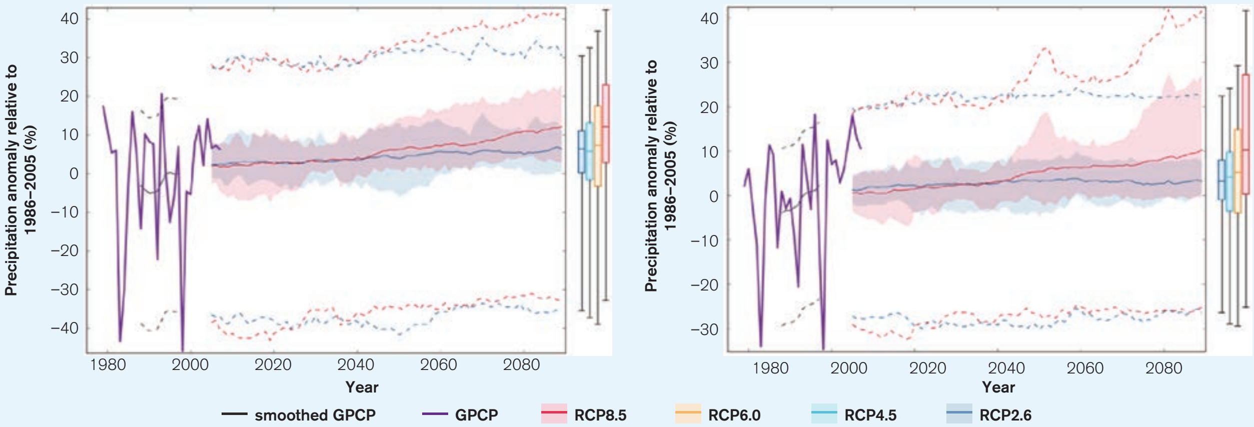
that ocean cover can also distort model simulations, and the current iteration of global models does not have the spatial accuracy to reliably capture climate processes over small island states, these projections should be approached with caution.

As well, it is understood that the temperature on extremely hot days is likely to increase in tandem to average temperature increases – the projected temperature increase of the 1-in-20-year hot day by the 2090s is 0.8°C for RCP2.6 and 3.1°C–3.2°C for RCP8.5. Also, it is expected that there will be an increase in the frequency and intensity of extremely hot days and a decrease in the frequency and intensity of cool days in FSM, although the magnitude of the projected changes is less certain.[4]

Precipitation

While the Federated States of Micronesia experienced a general increase in mean precipitation over the 1979–2006 period, especially within the western islands, and rainfall projections indicate an increase in the long-term average rainfall (as shown in **Figure 4**), "year-to-year rainfall variability . . . is still the same or larger than the projected change."[4] This implies that the historical increase could be due in part to natural variability, rather than purely

FIGURE 4. Historical and simulated annual average rainfall time series for the region surrounding the eastern (left) and western (right) Federated States of Micronesia. The graph shows the anomaly (from the base period 1986–2005) in rainfall from observations (the GPCP 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 rainfall, 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 rainfall could be above or below the projected long-term averages due to interannual variability. The ranges of projections for a 20-year period centred on 2090 are shown by the bars on the right for RCP8.5, 6.0, 4.5 and 2.6.[4]



driven by global warming, and/or that perhaps rainfall models miss a key driver of change.[4] The importance of this difference and its cause is difficult to ascertain since the recent change in precipitation is not that large and as well there has been only 28 years of records to understand historical observations.[4]

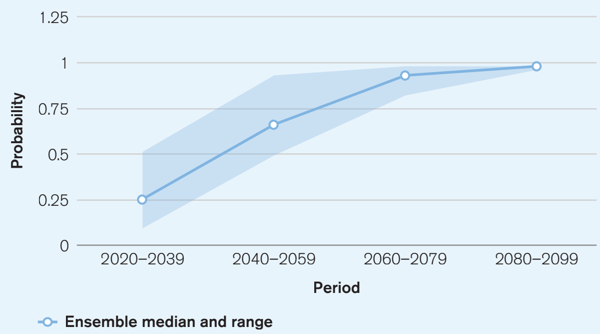
As such, there is much uncertainty around future changes in average annual precipitation since none of the model ensemble predictions are statistically significant and the estimated ranges are large (see **Figure 2**). Generally, there is *medium confidence* in increases in long-term rainfall, due to general understanding based on either models or physical processes that a warmer climate may be associated with increased rainfall in the ITCZ and the West Pacific Monsoon. Challenges to the certainty of the model average rainfall change are affected by the usual complexity in simulating tropical rainfall, as well as uncertainty in ENSO changes, which especially influences year-to-year rainfall variability within the region.[4]

In terms of extreme rainfall events, a warmer atmosphere is likely to lead to an increase in their frequency and intensity. However, the magnitude of such changes in extreme rainfall is not as certain due to possible underestimation and difficulty to capture certain processes related to extreme rainfall events, as well as the general coarse spatial resolution of GCMs.[4]

Heat Waves

Heat waves are defined as a period of 3 or more days when the daily temperature remains above the 95th percentile.[16] **Figure 5** shows the projected change in heat wave probability under RCP8.5 (compared to 1986–2005), highlighting the daily probability of a sudden heat wave in subsequent time periods. For FSM, this probability steadily increases in the long term. This is held within the global context in which probabilities are expected to increase. It should also be noted that the tropics are particularly where systematic warming might lead to the largest increases in heat wave probability, simply because the day-to-day and month-to-month variabilities are small.

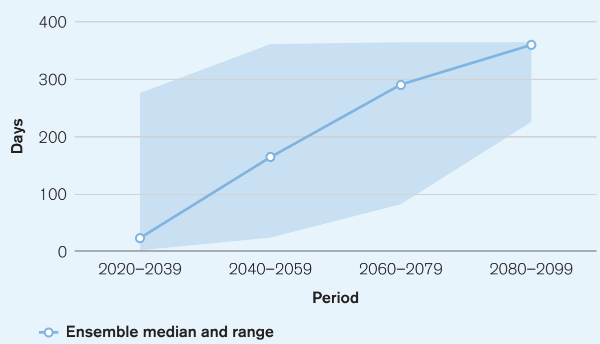
FIGURE 5. Projected change in probability of Heat Waves in FSM under RCP8.5 (compared to 1986–2005)[16]



FSM regularly experiences high temperatures, with a mean annual temperature of around 27.1°C and highest temperatures in March to May (see **Figure 1**. Ensemble-based mean annual temperatures anomalies in FSM are projected to reach up to 3°C by 2100 (**Table 2**), with a projected ensemble mean change in the maxima of daily maximum temperature of 3.1°C by 2100, compared to the historical mean.[16]

When this rise is considered in combination with local humidity, as captured in the Heat Index measure, this highlights a significant increase in the number of days in which uncomfortable temperature conditions are reached. From a baseline situation in which the key threshold of Heat Index 35°C is rarely breached, FSM can expect multiple breaches per year under all climate change scenarios (**Figure 6** shows RCP8.5). The projected change for the Federated States of Micronesia likely signals the potential for extremely uncomfortable conditions, with local impacts and serious health repercussions. However, it is noted that 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.

FIGURE 6. Projected change in the count of days in which climate conditions breach the Heat Index >35°C threshold, under RCP8.5[16]



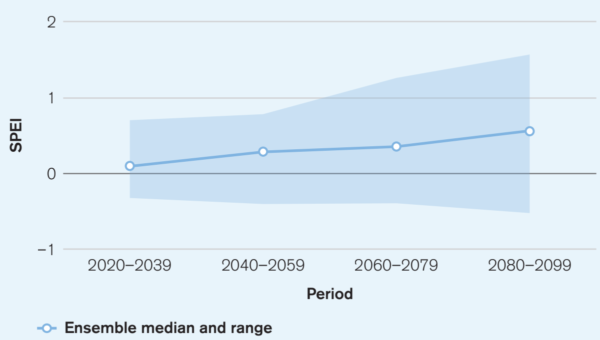
An additional factor for consideration is the potential for marine heat waves. Research has shown that "from 1925 to 2016, global average marine heat wave frequency and duration increased by 34% and 17%, respectively, resulting in a 54% increase in annual marine heat wave days globally".[18] While such research has not specifically identified FSM under threat, the consequences of these trend may be serious for marine ecosystems in the region, which are adapted to survive under very stable temperature regimes, as well as the livelihoods dependent on them.

Drought

Drought can be expressed in many ways, from looking at simple precipitation deficits to complex estimates of remaining soil moisture. Research done for the report on "Climate Variability, Extremes and Change in the Western Tropical Pacific 2014" (Australian Bureau of Meteorology and CSIRO, 2014), defines projected changes in the frequency and duration of mild, moderate, severe and extreme meteorological droughts using the Standardised Precipitation Index (SPI). This index is based solely on rainfall (i.e. periods of low rainfall are classified as drought), and does not take into account factors such as evapotranspiration or soil moisture content. (It is noted that the SPI is commonly used in many regions including the Pacific due to the relative simplicity with which it is calculated, as well as its relevance across temporal and spatial scales.)[4] For FSM, it is likely that the percent of time spent in drought may decrease, and this is generally shown across emissions scenarios.[4] However, it should be noted that complex processes relating to rainfall projections, including the limited consensus of future ENSO influence for the region, hinder the confidence of these projections of drought frequency and duration, as well as magnitude of change.[4]

Another lens through which to view drought risk is the standardised precipitation evapotranspiration index (SPEI), which is computed over 12-month periods and captures the cumulative balance between gain and loss of water across the interannual time scale by incorporating both precipitation input variations as well as changes in the loss of water through evapotranspiration. It is widely used today as a global measure for drought monitoring over various cumulative time intervals. **Figure 7** looks the projected changes in the annual mean drought index for FSM in subsequent time periods, under RCP 8.5, compared to 1986–2005. Since positive values indicate positive water balance (or wet) conditions and negative values indicate negative water balance (or dry) conditions, this signals that SPEI trends to 2100 in FSM may vary widely. Overall confidence is very low and as such further research is required.

FIGURE 7. Projected change in Annual Mean Drought Index for FSM, under RCP8.5[16]



For the Federated States of Micronesia, ENSO strongly moderates the climate and sea level, and drought conditions are typically felt during the El Niño phase. The country's Second National Communication to the UNFCCC highlights that almost "all extremely dry years on Pohnpei [in which the capital is location] occur during the year following an El Niño event . . . [and in] some years, drought conditions have continued through the wet season."[1] According to EM-DAT data, the worst two disasters to affect FSM have been droughts.[19] In 1998, drought associated with

[18] Oliver, E. C., Donat, M. G., Burrows, M. T., Moore, P. J., Smale, D. A., Alexander, L. V., . . . & Holbrook, N. J. (2018). Longer and more frequent marine heatwaves over the past century. Nature communications, 9(1), 1324. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5893591/

[19] EM-DAT (2019). Emergency Events Database. URL: https://www.emdat.be/ [accessed 28/10/2019]

El Niño, i.e. the warm phase of the El Niño-Southern Oscillation (ENSO) phenomenon, affected some 28,800 persons. The 2015/2016 strong El Niño induced a moderate to severe drought affecting several islands across the Pacific.[20] In the FSM in 2016, an official drought was recorded, within which it is estimated that 100,000 persons were affected, i.e. about 96% of the total population.[19] Further than affected population, drought events have also led to food shortages, wildfires, the desiccation of grasslands and forests, groundwater supplies under pressure, threats to local biodiversity as well as challenges due to invasive species, as well as water rationing.[1]

Flood, Cyclones, and Storm Surge

Analysis from the World Bank Group's Climate Change Knowledge Portal highlights that the most extreme rainfall episodes generally have the danger of leading to significant floods.[16] Individual daily rainfall is often linked to flash-floods of limited spatial extent, but multi-day rainfall generally has a broader spatial footprint and thus more extensive flooding can be explained. Rare precipitation events are often referred to as events of a certain return level, and the 5-day cumulative rainfall indicator focuses on the maximum rainfall amount over any 5-day period that can be expected once in an average 25-year period. Changes in this indicator may have potentially significant impacts on infrastructure and endanger life and property through direct physical effects and perhaps through water quality issues. As such, any significant changes in their magnitudes would need to be understood.

The boxplot in **Figure 8** shows recorded 5-Day Cumulative Rainfall for 1986–2005 and projected 5-Day Cumulative Rainfall 25-yr Return Level by the 2050s under all RCPs of CIMP5 ensemble modelling for the Federated States of Micronesia. From this, it is noted that compared to the historical value, while median ensemble projections seem to generally be similar, and there is some difference in the range of change under the different scenarios.

Looking at further future projections, **Figure 9** highlights the projected change in annual maximum 5-day rainfall of a 25-year return level (under RCP8.5), projected ensemble median changes seem to be close to 0 initially then slightly increase closer to 2100, but the range of values is quite broad and varied and needs to be further contextualised and understood.

Tropical cyclones have historically affected the Federated States of Micronesia, mainly between June and November,[4] although it is noted that the "main

FIGURE 8. 5-day precipitation — historical and projected scenarios of 25-year return level in FSM for period 2040–2059[16]

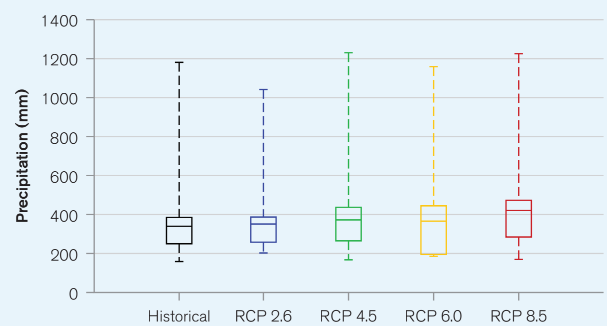
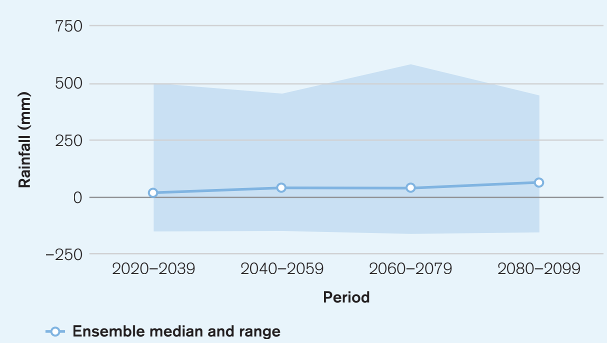


FIGURE 9. Projected change in annual maximum 5-day rainfall (25-year return level) for FSM, under RCP8.5[16]



[19] ReliefWeb (2015). Pacific: Drought – 2015–2017. URL: https://reliefweb.int/disaster/dr-2015-000127-fji [accessed 28/10/2019]

tropical cyclone season for the western North Pacific extends from mid-May through mid-December."[1] Historical data indicates that there have been at least 248 tropical cyclones developing within or crossing the FSM EEZ between seasons 1977 and 2011 seasons, for an average of 71 cyclones per decade (albeit with high interannual variability).[4] Over the past 4 decades since 1981, there have been 212 tropical cyclones, of which 37 (17%) were considered severe events (i.e. Category 3 or higher). ENSO conditions are associated with differences in cyclone frequency — there is a higher frequency of storms during El Niño and neutral years, and lower frequency during La Niña years.

For FSM, the general projection is for a decrease in cyclone genesis (formation) frequency for the south-east basin, with *high confidence*, consistent with a general global projection for decreased cyclone frequency by 2100.[4] However, there is much model inconsistency in these results — some show that conditions for cyclone formation are favourable within some models, while specific parameters might show unfavourable conditions otherwise[4] — and as this should generally be understood in the context of ENSO, which is not well understood for the region.

According to available information compiled by the Global Facility for Disaster Reduction and Recovery (GFDRR) ThinkHazard! web-based tool, the risk of cyclone (hurricane/typhoon) hazard is classified as *high* in FSM.[21] This means that there is more than a 20% chance of potentially-damaging wind speeds for the country in the next 10 years. While 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.[22] 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.

As well, such risk potential is important to consider in the historical context of cyclone impacts for the country. The EM-DAT database highlights that there have been at least 7 tropical cyclones which have led to officially designated disasters within the FSM island group since 1900.[19] Tropical storms top the list of costly disaster events for the country, with events in 1987 and 2015 having estimated economic damage tallies of US$6 and US$11 million, respectively.[19] In total, tropical storms have led to a cumulative sum of US$17.5 million, and have affected at least 53,800 persons. Of these, Tropical Storm Chataan affected the state of Chuuk in 2 July 2002, causing 20 inches (~500 mm) of rainfall in a 24-hour period. The storm contributed to 265 landslides, of which perhaps 62 alone happened on 2 July, leading to 43 deaths, hundreds of injuries, as well as damage to at least 231 building structures.[1]

In general, tropical cyclones also affect many of FSM's islands low-lying atolls through sea salt deposition, via the interaction of strong winds and rains with ocean spray. This has led to agricultural damage and power outages due to electrical shorts, which is often felt immediately, but also corrosion, which is a longer-term and cumulative effect.[1]

Concerning wave activity, estimates by Australian Bureau of Meteorology and CSIRO (2014) highlight potential decreases in wave height, but there is currently generally a low confidence in potential changes over the year, likely due to the complexity and uncertainty of ENSO influence, as well as challenges reconciling simulated and hindcast estimates.[4]

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[21] GFDRR (2016). ThinkHazard! Profile for FSM. URL: http://thinkhazard.org/ [accessed 31/10/2019]

[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/full/10.1002/wcc.371

Natural Resources

Water

The diversity of the 74 inhabited islands of the Federated States of Micronesia makes it difficult to quickly summarise the nature and state of freshwater in the country. Generally, roughly 60% of water resources are in the form of surface water in small, intermittent streams, although this water requires expensive treatment before use. As well, though these streams are low for about 2.5 months of the year, it is quite expensive to develop dams to facilitate water use during dry periods.[1] The remaining 40% of freshwater comes from groundwater sources, although drilling for this is also expensive.[1] Across the islands of FSM, there is insufficient research about sustainable groundwater withdrawal rates, and in atoll regions, aquifer systems are poorly understood.

Noting the disparity in rainfall rates across the 4 states, one of the main challenges for FSM is in limited rainwater storage. This is further intensified by ENSO-related seasonal variations, which is often linked to drought, as well as tropical cyclone events. Awareness and preparedness to better utilise available climate information is not yet developed in this regard. As well, there is a rich traditional culture and indigenous knowledge about effective water management which is not yet tapped into.[1] However, since limited water availability and poor water quality has been linked to health hazards, and as well, increased population growth and urbanization, developing industries, and the emerging tourism sector all demand increased freshwater, such knowledge would be vital for a sustainable FSM.

As is for other small island states, rising sea levels are also a threat to water resources. FSM's small size, minimal amount of storage, and limited fresh water render it highly susceptible to threats to fresh water availability and groundwater supplies are threatened by salt-water intrusion as a result of increasing sea levels.[2] Associated damage to water supplies, water treatment and hydrological research infrastructure may also prove to be significant and costly.

The Coastal Zone

According to its Second National Communication to the UNFCCC, the islands of the Federated States of Micronesia are in an area of the global area that has "experienced some of the highest rates of sea-level rise."[1] Estimates show increases of an average of 0.2–0.4 inches (5–10 mm) per year for the tropical western Pacific since 1993; for FSM, this value is over 0.39 inches (10 mm) per year, and above the global mean of 0.12 inches (3 mm) per year for the same period.[1] While there has been some understanding of this increase in mean sea levels due in part to interannual and interdecadal climate variability, connections to global warming, or a combination of climate change and natural variability, or another process, is still pending research.[1]

Sea-level rise threatens significant physical changes to coastal zones around the world. Global mean sea-level rise was estimated in the range of 0.44–0.74 m by the end of the 21st century by the IPCC's Fifth Assessment Report,[23] but some studies published more recently have highlighted the potential for greater rises (**Table 4**).

[23] 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

TABLE 4. 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).[24]

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)

For FSM, it is very likely that sea level rise will continue to increase. As shown in **Figure 10**, model estimation highlight possible increases of 7–18 cm by 2030, with a range of 41–90 cm under the RCP8.5 scenario by 2090. Since sea level changes in FSM is also modulated by ENSO activity, these are likely to continue to affect a myriad of coastal concerns. For instance, observational evidence shows that mean sea levels are often lower during an El Niño year, but higher during La Niña. As well, this should be considered in context of another natural phenomenon – tides. Coastal flooding has been associated with "king tides", which are exceptionally high tides or the "highest predicted high tide of the year at a coastal location"[25] which have occasionally affected FSM since 2000.

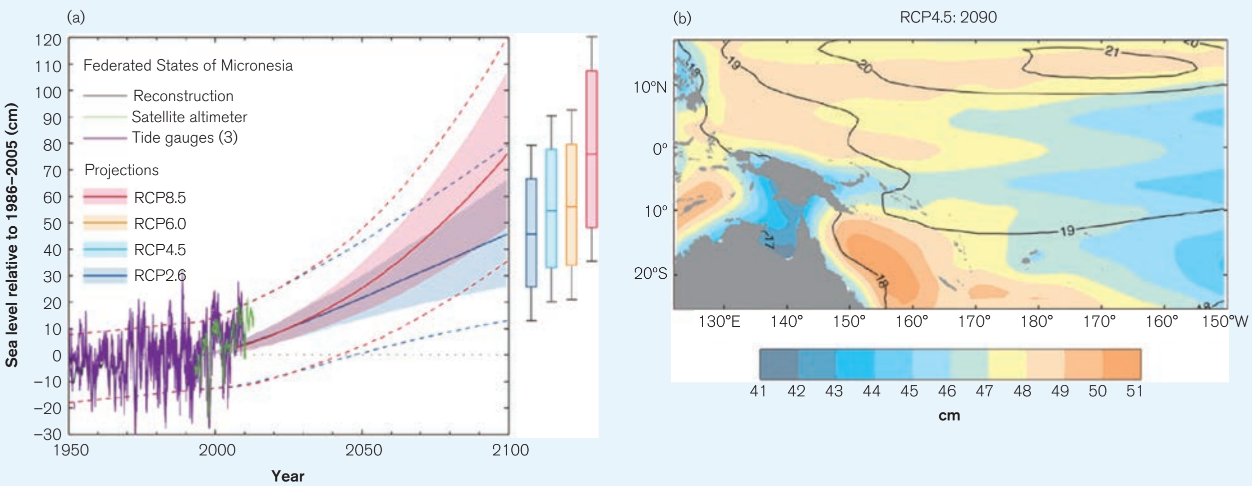
GFDRR's ThinkHazard! tool highlights a *medium* risk of tsunamis in the FSM, indicating a more than 10% chance of the occurrence of a potentially-damaging tsunami in the next 50 years.[21] As tsunami waves are likely to increase in height and damage potential due to sea-level rise, this highlights the critical need for adaptation action. FSM has faced destructive tsunamis at least three times since the 1800s, and it is noted that the state of Yap lies closer to the Pacific "ring of fire" and may be more susceptible to such impacts.[1]

These changes in sea level have contributed to coastal flooding which has damaged groundwater resources, especially on low-lying atolls, as well as general flooding and drainage issues.[1] Further, this has profound effects on drinking water and food supplies, as agricultural products and soils are compromised. This is especially felt on low-lying atoll islets, which are not only more vulnerable to sea level rise than the higher volcanic islands, but on which are usually traditional low-technology communities which are highly dependent on the coastal areas and sea for their livelihood.[1] As such, sea level rise and related effects not only threaten physical resources and infrastructure, but also cultural norms, traditions and language, as well as ancestral lands.

[24] 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

[25] EPA (n.d.). King Tides and Climate Change. URL: https://www.epa.gov/cre/king-tides-and-climate-change [accessed 31/10/2019]

FIGURE 10. (a) The observed tide-gauge records of relative sea-level (since the late 1970s) are indicated in purple, and the satellite record (since 1993) in green. The gridded (reconstructed) sea level data at FSM (since 1950) is shown in black. Multi-model mean projections from 1995–2100 are given for the RCP8.5 (red solid line) and RCP2.6 emissions scenarios (blue solid line), with the 5–95% uncertainty range shown by the red and blue shaded regions. The ranges of projections for four emission scenarios (RCPs 2.6, 4.5, 6.0, 8.5) by 2100 are also shown by the bars on the right. The dashed lines are an estimate of interannual variability in sea level (5–95% uncertainty range about the projections) and indicate that individual monthly averages of sea level can be above or below longer-term averages. (b) The regional distribution of projected sea level rise under the RCP4.5 emissions scenario for 2081–2100 relative to 1986–2005. Mean projected changes are indicated by the shading, and the estimated uncertainty in the projections is indicated by the contours (in cm).[4]



Like many low-lying island nations FSM faces the prospect of permanent loss of land and displacement of communities.[26] Research is critically lacking into the impacts of climate change, which may already have driven movement of peoples. Studies have highlighted the above average rates of sea-level rise in Yap State, and its low-lying atolls, as a vulnerable area.[27]

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.[28] 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.[29] Studies have shown that the extent of wave-driven flooding is impacted by coral reef height and health, highlighting the

[26] Storlazzi, C. D., Elias, E. P. L., & Berkowitz, P. (2015). Many Atolls May be Uninhabitable Within Decades Due to Climate Change. Scientific Reports, 5, 14546. URL: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4585922/

[27] Perkins, R. M., & Krause, S. M. (2018). Adapting to climate change impacts in yap state, federated states of micronesia: The importance of environmental conditions and intangible cultural heritage. Island Studies Journal, 13(1), 65–78. URL: https://islandstudies.ca/sites/default/files/ISJPerkinsKrauseYapClimateChangeAdaptation.pdf

[28] 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

[29] 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

importance of coral conservation as an adaptation.[30] Without successful adaptation some studies have estimated that wave-driven flooding will make many atoll islands uninhabitable by the mid 21st century.[31] 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.[32] The future picture is likely one of dynamic ecosystems, which will demand adaptive lifestyles and livelihoods from inhabitants.

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.[33]

Data for FSM shows that there has already been a decline in the aragonite saturation state, a proxy for coral reef growth rate, from around 4.5 to about 3.9 ± 0.1 between the late 18th century and 2000. **Figure 11** shows that the projected aragonite saturation state under three emission scenarios for both the western and eastern regions of the Federated States of Micronesia is likely to follow this trend. Under RCP4.5 and RCP8.5, the saturation state is expected to decrease below the threshold needed to sustain healthy coral reefs, even as early as 2030.

While there is a high degree of confidence of the increased risk of coral bleaching due to a warmer ocean, there is only medium confidence in the ranges of estimates of projected changes in severe coral bleaching risk for FSM. This is due to limited confidence in the sea surface temperature change projections as well as complexities of understanding reef-scale changes.[4] As well, such potential changes may not include other reef stressors, such as local environmental concerns, and impacts of ocean acidification are also likely to affect the entire marine ecosystem impacting the key ecosystem services provided by reefs.

The fisheries sector in FSM has been identified as a sector with economic potential to contribute to the local economy,[1] and has been developing within recent years. The fishing sector is estimated to contribute about 2% to the local economy, with average annual catches valued at around US$50 million (**Table 5**). FSM also gains revenue through fishing licence fees — "licensed foreign fishing vessels consist of mainly purse-seine and long-line tuna boats and earn around US$150 million per annum from fishing in FSM waters."[1] It is of interest to note that FSM's EEZ includes much of the world's major equatorial tuna migratory paths, highlighting the value of offshore tuna.[1] Not only is this important for local diets, as tuna is an essential source of nutrition within the Micronesian diet, but ensuring the viability of the tuna fishery stock in the local EEZ is also essential for the interconnected global fish stock.[34]

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30 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

31 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://advances.sciencemag.org/content/4/4/eaap9741

32 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

33 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/

34 Ramesh, N., Rising, J. A., & Oremus, K. L. (2019). The small world of global marine fisheries: The cross-boundary consequences of larval dispersal. *Science*, 364(6446), 1192–1196. URL: https://science.sciencemag.org/content/364/6446/1192

FIGURE 11. Projected changes in aragonite saturation state in western (left) and eastern (right) FSM 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.[4]

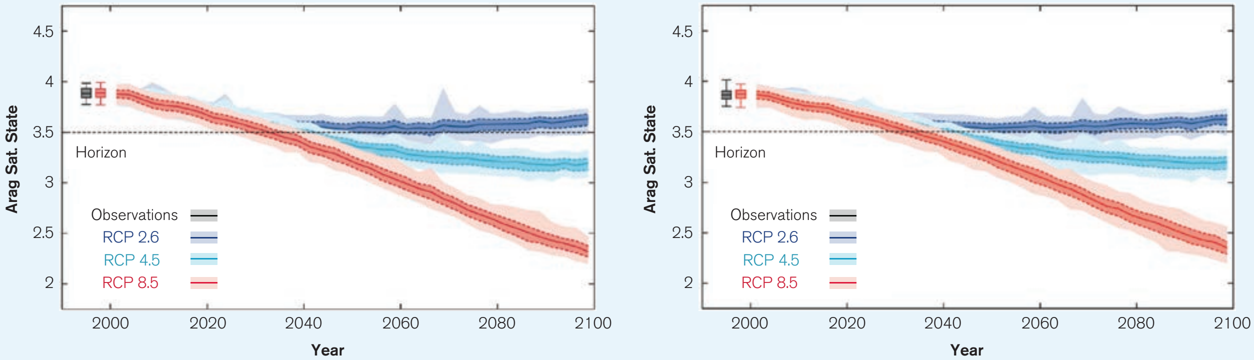

TABLE 5. Annual average catch amount and value (2004–2008) for oceanic and coastal fisheries in FSM, from FSM (2015)[1]

	Fisheries Types	Catch (Tonnes)	US$ Value (millions)
Ocean Fisheries	Tuna-Purse Seine	19,554	23.1
	Tuna-Long Line	938	4.9
	Other Oceanic Fish	136	0.1
	Total	**20,618**	**28.1**
Coastal Fisheries	Dermersal Fish	6,290	11.7
	Nearshore Pelagic Fish	3,560	6.1
	Invertebrates	2,750	5.5
	Total	**12,600**	**23.3**

While research is lacking on future fisheries catch and landings, making it difficult to fully analyse and explain the influence of climate change, among other factors, on the local fisheries product, it is likely that warmer global temperatures, coral bleaching, as well as ocean acidification may play a central role. 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.[35] 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 FSM.[36] As a result there have been strong calls

[35] 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

[36] 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://data.globalchange.gov/article/10.1016/j.marpol.2017.08.015

for support to communities to identify suitable responses and financing mechanisms, and to adapt to the changing marine environment.[37]

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.[38] Research has shown that inundation of low-lying islands has the potential to remove important refuges for migrating sea birds.[39] 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 Pacific islands, for example endemic lizards, which may become trapped in a shrinking habitat.[40] 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%.[41]

Economic Sectors

Agriculture and Food

For the Federated States of Micronesia, while commercial agriculture only contributes about 1% to the local economy, small-scale agriculture is the main source of food and labor. In-country agricultural activities are responsible for over 60% of local food and about 50% of the labor force (full-time or seasonal basis). Despite suitable climate for year-round agriculture, diversity in terrain affects arable land supply, especially on the mountainous volcanic islands, and inhibits commercial-scale farming. Livestock production is important and largely for subsistence and cultural use.

In considering land resource management in the Federated States of Micronesia, it is important to note local land and marine ownership rights and patterns. As shown in **Table 6**, there is a variety of public and private ownership between states, with private land likely acquired through inheritance and subject to traditional control.[1] Such tenure patterns have likely affected landlessness in an environment of growing population and urbanisation, and squatting is already a major problem in Pohnpei.[1] FSM's Second National Communication to the UNFCCC also notes that "access to land is compounded by a low employment rate as well as low food production."[1] It will become important to note if and how these tenure patterns may affect future changes in land use, including land available for agricultural purposes, given climate change impacts and effects.

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[37] 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

[38] 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

[39] 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

[40] 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

[41] 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

TABLE 6. Land tenure by state and for FSM (Percent of total land area), from FSM (2015)[1]

	Yap	Chuuk	Pohnpei	Kosrae	FSM
Private Land	98.3	99.2	66.8	31.2	72.5
Public Land	1.7	0.8	33.2	68.8	27.5

Tourism

Tourism is an emerging economic sector in the Federated States of Micronesia, representing about 2% towards the local economy and with potential for long-run growth and comparative advantage.[1] Current low levels are contrasted to growth in tourist numbers in the early 2000s by as much as 10%.[1] Tourism infrastructure on the islands is limited at the moment, but there is reported potential for "boutique-style tourism to cater for the scuba diving, surfing and sailing communities".[1]

As with other small islands, tourism sector development should be reconciled with concerns for environmental sustainability, especially in the face of climate change impacts. The dual threats of rising sea levels and coastal erosion could reduce the quantity and quality of available beach space and, without significant adaptation measures, could therefore reduce the attractiveness of the country as a tourist destination. As well, potential losses to land area due to sea level rise would need to be considered for the building of desirable beachfront properly locations. However, rates of coastal erosion are not currently measured and there is limited understanding of how to confront beach loss. Challenges to already-limited freshwater could become a problem in times of drought conditions, and storm threats could hinder the sun, sea, sand experience and require sufficient disaster preparedness actions.

In addition to direct physical impacts, climate change may affect the tourism sector in FSM through global efforts to mitigate climate change. Changes to the cost of international flights can certainly potentially affect visitor arrivals. One study estimated that while the cost of achieving an emissions-target compatible tourism sector may be proportionately low (3.6%), the necessary increase in trip costs (estimated at $11 when averaging across every global trip but potentially higher on a long-haul destination) may further reduce a country's attractiveness as a tourist destination.[42] Further research is required to better constrain the suite of potential climate change impacts on the sector.

Communities

Poverty, Inequality and Vulnerability to Climate-Related Disaster

The current rate of poverty in the Federated States of Micronesia is estimated at 41.2% in 2013.[3] However, there are local socio-economic challenges due to low local food production due to limited arable land (and especially in atoll islands), imported food preferences affecting local consumption and low nutrition, high unemployment rates, high dependency rates, high reliance on foreign aid, and high migration affecting the rural labor supply.[1] Such

[42] 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://www.tandfonline.com/doi/abs/10.1080/09669582.2015.1107080

compounded vulnerability, and in particular, dependence on foreign imports and aid, limits local resilience in times of external shocks. Further, climate change effects such as increasing temperatures, sea levels, and extreme weather events, alongside changing precipitation, has the potential to further exacerbate local vulnerability, disrupting local freshwater supplies and agricultural practices, affecting subsistence incomes, food security and cultural traditions.

As for many countries, most 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.[43] 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.

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.[44]

Human Health

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.[45] Temperatures significantly lower than the 35°C threshold of 'survivability' can still represent a major threat to human health. Climate change will push global temperatures closer to this temperature 'danger zone' both through slow-onset warming via an increase mean annual temperature and the intensity and frequency of heat waves. Although there are challenges of limited downscaled climate information to specify projections, it is likely that climate change will result in an increased number of people at risk of heat-related medical conditions, perhaps specifically related to the elderly, children, the chronically ill, the socially isolated and at-risk occupational groups. It should be noted that the potential reduction in heat-related deaths achievable by pursuing lower emissions pathways is significant, as demonstrated by Mitchell et al. (2018).[46]

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[43] 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

[44] 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

[45] 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

[46] 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/

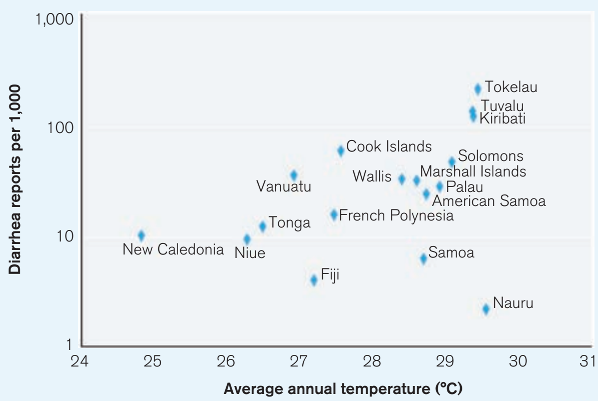
Disease and General Health

In the FSM, a key health concern is due to the limited local food resources. Challenges of local food production has encouraged a preference for imported foods with little nutritional value which in turn leads to a variety of non-communicable diseases (NCDs). FSM's Second National Communication to the UNFCCC notes that 8 out of 10 reported deaths are caused by cancer, heart disease, stroke, hypertension, or diabetes.[1] Further, "a 2002 survey of the prevalence of disease and risk factors for Pohnpei found that 57% of adults (60% of men and 53% of women) had three or more risk factors for NCDs. The prevalence rate for hypertension is 21% and for diabetes is 32%."[1]

According to the WHO "some of the world's most virulent infections are also highly sensitive to climate: temperature, precipitation and humidity have a strong influence on the life-cycles of the vectors and the infectious agents they carry and influence the transmission of water and foodborne diseases."[47] Climate change threatens to slow progress in tackling the spread of disease. Specifically, for FSM, the most prominent vector-borne diseases in FSM are transmitted by mosquitoes, including dengue fever and Zika.[1] Pooled water sources such as those around houses were considered as prime mosquito breeding grounds and contributed to the disease development.

As in other countries, loss of a clean water supply can result in water contamination, which will have significant medical concerns. Generally, an increase in atmosphere and sea temperatures could also intensify risks in water and vector-borne diseases, such as diarrhoea, disaster-related fatalities, injuries and illnesses, heat stress and conjunctivitis (pink-eye). It is noted that while the interaction between temperature and diarrheal disease is still unclear, one explanation of the association is that rotavirus and other bacteria that cause diarrhoea 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.[48] **Figure 12** shows research by Singh et al. (2001), which demonstrated the link between annual average temperature and average reporting rates of diarrheal disease specifically amongst Pacific island states.[48]

FIGURE 12. Annual average temperature and average reporting rates for diarrheal disease, Pacific islands (1986–1994). $r^2 = 0.49$; $p < 0.05$[49]



[47] World Health Organisation (2015). Climate and Health Country Profile – 2015 Maldives. URL: http://www.searo.who.int/entity/water_sanitation/mav_c_h_profile.pdf?ua=1. [accessed 30/06/2019].

[48] 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/

[49] 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/

POLICIES AND PROGRAMS

National Adaptation Policies and Strategies

- Intended Nationally Determined Contribution (INDC) (2016)
- Second National Communication (2015)
- Climate Change Act (2013)
- Nationwide Climate Change Policy (2009)
- First National Communication (1997)

Climate Change Priorities of the WBG

WBG — Regional Partnership Framework

The WBG 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 FY2017–FY2021. 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 Regional Partnership Framework (RPF) aims to continue to support regional and single-country activities that help the nine Pacific island countries (PIC9) strengthen their resilience against natural disasters and climate change. The Pacific island countries (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 percent 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

MICRONESIA

WORLD BANK GROUP