Tuvalu National Adaptation Plan: Climate Impact, Vulnerability & Risk Assessment

Risk Assessment: Technical Supplement

May 2024

1 Introduction

1.1 Background

SPREP is an intergovernmental organisation charged with promoting cooperation among Pacific Island countries and territories to protect and improve their environment and ensure sustainable development, it comprises 21 members and includes metropolitan members: Australia, New Zealand, France, United Kingdom and United States of America.

SPREP is currently supporting Federated States of Micronesia (FSM), Nauru, Niue and Tuvalu to undergo a national adaptation planning process and the development of a National Adaptation Plan under the Green Climate fund (GCF), that will form a sustainable platform for future adaptation investments.

The adaptation planning process consists of:

- Capacity and institutional strengthening
- Adaptation planning governance and institutional conditions
- Evidence-based adaptation solutions for maximum impact
- Adaptation Framework; and
- Concept notes to advance the implementation of the NAP

To support evidence-based adaptation solutions for maximum impact, SPREP has requested climate impact, risk and vulnerability assessments (CIVRA) for the four participating countries. SPREP have engaged CSIRO to conduct CIVRAs for FSM, Nauru, Niue and Tuvalu. The CIVRAs will inform the prioritisation of climate action and investment in adaptation.

1.2 Purpose of this report

Deloitte assisted the CSIRO team to conduct a national scale climate change risk assessment for Tuvalu. The risk assessment has integrated climate hazards, its associated impacts on key sectors/domains of Tuvalu and inherent vulnerability of these systems following a risk-based approach, consistent with international best practice approaches.

Separate stand-alone reports are prepared for identifying a) hazards and impacts and b) vulnerability of Tuvalu to climate change. This report (risk assessment technical supplementary report) combines information from reports mentioned in a and b and presents results of climate change risk assessment for Tuvalu. For further detailed information on Hazard, impacts and vulnerability, please refer to the respective reports.

This report presents an overview of the approach that was followed in the risk assessment process, lists key climate change projections for Tuvalu that were considered in the risk assessment process and then presents detailed risk profiles for key priority sectors/domains of Tuvalu.

1.3 Structure of this report

This report has five sections. They are discussed in Table 1.

Table 1: Structure of the report

Chapter	Description of content
Chapter 1: Introduction	This chapter presents the overview of the background and objectives of the Tuvalu climate change risk assessment (TCCRA), and how the report is structured.
Chapter 2: Risk assessment approach	This chapter presents the summary of the TCCRA approach.
Chapter 3: Climate change in Tuvalu	This chapter presents a summary of the climate change projections and vulnerability assessments for Tuvalu that informed TCCRA.
Chapter 4: Summary of risk assessment results	This chapter will present the summary of the final results of TCCRA.
Chapter 5: Detailed risk profiles	This chapter presents detailed risk profiles and associated scores for the key sectors/domains of Tuvalu.
Appendices	Supplementary information
References	Citations in this report

2 Approach

2.1 Context

This chapter presents a high-level overview of the climate change risk assessment approach for Tuvalu. The completion of the risk assessment of Tuvalu has required a combination of research methods, including literature review, climate change data analysis and some stakeholder engagement. The outcomes of this research have been used to inform the analysis and results of the risk assessment. The sections below present key components of the risk framework used in this process.

2.2 Risk framework overview

The climate change risk framework used for this project incorporates guidance from the Intergovernmental Panel on Climate Change (IPCC, AR6), National Climate Change Risk Assessment of Australia (NCRA), UK Climate Change Risk Assessment, New Zealand Climate Change Risk Assessment). The framework defines risk as a function of a climate 'hazard', 'exposure' of a system to that hazard and any underlying 'vulnerabilities' of the system (Figure 1).

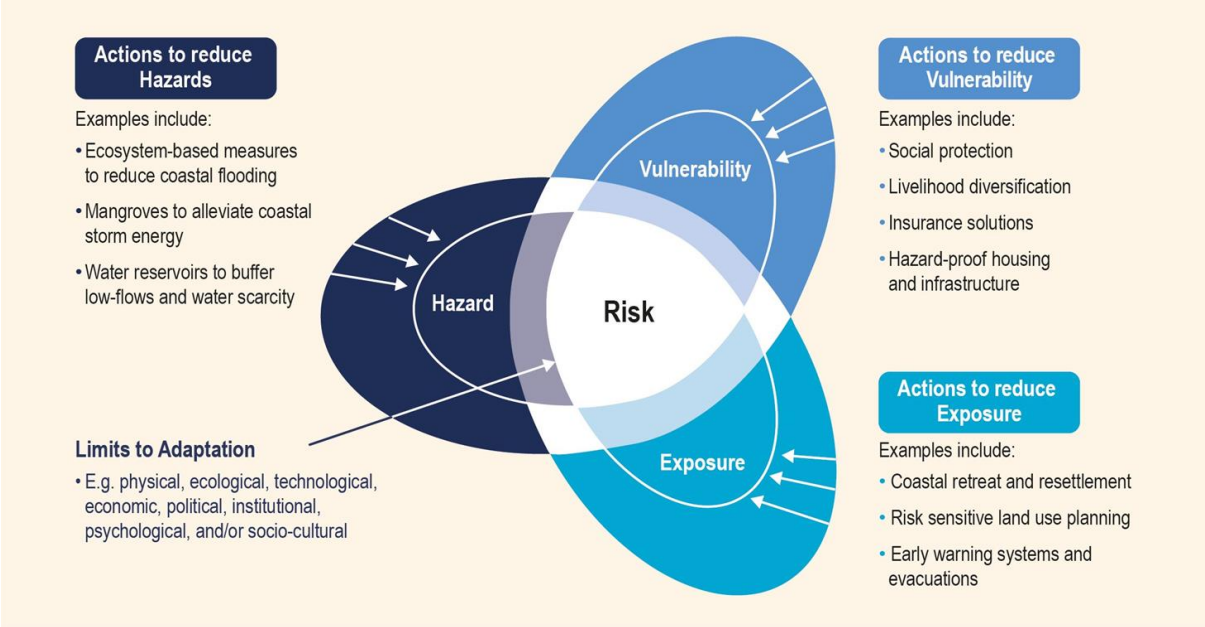

Figure 1: Risk framework presented in IPCC AR6 along with actions to reduce the hazards, vulnerability and exposure. Three propellers show three key components of risk (e.g., hazard, exposure and vulnerability) and arrows show response across each component. (Source: Adapted from IPCC AR6)

2.3 Key parameters for the risk assessment

The risk assessment process was based on a series of parameters and climate change scenarios (Table 2) presents the summary of the key parameters for the assessment. Further detailed discussion on climate change projections is available in CSIRO hazard assessment report.

Table 2: Summary of key parameters for Tuvalu Risk Assessment

Risk assessment parameters	Adopted features
Climate risk framework	IPCC AR6/AR5[1], ISO31000, ISO14091, NCRA, NZCCRA, UKCCRA
Time horizons	• Present-day[2] • 2030[3] • 2050[4]
Greenhouse gas emissions scenarios	High greenhouse gas emissions scenario: RCP 8.5 Low greenhouse gas emission scenario: RCP 2.6
Exposure	A comprehensive hazard and impact report for Tuvalu conducted by CSIRO[5]
Vulnerability	Tuvalu Integrated Vulnerability Assessment (TIVA) conducted by Tuvalu Government and aggregated to the national level by CSIRO (2024)
Climate hazards	**Acute hazards:** Extreme heat, extreme rainfall, tropical cyclones, marine heatwaves, extreme sea level events **Chronic hazards:** Sea level rise, annual-average air/ocean temperature, ocean acidification, annual-average rainfall, drought, ENSO frequency and intensity
Scale	National

The Tuvalu NAP has prioritised six sectors/domains which have been used to frame this risk assessment. Two additional cross cutting sectors/domains, "Social cohesion & cultural heritage" and "Infrastructure" are

[1] Changes in wind speed, marine heatwaves and ocean acidification are based on CMIP6 GCM for low (SSP1-2.6) and high (SSP5-8.5). All other hazards are based on simulations from CMIP5 global climate models for low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios.

[2] Present day with 20 years centred on 1995 or 2005.

[3] 20 years centred on 2030

[4] 20 years centred on 2050

[5] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

added with priority sectors/domains which were requested by local stakeholders during consultation (Figure 2).

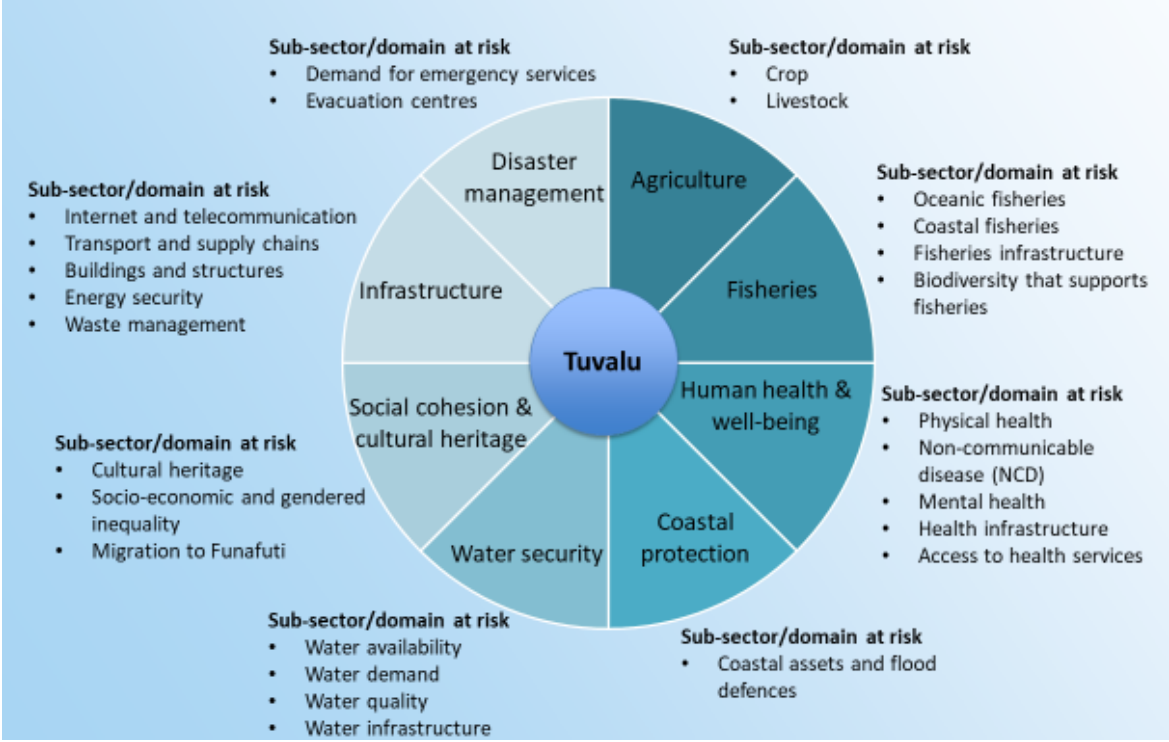

Figure 2: Sectors/domains and sub-sectors/sub-domains that were covered in the risk assessment.

Risk assessment process

A high-level overview of the risk assessment approach is presented below (Figure 3). This process follows leading practice in multi-sectoral/domain risk assessments at the state and national scale with key aspects tailored to Tuvalu.

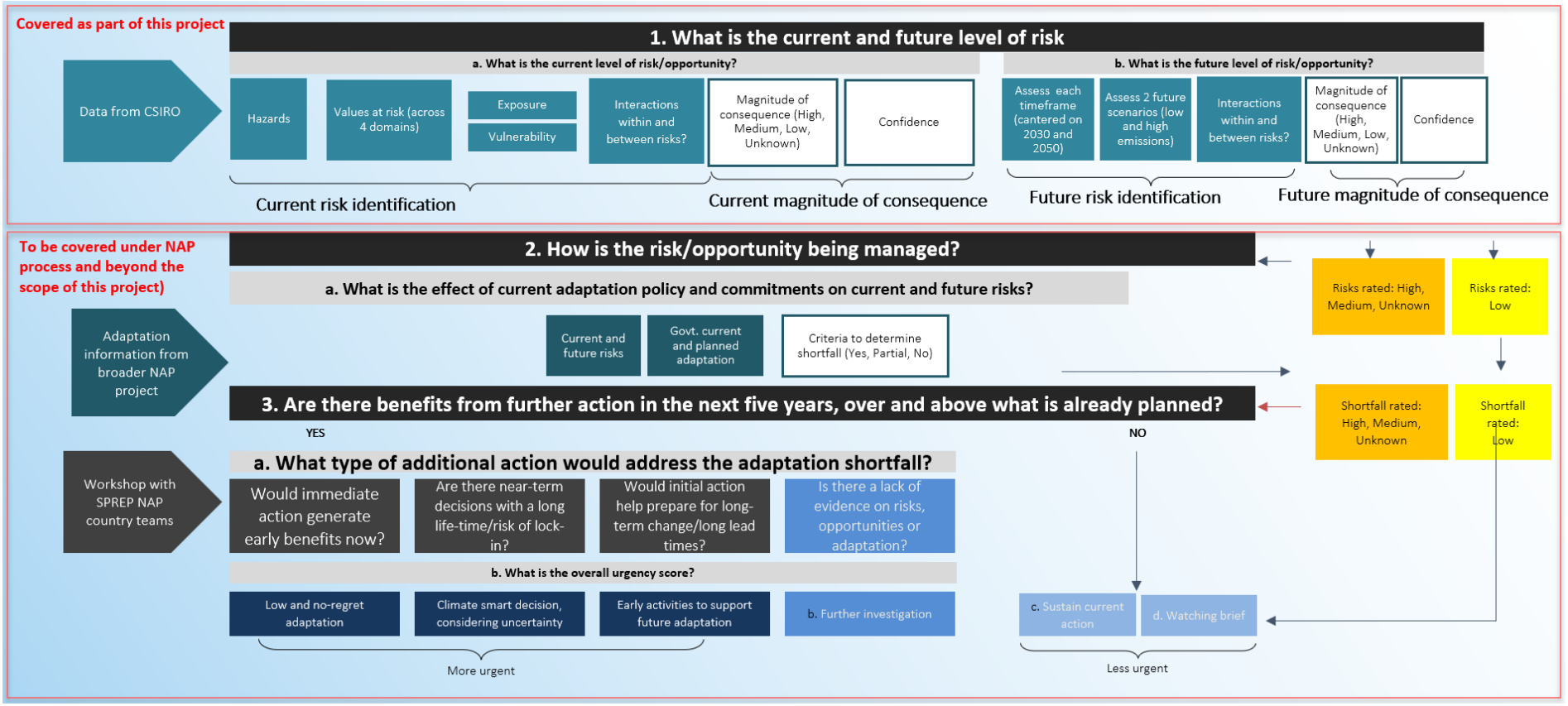

Figure 3: Overview of the risk assessment process

For each prioritised sector/domain in Tuvalu, a risk statement was developed. The risk statement encapsulates information about how climate hazards, exposure and vulnerability can impact the sector/domain and what are likely consequence and impacts for Tuvalu. Detailed risk profiles are developed for each risk statement capturing, how different climate hazards, exposure and vulnerability can impact the sector/domain (under present day and future). Magnitude of consequence ratings were developed for each risk statement (and reported under individual risk profiles), using a criteria which were adapted from equivalent international climate change risk assessments and further tailored for Tuvalu (see appendix 1 for the criteria). These scores aid the comparison of risks and thus provide an important input to the Tuvalu NAP (Figure 4). A confidence score is also developed for each risk statement based on the strength of the available evidence (see appendix 1 for the criteria).

Figure 4: High-level overview of the information flow from risk assessment stage to NAP.

Summary results of the risk assessment was presented to Tuvalu Stakeholders during an in-country mission. Feedback collated from that engagement were incorporated in the final results.

3 Climate change in Tuvalu

3.1 Background

This integrated risk assessment draws from two crucial pieces of work detailing the climate hazards, impacts and vulnerabilities Tuvalu is exposed to. They are:

- A comprehensive hazard and impact report for Tuvalu conducted by CSIRO (hereon referred to as the 'Hazard Report') which discusses future climate projections for Tuvalu (CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP).
- Tuvalu Integrated Vulnerability Assessment (TIVA) conducted by Tuvalu Government and aggregated to the national level by CSIRO (2024). (CSIRO, Tuvalu Government (2024). Community vulnerability assessment. Tuvalu).

These two studies provide necessary climate context and vulnerability of different sectors within Tuvalu and informed this risk assessment. Hazard report specifically has identified how different climate drivers can impact Tuvalu sectors/domains. A summary of that assessment is provided in Appendix-2. For full context and approach of developing this summary please refer to the Hazard report.

To avoid repetition, a full description of how climate is likely to change in Tuvalu is not provided in this document as it is covered in detailed in the Hazard report. Rather a succinct summary of climate change projections is presented in this report.

3.2 Future climate change projections for Tuvalu

The intensity and frequency of numerous climate hazards are projected to increase as global temperatures continue to rise. Please see Figure 5 for a high-level schematic of these changes. Estimates of future climate change are affected by three main sources of uncertainty: (1) greenhouse gas emissions pathways, (2) regional climate responses to global change and (3) natural climate variability due to factors such as El Niño and La Niña. Projections under two emissions scenarios (a low and high) have been prepared to examine future changes in climate-related hazards.

Figure 5: Simplistic overview of projected climate variables and hazards in Tuvalu. Source: CSIRO, Federation University. Assessment of climate hazards for Tuvalu under current and future conditions

Table 3 displays the summary of findings from the Hazard Report, which illustrates historical climate (20-years centred on 1995) and projected climate change for 2030 and 2050, relative to the 1995 baseline. Changes are based on simulations from CMIP5 global climate models (GCMs) for low (RCP2.6) and high (RCP8.5) greenhouse gas emissions scenarios. However, changes in extreme wind speed and marine heat waves are based on CMIP6 GCMs for low (SSP1-2.6) and very high (SSP5-8.5) emissions scenarios.

For some variables, the Tuvalu exclusive economic zone (EEZ) region is assessed, rather than Funafuti, as indicated. Confidence ratings are based on the IPCC framework (Mastrandrea et al, 2010) involving an assessment of the amount of evidence and the degree of agreement between lines of evidence.

Table 3: Climate hazards projections for Tuvalu as identified in the CIVRA-Tuvalu Hazard Report.

Historical climate	Climate variable	Projected change			
20-years centred on 1995		2030	2050 Low emissions RCP2.6	2050 High emissions RCP8.5	Confidence
ATMOSPHERIC VARIABLES					
Min 26 °C Max 31 °C	**Annual average temperature (°C)**	+0.7 (0.4 to 1.0)	+0.8 (0.5 to 1.2)	+1.4 (1.0 to 1.9)	high
12 (0 to 31)	**Hot days (days > 33 °C)** [a]	No data	+181 (140 to 222)	+264 (140 to 331)	high
3460 mm	**Annual average rainfall (%)**	+4 (-4 to +12)	+3 (-6 to +11)	+3 (-11 to +17)	medium
134 (119 to 160) mm/day	**Annual maximum daily rainfall (mm/day)**	No data	+12 (-17 to 39)	+15 (-15 to 65)	medium
	Average drought intensity (more negative = more intense)	Slight increase	No data	Slight increase	medium
1.2 per 20 years	**Average drought frequency (per 20 years)**	Slight decrease	No data	Slight decrease	medium
~17 months	**Average drought duration (months)**	Slight decrease	No data	Slight decrease	medium
~30 (20-39) m/s	**Tropical cyclone windspeed (m/s)**	No data	No data	Increase	low
12 per decade	**Tropical cyclone frequency (%)**	No data	No data	Decrease	low
OCEAN VARIABLES					
0m	**Annual average sea level (m)**	+0.13 (0.09 to 0.17)	+0.22 (0.17 to 0.29)	+0.27 (0.19 to 0.37)	high
11 km^2	**Extreme sea level proxy: 50-yr ARI Tuvalu flooded area (km^2)** [b]	No data	~16 (2060; SSP2-4.5)	~16.5 (2060)	high

28.6-29.5 °C	**Sea surface temperature (°C) over EEZ [c, f]**	+0.7 (-0.6 to 1.7)	+0.9 (-0.5 to 2.1)	+1.3 (0.0 to 2.5)	high
~ 10 days/ yr	**Marine heatwave frequency (days/year) [c,f]**	110-290	130-340	220-360	high
0 days/ 20 yr	**Coral bleaching days (per 20 years) [d,f]**	No data	169-2934	1652-6460	high
~8.08 (8.1-8.07)	**Annual average ocean pH over EEZ ([c,e])**	8.02 (7.99-8.04)	8.0 (7.99-8.02)	7.95 (7.93-7.96)	high
~4.1 (4.0-4.2)	**Annual average aragonite saturation ([c,e])**	3.77 (3.51-4.06)	3.69 (3.53-4.01)	3.4 (3.18-3.70)	high

[a] number of days over the 95th percentile of 1985-2014 daily temperatures [b] data source Wandres et al, 2021.[c] Future values are reported, not changes. [d] Exceed coral bleaching Alert level 2 at Niutao. [e] Baseline figures are estimated from Figure 112. [f] CMIP6/SSPs and baseline period 1994-2014 used.

4 Summary of results

Risk assessment process discussed in Chapter 2 is applied using climate change projections for Tuvalu to understand key risks for different sectors/domains. This chapter presents the summary consequence ratings for key sectors/domains across different timeframes (Table 4). Each sector/domain is divided into key sub-sectors/domains that are relevant for Tuvalu. A dominant hazard for the sub-sector/domain is determined using inputs from CSIRO Hazard Report and TIVA. Consequence for each timeframe and scenarios are then estimated using the magnitude of consequence criteria (see appendix 1).

For detailed discussion of identified risks for each sector/domain, please see Chapter 5.

Table 4: Scorecard of consequence of climate hazards to Tuvalu's 7 key sectors/domains by 2030 (low and very high emissions), 2050 (low emissions), and 2050 (very high emissions)

	Sub-systems being assessed	**Most prominent hazard being assessed**	**Baseline**	**Future magnitude of consequence score**		
Sector/domain	***Sub-sector/domain***	***Hazard***	***Current***	**2030 Low and high emissions scenario**	**2050 Low emissions scenario**	**2050 High emissions scenario**
Agriculture	Crops	Saline intrusion due to sea level rise	Major	Major	Major	Extreme
	Livestock	Temperature increase	Moderate	Major	Major	Major
Fisheries	Oceanic fisheries	Sea surface temperature	Minor	Moderate	Major	Extreme
	Coastal fisheries, lagoons	Marine heatwaves/tropical cyclones	Moderate	Moderate	Major	Extreme
	Fisheries infrastructure	Temperature increase/extreme heat	Minor	Moderate	Moderate	Moderate
	Biodiversity that supports fisheries	Marine heatwaves	Moderate	Major	Major	Extreme
Health and wellbeing	Physical health	Heatwaves and increased temperature	Minor	Minor	Major	Major
		Sea level rise, extreme rainfall, drought	Minor	Moderate	Major	Extreme
	Non-communicable disease (NCD)	All hazard	Minor	Moderate	Major	Extreme
	Mental health	All hazard	Minor	Moderate	Major	Extreme

	Health infrastructure	Sea level rise, coastal inundation	Minor	Minor	Major	Extreme
	Access to health services	Sea level rise, coastal inundation	Minor	Minor	Major	Extreme
Social cohesion & heritage	Cultural heritage	Coastal inundation, sea level rise and marine heatwaves	Moderate	Major	Extreme	Extreme
	Socio-economic & gendered inequality	All hazard	Moderate	Major	Extreme	Extreme
	Migration to Funafuti	Coastal inundation, sea level rise	Major	Major	Extreme	Extreme
Disaster management	Demand for emergency services	Tropical cyclone and storm surge	Moderate	Major	Extreme	Extreme
	Evacuation centres	Tropical cyclone and storm surge	Major	Major	Major	Major
Water	Water availability	Extreme drought	Major	Major	Extreme	Extreme
	Water demand	Extreme heat	Moderate	Moderate	Major	Major
	Water quality	Saline intrusion due to sea level rise	Major	Major	Major	Extreme
	Water infrastructure	Sea level rise, coastal inundation	Major	Major	Extreme	Extreme
Coastal protection	Coastal assets and flood defences	Tropical cyclone induced storm surge	Major	Major	Extreme	Extreme
Infrastructure	Transport & supply chains	Sea level rise, coastal inundation	Moderate	Major	Extreme	Extreme
	Buildings and structures	Sea level rise, coastal inundation	Major	Major	Extreme	Extreme
	Electricity supply	Sea level rise, coastal inundation	Moderate	Major	Extreme	Extreme
	Internet and telecommunication	Sea level rise, coastal inundation	Minor	Moderate	Major	Major
	Waste management	Coastal inundation and flooding	Moderate	Major	Major	Major

5 Risk statements and profiles

This chapter presents detailed findings of the risk assessment. Information is presented as a form of 'risk profiles' for each of the risk statements highlighting current and future exposure, vulnerability and consequences across different timeframes. Each detailed risk profile follows the following structure:

Heading	Overview
Sector/Domain Summary	• Overview of the sector/domain and context in Tuvalu.
Risk Statement	• Sector/domain-specific risk qualitative risk statement.
Risk Summary	• Summarise the impacts of climate pressures to key components of the sector/domain.
Current and future exposure to hazards	• Establish key climate hazards impacting sector/domain. • Consider how the key components risk (e.g. crops and livestock for agriculture) have already been impacted by these hazards. • Consider future impacts of climate pressures on key components.
Vulnerability	• Summarise the key sources of vulnerability relevant to the risk. • Establish how this vulnerability varies across different islands.
Complex Risks	• Establish how the risk and its consequences are impacted by interaction with other climate risks/compounding factors.
Consequence	• Determine the current consequences of climate change for the sector/domain. • Determine the future consequences of climate change for the sector/domain under both scenarios for 2030 and 2050 (medium and high emissions).
Confidence	• Describe the quality and amount of evidence supporting the risk assessment.
Knowledge Gap	• Recognise information and data gaps

5.1 Agriculture

Summary of this Sector

Tuvalu's land-based agriculture sector is a significant part of the economy and is made up of crops and livestock. The crop sub-sector's value to the national GDP in 2017 was AUD 3.7 million (or 6.6%) and the livestock sub-sector accounted for AUD 2.7 million (4.8%)[6]. The subsistence economy is dominated with women, making up 78% of the workforce[7].

Many Tuvaluans are involved in subsistence agriculture with 69% of the population growing crops including coconut, pulaka (swamp taro), taro, breadfruit, pandanus, banana, pumpkin, sweet potatoes and pawpaw. Crop diversity and the extent at which crops can be grown is severely restricted by an ecosystem of poor soil, and fresh water supplies which are limited to shallow sub-surface lenses8. There is minimal availability of compost which is an issue for household planting.

Livestock is more widespread throughout the islands with 90% of the population raising animals including pigs, chickens and ducks which are the main commodities for consumption[9]. Livestock production is constrained by the cost and availability of animal feed which is imported into Tuvalu[10]. Most pigs are kept in modern pens (60%) or locally constructed pens (20%), or both (9%). Over 8% of households have no pig housing for the remaining 11% of pigs. Most pigs (89%) are housed in pens, with the remaining 11% being un-penned and roaming free. The unpenned pigs belong to 8% of households. These households own, on average, more pigs (11.8) compared to the national average of 8.8 pigs per household. Almost 70% of households with free-range chickens do not have chicken pens, and the chickens roam freely. The average number of chickens per household is 22.6 chickens[11].

Agriculture is located across all islands of Tuvalu. The island of Nukufetau has higher proportions of households engaged in growing crops with 96% of households were growing crops. Other islands to report high proportions of households undertaking multiple agriculture activities were Nanumea, Niutao, Nui and Nukulaelae as seen in Figure 6 below. Therefore, it is likely that these islands have been (and will) hit hard by any agriculture related impacts.

[6] Central Statistics Division (CSD) of the Government of Tuvalu. (2017). Tuvalu Agriculture and Fisheries Report

[7] World Bank Group (2021). Climate risk country profile. Tuvalu.

[8] Central Statistics Division (CSD) of the Government of Tuvalu. (2017). Tuvalu Agriculture and Fisheries Report

[9] Tui, Saamu, Fakhruddin, Bapon. (2022). Food for through: Climate change risk and food (in)security in Tuvalu. Elsevier Vol 16 https://doi.org/10.1016/j.pdisas.2022.100255

[10] Central Statistics Division (CSD) of the Government of Tuvalu. (2017). Tuvalu Agriculture and Fisheries Report

[11] Central Statistics Division (CSD) of the Government of Tuvalu. (2017). Tuvalu Agriculture and Fisheries Report

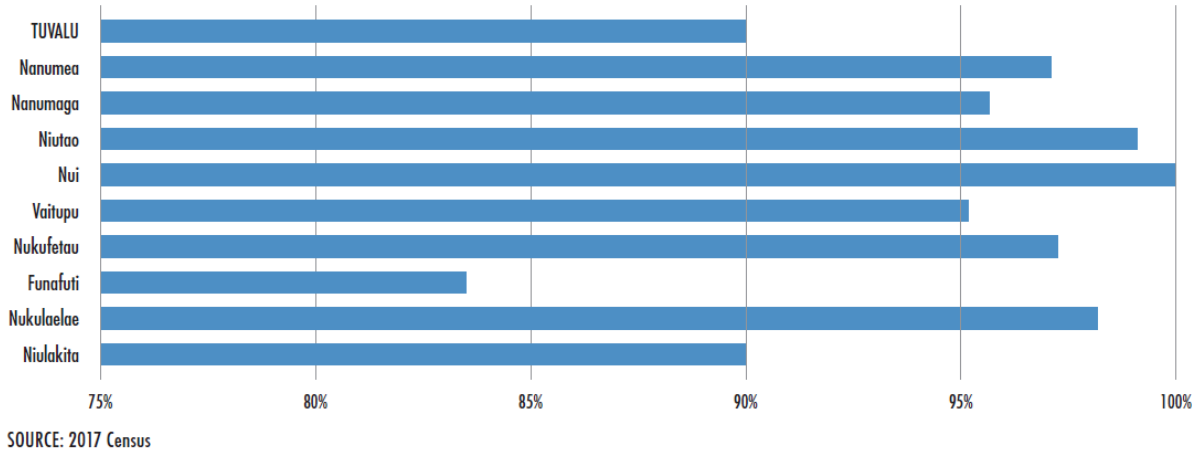

Figure 6: Percentage of households engaged in agriculture by island: 2017. (Source: Central Statistics Division of the Government of Tuvalu. 2017. Tuvalu Agriculture and Fisheries Report.)

The following risk statement (**R1**) has been developed through consultation during the Tuvalu NAP Project-Mission (2024). It discusses the risks that climate change present for agriculture that have been identified and analysed.

R1: Risks to Agriculture

Increasing chronic and acute climate hazards, including sea level rise, increasing temperatures, variability in rainfall and extreme drought currently and will increasingly impact suitability and productivity of crops and livestock. These impacts will have flow-on impacts to subsistence households and communities reliant on cash crops and associated workforces (including the services sector) and the transportation, storage and processing of products. Together, these will negatively affect crop productivity and associated food security, community health and livelihoods, and economic development of the islands, including increased dependency on imported, relatively expensive and highly processed food products with implications for management of NCDs and community health (see also R4). Availability of suitable land for agricultural production in Funafuti is being impacted by competing demand for location of other key assets such as rainwater storage tanks. In some outer islands increased cropping is impacting the sustainability of wild-harvested natural resources such as land crabs utilised as a supplementary food source by local communities.

Risk Summary

The agriculture sector of Tuvalu is at risk from climate change through chronic and acute climate change events such as sea level rise, increase in average temperature and extreme heat, variability in annual average rainfall, extreme drought, coastal inundation, storm surge, and coastal erosion and a potential increase in extreme windspeed. The effects of these climate change events include limited land availability for crops and livestock, saltwater intrusion, changes in soil moisture and temperature, water scarcity and poor water quality, and an increase in the arrival of invasive species and pests due to higher temperatures. Tuvalu's distance from markets, small and dispersed population and vulnerability to economic and environmental shocks increases food security risks to the nation.

Current exposure to hazards

This section discusses the exposure of the agricultural sector to key hazards.

Increasing air temperature and extreme heat events

The agriculture workforce is impacted by increasing air temperature and extreme heat temperature. Extreme heat is affecting the farming workforce through reduced workforce productivity on hot days. Extreme heat is also resulting in adverse health outcomes such as heat stress, dehydration, and heat stroke.

Increasing average temperatures and extreme heat events are affecting crops resulting in heat stress, affecting photosynthesis, respiration, water balance and membrane stability of leaves[12]. This leads to low crop performance and limited growth and metabolism, increased crop disease and poor crop suitability together with the associated increase in water intake required for crops to respond to heat.

There has been an increase in invasive species and pests on crops, negatively affecting crop performance[13]. While the climate triggers causing disease outbreak in crops remain unclear, increasing temperature and extreme droughts may be a contributing factor. In Nanumaga and Vaitupu, higher temperatures have resulted in increased fruit flies and coconut scale pests, while fungal disease in coconut trees, albeit known for many years, is becoming more pronounced. Invasive species such as the yellow crazy ant are destroying crops and attacking wildlife such as chicken and land crabs[14]. This is more pronounced during hotter, humid days.

Increasing air temperatures and increasing frequency of extreme heat events are negatively impacting livestock welfare, causing heat stress particularly in pigs and free-range chickens. When temperatures increase, sows and newly farrowed sows can become lazy and forget to drink, which will result in lost body condition and low production of milk for piglets[15]. Throughout the Pacific region free-range chickens and pigs, and home gardens, are an integral part of self-sufficiency. An assessment by Taylor et al. (2016)[16], indicates chickens are less tolerant of excess heat with the thermal comfort zone of 10-20 °C, with adult pigs being 16-25 °C, and young pigs 25-32 °C, although this may vary with Tuvalu-specific livestock breeds. Pigs do not sweat and rely on the addition of water (spray infrastructure) and air movement to allow evaporative cooling. Farms that do not have shade and shelter infrastructure and enough water supply to meet the associated increase in water demand are more vulnerable to extreme heat events.

Vaitupu, Niutao and Nanumaga account for 60% of the nation's free-range chicken population, therefore these islands may be impacted more by extreme temperatures. Nukufetau households contain no modern bird pens for chickens which may cause chickens to be more at risk to extreme heat and heat-related illness. Nanumea and Vaitupu households mostly use local pens or no pig housing, therefore pigs on these Islands are more exposed to extreme heat than other islands.

Sea level rise, coastal inundation, coastal erosion

Sea level rise, coastal inundation, coastal erosion and flooding pose major challenges to the food security of Tuvalu. Coastal erosion and flooding are destroying coconut palm plantations, the main export commodity of Tuvalu. Root crops such as taro and pulaka are significantly affected by saline groundwater intrusion and coastal storm surges. Other crops such as bananas, breadfruits, pandanus, coconut palms are also affected. Sea level rise and the resulting saltwater intrusion has destroyed 60% of pulaka pit plantations, with the

[12] Kaushal, N., Bhandari, K., Siddique, K. H. M., Nayyar, H., & Tejada Moral, M. (2016). Food crops face rising temperatures: An overview of responses, adaptive mechanisms, and approaches to improve heat tolerance. Cogent Food & Agriculture, 2(1). https://doi.org/10.1080/23311932.2015.1134380

[13] Hennessy, K., Sheppard, M., (2023). Tuvalu climate impacts and risks. Environmental scan of available literature 5 December 2023

[14] RNZ. (2014). Yellow crazy ants cause havoc in Tuvalu. Yellow crazy ants cause havoc in Tuvalu | RNZ News

[15] Western Australia. Department of Primary Industrie and Regional Development. (2024). Water: the forgotten nutrient for pigs.

[16] Taylor, M., A. McGregor, and B. Dawson. (2016). Vulnerability of Pacific Island agriculture and forestry to climate change. SPC.

remaining 40% highly sensitive to sea level rise. Root and tuber crops, the main staples of Tuvaluan diets, are predominately salt -sensitive, with significant reductions in growth and yield under moderate salinity exposure[17].

On the island of Nui, 70% of households have experienced loss of land due to soil erosion, with almost half also impacted by king tides. Soil erosion has also impacted more than 40% of households on Nanumea and Nukufetau. These islands may be experiencing impacts of sea level rise and coastal inundation and erosion more than other islands with resultant implications for agricultural activity.

Threats to crop yields and a decrease in food production in the context of widespread subsistence farming represent a threat to Tuvalu's food security, and may result in an increased demand for and reliance on in imported products (with resultant resource implications) and associated exposure to global food shortages and market shocks.

Livestock is affected by sea level rise, coastal inundation and erosion, and flooding which decrease land availability. Increased sea-levels also decrease poor water quality as a result of thinning of freshwater lenses which has negative consequences for watering livestock.

Drought

Large proportions of crops that have been typically resilient to the past climate in Tuvalu, such as coconut, breadfruit, bananas and pulaka taro, wilt and die during periods of drought. Challenges for water access during these times are exacerbated as water is a highly contested resource and is prioritised for people rather than livestock and crops. Composting is slightly better in The Outer Islands which have better topsoil compared to Funafuti making them more drought resilient. Funafuti agriculture activities are more vulnerable to drought exacerbated by poor soil and poor water quality.

Drought limits water availability for animal husbandry, in particular domestic pig production. which requires continuous access to water[18]. A Piglet's body is 80% water, compared to 50% in a finisher pig, these water levels need to be maintained by consuming water[19]. Water scarcity impacts to livestock include an increase in waterborne disease caused from poor water quality. Increased salinity causes salt poisoning, and the presence of contaminants causes illnesses such as diarrhea and an overall decline in animal health.

Farmers without water tanks, or who don't have appropriate sized water storage and irrigation systems are at greater risk of drought and rainfall variability.

Tuvalu's reliance on rainwater makes communities, including the agriculture workforce, particularly vulnerable to drought and associated water, sanitation and hygiene (WASH) issues. Drought-induced water scarcity and reduced water quality can impact human health and productivity by increasing infection rates and disease issues, including water-borne bacteria (such as myxosporidia) and suspected water-borne typhoid[20]. Sewage leakage from ageing septic tank systems increases the vulnerability of Tuvalu

[17] Lloyd, G.G, Uesugi, A., Gleadow, R.M, (2021). Effects of salinity on the growth and nutrition of taro: Implications for food security. *Plants*. 10:2319 doi.org/10.3390/plants10112319

[18] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[19] Western Australia. Department of Primary Industrie and Regional Development. (2024). Water: the forgotten nutrient for pigs.

[20] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

communities to drought by compounding the community health problems linked to water security issues[21].

Extreme rainfall and tropical cyclones

Extreme rainfall poses challenges for the transportation of agriculture products as well as the movement of the workforce due to flooding and damage of coastal infrastructure, including the international airport, roads, docks and seawalls.

Increased water pooling following extreme rainfall may increase mosquito vector species of dengue, *Aedes aegypti* and *A.Albopictus,* and may impact upon the workforce through transmission of diseases resulting in poor health and disruptions to productivity. Increased waterborne diseases following extreme rainfall also affects livestock. Cyclone conditions of extreme winds, storm surge and heavy rains threaten the physical safety of livestock, and can cause damage to pig and chicken housing. Livestock have been observed being washed off the island and lost in the ocean.

Cyclones can damage and destroy crop plantations, with trees such as bananas and coconuts at risk of destruction or losing branches and fruit. Root tubers are at risk of flooding and waterlogging from rainfall and storm surge.

Future exposure to hazards

This section discusses the future exposure of the agricultural sector to the key hazards.

Climate change hazards across the board will impact commercial agriculture with resultant consequences to the economy through declining GDP and reduced income through impacts on employment. Impacts to subsistence farming are also likely to have significant effects on the diets of Tuvaluan people and have associated health and wellbeing challenges.

Increasing air temperature and extreme heat events

Increases in annual average temperatures and extreme heat are likely to affect suitability of existing crops and exacerbate the likelihood of crop diseases. These may result in poor crop performance and a decrease in the diversity of food crops.

Annual average temperature increases and extreme heat will increase livestock (pig and chicken) stress.

Sea level rise, coastal inundation, coastal erosion

Sea level rise will result in increased salt-water intrusion into groundwater. In low lying areas of Tuvalu, the lack of unsaturated areas may drive the groundwater table to alternate discharge pathways or cause local flooding with salt water. This will affect all crops, especially root crops such as pulaka, impacting food security and potential loss of cultural practices that are tied to traditional agriculture and food preparation.

Nukufetau, Nanumaga and Nui have a higher proportion of households involved in pulaka pit plantations. These islands may face larger consequences due to salinization of pits.

[21] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

Drought

Drought vulnerability of crops is increased by the lack of irrigation infrastructure,[22] contributing to crop stress, reduced production and associated impacts to livelihood and income. Prolonged drought poses negative impacts to crop yields through water stress and the influence of salt-coated soil caused by high evaporation in the pits.

Despite the projected decrease in drought frequency and duration, the projected increase in drought intensity will impact livestock through water scarcity and declines in water quality, affecting health, quality and production.

Water scarcity will impact upon subsistence agriculture with associated impacts on diets. This can lead to increased rates of infection and disease threatening health and wellbeing of the workforce.

Extreme rainfall and tropical cyclones

More frequent extreme rainfall events will increase surface water and associated water logging of soil with resultant damage to crops. Episodic flooding will worsen water catchment pollution, septic overflow and drain and pipe blockages and result in significant infrastructure damage with an increased risk disease for workforce and livestock.

While cyclone frequency is projected to decrease with low confidence, a projected increase in the intensity of cyclone windspeeds may reduce water security by causing ocean overtopping of barriers, resulting in further saltwater intrusion and reduced groundwater quality. There is also strong potential for storm surge and severe winds to damage water infrastructure, as well as damage crops such as bananas and coconut palms. Livestock that are not safely penned or moved away from the coast are at risk of being swept into the ocean during storm surges. Transportation will be disrupted due to damage to travel routes.

Vulnerability

Tuvalu is particularly vulnerable to degradation of their agricultural systems due to climate change. Vulnerability of agriculture commodities is driven by a range of factors including infrastructure, location of catchments, location of the farm and type of enterprise.

Hazard	Factor relevant for vulnerability
Average temperature and extreme temperature	• Water is prioritised for human health during extreme heat events, reducing water availability for livestock and crops. • Reliance on root crops which may be outside of their optimal temperature range, causing the plants to wilt and die. • Outdoor workers lack sufficient water and shade. • Pigs and chickens (integral to self-sufficiency) are prone to heat related illness. • Invasive species thrive during hotter, humid days. Breaches in biosecurity and control mechanisms will see a flourishment of invasive species.
Drought	• Limited water storage capacity reduces water availability and water quality for livestock and crops during drought.

[22] World Bank Group, Asian Development Bank (2021). Climate Risk Country Profile: Tuvalu

	• Irrigation systems are still underdeveloped on some islands. • Crops have shown low resilience to droughts in the past.
Sea level rise	• Root and tuber crops, which are the main staples of the Tuvalu diet, are salt-sensitive. • Some islands reliant on bores for livestock water are at risk of increasing salinity of groundwater. • High exposure in low lying coastal areas with reducing resilience to coastal inundation, declining or poor soil quality for farming with saltwater intrusion and storm surge (Vaitupu in particular).
Extreme rainfall and average rainfall	• Crops are often grown in poor soil or lower areas at risk of waterlogging. • Crops have shown low resilience to floods causing recurrent crop failure.
Coastal inundation, storm surge, coastal erosion	• Proximity of crops to the coast increases vulnerability to flooding, storm surge and erosion. • Crops can become inundated with saline water from wave overtopping. • Coastal infrastructure (roads, runways, docks) are vulnerable to damage, disrupting the movement of agricultural goods.
Cyclone	• Low resilience of crops to tropical cyclone winds and waves e.g. breadfruit dropping • Unsecured livestock are at risk physical safety during cyclones from wind-borne hazards and being swept away in tidal surges • Agriculture and coastal infrastructure (roads, runway) are vulnerable to cyclone damage, disrupting movement of goods and workers

Variations across the islands

Climate risks and impacts to the agricultural sector vary across the islands according to commodity, geographical location, and farming infrastructure. The following island-specific vulnerabilities have been identified:

Region	Vulnerability issues
Funafuti	• Low resilience of land-based food crops. • Inadequate water tank capacity. • Limited to or no access to land for farming, including commercial agriculture. • Declining or poor soil quality for farming (fertility/salinity). • Poor groundwater quality. • Limited or no access to agriculture equipment and resources (seedlings, nurseries, tools, fertilisers, pesticides). • Funafuti which hosts 40% of the country's crop-growing households may be impacted by food shortages due to the damage and disruptions caused by a range of climate hazards. This may increase reliance on food production from the Outer Islands and imports from other countries.
Nanumaga	• Declining or poor soil quality (fertility/ salinity). • Presence of land-based invasive species.

Nanumea	• Declining or poor soil quality for farming. • Presence of land-based invasive species. • Unmanaged or poor management of livestock and domestic animals. • Inadequate household water tank capacity.
Niulakita	• Declining or poor soil quality (fertility/salinity), • Rainfall not sufficient to meet community water security.
Niutao	• Declining or limited crop diversity. • Existing natural water source insufficient to support water security needs. • Saltwater intrusion due to sea level rise impacting land-based food crops.
Nui	• Declining or limited crop diversity. • Low resilience of land-based crops. • Inadequate water tank capacity. • Presence of invasive species.
Nukufetau	• Presence of land-based invasive species. • Limited to no access to supplementary story-based food outlets.
Nukulaelae	• Declining poor soil quality. • Increasing groundwater salinity. • Limited to no access to inter-island transportation to support access to markets.
Vaitupu	• Presence of invasive species. • Low resilience of land-based food crops to storm surge and inundation. • Existing natural water source insufficient to support water security needs.

Complex risks

Agricultural risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Water security:** Extreme heat and drought, coupled with water scarcity will have major impacts affecting both agriculture and domestic use of potable water, more so in northern Tuvalu. Water is prioritised for people first, creating water scarcity for livestock and crops.
- **Social cohesion:** Increased migration to Funafuti will pose problems for agriculture in terms of competing land for agriculture activities and biosecurity hazards caused from crops and livestock.
- **Human health & well-being:** Adverse consequences on the agriculture sector including subsistence farming will cause food security problems, placing a higher burden on public health.
- **Infrastructure**: Unreliable energy supply will affect the agricultural sector through inability to access water supply from pumped tanks and/or desalination units.
- Poor telecommunications will limit ability to access real-time market intelligence (demand, prices etc).
- Population density and limited farming land availability reduces livestock activities on any large scale on the island of Funafuti, including room for water tanks.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R1- Crops	**Saline intrusion due to sea level rise** Crop salinity is affecting crop performance and size of yields. The main staples of Tuvalu diet, roots and tuber crops are salt-sensitive.	**Major**	60% of pulaka pits have been destroyed, with remaining 40% highly sensitive to sea level rise.
R1 – Livestock	**Temperature increase** Livestock in Tuvalu are sensitive to extreme temperatures as they are prone to heat related illnesses.	**Moderate**	Heat related illnesses affect livestock. Temperature changes also alter yields and suitability of their feed growing regions.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R1- Crops	**Saline intrusion due to sea level rise** Crop salinity is affecting crop performance and size of yields. The main staples of Tuvalu diet, roots and tuber crops are salt-sensitive.	**Major**	Further damage to pulaka pit plantations, as well as poor crop performance of other crops such as bananas, breadfruits, pandanus and coconut palms will continue as sea levels rise and the resulting increases to salinity. Widespread damage to root and tuber crops caused under a moderate salinity exposure will significantly affect subsistence farming and food production

R1 – Livestock	**Temperature increase** Livestock in Tuvalu are sensitive to extreme temperatures as they are prone to heat related illnesses.	**Major**	Projected increases in average and extreme temperatures will lead to economic activity from meat and livestock production. However, a slight projected increase in annual rainfall may increase the availability of freshwater however, the impacts of extreme heat are expected to prevail.

2050 High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R1 – Crops	**Saline intrusion due to sea level rise** Crop salinity is affecting crop performance and size of yields. The main staples of Tuvalu diet, roots and tuber crops are salt-sensitive.	**Extreme**	Increasing sea level rise (19-37 cm) will continue to impact upon subsistence crop performance and production through groundwater intrusion and other sea level hazards such as coastal erosion and coastal inundation. Coastal plantations and remaining pulaka pits are at high risk of widespread, permanent damage and/or destruction. Food production will significantly decrease leading to widespread food shortages. A loss of cultural practices tied to traditional agriculture practices such as pulaka pits will occur. Widespread, significant impacts to the agriculture workforce will occur due to decreased viability of crop production.
R1 – Livestock	**Temperature increase** Livestock in Tuvalu are sensitive to extreme temperatures as they are prone to heat related illnesses.	**Major**	Projected increases in average and extreme temperatures will lead to economic activity from meat and livestock production. However, a slight projected increase in annual rainfall may increase the availability of freshwater however, the impacts of extreme heat are expected to prevail.

2050 Low emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R1 – Crops	**Saline intrusion due to sea level rise** Crop salinity is affecting crop performance and size of yields. The main staples of Tuvalu diet, roots and tuber crops are salt-sensitive.	**Major**	Sea level rise under a low emissions scenario is projected to be 17-29 cm. Saline intrusion due to sea level rise will continue to cause widespread damage and destruction to salt-sensitive crops such as roots and tubers, as well as negatively impact upon other crops. Damage to subsistence farming will be extensive, impacting upon livelihoods, cultural practices and food supply of the population, as well as causing a decrease in economic output from the industry.
R1 – Livestock	**Temperature increase** Livestock in Tuvalu are sensitive to extreme temperatures as they are prone to heat related illnesses.	**Major**	Projected increases in average and extreme temperatures will lead to economic activity from meat and livestock production. However, a slight projected increase in annual rainfall may increase the availability of freshwater however, the impacts of extreme heat are expected to prevail.

Confidence

Component	Hazard	Confidence score	Comments
Crops	**Saline intrusion due to sea level rise**	**Medium**	• It is unsure the thresholds of salinity intrusion required to cause damage to crops. • The damaging effects of interacting climate risks on crops in Tuvalu is not widely studied.

Livestock	**Temperature increase**	**Medium**	• Limited information on livestock and how climate change will affect them in the future. • There is no extreme heat projection for 2030 which makes it difficult to assess the consequence of temperature increase on livestock. • It is unclear whether chicken coops and pig housing will help alleviate heat related stress during extreme heat.

Knowledge Gaps

- Limited information on livestock in current and projected climate change and how this will affect livestock in the future.
- Limited information on tolerance levels of crops to salinity.
- Limited information on agriculture workforce and agriculture supply chain/transportation.

5.2 Fisheries

Summary of this sector in Tuvalu:

The fisheries industry of Tuvalu is critical for food security of the nation and is responsible for a significant portion of Tuvalu's economy. Although coastal fishery productivity is limited due to land availability and over-fishing in various locations, Tuvalu has a large expanse of ocean in its Economic Exclusion Zone (EEZ) and oceanic tuna fishing accounts for up to 50% of Tuvalu's GDP, underpinning significant government investment in health, education and other critical services. A large part of fishing revenue comes from selling fishing days and licencing, bringing in US$36million in 2022[23]. The flag ship management fee accounted for 52% of the total licensing fee, with most of this revenue coming from bilateral and multilateral vessels[24]. Commercial fishing in Tuvalu's EEZ had a total harvest of 90,000 tonnes in 2015, largely consisting of skipjack tuna, with only 1100 tonnes in domestic vessel fishery production[25].

Tuvalu is highly dependent on coastal and oceanic fishery resources to meet domestic nutritional needs and safeguard food security. Fish provides 50–90% of animal protein towards the diet of coastal communities across the Pacific islands. In Tuvalu the national average fish consumption per person is around 100kg per person, more than 3–4 times the global average[26]. Roughly 74% of households participate in coastal fishing and 63% in ocean fishing[27].In 2016, reef fish accounted for 25% of fish consumed, with the remaining being oceanic fish. Funafuti is responsible for 50% of the total fish catch, and the other 50% comes from the remaining islands and lagoons.

Aquaculture in Tuvalu is very limited with small-scale milkfish farming on Vaitupu and some sea-cucumber farming primarily for local consumption[28].

Traditional knowledge and fishing methods are used in several Outer Islands to safeguard sustainable fishing in Special Protected Areas under local community management[29].

Tuvalu's marine and coastal biodiversity is underpinned by a wide variety of reef habitat types, including typical high-energy oceanic reef systems and sheltered lagoon communities[30]. Reef fish communities in Tuvalu are typical of the Central Pacific and there have been recorded sightings of critically endangered Hawksbill and Leatherback sea turtles in coastal communities[31]. Tuvalu has established ten conservation

[23] Ministry of Fisheries & Trade (2022). Tuvalu Fisheries Annual Report 2022.

[24] Ministry of Fisheries & Trade (2022). Tuvalu Fisheries Annual Report 2022.

[25] Preston, G., Stuart, M., and Finikaso, S. (2016). Tuvalu Fisheries: Moving into the 21st Century.

[26] Preston, G., Stuart, M., and Finikaso, S. (2016). Tuvalu Fisheries: Moving into the 21st Century.

[27] Preston, G., Stuart, M., and Finikaso, S. (2016). Tuvalu Fisheries: Moving into the 21st Century.

[28] Tuvalu NAP Project-Mission (2024).

[29] Tuvalu NAP Project-Mission (2024).

[30] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[31] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

areas on eight of its nine islands[32]. The conservation area in Funafuti was established under formal legislation, with the remainder set up by local communities and managed with their traditional systems[33].

Tuvalu's biodiversity faces extreme pressure, with the loss of some species of fish, coral, bird and terrestrial species which affects subsistence fishing. Past declines in coral cover have been documented as a consequence of storms, destructive fishing, crown-of-thorns seastars and bleaching[34]. Exotic pests such as Yellow Crazy Ants, *Anoplolepis gracilipes*, have also adversely affected both land and coconut crabs, earthworms, turtles, seabirds and other fauna populations in some islands[35]. Other major threats currently impacting coastal marine life include pollution, overfishing and coastal degradation, particularly around Funafuti. Given the high dependency on fisheries resources, a loss of fisheries productivity and impacts on marine aquatic biodiversity threatens the national economy and food security of Tuvalu.

The following risk statements have been developed through consultation during the Tuvalu NAP Project-Mission (2024). They include risks to oceanic fisheries (**R2**) and risks to coastal fisheries (**R3**). This includes four key sub-sectors, namely ocean fisheries, coastal fisheries, fisheries infrastructure and biodiversity that supports fisheries.

R2: Risks to oceanic fisheries

Increasing chronic and acute climate hazards, including ocean warming (SSTs) and associated marine heatwaves, and ocean acidification, currently and will increasingly impact oceanic fisheries within Tuvalu's EEZ, in particular the productivity, catch and associated quota value of commercial deepwater pelagic fisheries such as various Tuna spp. The year-to-year distribution and abundance of the commercially valuable oceanic tuna resource depends in large part on ENSO variability, which in turn is being impacted by climate change. The implications for Tuvalu's oceanic tuna quota value, and by association the national economy, vary considerably depending on global emissions scenarios over the next several decades. Any sustained, significant reduction in quota value for Tuvalu will impact all sectors/domains of the economy. More broadly, the combined impacts of increased deep ocean warming and acidification are unclear for the water tropical Pacific, including Tuvalu, in terms of implications for recruitment, productivity, biodiversity and commercial value of oceanic fisheries.

[32] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[33] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[34] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[35] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

R3: Risks to coastal fisheries

Increasing chronic and acute climate hazards, including marine heatwaves, tropical cyclones and ocean acidification, currently and will increasingly impact coastal fisheries biodiversity, productivity and catch. Tropical cyclone-related storm damage of coral reefs and coral bleaching due to MHWs are significant environmental threats in Tuvalu with direct implications for sustainability of coastal fisheries. In Funafuti lagoon, these impacts are being compounded by nutrient-rich run-off of stormwater and wastewater resulting in reduced water quality and increased presence of invasive seaweed species such as Sargassum spp. Existing management regimes including FADS and marine and special protected areas in Tuvalu are potentially insufficient to address such increased environmental stressors. It is expected that spoilage of locally caught fish will increase during the post-harvest transport, storage, and processing at port and on vessels. Likewise, workforce productivity of fishers and processors, will be increasingly impacted along with days suitable for fishing, fishing locations and resource accessibility and commercial viability. Loss of aquatic biodiversity will impact the food chain and overall ecosystem health in and around coral reefs and lagoons, with knock-on impacts on coastal fishing. This can result in a decrease in economic output of coastal fisheries with consequences for food security of local communities with greater dependence on other (agricultural and processed) food sources, and an increase in adverse health outcomes and lost livelihoods for the workforce and community (see also R1 and R4).

Risk Summary

Climate change is impacting the fisheries industry through increasing atmospheric heatwaves, increasing sea surface temperature and marine heatwaves, ocean acidification, rising sea levels, increasing intensity of tropical cyclones and extreme winds, and storm surge, and increase incidence of the toxic algae that contain ciguatera toxin. The impacts of these hazards will affect the quality and size of catch, fishing locations, fishing infrastructure, marine biodiversity supporting fisheries, workforce health and productivity and consumer health. Reduced or compromised catch will result in acute and potential chronic health conditions and lower economic output of fish consumers in Tuvalu.

Current exposure to hazards

This section discusses the exposure of the fisheries sector to key hazards.

Sea surface temperatures and marine heatwaves

Rising sea surface temperatures and more frequent marine heatwaves, which occur with greatest intensity in the south, result in higher frequency of coral bleaching events and alter the migration and viability of aquatic species such as tuna and hawk beak turtles (Figure 7). Marine heatwaves affect coastal fisheries by impacting the spawning of high value species (such as Grouper). High water temperatures cause coral bleaching which leads to the loss of reefs and degradation of marine biodiversity in coastal fisheries. The failure of coastal fisheries has significant implications for subsistence fishing and food security in Tuvalu, with resulting impacts on public health issues such as micronutrient deficiencies and chronic health

conditions including obesity and diabetes[36]. Cultural activities are also be affected by the impacts of ocean warming on coastal fish stocks and habitat.

Rising sea surface temperatures can reduce the productivity of oceanic fisheries by impacting the spawning and recruitment of deepwater species. Movement of tuna stocks due to ENSO variability is also linked to changes in sea surface temperature and nutrient flux in adjacent coastal zones[37]. Different species of tuna have limited ranges of sea surface temperature in which they live (Table 5). Skipjack experience large scale displacement during warmer sea surface temperature events[38]. Changes to oceanic fish migration and fish stocks due to rising sea surface temperatures has significant implications for the livelihoods, economic productivity and food security of Tuvalu[39].

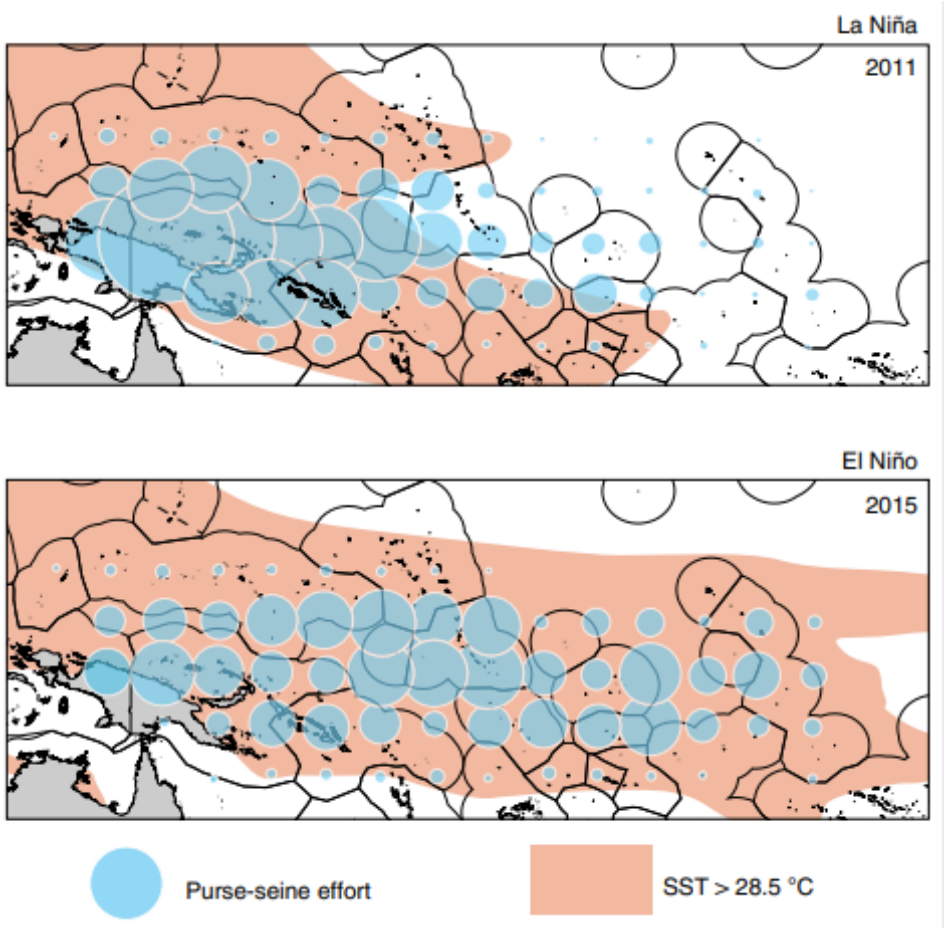

Figure 7: Distribution of purse-seine effort in La Niña and El Niño conditions around the Pacific. (Source: Bell, J.D., et al. (2021). Pathways to sustaining tuna-dependent Pacific Island economies during climate change. Nat Sustain 4, 900–910.)

[36] Hennessy, K., Sheppard, M. (2023). Tuvalu climate impacts and risks environmental scan of available literature. Tuvalu scan of climate impacts and risks_12-Dec-2023.docx (sharepoint.com)

[37](Jan 2024). Tuvalu Mission Summary Report. Tuvalu_Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[38] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[39] Hennessy, K., Sheppard, M. (2023). Tuvalu climate impacts and risks environmental scan of available literature. Tuvalu scan of climate impacts and risks_12-Dec-2023.docx (sharepoint.com)

Common name	Species	All occurrences (°C)	Abundant occurrences (°C)
Skipjack	*Katsuwonus pelamis*	17–30	20–29
Yellowfin	*Thunnus albacares*	18–31	20–30
Bigeye	*T. obesus*	11–29	13–27

Table 5: Different species of tuna are abundant across different temperature thresholds. (Source: Adapted from CSIRO, Federation University, Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions.)

Heatwaves and rising air temperatures

Heatwaves are impacting upon the fisheries workforce as well as fish storage and processing. Heat stress reduces workforce performance and work capacity. Fish storage, transport and processing facilities are vulnerable to heatwaves if they lack the appropriate cooling infrastructure[40]. Boats, processing hubs, storage facilities and fish markets that lack cooling infrastructure have a higher risk of causing fish to spoil. As a result, food security, human health and economic productivity are all affected. In addition, coastal biodiversity is impacted by rising temperatures. For example, sea turtle hatchling sex determination is controlled by sand temperature, leading to potential gender imbalances in turtle populations.

Sea level rise

Sea level rise is impacting fisheries by changing the coral makeup of reef habitats and reducing the physical protection of atolls provided by coral reefs. The highly sensitive nature of coral reef ecosystems makes parts of these habitats vulnerable to changes in sea level which can limit access to sunlight, causing some coral species to die and changing the structure of reefs. This damage to reef habitats is placing pressure on coastal fish stocks. Higher sea levels also limit the ability of reefs to protect Tuvalu's islands from wave incursion, potentially exposing fishing vessels, equipment and facilities to wave related damage. Turtle nests are also at higher risk of inundation due to sea level rise and storm surges.

Ocean pH and aragonite saturation

Ocean acidification and aragonite saturation pose a significant global threat to the long-term viability of corals, shellfish and fish. Compounding the impacts of increasing sea surface temperatures and marine heatwaves, ocean acidification is negatively affecting coral growth and decreasing chlorophyll concentrations (an indicator of phytoplankton biomass which supports the marine food chain). Associated habitat loss, shifting fisheries and reduction in fish size[41] reduce commercial and subsistence catches and adversely impact biodiversity.

Tropical cyclones and extreme rainfall

Tropical cyclones, storm surge and extreme winds impact reefs, coastal resources and fishing days. Storms damage coral reefs, reducing fish habitat and fish stocks. Coastal fisheries are also impacted by nutrient run-off and pollution from piggery waste, septic tank seepage and surface waste during extreme rainfall

[40] Tuvalu NAP Project-Mission (2024).

[41] Hennessy, K., Sheppard, M. (2023). Tuvalu climate impacts and risks environmental scan of available literature. Tuvalu scan of climate impacts and risks_12-Dec-2023.docx (sharepoint.com)

and inundation events. This pollution can cause water quality issues in the lagoon and reef fisheries as well as algal blooms of invasive sargassum that smothers coral[42].

Fishing infrastructure and equipment have also been badly affected by waves and wind from past cyclones and by salt spray, further impacting both food security and livelihoods[43]. Storms also threaten workforce safety, particularly in small fishing vessels.

Future exposure to hazards

This section discusses the future exposure of the fisheries sector to the key hazards.

Sea surface temperatures and marine heatwaves

Increasing sea surface temperatures and worsening marine heatwaves will continue to place pressure on coastal and oceanic fisheries, jeopardising the viability of fish stocks with significant consequences for economic activities, human health and food security (Table 6). The location of prime fishing grounds will change with ocean warming and increasing occurrence of ENSO events, potentially reducing the availability of fish in the Tuvalu EEZ and altering the catchability of tuna by surface and longline fisheries. Changes to locations of fish stocks may reduce the revenue that Tuvalu can gain from fisheries licences.

More frequent and intense marine heatwaves will also cause more significant coral bleaching events that could lead to the collapse of coastal marine ecosystems, threatening a critical source of food and income for Tuvalu. Evidence suggests ciguatera poisoning may also be positively related to warming sea surface temperature with increases in production of toxic algae and associated bioaccumulation in in coastal fisheries. Invasive species such as crown of thorns starfish are also affecting marine food sources as they compete for the same food source. Invasive species thrive during higher SST and marine heatwaves. As a result, fish stocks and human wellbeing are threatened by warming sea surface temperatures and marine heatwaves.

[42] Tuvalu NAP Project-Mission (2024).

[43] Tuvalu NAP Project-Mission (2024).

Pacific SIDS	Average 2015–2018			Change by 2050 (RCP 8.5)			Change by 2050 (RCP 4.5)		
	Government revenue (million US$)	Access fees (million US$)	Access fees as % of government revenue	Purse-seine tuna catch (%)[a]	Access fees (million US$)	Government revenue (%)	Purse-seine tuna catch (%)[a]	Access fees (million US$)	Government revenue (%)
Cook Islands	126.1	13.5	10.6	−4.0	−0.5	−0.4	+8.9	+1.2	+1.0
FSM	150.6	68.4	47.6	−13.0	−8.9	−5.9	−2.7	−1.8	−1.2
Kiribati	181.7	128.3	70.6	−8.2	−10.5	−5.8	+6.9	+8.9	+4.9
Marshall Islands	66.1	31.0	47.8	−0.7	−0.2	−0.3	+2.1	+0.7	+1.0
Nauru	98.6	29.5	31.1	−21.6	−6.4	−6.5	+5.7	+1.7	+1.7
Palau	75.2	7.1	9.4	−0.3	−0.02	−0.03	+3.1	+0.2	+0.3
PNG	3,360.8	134.3	4.0	−33.1	−44.4	−1.3	−15.5	−20.8	−0.6
Solomon Islands	429.0	41.3	9.6	−26.1	−10.8	−2.5	−8.7	−3.6	−0.8
Tokelau	16.0	13.4	84.2	−16.1	−2.1	−13.4	+5.7	+0.8	+4.8
Tuvalu	47.4	25.6	53.9	−23.4	−6.0	−12.6	+3.4	+0.9	+1.9
Total		492.4			−89.9			−12.0	

Average government revenue (excluding grants), tuna-fishing access fees and the percentage of government revenue derived from access fees for ten tuna-dependent Pacific SIDS between 2015 and 2018, together with estimated changes in purse-seine tuna catch, access fees and government revenue, by 2050 under the RCP 8.5 and RCP 4.5 emissions scenarios. See Supplementary Tables 15 and 16 for ranges of estimated percentage changes in access fees and government revenue by 2050, and details of the calculations summarized here. PNG, Papua New Guinea. [a]Projected change in average total purse-seine catch due to climate-driven redistribution of total tuna biomass (Supplementary Tables 17 and 18).

Table 6: Tuvalu government revenue (present day) and future projections of purse-seine tuna catch, access fees, and government revenue. (Source: Bell, J.D., et al. (2021). Pathways to sustaining tuna-dependent Pacific Island economies during climate change. Nat Sustain 4, 900–910.)

Heatwaves and rising air temperatures

By 2050, it is projected that number of days per year with air temperatures exceeding 33°C will increase by between 181 days (low emissions) and 264 days (high emissions). This will have significant impacts on the fishery workforce and supply chain. Fishery workers will suffer from reduced workforce productivity and increasing heat-related illnesses. Fish storage and processing boats and facilities that lack cooling infrastructure will struggle to ensure fish are stored and processed in safe manner. This may result in food poisoning, reduced fish sales and ultimately lead to the loss of revenue to the sector that makes the largest contribution to Tuvalu's economy[44]. Some marine species, such as sea turtles, will also be significantly impacted by the rising temperatures.

Sea level rise

Rising sea levels in Tuvalu threaten to drown coral reefs that cannot grow at the rate of sea level rise. Additionally, increased wave energy with rising sea levels may damage and destroy already stressed reef ecosystems, reducing fish stocks and impacting critical fishing infrastructure. As such, continued sea level rise will pose greater threats to both coastal and oceanic fisheries.

Ocean pH and aragonite saturation

Increasing sea surface temperature, ocean acidification and decreasing chlorophyll concentration will continue to change fish distribution, reduce the productivity of coastal fisheries and degrade coral reefs[45]. As a result, subsistence catches will be impacted with implications for food security and livelihoods.

[44] Hennessy, K., Sheppard, M. (2023). Tuvalu climate impacts and risks environmental scan of available literature. Tuvalu scan of climate impacts and risks_12-Dec-2023.docx (sharepoint.com)

[45] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

Tropical cyclones and extreme rainfall

Increasing extreme rainfall and low confidence projections for increases in the intensity of cyclones will cause significant damage and destruction to coastal fisheries and fishing infrastructure, threatening food security, livelihoods, and cultural practices in Tuvalu. In addition to direct storm damage to coral reefs, more severe coastal flooding and inundation will also cause worsening nutrient, sediment and waste pollution, further impacting coastal ecosystems and fish stocks. Increasingly severe cyclones and extreme rainfall events may also damage or destroy fishing vessels, facilities, and equipment. Changes in coastal wind climatology and a projected increase in storminess days may reduce safe fishing days, especially for small boats and all vessels in the open sea.

Vulnerability

This table presents sources of fisheries vulnerability to hazards in Tuvalu.

Hazard	Factor relevant for vulnerability
Sea surface temperature, marine heatwaves	• High reliance on climate-sensitive coastal and ocean fisheries for food and commercial trade. • Tuna availability projected to decline in Tuvalu EEZ due to rising sea surface temperatures. • Invasive species and algae blooms will affect fishing stock due to competition for food source.
Ocean acidification	• High reliance on climate-sensitive coastal fisheries for food and commercial trade.
Heatwaves	• Limited cooling infrastructure across the fishing supply chain. • Sea turtle gender is affected by sand temperature
Extreme rainfall	• Limited drain and storm water management facilities increase the risk of nutrient and waste run-off entering marine habitats and impacting coastal fisheries.
Sea level rise	• Proximity of fishing infrastructure to the coast. • High reliance on climate-sensitive coastal fisheries for food and commercial trade.
Storms, cyclones	• Proximity of fishing infrastructure to the coast. • Local use of small fishing boats that are not safe during high wind/wave days.

Variations across the islands

Variation in marine and coastal fisheries and biodiversity vulnerabilities across the islands:

Region	Vulnerability Issues
Funafuti	• Limited or no access to fisheries and marine environmental management support services from government and NGOs. • High population density produces high nutrient levels in lagoon causing algal blooms of invasive sargassum that smothers coral.
Nanumea	• Comparatively longer duration of annual marine heat waves. • Fisheries infrastructure and equipment have been badly affected by past cyclones.
Niutao	• Comparatively longer duration of annual marine heatwaves. • Coral bleaching is more widespread with bleached coral making up an average of 31% of the surveyed coastal substrate. This may be impacting reef fish.
Nukufetau	• Reef fish is more popular in 58% of households, therefore diets of residents and incomes tied to fishing may be impacted more by climate change effects on reef fish. • Limited access to supplementary store-based food outlets.
Nukulaelae	• Low drought resilience of marine food sources has been observed during past droughts, potentially due to low water flushing through the lagoon.

Complex risks

Fisheries risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Human health & well-being:** Disruptions to the fisheries sector, depleting catch will have flow on consequences for the health sector. The dominance of a fish-based diet will decrease, creating nutrient deficiencies and other health impacts.
- **Social cohesion and heritage:** Disruption to fishing will have flow on consequences for cultural practices, resulting in a loss of shared identity, values and beliefs. This will impact the cohesiveness of the Tuvaluan society.
- Loss of income from reduced catch and lower fish availability in ocean fisheries will have significant consequences for the Tuvaluan economy, with flow on effects across the nation.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R2 - Oceanic fisheries	**Sea surface temperature** The location of the convergence zone is affected by sea surface temperatures. This will cause tuna to migrate, affecting the number of fish caught	**Minor**	Pelagic tuna quota for Tuvalu increases during El Nino and decreases during La Nina as the fish move away. Minor disruptions and impacts to food security, government revenue, employment.
R3 - Coastal fisheries, lagoons	**Marine heatwaves and tropical cyclones** Causes coral bleaching and reef destruction, in addition to overfishing, will reduce the resilience for the fish stock and the depletion of fish catch	**Moderate**	Coral bleaching, reef damage and overfishing is occurring. Increases in annual marine heatwave frequency with 60 or more days is causing algal blooms. Cyclones destroy fragile coastal ecosystems, reducing fish habitat.
R3 - Fisheries infrastructure	**Temperature increases/extreme heat** Impacts to workforce productivity and fish storage and processing conditions.	**Minor**	Lower and disrupted workforce productivity due to extreme heat. Fish storage and processing conditions without cooling is causing food spoilage.
R3 - Marine and coastal biodiversity	**Marine heatwaves** Ocean warming and acidification will affect marine organisms and coral around the coast of Tuvalu	**Moderate**	Increase of frequency marine heatwaves is impacting the ability for coral to recover after each event.

2030 Low and high emissions scenario

Risk statement number	Component and hazard	Low and high emissions scenario	Comments
R2 - Oceanic fisheries	**Sea surface temperature** The location of the convergence zone is affected by sea surface temperatures. This will cause tuna to migrate, affecting the number of fish caught	**Moderate**	SST is projected to increase by 0.7°C by 2030. This may cause tuna displacement during warmer times of the year, causing disruptions to the sector resulting in economic fluctuations.
R3 - Coastal fisheries, lagoons	**Marine heatwaves and tropical cyclones** Coral bleaching and reef destruction, in addition to overfishing, will reduce the resilience for the fish stock and the depletion of fish catch.	**Moderate**	Projections of 110-290 days of marine heat waves and annual severe bleaching will cause fish stock depletion. Increasingly intense tropical cyclones will destroy already-stressed reef habitats. This will cause medium-term reductions in productivity and profitability of the sector and moderate disruptions to coastal fishing across multiple islands.
R3 - Fisheries infrastructure	**Temperature increases/extreme heat** Impacts to workforce productivity and fish storage and processing conditions.	**Moderate**	Spoilage of fishes may cause loss of revenue to the sector resulting in major losses to GDP by 2030 due to inadequate cooling of fish.
R3 - Marine and coastal biodiversity	**Marine heatwaves** Ocean warming and acidification will affect marine organisms and coral around the coast of Tuvalu	**Major**	With the projections of high increases in the number of marine heatwaves per year reaching 110 to 290, this will impact the ability for coral to recover after each event.

2050 High emissions scenario

Risk statement number	Component and hazard	High emissions scenario	Comments
R2 - Oceanic fisheries	**Sea surface temperature** The location of the convergence zone is affected by sea surface temperatures. This will cause tuna to migrate, affecting the number of fish caught	**Extreme**	Projected increases in SST of 1.3°C is likely to cause large scale displacement of tuna species, and may lead to the migration away from Tuvalu EEZ causing permanent and widespread damage to the fisheries industry, economic livelihoods, and food security.
R3 - Coastal fisheries, lagoons	**Marine heatwaves and tropical cyclones** Coral bleaching and reef destruction, in addition to overfishing, will reduce the resilience for the fish stock and the depletion of fish catch.	**Extreme**	220-360 days of marine heatwaves may collapse the fishing environment through the destruction of coral reefs, seagrass and kelp beds. This damage to coastal habitats will be compounded by increasingly severe tropical cyclones. The loss of habitat is likely to be permanent will cause the depletion of coastal fish species with widespread impacts to the economy, livelihoods and population.
R3 - Fisheries infrastructure	**Temperature increases/extreme heat** Impacts to workforce productivity and fish storage and processing conditions.	**Moderate**	Projections of 140-331 Annual hot days will be too hot to work outdoors at certain times of the day and year. Fish spoilage will occur more frequently if fish storage and processing facilities do not possess cooling equipment.
R3 - Marine and coastal biodiversity	**Marine heatwaves**	**Extreme**	The number of marine heat waves per year will approach 360. The consequence to coral reef structures and associated fish habitats will be

	Ocean warming and acidification will affect marine organisms and coral around the coast of Tuvalu		permanent and irreversible, causing widespread damage to livelihoods and the economy.

2050 Low emissions scenario

Risk statement and sub component	hazard	Low emissions scenario	Comments
R2 - Oceanic fisheries	**Sea surface temperature** The location of the convergence zone is affected by sea surface temperatures. This will cause tuna to migrate, affecting the number of fish caught	**Major**	An increase in SST of 0.9°C may see lower abundance of tuna catches and potential migrating away from Tuvalu EEZ waters. Flow on damage to the economy will be significant as the fishing sector, including fishing licensing is the biggest revenue earner. Prolonged disruption to food security and livelihoods will affect health and wellbeing of the community.
R3 - Coastal fisheries, lagoons	**Marine heatwaves and tropical cyclones** Coral bleaching and reef destruction, in addition to overfishing, will reduce the resilience for the fish stock and the depletion of fish catch.	**Major**	130-340 days of marine heatwaves may cause widespread and significant coral mortality. More severe cyclones will have more significant impacts on vulnerable coastal ecosystems. Fish habitats will be extensively damaged but may be reversible depending on the resilience of coastal environments. This will have major and widespread impacts to livelihoods, food security and the economy.

R3 - Fisheries infrastructure	**Temperature increases/extreme heat** Impacts to workforce productivity and fish storage and processing conditions.	**Moderate**	Projections of an increase in annual hot days by 140-222 days will make it too hot to work outdoors at certain times of the day and year. Fish spoilage will occur more frequently if fish storage and processing facilities do not possess cooling equipment.
R3 - Marine and coastal biodiversity	**Marine heatwaves** Ocean warming and acidification will affect marine organisms and coral around the coast of Tuvalu	**Major**	A projected 130-340 marine heatwave days per year will impact the ability for coral to recover after each event.

Confidence

Component	Hazard	Confidence score	Comments
Oceanic fisheries	**Sea surface temperature**	**Medium**	• Some uncertainties in models projecting tuna migration and associated temperature thresholds.
Coastal fisheries and lagoons	**Marine heatwaves and tropical cyclones**	**Medium**	• More information on coral reef resilience and impacts to fisheries. • Cyclone projections are low confidence.
Fisheries infrastructure	**Temperature increase/extreme heat**	**Low**	• More information needed on fishing infrastructure, cooling equipment and impacts on the sector
Marine and coastal biodiversity	**Marine heatwaves**	**High**	• There is high confidence in the increase of number of marine heat waves per year. Although, local impacts may vary.

Knowledge Gaps

- Limited quantitative information analysing the impact of several hazards on fish stocks

5.3 Human health & well-being

Summary of this sector in Tuvalu

Tuvalu has one of the world's highest total expenditure on health as a percentage of GDP at 16.54% of GDP in 2014[46]. This accounts for 16.91% of total government expenditure. The health sector is comprised of a range of components including public health, healthcare workers and health infrastructure.

Tuvalu's public health profile, like many Pacific Island countries, is in a state of transition. Historically Tuvalu's public health profile was dominated by communicable or infectious disease. Now it is characterised by non-communicable diseases with 75% of the disease burden coming from non-communicable diseases including hypertension, heart disease and type 2 diabetes[47,48] . As of 2016, 51% of the Tuvalu adult population is considered obese, and the prevalence of diabetes in the adult population was 23.1% in 2014[49]. Non-communicable diseases are a major cause of morbidity and mortality in Tuvalu and are caused by food and nutrition, increased urbanization, imported foods and migration, among other things[50]. Many communities in Tuvalu now rely on imported processed and frozen food, particularly in the capital, increasing the prevalence of non-communicable diseases. This is compounded by increases in food prices following disasters, and the loss of fresh produce including fish. This has a range of implications for food security, micronutrient deficiencies, obesity and diabetes, and makes Tuvaluans highly vulnerable to health problems caused by climate change.

Determinants of health include the social and economic environment (income, social status, education, social support networks), the physical environment (safe water, clean air, healthy workplaces, safe housing, communities and roads, access to health services) and the person's individual characteristics and behaviours. Individuals are unlikely to be able to directly control many of the determinants of health. Under projected climate change, determinants of health are likely to deteriorate, posing problems for the health of the Tuvalu population, in particular mental health.

People living in rural areas and disaster-prone areas like Tuvalu are vulnerable to water, sanitation and hygiene (WASH) related disease. The consequences of unsafe water, sanitation and hygiene can be deadly, especially in vulnerable cohorts like children. Tuvalu has made progress in improving WASH with Figure 8 showing the increasing percentage of the population with access to basic sanitation services from 2000. While increases did occur, it is evident that a plateauing has happened between 2015-2020 for those with access to clean fuels and technologies for cooking and those with access to basic sanitation services.

[46] WHO (2018). Tuvalu country cooperation strategy at a glance. https://iris.who.int/rest/bitstreams/609186/retrieve

[47] Doctors Assisting in South-Pacific Islands. (2014). Princess Margaret Hospital, Tuvalu. DAISI. https://daisi.com.au/princess-margaret-hospital-pmh/

[48] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

[49] WHO. UNFCC (2021). Health & Climate Change Country Profile 2020. https://iris.who.int/bitstream/handle/10665/330009/WHO-CED-PHE-EPE-19.3.3-eng.pdf?sequence=1

[50] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

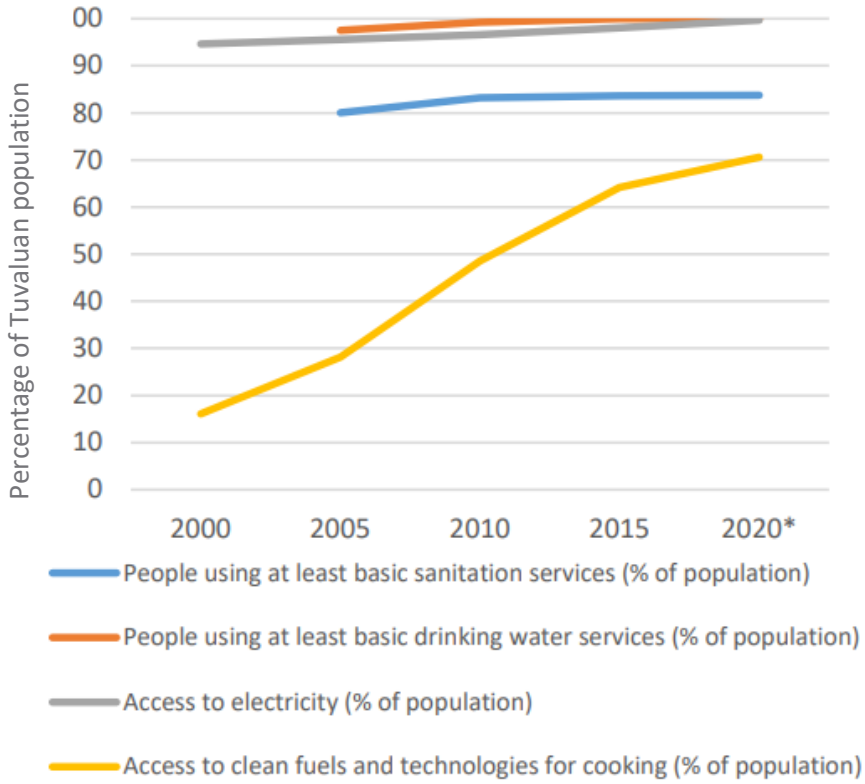

Figure 8: Percentage of the population with access to selected basic services between 2000-2020. (Source: International Labor Organisation, 2022[51].)

Increases in heat, extreme rainfall, extreme drought and sea level rise will cause a rise in food/vector/water-borne diseases and influence the proportion of population at risk of disease. This is further compounded by faulty septic systems and water quality issues. All placing further strain on the capacity of the health system.

The main national hospital, Princess Margaret Hospital, is located on Funafuti. It is a 50-bed hospital with an operating theatre, high dependency unit, x-ray and ultrasound, laboratory and pharmacy, making it the primary provider of medical services for all the islands of Tuvalu. Currently, during times of higher demand, the hospital is over capacity, and there are not enough beds in the hospital for all patients.

Princess Margaret Hospital relies on surgical and anaesthetic locum medical specialists as it is difficult to attract experienced specialists to stay long-term in Tuvalu[52]. These medical specialists fly in from other countries, relying on Funafuti International Airport operating. Reliance on a functioning

Princess Margaret Hospital. Source: Tuvalu NAP Project-Mission 2024.

[51] International Labor Organisation. (2022). Tuvalu The employment – environment – climate nexus. https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/publication/wcms_862816.pdf

[52] Doctors Assisting in South-Pacific Islands. (2024). Princess Margaret Hospital, Tuvalu. DAISI. https://daisi.com.au/princess-margaret-hospital-pmh/

airport also affects those Tuvalu residents who are required to leave Tuvalu for specialist treatment in other countries. The health workforce that resides in Tuvalu is made up of nine doctors, 37 nursing and midwifery personnel and one environmental and occupational health and hygiene professional[53].

Fongafale has two medical clinics, one on the north, and the other positioned in the southern end of the island. Each clinic is staffed by one registered nurse. Once a week, a medical officer and the NCD nurse from the Public Health Department conduct weekly NCD clinics[54].

There are 11 medical facilities on the Outer Islands. The health of people in the Outer Islands is managed by small medical clinics run by two to three nurses, except for Niulakita where there is one registered nurse[55]. The Ministry of Health organises integrated medical outreach teams from Princess Margaret and the Department of Public Health visit each island twice a year[56]. Residents of the Outer Islands travel to Funafuti for more complex treatment. Travel to and from the Outer Islands is via the government ferry service. Disruptions to the Tuvalu health system caused by climatic events are, and will increasingly, impact upon the workforce, health facilities and resources such as water, sanitation and electricity, to deliver health services to the population.

The following risk statements (**R4**, **R5**) have been developed through consultation during the Tuvalu NAP Project-Mission (2024). They discuss the risks that climate change presents for public health that have been identified and analysed.

R4: Risks to Public Health

Increasing chronic and acute climate hazards, including heatwaves, floods, and rising sea levels will lead to increased public health problems including heat-related illness, food/vector/water-borne disease, threats to physical safety and mental health illness. Increasing consumption of inferior food and nutrition, imported foods, and increased urbanisation is causing a rising prevalence of non-communicable disease. All these, including net migration into Funafuti from the Outer Islands, will increase pressure on Tuvalu's healthcare system as well as food, water and energy security and, thereby affecting the livelihoods and income of the population more generally.

[53] WHO, UNFCC. (2020). Tuvalu health & climate change country profile.

[54] Doctors Assisting in South-Pacific Islands. (2024). Princess Margaret Hospital, Tuvalu. DAISI. https://daisi.com.au/princess-margaret-hospital-pmh/

[55] Doctors Assisting in South-Pacific Islands. (2024). Princess Margaret Hospital, Tuvalu. DAISI. https://daisi.com.au/princess-margaret-hospital-pmh/

[56] Doctors Assisting in South-Pacific Islands. (2024). Princess Margaret Hospital, Tuvalu. DAISI. https://daisi.com.au/princess-margaret-hospital-pmh/

R5: Risks to Health Infrastructure

Increasing chronic and acute climate hazards, including TCs/extreme winds and floods from groundwater intrusion, coastal inundation and extreme rainfall and cyclones, will lead to increased damage to health infrastructure (hospitals, primary care facilities, evacuation centres etc.), staff shortages, medical supply-chain and transport disruption, and indirect impacts due to loss of electricity (water, lighting, cooling, refrigeration etc.) and telecommunications. Functionality and physical integrity of septic systems, management and maintenance of rainwater storage tanks and reservoirs, and operability of de-sal plants for emergency water will increasingly be impacted as a result of sea level rise and groundwater intrusion, further compounding WASH-related environmental health issues for local communities. Increased incidence of extreme heat, compounded by lack of greenspace and unreliable energy and water services, will increase demand for health services and related infrastructure during heatwaves. Increasing chronic and acute hazards will impact the ability of Tuvalu's healthcare system to deliver essential health services to its citizens and widening the health inequalities between Funafuti and the Outer Islands, as well as between socio-economic groups.

Risk Summary

Climate change events including rising temperatures, increasingly intense tropical cyclone and extreme rainfall events, extreme droughts, extreme sea level events, coastal erosion and marine heatwaves are impacting human health and wellbeing. These hazards are causing increases in communicable and non-communicable diseases (NCD), threats to physical safety and exacerbating gendered violence. All of this is placing pressures onto the health care system including the infrastructure and health workforce. Climate change impacts in Tuvalu are projected to be the second highest among the Climate Vulnerable Forum members by 2030, with nearly 25% loss of GDP. This is expected to further decrease the country's capacity to address health problems unless the resilience of the health system to climate change is improved[57].

Current exposure to hazards

This section discusses the exposure of the human health and wellbeing sector to key hazards.

Increasing air temperature and rainfall

Wider distribution and transmission of vector-borne disease is caused by increases in air temperature as well as increases in average rainfall, and extreme rainfall. The two most common mosquito vector species for dengue, *Aedes aegypti* and *Ae. Albopictus*, is causing infections and creating a substantial burden of ill-health on the population[58]. Although not endemic with spikes every two to three years, it is now becoming more common. Figure 9 shows data from a recent Dengue outbreak in Tuvalu that demonstrates the association between weekly rainfall and the incidence of dengue cases over the period of January to June 2019. This highlights that children are particularly vulnerable to contracting dengue. With 29% of the

[57] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu

[58] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

population under the age of 15 (current as of 2016)[59], vulnerability to vector-borne disease will likely place additional stress on the paediatric health system which is reliant on locum specialists. Unsealed water tanks, and pools of stagnant water are breeding grounds for mosquitos, increasing the spread of vector borne diseases.

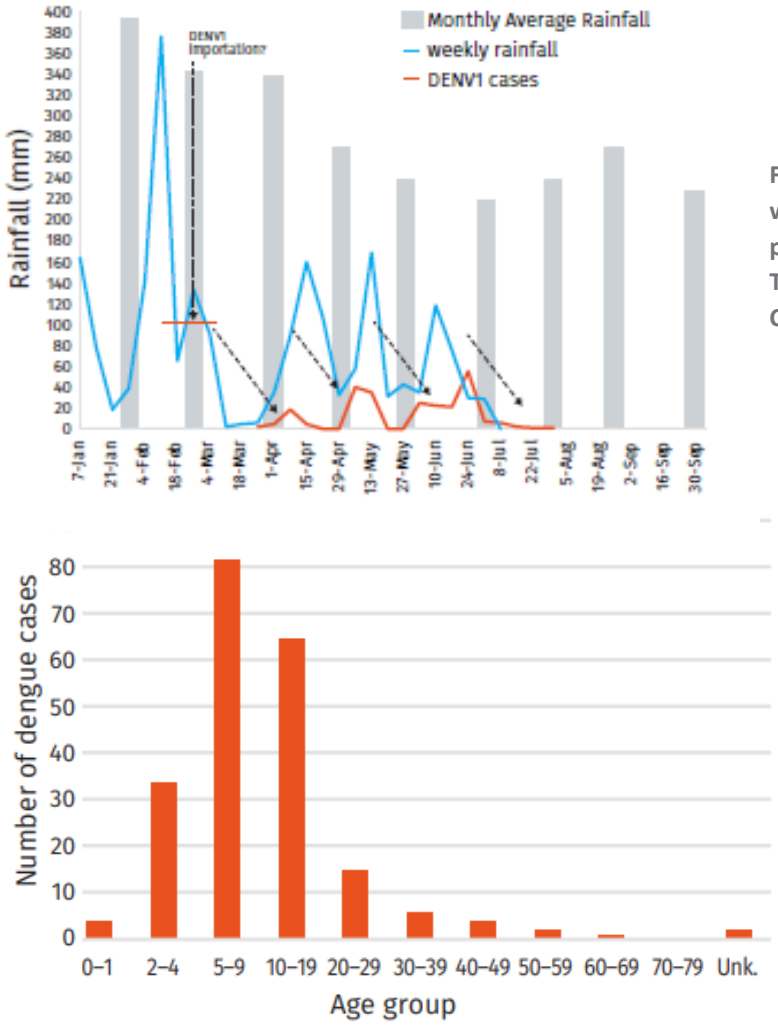

Figure 9: Top: March 25th to July 28th, 2019, with corelating rainfall pattern over the same period. Bottom: Dengue cases by age group in Tuvalu. (Source: Health & Climate Change Country Profile 2020.)

Heat related illnesses such as heat stroke and heat stress are caused by increasing air temperature and extreme heat. While is it generally not seen as a community health issue, heat has impacted upon the workforce productivity of Funafuti through effects on business continuity, food and water security, infrastructure development and health. There has also been an increase in morbidity within the population caused from exposure to heat. Extreme heat is known to exacerbate existing respiratory and cardiovascular diseases and diabetes. Certain cohorts of the population (children and seniors) have higher rates of heat stroke and dehydration, particularly during daytime. High numbers of the Tuvalu workforce are susceptible to heat, with 29% employed in agriculture[60].

[59] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu

[60] International Labour Organisation. (2022). Tuvalu employment and environmental sustainability factsheet. https://www.ilo.org/wcmsp5/groups/public/---asia/---ro-bangkok/documents/publication/wcms_862816.pdf

Increased hospital admissions and health care needs are associated with extreme heat, with higher cases of people suffering from dehydration and flu. Extreme heat has also worsened mental health symptoms61. Funafuti in particular has experienced more extreme heat compared to the Outer Islands.

Extreme heat also causes food-borne disease due to poor food handling and inadequate cooling of perishable food products resulting in increased clusters of gastro-intestinal disease outbreaks. This includes the spoilage and contamination of imported foods shipped in containers at higher ambient temperatures due to no large-scale cool storage infrastructure.

Extreme rainfall and cyclones

Physical safety is threatened during cyclones and extreme windspeeds due to airborne debris and building collapse, contributing to increases in mental health-related illnesses, straining the health systems capacity[62].

Surface water quality is impacted by extreme rainfall events, which can cause land-based pollution and septic effluent to enter water catchments and increase the risk of diarrhea[63]. On many of the islands, groundwater is available under villages, which was probably a driver as to why settlement occurred in these locations. However, because of the extensive use of pit latrines and septic tanks, the water is contaminated and leads to disease[64.]

Drought

Access to fresh food decreases during times of drought, impacting upon the diets and health of the population, leading to increases in chronic health conditions and higher admissions to hospital.

Psychological impacts, such as increased stress levels due droughts/climate-induced disease outbreaks (e.g., typhoid) is causing concern[65]. This requires a multi-disciplinary clinical team to treat which Tuvalu does not currently have. Untreated psychological impacts have flow on consequences for social cohesion and the economy at large.

Cross-contamination of groundwater from poorly maintained septic systems is more pronounced during drought, and represent sources of water-borne disease, skin disease and eye infections[66].

Sea level rise, coastal inundation and coastal erosion

The Funafuti International Airport experiences flooding from king tides and heavy rain which cause closure and damage to the airstrip. Locum specialist health practitioners rely on a functioning airport, as along with residents who must travel overseas for advanced clinical care. Flooding of roads due to king tides and/or extreme rain also disrupts internal movement of people seeking health care, especially those with decreased mobility. Flooded roads also prohibits the use of ambulances.

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[61] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[62] Hennessy & Sheppard. (2023). Tuvalu Climate impacts and risks, Environmental scan of available literature

[63] Levy, K., et al. (2016). Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. Environmental science. 50(10): p. 4905-4922.

[64] Pacific Community (2007). Water, sanitation program. http://www.pacificwater.org/pages.cfm/country-information/tuvalu.html

[65] Tuvalu NAP Project-Mission (2024) Water workshop

[66] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

The location of the hospital on Funafuti and the location of the Vaitupu Medical Clinic lies in an area at risk of damage from climate change hazards as shown in Figure 10 and Figure 11. The red highlights buildings that are exposed to hazards present day.

Figure 10: Location of Princess Margaret Hospital, Funafuti and Buildings currently impacted by climate change hazard damage. The red highlights buildings that are exposed to hazards present day. (Source: Tuvalu Coastal Adaptation Project.)

Figure 11: Location of Vaitupu Medical Clinic and buildings currently exposed by 1% AEP storm surge. The red highlights buildings that are exposed to hazards present day. (Source: Tuvalu Coastal Adaptation Project.)

Saline groundwater inundation of septic systems is linked to increasing king tides due to sea level rise. This is causing water-borne diseases due to poor water quality. Pumped septic effluent from tanks is discharged to land adjacent to landfill/waste dump at one end of Funafuti[67]. Its proximity to the lagoon poses a risk to water quality of the lagoon, which could lead to fish poisoning.

All climate hazards

Non-communicable diseases are a major cause of morbidity and mortality in Tuvalu and are caused by a range of factors including poor food and nutrition, increased urbanization, imported foods and migration

[67] (2023). Tuvalu NAP CIVRA Project Inception Mission

among other things68. Climate change impacts on the agriculture and fisheries sector, water security, urbanization and a shift to sedentary lifestyles is increasing the prevalence of non-communicable diseases. Dietary practices are adopted at home. There needs to be more social learning in homes and schools on healthy eating[69]. The health system lacks critical services such as dialysis for these growing number of residents with non-communicable diseases like diabetes[70].

There is awareness of mental health issues within the Tuvalu community, however data on mental health is not currently captured[71]. Mental health issues may be caused and/or worsened by the impacts of climate change such as sea level rise, coastal inundation and anxiety of water scarcity within agriculture. The population of Tuvalu live within 1km of the coast and are highly exposed to sea level rise and coastal inundation with some permanent relocations already occurring. Loss of livelihood, loss of cultural connections and transition to sedentary lifestyle may be causing mental health problems.

Cases of gendered violence increases during climatic events[72]. The prevalence of physical or sexual intimate partner violence in Tuvalu is higher than the global average with 40% of women experiencing physical violence by their current husband or partner[73]. The Tuvalu government has continuously worked towards addressing this issue since 2008 through its Universal Periodic Review Report to the Human Rights Council. However, the impacts of climate change have further limited financial and technical resources available to address human rights violations[74].

Net migration to Funafuti (from Outer Islands and other countries) is higher than what the natural and built infrastructure/resources can support. This is impacting/putting a lot of stress on the systems of Funafuti including pressures on water, sanitation, health, land.

The World Bank granted US$15m in 2022 towards increasing the capacity of health service across Tuvalu. The grant will go towards building a new hospital wing, increase capacity of staff at the hospital and strengthen service levels in emergency, surgery, rehabilitation, mental health, counselling and management of non-communicable diseases. Additionally, resources will be made available to support survivors of family and gender-based violence[75]. The new project will also support potential new health information management and asset management systems, as well as the development of accessible public feedback systems which will be used to monitor and improve health sector performance.

Marine heatwaves and sea surface temperature

Food poisoning caused by ciguatera in certain reef fish is increasing. Sea surface temperature and marine heat waves are the driving factor associated with this as they promote the growth of the toxic algae which contain ciguatera. Outbreaks of ciguatera poisoning may increase as the impacts of climate change increase, placing higher numbers of the population at risk of food poisoning with flow-on effects to the

[68] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

[69] Tuvalu NAP Project Mission (2024) Health workshop

[70] Tuvalu NAP Project Mission (2024) Health workshop.

[71] Tuvalu NAP Project Mission (2024) Health workshop.

[72] Tuvalu NAP Project Mission (2024) Health workshop

[73] UN Women, SPC, The Equity Trust (2022). Pacific partnership to end violence against women and girls. Tuvalu Country Summary. 7-Tuvalu-Country-Summary-FINAL-21.06.22.pdf (unwomen.org)

[74] Human Rights Council. (2023). National report submitted pursuant to human rights council resolutions 5/1 and 16/21. Tuvalu.

[75] The World Bank. (2022). US$15m Boost for Health Care in Tuvalu. The World Bank. https://www.worldbank.org/en/news/press-release/2022/06/29/us-15-million-boost-for-health-care-in-tuvalu

health system.

Future exposure to hazards

This section discusses the future exposure of human health and wellbeing to the key hazards.

Increasing air temperature and rainfall

Infectious and vector borne diseases, especially dengue from the mosquitos *Aedes aegypti* and *A. albopictus*, and lymphatic filariasis will continue to increase as temperatures increase and as rainfall becomes more extreme. The projected temperature range increase correlates with the optimum temperature range for vector borne diseases as seen in Figure 12. As such, a dengue epidemic potential remains high in all future scenarios[76].

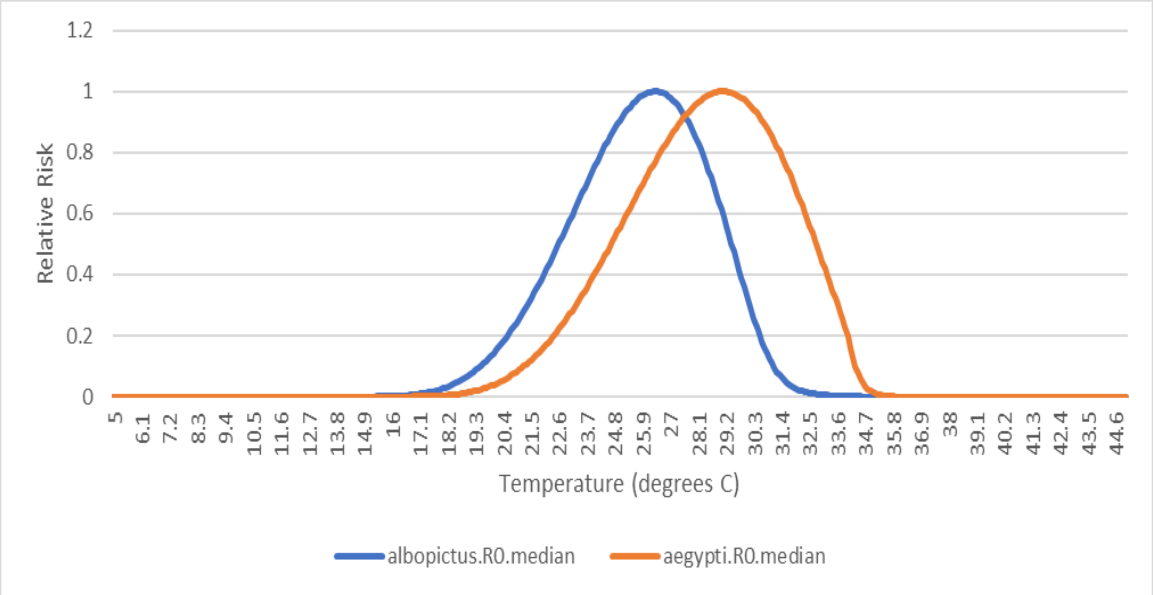

Figure 12: Dengue viruses *Aedes aegypti* and *Ae. Albopictus*, are related to temperature. Relative R0 across constant temperatures for Ae. albopictus (light blue) and Ae. aegypti (orange). (Source Health & Climate Change Country Profile 2020.)

A greater number of people will be at risk of heat stress, heat stroke and respiratory health issues as temperature and extreme heat increases. Prolonged periods of excessive heat cause illnesses such as dehydration, heat rash/cramps, heat exhaustion/ heat stroke and can result in loss of life, livelihood, socioeconomic output, reduced labor productivity and higher demand and cost of cooling options. People that are particularly vulnerable include children, the elderly, individuals with pre-existing conditions such as diabetes and the socially isolated.

Increases in food borne illnesses due to poor food handling and cooling during extreme heat will continue to rise unless interventions are introduced.

[76] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

Drought

Despite the projected decrease in overall drought frequency and duration, the projected increase in extreme droughts and drought intensity will continue to make potable water quality and quantity one of the most pressing challenges in Tuvalu. Health impacts associated with this include water security and sanitation with communicable diseases likely to continue to be a major cause of morbidity, with alarming numbers of acute respiratory, eye and skin infections projected[77]. A sewage treatment plant is planned for the future to mitigate impacts from septic tanks, as well as enhanced septic design to reduce impacts[78]. The precise links between drought and infectious disease transmission (e.g., diarrhea) require better understanding[79].

Sea level rise, coastal inundation and coastal erosion

Water contamination due to saltwater intrusion will continue to cause illnesses unless interventions associated with faulty septic tanks and water tanks are introduced.

Reliance on visiting specialist medical staff from other countries is at risk due to sea level rise and king tides impacting on the international airport. Tuvalu patients requiring medical treatment in other countries are also placed at risk if the airport is shut down for a period of time.

Health facilities are at risk of inundation due to their proximity to lagoons and the ocean (Figure 13). Potential flooding of the health facilities will impact upon patient care, accessibility to the facility and potential damage to infrastructure such as sanitised water and power.

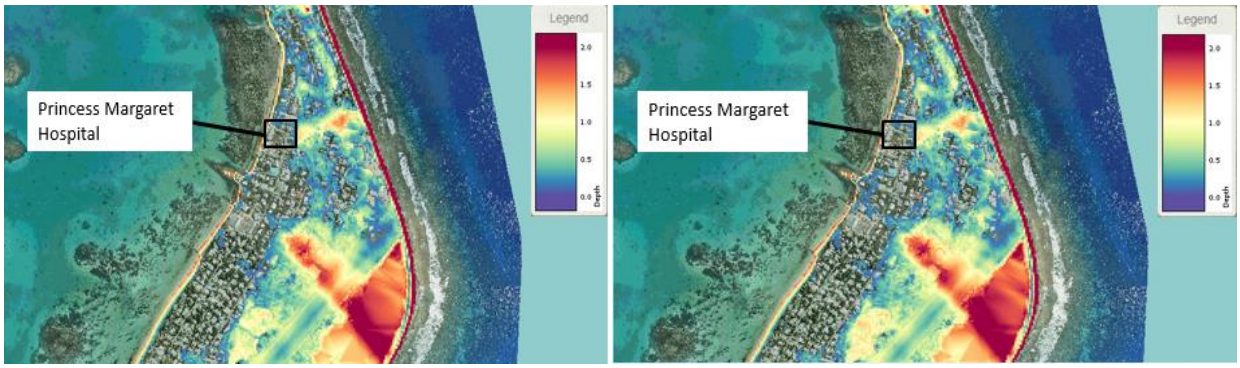

Figure 13: Exposure of Princess Margaret Hospital to a one-in-five-year coastal inundation event in 2060 under medium (left) and high (right) emissions scenario. (Source: Tuvalu Coastal Adaptation Project.)

Extreme rainfall and cyclone

Physical safety will continue to be threatened during severe cyclones, with low confidence projections for an increase in extreme windspeed, as well as during extreme rainfall. These hazards will all also contribute to increases in mental health related illness, further straining health service capacity.

[77] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

[78] (2023). Tuvalu NAP CIVRA Project Inception Mission

[79] WHO. UNFCC (2021). Health & Climate Change Country Profile 2020. https://iris.who.int/bitstream/handle/10665/330009/WHO-CED-PHE-EPE-19.3.3-eng.pdf?sequence=1

All climate hazards

As environmental conditions become more favorable for the transmission of infectious diseases, there is a risk that recent progress in reducing disease outbreaks will slow. As a result, there will be an increase in populations at risk if control measures are not maintained or strengthened[80]. The increase in infections will continue to cause pressure on health care services as well as on the health of the population.

Climate change will increase vulnerability to food and nutrition security due to lack of arable land, external economic shocks, acute and chronic climate hazards, increasing dependence on food imports, limited number of economic sectors and distance to global markets. Further, Tuvalu is at risk of a 'triple-burden' of malnutrition whereby undernutrition, micronutrient deficiencies and overweight and obesity exist simultaneously within the population. The effects of agriculture and fisheries, water security, dependency on imported foods, urbanization and migration and health service disruption will exacerbate the triple-burden of malnutrition and metabolic and lifestyle risk factors[81]. This issue is of greatest concern in the Outer Islands of Tuvalu[82].

Mental health illnesses will continue to increase as the determinants of health decrease with climate change. Net migration into Funafuti will continue to add additional pressures on the health care system.

Damage to health facilities caused by climate change, including interruptions to access to water, sanitation and energy will affect their capacity to provide health care, particularly when most needed during emergency situations[83].

Climate-sensitive diseases and the likelihood and impact have been measured by WHO et.al below:

Climate-sensitive disease	Risk (of increasing burden of disease with climate change)
Diarrhoeal disease (due to contaminated food and/or water)	High
Respiratory disease (infective and obstructive)	High
Compromised food security (with impacts on nutrition and NCD's)	Medium-high
Vector-borne diseases	Medium
Mental health/psychosocial problems	Medium
Injuries and deaths from extreme weather events	Medium
Fish poisoning (ciguatera)	Low- medium

[80] WHO. UNFCC (2021). Health & Climate Change Country Profile 2020. https://iris.who.int/bitstream/handle/10665/330009/WHO-CED-PHE-EPE-19.3.3-eng.pdf?sequence=1

[81] WHO. UNFCC (2021). Health & Climate Change Country Profile 2020. https://iris.who.int/bitstream/handle/10665/330009/WHO-CED-PHE-EPE-19.3.3-eng.pdf?sequence=1

[82] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

[83] WHO. (2017). Building resilience of health systems in Pacific Island LDCs to climate change. https://www.who.int/news/item/01-11-2017-building-resilience-of-health-systems-in-pacific-island-ldcs-to-climate-change#:~:text=The%20goal,Solomon%20Islands%2C%20Tuvalu%20and%20Vanuatu.

Skin infections/infestations	Low

Source: WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

Marine heatwaves and sea surface temperature

Ciguatera in certain reef fish will continue to increase as sea surface temperature and marine heat waves increase and potentially result in increased blooms of harmful algae. More and frequent outbreaks of ciguatera will place higher numbers of the population at risk of food poisoning with flow-on effects to the health system and economy.

Vulnerability

This table presents sources of public health vulnerability to hazards in Tuvalu.

Hazard	Factor relevant for vulnerability
Average temperature and extreme temperature	• Areas with stagnant water, along with favourable temperature conditions for mosquitos can lead to higher numbers of mosquitos and greater probability of transmission of vector borne disease. • Households with no cooling infrastructure and/or high household sizes will be hotter, and the occupants may experience heat related illnesses. • Vulnerable cohorts (children, seniors, chronic health conditions) at higher risk than other population groups to heat stress. • Outdoor workers without adequate water and sun protection are at high risk to dehydration and heat stress. • Impacts of heat on perishable food, and a lack of cooling equipment will lead to higher food-borne illnesses. • Lack of cooling equipment and timely transportation of medical supplies • International aid during disaster recovery cannot be accessed unless a State of Emergency is declared.
Drought	• Households with damaged water tanks increase the risk of water-borne diseases through lower water quality. • Sewage leakage from ageing septic tank systems on some islands compounds community health problems linked to water security issues during drought. • Vulnerable populations (children, seniors, people with existing health conditions) are at higher risk to water-borne diseases. • Crop failure leading to increased reliance on imported processed and/or frozen food.

Sea level rise, coastal inundation	• Coastal communities and loss of livelihood at higher risk of mental health issues. • Proximity to faulty septic tank and effluent run-off/ discharge. • High density locations have higher risk of drinking water contamination from septic tank effluent. • Damage to critical transport infrastructure causing disruption to the food supply chain. • Crop failure due to salinisation will lead to increased reliance on imported processed and/or frozen food.
Extreme rainfall and increase in average rainfall	• Households with unsecured water sources can lead to increase in mosquito habitats and vector- borne disease transmission. • Households with faulty septic tanks are at higher risk to cross-contamination with potable water. • Proximity to locations of flooding carries higher risk to drowning, physical safety risks. • Crop failure due to salinisation will lead to increased reliance on imported processed and/or frozen food.
Storm surge, extreme windspeed	• Proximity to locations of storm surge carries higher risk to drowning, physical safety risks. • Inadequate housing can lead to physical safety risks due to wind damage.

Variations across the islands

Variation in public health and health infrastructure vulnerabilities across the islands:

Region	Vulnerability Issues
Funafuti	• High population density (up to 8,300 people/km^2) and crowded housing increases risk to heat-related illnesses. • No centralised treatment system (wastewater treatment plant) and inadequate toilets and creates poor sanitary conditions. 424 of the 639 households on Fongafale Islet have buried septic tanks that receive domestic wastewaters; 163 have pit toilets with a pour flush[84]. • Inadequate household water tank capacity. • Leaky/faulty household water tanks and inability to pay for the operations/maintenance and upgrade of the household water system. • Rainfall not sufficient to meet community water security requirements. • Poor groundwater quality.

[84] WHO, GEF, UNDP. (2018). Building resilience of health systems in Pacific Island LDCs to climate change. Tuvalu.

	• Limited to no access to sanitation health services. • Falekaupule and Kaupule lack capacity to mobilise community in addressing their health concerns.
Nanumaga	• Inadequate housing increases vulnerability to cyclones, storms and other acute climate events. • Low resilience of health buildings and equipment to disasters (cyclone/storm/inundation and droughts).
Nanumea	• High vulnerability to disease outbreaks due to the presence of mosquitos. • Inadequate household water tank capacity.
Niulakita	• Limited to no access to reliable and adequate ferry service. • Rainfall not sufficient to meet community water security requirements.
Niutao	• Ongoing waste management and biosecurity issues, with no appropriate solutions identified. • Declining agricultural diversity creates nutrition issues and increases non-communicable disease rates. • Existing natural water source insufficient to support water security needs.
Nukufetau	• Inability to pay for the medical response to disaster induced injuries/illnesses and health needs (water-borne disease and malnutrition) leaves the community highly vulnerable to uncontrolled disease outbreaks. • Food security issues may increases non-communicable disease rates due to poor nutrition and poor health of the community. • Inadequate housing and evacuation centre infrastructure increases vulnerability to cyclones, storms and other acute climate events.
Nukulaelae	• Limited to no access to general health services.
Nui	• Declining agricultural diversity creates nutrition issues and increases non-communicable disease rates. • Inadequate housing and evacuation centres increases vulnerability to physical safety during cyclones, storms and other acute climate events. • Inadequate household and communal water tank capacity.
Vaitupu	• Food security issues may increase non-communicable disease rates due to poor nutrition and poor health of the community. • Inadequate evacuation centres increases vulnerability to cyclones, storms and other acute climate events. • Insufficient natural water sources to support water security needs.

Outer Islands	• High proportions of children and people over the age of 75, increasing vulnerability to illnesses caused by climate change.

Complex risks

Human health and well-being risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Infrastructure:** Currently no agreement in place between the Ministry of Health and other sectors (Transportation, agriculture, social services, electricity) in relation to health and climate change policy[85].
- Disruptions and breakdowns in the infrastructure sector such as disrupted power supply, damaged roads, airstrip or ferry landings, damage to buildings will have flow-on consequences to the health of the population and health infrastructure through disrupted movement of patients and healthcare staff between islands and to/from Tuvalu; powering of cooling equipment during heatwaves; unsafe buildings posing a physical safety risk.
- **Agriculture/Fisheries:** Problems arising in the agriculture and fisheries sector will have flow-on consequences to the health of the population through food security causing malnutrition and non-communicable disease.
- **Water security:** Breakdown in water security will have large consequences to the health of the population through disease outbreaks, and the level of sanitation of water used in health facilities.
- Many water tanks are not covered or are not protected with netting, making them more likely to provide habitat for breeding mosquitos.

[85] WHO, UNFCC. (2020). Tuvalu health & climate change country profile.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R4 – Physical health	**Heatwaves and increased temperature** Favourable conditions for infectious & vector borne disease. Heat related illnesses affecting more people. Food-borne disease due to inadequate cooling.	**Minor**	Vector-borne disease spikes every 2-3 years, it is now becoming more common. There is evidence of higher cases of food poisoning. Some vulnerable populations are being impacted by extreme heat.
R4 – Physical health	**Sea level rise, extreme rainfall, drought** Water contamination and health impacts associated with poor water quality.	**Minor**	Water-borne diseases, skin disease and eye infections are occurring due to limited supply of quality water. Cross-contamination is occurring from poorly maintained septic systems, which is more pronounced during drought
R4 – Non-communicable disease	**All** Climate change impacts on food security, water security, imported food, urbanization, migration will result in higher population with NCDs.	**Minor**	75% of the public health profile of Tuvalu is made up of non-communicable diseases, including 23.1% of the population with diabetes.
R4 - Mental health	**All** Climate induced mental health will increase as of determinants health decrease.	**Minor**	The current capacity is considered adequate in terms of outpatient and inpatient management by health staff.
R5 – Health infrastructure	**Sea level rise and coastal inundation**	**Minor**	Many of the health care facilities are situated in low-lying areas, making them vulnerable to damage and destruction. Many

	Health care facilities are situated in low-lying areas, making them vulnerable to becoming inaccessible, damage and destruction.		health procedures need access to high amounts of sanitised water and a stable energy supply.
R5 – Access to services	**Sea level rise and coastal inundation** There is a reliance on locums for specialists. Outer Islands facilities are staffed with one nurse and have weekly visits from main hospital.	**Minor**	Reliance on fly-in/fly-out specialist locums. Outer Islands facilities are staffed with one nurse and have visits from main hospital.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R4 – Physical health	**Heatwaves and increased temperature** Favourable conditions for infectious & vector borne disease. Heat related illnesses affecting more people. Food-borne disease due to inadequate cooling.	**Minor**	The projected temperature increase of 0.7°C by 2030 will continue to affect vulnerable populations, especially children, the elderly and people with existing health conditions through food poisoning, heat related illness and vector-borne disease.
R4 – Physical health	**Sea level rise, extreme rainfall, drought** Water contamination and health impacts associated with poor water quality	**Moderate**	Ground water cross-contamination between septic systems will continue to be a source of water-borne disease, especially in higher density communities. The increasing burden of disease due to contaminated water and impact on the community is a high risk of increasing burden.
R4 – Non-communicable disease	**All**	**Moderate**	NCD will continue to be a major cause of mortality and morbidity as a result of a decrease in arable land and the effects of climate

	Climate change impacts on food security, water security, imported food, urbanization, migration will result in higher population with NCDs.		change on agriculture, fisheries, water, urbanisation and the associated decrease in socio-economic outputs. Compromised food security and impacts to nutrition and NCD is medium-high risk of increasing burden
R4 - Mental health	**All** Climate induced mental health will increase as of determinants health decrease.	**Moderate**	Declining determinates of health will continue to cause mental health issues across the nation
R5 – Health infrastructure	**Sea level rise and coastal inundation** Health care facilities are situated in low-lying areas, making them vulnerable to becoming inaccessible, damage and destruction.	**Minor**	The main hospital is exposed to damage from climate hazards due to its location.
R5 – Access to services	**Sea level rise and coastal inundation** There is a reliance on locums for specialists. Outer Islands facilities are staffed with one nurse and have weekly visits from main hospital.	**Minor**	Accessibility to the outer island health clinics may be constrained due to absence of sealed roads, flooding of ports, runways. The main hospital may be impacted by closure of the international terminal affecting locums.

2050 High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R4 – Physical health	**Heatwaves and increased temperature** Favourable conditions for infectious & vector borne disease. Heat related illnesses affecting more people.	**Major**	Increase in the number of hot days per year of 140-331 days will impact workforce productivity, affecting water security, food security and health services. Increases in heat-related illness and food poisoning unless cooling interventions are addressed.

	Food-borne disease due to inadequate cooling.		Vector-borne diseases are at high risk of epidemics.
R4 – Physical health	**Sea level rise, extreme rainfall, drought** Water contamination and health impacts associated with poor water quality	**Extreme**	If interventions into water quality do not occur, water-borne disease will continue to be a major problem for the population with sea level rise of 19-37 cm. Populations living in high density locations, children, the elderly and people with existing problems will be at heightened risk.
R4 – Non-communicable disease	**All** Climate change impacts on food security, water security, imported food, urbanization, migration will result in higher population with NCDs.	**Extreme**	Climate change will exacerbate the triple burden of malnutrition and the metabolic and lifestyle risk factors for NCD. NCD will continue to rise and be a major cause of mortality and morbidity, with flow on effects and disruptions to the health care system unless intervention occurs.
R4 - Mental health	**All** Climate induced mental health will increase as of determinants health decrease.	**Extreme**	Declining determinates of health will continue to cause mental health issues across the nation as a high emissions scenario and their impacts are realised
R5 – Health infrastructure	**Sea level rise and coastal inundation** Health care facilities are situated in low-lying areas, making them vulnerable to becoming inaccessible, damage and destruction.	**Extreme**	By 2060 under a high emissions scenario, under high emissions for 2060, 69% of buildings, including the main hospital and other health care facilities are exposed to coastal inundation. Access to sanitised water may be restricted, holding adverse consequences for the operation of the hospital.
R5 – Access to services	**Sea level rise and coastal inundation** There is a reliance on locums for specialists. Outer Islands facilities are staffed with one nurse and have weekly visits from main hospital.	**Extreme**	By 2060 under a high emissions scenario, aaccessibility to health care facilities will be impacted upon due to 80% of the population exposed to coastal inundation. Main runways and ports are affected causing major disruption to health care professionals' movement to and around Tuvalu.

2050 –Low emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R4 – Physical health	**Heatwaves and increased temperature** Favourable conditions for infectious & vector borne disease. Heat related illnesses affecting more people. Food-borne disease due to inadequate cooling.	**Major**	The projected temperature increase range correlates with optimum temperature range for vector borne diseases from mosquitos, with the threat of dengue epidemics high. Increase in the number of hot days by 140-222 days per year will continue to cause heat related illnesses, especially among vulnerable groups if interventions do not occur.
R4 – Physical health	**Sea level rise, extreme rainfall, drought** Water contamination and health impacts associated with poor water quality	**Major**	Sea level rise is projected to be 17-29 cm. Groundwater and coastal water contamination will continue to pose health problems unless increased monitoring of water quality and controlling risks occur.
R4 – Non-communicable disease	**All** Climate change impacts on food security, water security, imported food, urbanization, migration will result in higher population with NCDs.	**Major**	As climate change affects the agriculture & fisheries sector, malnutrition and food insecurity will increase reliance on unhealthy imported food. Increased urbanisation and migration will cause lifestyles to become sedentary. NCDs will continue to rise and will continue to be a major cause of mortality and morbidity, with flow on effects and disruptions to the health care system unless government intervention occurs.
R4 - Mental health	**All** Climate induced mental health will increase as of determinants health decrease.	**Major**	Declining determinates of health will continue to cause mental health issues across the nation as a low emissions scenario and their impacts are realised
R5 – Health infrastructure	**Sea level rise and coastal inundation**	**Major**	Widespread coastal inundation may impact upon the capture, storage and treatment of potable water required to continue

	Health care facilities are situated in low-lying areas, making them vulnerable to becoming inaccessible, damage and destruction.		health procedures, as well as energy supply. Access to many health facilities may be at risk.
R5 – Access to services	**Sea level rise and coastal inundation** There is a reliance on locums for specialists. Outer Islands facilities are staffed with one nurse and have weekly visits from main hospital.	**Major**	By 2060 under a medium emissions scenario, 60% of population exposed to coastal inundation, causing disruption of movement of medical specialists and patients.

Confidence

Component	Hazard	Confidence score	Comments
R4 - Physical health	Heatwaves & increase temperature	Low	• Limited information on projected impacts of temperature increase on people. Health data and health system pressures.
R4 - Physical health	Sea level rise, extreme rainfall, drought	Low	• Limited information on water-borne disease and effects of poor water quality on the population, limited information on projections of public health pressures.
R4 - Non-communicable disease	All	Low	• Limited information on projected pressures on health system, health initiatives and projections of NCD.

R4 - Mental health	All	Low	• Limited information on climate induced mental health and health system capacity.
R5 - Health infrastructure	Sea level rise and coastal inundation	Low	• Limited information on health facilities including infrastructure, accessibility, power and water.
R5 – Access to services	Sea level rise and coastal inundation	Low	• Limited information on access to health services and movement of health staff

Knowledge Gaps

- There is no data on mental health and projections associated with climate change.

5.4 Social cohesion and heritage

Summary of this domain in Tuvalu

Social cohesion can act as a catalyst for developing resilient communities. Conversely, climate change may erode the elements that make up social cohesion - the bonds that keep a society together. Elements such as social trust, an inclusive identity and cooperation for the common good enhances the well-being of a community, mobilising resilience and provides for a more effective response to climate-related disasters. Tuvalu boasts a well-established Polynesian culture that promotes a harmonious interaction between people and nature. Tuvaluan traditions are continuing and persist for the people's own values, beliefs and identity. The persistence of this cultural autonomy exhibits a firm kinship and descent-based society with a traditional system of chiefly-based governance, and one dominant religion. Tuvalu's egalitarian social institutions are grounded in sharing-based economic traditions, where land use and sea use has survived colonial experiences, World War 2 and westernisation[86]. Climate change, however, is placing social challenges on the population, which may erode social cohesion.

The following risk statement (**R6**) has been developed through consultation during the Tuvalu NAP Project-Mission (2024). It discusses the risks that climate change present for social cohesion and heritage that have been identified and analysed.

R6: Risks to Social Cohesion and Heritage

Increasing chronic and acute climatic hazards, including coastal inundation, groundwater intrusion and pluvial floods, impact places of cultural significance and heritage including grave sites, culturally significant community meeting places and related natural assets (e.g. large shade trees, beaches and bathing areas etc.). Net migration of people re-locating from outer islands to Funafuti is expected to compound these issues. This can result in loss of social identity and social cohesion and a related sense of personal loss and trauma, and risks to intergenerational, loss and trauma, and with negative consequences for mental health and wellbeing for individuals and local communities over intergenerational timescales.

Risk Summary

Tuvaluans live in a dynamic ecosystem to which they have adapted. Climate change is likely to pose new threats, placing stress on the social bonds that form a safe, cohesive society. Tuvalu performs relatively well on certain key human indicators such as access to health services and formal education with adult literacy rate at 99%.

Tuvalu, however, faces an array of social challenges. According to World Bank findings, 26.6% of the population were living below the national poverty line in 2010[87], leaving many households dependent on remittances. The prevalence of physical or sexual intimate partner violence in Tuvalu is higher than the global average with 40% of women reported to have experienced physical violence by their current husband or partner[88]. Internal migration into Funafuti is further worsening population density and placing pressure on services, which are having flow on impacts to community tolerance levels. The Tuvalu

[86] UNESCO. (2024). The Pacific atoll-island cultural landscape of Tuvalu. https://whc.unesco.org/en/tentativelists/6707/

[87] World Bank Group. (2021) Tuvalu Country risk profile.

[88] UN Women, SPC, The Equity Trust (2022). Pacific partnership to end violence against women and girls. Tuvalu Country Summary. 7-Tuvalu-Country-Summary-FINAL-21.06.22.pdf (unwomen.org)

Government are making strong attempts to address these social challenges. However, the impacts of climate change affect all aspects of wellbeing, degrade quality of life and undermine the social connectivity of communities.

Tuvalu has been settled by humans for thousands of years, with strong elements of Polynesian culture. Cultural heritage and values are deeply ingrained within a harmonious interaction between people and nature that is firmly place-specific, living and enduring. Cultural traditions include land practices and sea use with familiar atoll-island traits that have survived due to the environmental and geopolitical circumstances. Each island has an identity with political and religious leadership, administration and legal ordinances based to fit local custom[89]. Spiritual places and sacred sites include ancestral 'canoe landing places', battle sites and natural features with symbolic value or mythological association[90]. There are social, political, religious, economic and cultural differences between each island including ancestry and dialect. However, while home-island loyalties are evident, there are common shared attributes that identify wider cohesive cultural traditions and heritage.

Funafuti grave site. (Source: Tuvalu NAP Project-Mission (2024)

Tuvaluans have long practiced migration, and it remains a major factor in their economic and demographic development paths. The World Bank reported that a majority of the population are considering immigration, but many don't have the financial resources to do so[91]. Younger cohorts (aged 15-30) have the highest level of mobility related to secondary school movements and entry to the labour force. Most of the latter involves movement to Funafuti which has had an impact on the island's age-sex structure, making it much younger than the age structure of the Outer Islands[92].

There have already been instances of permanent relocation of inhabitants to higher ground or beyond Tuvalu due to the threat of rising sea levels and retreating shorelines. Climate disasters and forced migration have far-reaching impacts on people and the communities in which they belong. People who are displaced often have little control over when, where and how they move. Separation from community and family undermine social support systems. Migrating to urban centres reduces sustainable subsistence economies and places pressure on services, medical care, water supply and waste disposal. Funafuti is considered the only urban area in Tuvalu. Population density is high with houses crowded closely together and higher pressure on services such as energy, water and waste disposal. The Tuvalu Government has long recognised urbanisation problems such as land rights, provision of services, provision of water supply and waste disposal.

Climatic events amplify both the strengths and weaknesses of a social system, which in most cases, increases gender inequality and reduces the protective factors that work to prevent violence against women, girls and minority groups. The widespread acceptance of gendered violence highlights the

[89] UNESCO. (2024). The Pacific atoll-island cultural landscape of Tuvalu. https://whc.unesco.org/en/tentativelists/6707/

[90] UNESCO. (2024). The Pacific atoll-island cultural landscape of Tuvalu. https://whc.unesco.org/en/tentativelists/6707/

[91] World Bank. (2021). Climate risk country profile: Tuvalu.

[92] Tuvalu Government. (2012). Tuvalu national population and housing census 2012. Migration, urbanization and youth monograph.

pervasiveness and socialisation of this issue, with more than seven in ten men agreeing that 'wife beating is justified for at least one of the specified reasons' that were listed within a study, *The National Domestic Violence Prevalence Studyii*[93]. The study also reveals that rates of domestic violence against women are not linked to place or residence, employment status, marital status or educational level. It is estimated that approximately half of all reported acts of physical violence were reported by women aged 25-29.

Domestic violence is not an isolated event, but a dynamic between people. This relationship is maintained by the wider family system, community system and cultural beliefs. The Tuvalu Government believes gender equality is a key indicator of development and social well-being of a nation[94]. It is responding to gendered violence by partnering with the *Pacific Community (SPC) Human Rights and Social Development (HRSD) Division*[95] with programs to promote gender equality, equal opportunities and prevent violence. The Government also has the *Tuvalu National Gender Policy* to operationalise the Government's commitments to gender equality and empowerment[96]. The impacts of climate change however act as an accelerant to gender inequality and violence[97], meaning prevention and intervention methods will face an up-hill battle in meeting their objectives.

Employment and participation in the labour market (aged 15+) comprises 38.3% of the population. Women had a labour force participation rate of 55.4% compared to men at 71.2%[98]. Agriculture accounts for the largest sector with 29% of total employment. The subsistence economy is dominated with women, making up 78% of the workforce[99]. The unemployment rate of 8.5% is made up of 16.2% for women, 4.6% for men and youth unemployment at 20.6%. Additionally, 26.6% of the population live below the national poverty line[100]. Projected climate changes are likely to disproportionately affect the poorest groups in society due to limited resources to adapt[101]. Rising poverty rates and disparity in employment between genders and age groups will aggravate socio-economic inequality and exclusion within Tuvalu communities. A rise in crime and conflict may occur, fracturing the Tuvaluan construct of social cohesion.

New research into educational outcomes and the effects of climate change show that young people who experience a disaster are 4.5% less likely to complete high school, and more likely to experience psychological distress and homelessness[102]. Poorer educational and financial outcomes for children and young people will increase inequality with more people living with disadvantage. This will have further impacts on social cohesion.

[93] UN Women, SPC, The Equity Trust (2022). Pacific partnership to end violence against women and girls. Tuvalu Country Summary. 7-Tuvalu-Country-Summary-FINAL-21.06.22.pdf (unwomen.org)

[94] Tuvalu Government. Tuvalu National Gender Policy 2014-2016.

[95] UN Women, SPC, The Equity Trust (2022). Pacific partnership to end violence against women and girls. Tuvalu Country Summary. 7-Tuvalu-Country-Summary-FINAL-21.06.22.pdf (unwomen.org)

[96] Tuvalu Government. Tuvalu National Gender Policy 2014-2016.

[97] Thomas & Candolfi. (2019). "Is Climate change worsening gender-based violence in the Pacific Islands?" *Open Global Rights*. Is climate change worsening gender-based violence in the Pacific Islands? | OpenGlobalRights

[98] ILO (2022). Tuvalu. The employment – environment – climate nexus.

[99] World Bank Group (2021). Climate risk country profile. Tuvalu.

[100] World Bank Group (2021). Climate risk country profile. Tuvalu.

[101] World Bank Group (2021). Climate risk country profile. Tuvalu.

[102] Deloitte Access Economics. (2024). The impact of disasters on children and young people. UNICEF Australia.

Tuvaluans, however, have a long history of adapting to and mitigating climate change effects. Creative, and sustainable, adaptive initiatives will be critical for the ongoing resilience of Tuvalu and its special atoll-island culture[103].

Current exposure to hazards

This section discusses the exposure of social cohesion and heritage to key hazards.

Coastal inundation, sea level rise, marine heatwaves

Coastal inundation, sea level rise and marine heatwaves cause a range of consequences to Tuvalu including displacement of community, disruption and damage to cultural land and sea practices and landmarks, and disruptions to the agriculture and fisheries sector. This may cause a level of frustration and anxiety due to a loss of social identity and sense of belonging, shared common purpose and losses to income, impacting livelihoods, further straining the bonds that form a cohesive society.

Migration into Funafuti due to socio-economic reasons is occurring. Coastal inundation and sea level rise are compounding the pressures that net-migration and urbanisation cause such as a larger population, higher density living and reliance on limited services and resources. Subsistence agriculture occurs within a well-developed framework of traditional land tenure, with a high percentage of land held in traditional ownership. Migration into Funafuti may be posing problems on land tenure practices, with access to land being one of the fundamental issues in the urbanisation of Funafuti. This may cause lower trust and tolerance levels within the community, impacting on cohesion. The increased population of Funafuti is placing pressure on employment opportunities. This impacts upon social cohesion through the degradation of socio-economic equalities and may cause a higher risk of criminal activity and civil unrest.

Tropical cyclones and flooding

Floods and cyclones are known to increase the severity of domestic violence because women are separated from support networks that offer protection whilst these climatic events are occurring. While contextual data is limited, other Polynesian countries report that women and children are at higher risk of sexual abuse, with attacks taking place at temporary shelters during disasters[104]. Gendered violence creates conflict between individuals, eroding trust and weakening social relations and ultimately social cohesion.

Cyclones and floods disrupt education for children through the temporary closure of schools and/or accessibility issues to and from schools, as well as employment with the closure of businesses during these acute climatic events. Disruptions to school and employment may be exacerbating socio-economic inequalities through the loss of knowledge, and loss of income and livelihood, and reducing the capacity of support networks. The capacity of the Tuvaluan society to ensure the well-being and inclusion of all citizens may therefore be at risk, damaging social cohesion.

Temperature increase and heatwaves

Temperature increases and extreme heat is leading to more frequent power outages as cooling infrastructure is used to cool buildings. The reliance on energy from the power grid means that those who are socially isolated and those living in higher density households are at higher risk of heat stress illnesses

[103] UNESCO. (2024). The Pacific atoll-island cultural landscape of Tuvalu. https://whc.unesco.org/en/tentativelists/6707/

[104] Thomas & Candolfi. (2019). "Is Climate change worsening gender-based violence in the Pacific Islands?" *Open Global Rights*. Is climate change worsening gender-based violence in the Pacific Islands? | OpenGlobalRights

and transmittable diseases due to these power outages. As women fulfil traditional caring roles, the onus falls on the woman to care for the sick within the household. Social cohesion is impacted through exclusion of those socially isolated, a decrease in quality of life for those sick and by removing women from the workforce and economic participation to care for the sick.

Drought

Tuvaluans consider drought as a punishment from God for sin or bad traditional leadership. Some islands replace their chiefs for bringing this bad omen. This traditional belief demands that the leader steps down to give way for new leader with the hope of prosperity[105]. Maintaining these beliefs and values keeps social cohesion in order.

Drought can cause anxiety within affected communities because most households in Tuvalu do not have sufficient water storage capacity to withstand prolonged droughts, with a general storage capacity of one month[106]. Despite the introduction of the Sustainable and Integrated Water and Sanitation Policy 2012-2021 following the 2011 drought, up to 70% of Tuvalu inhabitants still lack access to adequate water catchment and storage capacity to face historically long dry spells[107]. There have been instances of people stealing their neighbours' water during droughts, as well as fights between those who line up to collect water from distribution centres[108]. Social cohesion is eroded during events such as drought as neighbourhood and community distrust between each other grows.

Drought increases the risk of gendered violence due to the gendered nature of domestic activities such as cooking and cleaning which rely on water. It was noted in a neighbouring country during times of water scarcity, "the woman is not able to cook, do the laundry or prepare the husband's clothes, increasing her risk of experiencing violence from a partner"[109]. Reciprocal loyalty and solidarity, strength of social relations and shared values are adversely affected, all eroding social cohesion.

Future exposure to hazards

This section discusses the future exposure of social cohesion and heritage to the key hazards.

Coastal inundation, sea level rise, marine heat waves

Coastal inundation and sea level rise will continue to compound the problems that migration, urbanisation and higher density living are having on Funafuti. Urbanisation and higher density living will trigger a move away from traditional practices and frameworks including subsistence agriculture, a sharing-based economy and land tenure rights. All of these factors may decrease the community's tolerance levels and increase the likelihood of conflict, increase inequality, and result in a loss of social identity and a shared common goal, all placing social cohesion at great risk.

[105] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[106] Tuvalu NAP Project-Mission (2024).

[107] Baarsch, F., Berg, L.M.N. (2015). The Significance of Contextual Vulnerability in Effective Adaptation to Climate Change on Tuvalu. Climate Change in the Asia-Pacific Region. https://doi.org/10.1007/978-3-319-14938-7_18

[108] Tuvalu NAP Project-Mission (2024).

[109] Thomas & Candolfi. (2019). "Is Climate change worsening gender-based violence in the Pacific Islands?" *Open Global Rights*. Is climate change worsening gender-based violence in the Pacific Islands? | OpenGlobalRights

The impacts marine heat waves and sea level rise will have on biodiversity, and the fisheries and agriculture sector will have consequences to the cultural landmarks and practices of the people of Tuvalu. Beliefs, values and identity may be at risk, along with their sharing-based economic traditions. A loss of a sense of identity, shared values and orientation towards a common good may be corroded, placing the society at a great risk of a lack of connectedness and solidarity. Further, losses to income will increase economic inequality, and reduce quality of life. Breakdown within the community identity and community life will have dire consequences to social cohesion.

Tropical cyclones and flooding

Cyclone frequency is projected with low confidence to decrease, whilst cyclone intensity may increase. During cyclones and floods, women and children who are seeking protection within temporary shelters and evacuation centres are at higher risk of sexual abuse and violence. Designing safer shelters that support and keep social networks together will provide better protection, and support trust among community members.

Increased damage and destruction to residential households during cyclones and floods may place people at risk of homelessness. Young people may experience disruptions to education due to damage to schools, placing them at risk of poorer educational outcomes and future economic disadvantage. Social cohesion will be strained due to decreased quality of life, increased inequality and marginalisation and loss of identity.

Higher intensity cyclones and floods will cause the destruction of sacred sites, and impact upon cultural identity and practice. An absence or erosion of cultural identity and social identity loss will impact upon shared values and beliefs.

Temperature increase, heat waves

People who are socially isolated, and people living in larger households will be at greater risk of heat related illness and transmittable diseases. If measures are not taken to address density living and pressure on services such as water and energy, more people will be at risk of suffering from degradation in quality of life, impacting upon the cohesiveness of the society.

Drought

Despite the projected decrease in overall drought frequency and duration, the projected increase in extreme droughts and drought intensity will continue to increase the risk of gendered violence. Water security may continue to cause distrust and low tolerance levels among each other within the community, with incidence of conflict over limited resources increasing.

Vulnerability

This table presents sources of social cohesion and heritage vulnerability to hazards in Tuvalu.

Hazard	Factors relevant for vulnerability
Drought	• Poorer farmers and communities are least able to afford local water storage and technologies for adaptation, increasing their likelihood of inequality. • Women and girls are more likely to experience violence due to gender-norms within society.

	• People in high density areas are at higher risk of conflict due to competing for limited resources such as water.
Heat	• Heavy manual labour jobs will be most affected by heat, affecting incomes and economic participation. • People with low social capital and limited social networks are at risk from experiencing heat related illness, placing them at risk of further social exclusion and marginalisation.
Coastal inundation, sea level rise and heat warming	• Poorer households, and migrants into Funafuti may experience impacts associated with higher household size including greater incidence of transmittable disease. • Populations reliant on agriculture and fisheries are at greater risk due to loss of identity and economic losses resulting in economic disparities and exclusion.
Cyclone, floods	• Women and girls are more likely to experience violence and sexual abuse due to isolation from support networks. • Children are at risk of future economic inequality due to disruptions to education because of damage of education infrastructure. • Damage and destruction of residential buildings may lead to these families becoming homeless, causing socio-economic inequality, loss of identity.

Variations across the islands

The variation in social cohesion and heritage vulnerabilities across the islands is unknown.

Complex risks

Social cohesion and heritage risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Water security:** Water security problems will create lower tolerance and distrust within the community as people compete for finite water.
- **Infrastructure:** Infrastructure disruptions will affect workplaces and residential buildings. This has flow on consequences to people through workforce and home duties disruption. Social cohesion is strained as these cohorts of people are placed under stressful situations.
- **Disaster risk management:** Disaster risk management and evacuations during acute climatic events may cause safety issues for certain cohorts of the community as social networks are disrupted.
- **Human health & well-being:** As fractures within social cohesion occur, mental health issues will rise, placing the health sector under strain.
- **Coastal:** As coastal protection is challenged and land erosion occurs, people will be forced to move further away from the coast, placing pressure on municipal services, and increasing density living. Additionally, cultural landmarks and places of significance may be damaged or destroyed. This has flow on consequences to social cohesion.

- **Agriculture/Fisheries:** Impacts to agriculture and fisheries will have consequences to cultural identity and practices, as well as workforce participation. This will challenge the bonds that form social cohesion in Tuvalu.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R6- Cultural heritage	**Coastal inundation, sea level rise and marine heat waves** Will cause a range of consequences to Tuvalu community through the disruption and erosion of cultural sites and practices causing loss of identity, values and beliefs.	**Moderate**	Coral bleaching and overfishing is occurring. Increases in annual marine heatwave frequency with 60 or more days is causing algal blooms. Impacts to cultural land and sea practices and sacred sites is occurring resulting disruptions to cultural practices, and damaging values and beliefs.
R6 - Socio-economic & gendered inequality	**All** Urbanisation, gendered violence and unemployment in certain cohorts will increase socio-economic inequality within Tuvalu. The impacts of climate change disproportionally affect the poorest and marginalised groups of society, undermining the social connectivity of communities.	**Moderate**	Youth unemployment sits at 20.6%. 26.6% of the population live below the national poverty line. Women and children are at greater risk to violence during climate events. 40% of women reported to have experienced physical violence by their current husband or partner.
R6 - Migration to Funafuti	**Coastal inundation and sea level rise** Pressures on services, increased population density and higher household size will cause impacts to cultural values, beliefs and practices, a decrease in quality of life and erosion of trust within the community due to competition of finite resources.	**Major**	Currently, 37% of the population of Tuvalu is exposed to coastal inundation of a 5-year reoccurrence interval. There are incidences of permanent relocation of people to higher ground and beyond Tuvalu. Migration to Funafuti due to socio-economic reasons is occurring with 57% of the country's population living in Funafuti, placing services under great pressure. There have been incidents of

			fights breaking out during water collection in drought. The Tuvalu government has long recognised urbanisation problems such as land rights, provision of services, provision of water supply and waste disposal.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R6- Cultural heritage	**Coastal inundation, sea level rise and marine heat waves** Will cause a range of consequences to Tuvalu community through the disruption and erosion of cultural sites and practices causing loss of identity, values and beliefs.	**Major**	Sea level rise around Tuvalu is projected to be 9-17cm by 2030. SST projected to increase by 0.7°C by 2030. Projections of 110-290 days of marine heat waves. Disruption and erosion of cultural practices and sacred sites will place shared values and beliefs at risk, as well as increase the loss of a shared identity.
R6 – Socio-economic & gendered inequality	**All** Urbanisation, gendered violence and unemployment in certain cohorts will increase socio-economic inequality within Tuvalu. The impacts of climate change disproportionally affect the poorest and marginalised groups of society, undermining the social connectivity of communities.	**Major**	Climate change is projected to increase inequality. Coping strategies are heavily dependent on socio-economic status, cultural norms, access to resources, poverty and gender. Poorer educational and financial outcomes for children and young people will increase inequality. Propensity for conflict and crime is increased as socio-economic disparities increases.
R6 - Migration to Funafuti	**Coastal inundation and sea level rise** Pressures on services, increased population density and higher household size will cause impacts to cultural values, beliefs and practices, a decrease in quality	**Major**	Sea level rise around Tuvalu is projected to be 9-17 cm by 2030. This may exacerbate impacts to Tuvalu social cohesion including permanent relocation of people to higher ground and beyond Tuvalu.

	of life and erosion of trust within the community due to competition of finite resources.		

2050 –High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R6- Cultural heritage	**Coastal inundation, sea level rise and marine heat waves** Will cause a range of consequences to Tuvalu community through the disruption and erosion of cultural sites and practices causing loss of identity, values and beliefs.	**Extreme**	Seal level rise is projected to be 19-37 cm. Destruction of biodiversity, and the fisheries and agriculture sector will have catastrophic consequences to the cultural practices of the people of Tuvalu, eroding sense of identity, values and orientation towards a common good.
R6 - Socio-economic & gendered inequality	**All** Urbanisation, gendered violence and unemployment in certain cohorts will increase socio-economic inequality within Tuvalu. The impacts of climate change disproportionally affect the poorest and marginalised groups of society, undermining the social connectivity of communities.	**Extreme**	People living in poverty is expected to increase because of urbanisation, adverse impacts to critical sectors and consequences such as homelessness and reduced education. Women and poorer cohorts experience climate change impacts more.
R6 - Migration to Funafuti	**Coastal inundation and sea level rise** Pressures on services, increased population density and higher household size will cause impacts to cultural	**Extreme**	Under high emissions for 2060, 80% of the population and 69% of buildings will be exposed to coastal inundation of a 5-year recurrence interval. There is widespread belief that Tuvalu will

	values, beliefs and practices, a decrease in quality of life and erosion of trust within the community due to competition of finite resources.		be a typical case of forced migration. This will cause permanent and irreversible consequences to social cohesion of Tuvalu.

2050 – Low emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R6- Cultural heritage	**Coastal inundation, sea level rise and marine heat waves** Will cause a range of consequences to Tuvalu community through the disruption and erosion of cultural sites and practices causing loss of identity, values and beliefs.	**Extreme**	Sea level rise is projected to be 17-29 cm. Destruction of biodiversity, and the fisheries and agriculture sector will have catastrophic consequences to the cultural practices of the people of Tuvalu, eroding sense of identity, values and orientation towards a common good.
R6 - Socio-economic & gendered inequality	**All** Urbanisation, gendered violence and unemployment in certain cohorts will increase socio-economic inequality within Tuvalu. The impacts of climate change disproportionally affect the poorest and marginalised groups of society, undermining the social connectivity of communities.	**Extreme**	Socio-economic and gendered inequality is expected to increase due to climate change. People living in poverty is expected to increase because of urbanisation and adverse impacts to major sectors, and a decrease in economic participation.
R6 - Migration to Funafuti	**Coastal inundation and sea level rise** Pressures on services, increased population density and higher household size will cause impacts to cultural values, beliefs and practices, a decrease in quality of life and erosion of trust within the community due to competition of finite resources.	**Extreme**	By 2060 under a SSP2-4.5 scenario, 60% of the population and 52% of building will be exposed to coastal inundation of a 5-year occurrence interval. This will cause permanent and irreversible consequences to social cohesion of Tuvalu. Urbanisation and higher density living will trigger a move away from traditional practices and frameworks including subsistence agriculture, a

		sharing-based economy and land tenure rights. Increase in inequality, degradation of quality of life and loss of identity, resulting in lower tolerance levels, increased conflict and crime.

Confidence

Component	Hazard	Confidence score	Comments
R6- Cultural heritage	**Coastal inundation**	**Medium**	• Limited research on the impacts of cultural and climate change.
R6 - Socio-economic & gendered inequality	**All**	**Medium**	• Research on socio-economic and gendered inequality in Tuvalu is somewhat limited.
R6 - Migration to Funafuti	**Coastal inundation and sea level rise**	**Medium**	• Extreme consequences have already happened, although to a smaller scale (permanent relocation of Tuvaluan inhabitants to higher ground or beyond Tuvalu). It is with high confidence that this hazard is projected to get worse.

Knowledge Gaps

- Knowledge on Tuvaluan social cohesion is limited, and data on certain metrics is not available.

5.5 Water security

Summary of this sector in Tuvalu

Water security is a critical consideration in Tuvalu because the limestone islands and atolls provide no permanent source of fresh surface water[110]. This results in a limited supply of potable water for domestic and agricultural use. Although groundwater is still used for non-potable purposes in some islands, Tuvalu is particularly vulnerable to saltwater intrusion because the islands are extremely low-lying, with the highest elevation being 4.6 meters above sea level on Niulakita[111]. As a result, groundwater is brackish and not generally considered safe for consumption, making rainfall and rainwater harvesting the primary source of freshwater, and only source of drinking water, in island communities. Rainwater is generally harvested via rooftop catchment and storage both collectively across public buildings (including underground reservoirs) and individually across private homes and rainwater tanks[112].

Maintenance of household rainwater tanks and gutters is a challenge because many households do not have adequate capacity to clean, maintain and flush out tanks and gutters[113]. Land availability for storage tanks is also an issue. Circular tanks take up a lot of space, with alternative rectangular, elongated tanks providing a more self-sufficient water catchment option[114]. Previous EU disaster risk reduction projects which have aimed to reduce community vulnerability by providing some households with water tanks have had limited effectiveness because guttering systems have not been adequately installed[115].

Circular rainwater tank in Funafuti. (Source: Tuvalu NAP Project-Mission (2024))

The first reverse osmosis system was installed on Funafuti in 1992[116], and there are now desalination plants operational on all nine islands. During normal conditions, households can purchase desalinated water if additional water is required, while emergency water is available from desalination plants for domestic use during drought[117]. Many community members choose to drink rainwater over desalinated water due to taste preferences, although stakeholders acknowledge that desalinated water is likely to be better quality due to the lower risk of microbial contamination[118]. The cost of producing and buying desalinated water remains high in some islands, with the 2014 PACCSAP report[119] finding the cost of desalinated water is approximately 20

Desalination infrastructure in Funafuti. (Source: Tuvalu NAP Project-Mission (2024))

[110] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[111] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[112] Government of Tuvalu. (2021). Te Vaka Fenua o Tuvalu National Climate Change Policy 2021-2030.

[113] Tuvalu NAP Project-Mission (2024).

[114] Tuvalu NAP Project-Mission (2024).

[115] Tuvalu NAP Project-Mission (2024).

[116] Government of Tuvalu and SOPAC. (2013). Sustainable and Integrated Water and Sanitation Policy 2012-2021.https://www.theprif.org/sites/default/files/documents/tuvalu_water_policy_2013.pdf

[117] Tuvalu NAP Project-Mission (2024).

[118] Tuvalu NAP Project-Mission (2024).

[119] Kinrade, P., Arold, N., Pickering, P., Rooke, E., Manfredo, J. (2014). Water Security in Tuvalu: Assessing Costs and benefits.

times more expensive than an equally effective gutter cleaning and maintenance programme. A government-funded technician from Funafuti is responsible for

desalination maintenance because there is limited capacity on the islands to maintain the units[120].

Septic tanks and pit latrines are the primary source of sewage disposal in Tuvalu, with aging septic systems on some islands exposing communities to septic overflow and sewage leakage into the sea, water catchments and surrounding land[121]. Maintenance of septic tanks is also the responsibility of households, and Kaupules (Island Councils) can penalise households if they identify malfunctioning tanks[122]. According to a 2021 UNICEF report, 46% of the population uses basic sanitation (i.e. flush, pour, composting or ventilated pit latrines).

The lack of resilience in Tuvalu's freshwater sector was highlighted during the 2011 La Niña–associated drought which affected island communities for almost three years. Following this drought, the government of Tuvalu introduced the Sustainable and Integrated Water and Sanitation Policy 2012-2021[123] with the aim of safeguarding community access to sustainable water and sanitation provisions. The key initiatives of this policy include improving water quality and sanitation, developing desalination, rainwater harvesting and water storage infrastructure, enhancing technical monitoring capabilities, and building capacity and resilience in communities to respond to water security challenges.

The following risk statements have been developed through consultation during the Tuvalu NAP Project-Mission (2024). They include risks to water availability, demand and quality (**R7**) and risks to water infrastructure (**R8**).

R7: Risks to Water Availability, Demand and Quality (Water Security)

Increasing chronic and acute climate hazards including heatwaves, droughts, floods and TCs, can impact water demand, availability and quality especially of potable drinking water but with related consequences for water for agricultural use also. Increasing surface and ground water pollution during flooding and saline groundwater intrusion due to sea level rise compounded by Spring tides, will impact water availability and quality. These impacts will be compounded by increasing temperatures and population growth which will drive increased demand for water for domestic and agricultural use. Inadequate household water harvesting and storage may place additional pressures on communal and government water supply, including desalination plants and competition for space (for locating rainwater tanks). Maintenance of critical water infrastructure including de-sal plants and rainwater tanks will compound these impacts, along with periodic interruptions to electricity supplies (due to heatwaves, TCs etc.) powering pumps and treatment plants. This can cause water shortages and impact community health and wellbeing, including WASH-related issues and psychological impacts (see also R4). Likewise, this will disrupt economic activities such as agricultural production, including animal husbandry and home gardens, with consequences for food security. This is particularly the case as limited water supplies are prioritized for human use over crops and livestock.

[120] Tuvalu NAP Project-Mission (2024).

[121] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[122] Tuvalu NAP Project-Mission (2024).

[123] Government of Tuvalu and SOPAC. (2013). Sustainable and Integrated Water and Sanitation Policy 2012-2021.

R8: Risks to Water Infrastructure

Increasing chronic and acute climate hazards, including heatwaves, coastal inundation and cyclones, will directly impact potable water infrastructure (e.g., pumps, storage tanks, wells, drains, de-sal and other treatment plants etc.), and indirectly via interruption to electricity supplies and maintenance services. Wastewater infrastructure (e.g. septic tanks) will be impacted particularly as groundwater intrusion compromises effective treatment, resulting in localized flooding and run-off of untreated effluent. This can reduce water supply and quality for human, agricultural and other uses, increasing maintenance and repair costs, and affecting community health and wellbeing, including WASH-related issues. Reliability of the electricity generation and distribution grid, for which supplementary de-sal water supply is dependent, will also be impacted by increasing temperatures, further compounding risks to water infrastructure through increased demand and treatment/supply interruptions.

Risk Summary

Water availability, demand, quality and infrastructure in Tuvalu is at risk from climate change through chronic and acute climate change events including sea level rise, an increase in the severity of extreme heat and extreme rainfall events, drought, coastal inundation and storm surge, variability in annual average rainfall and an increase in extreme windspeed. The impacts of these hazards on Tuvalu's water security include increased demand for freshwater and reduced water quality due to saline intrusion, reliance on rainwater harvesting, limited water storage capacity and land-based pollution. Together these impacts will likely reduce the amount of potable water available.

Additionally, these events will disrupt and harm Tuvalu's water supply and treatment facilities by damaging pumps, pipes, septic systems, wells and drains, polluting water catchments and hampering desalination operations. These water security issues will increase maintenance and repair costs, affect community health, livelihoods and agricultural productivity, and impact mental wellbeing. Drought-related water shortages and disease outbreaks have particularly significant psychological impacts, including increased stress and anxiety in affected communities[124].

Current exposure to hazards

This section discusses the exposure of Tuvalu's water sector to key hazards.

Extreme heat events

Periods of extreme heat place pressure on Tuvalu's limited water supply by increasing demand for freshwater for both domestic consumption and agricultural use, such as stock watering and crop irrigation. Extreme heat events also often cause power outages which disrupt water reticulation (from public tanks and reservoirs) and desalination operations, with severe implications for human health, livelihoods and agricultural productivity particularly during concurrent periods of drought.

[124] Tuvalu NAP Project-Mission (2024).

Drought

Tuvalu's reliance on rainwater makes communities particularly vulnerable to drought and associated water, sanitation and hygiene (WASH) issues. Drought-induced water scarcity and reduced water quality can impact human health and productivity by increasing infection rates and disease issues, including water-borne bacteria (such as myxosporidia) and suspected water-borne typhoid[125]. Sewage leakage from ageing septic tank systems increases the vulnerability of Tuvalu communities to drought by compounding the community health problems linked to water security issues[126].

During the 2011 drought, communal water supplies were rationed to as little as 2.1 L/person/day and in some islands 61% of households relied solely on brackish well water for bathing, washing clothes and flushing toilets[127]. The quality of well water was tested during this historically dry period and found not fit for human consumption, with a concurrent decline in sanitation and hygiene practices including decreased handwashing frequency[128]. A severe diarrhea outbreak ensued, hospitalising four children and three adults in Nukulaelae[129].

Drought can cause significant mental stress and anxiety within affected communities because most households in Tuvalu do not have sufficient water storage capacity to withstand prolonged droughts, with a general storage capacity of one month[130]. Despite the introduction of the Sustainable and Integrated Water and Sanitation Policy 2012-2021 following the 2011 drought, up to 70% of Tuvalu inhabitants still lack access to adequate water catchment and storage capacity to face historically long dry spells[131]. There have been instances of people stealing their neighbours' water during droughts, as well as fights between those who line up to collect water from distribution centres[132].

The reduction in potable water during drought places pressure on water infrastructure, including desalination plants and groundwater reserves, to meet community water security needs. The limited water supply is prioritised for people rather than livestock and crops[133], with desalination water generally available for emergency use by people during drought but not for agricultural or economic activities. As a result, the crops that can grow in the atoll environment of Tuvalu, such as coconut, breadfruit and bananas, often wilt and die or become inedible during prolonged dry spells[134]. Livestock also suffer from water

[125] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[126] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[127] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[128] Emont, J.P., et al. (2017). Epidemiological investigation of a diarrhea outbreak in the South Pacific island nation of Tuvalu during a severe La Niña–associated drought emergency in 2011. The American journal of tropical medicine hygiene. 96(3): p. 576.

[129] Sinclair, P., Atumurirava, F., and Samuela, J. (2021). Rapid drought assessment Tuvalu 13 October-8 November 2011: SOPAC technical report (PR38).

[130] Tuvalu NAP Project-Mission (2024).

[131] Baarsch, F., Berg, L.M.N. (2015). The Significance of Contextual Vulnerability in Effective Adaptation to Climate Change on Tuvalu. Climate Change in the Asia-Pacific Region. https://doi.org/10.1007/978-3-319-14938-7_18

[132] Tuvalu NAP Project-Mission (2024).

[133] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[134] Tekinene, M. (2014). An assessment of the impacts of climate change on cultivated pulaka (Cyrtosperma chamissonis) in Tuvalu. University of the South Pacific, Fiji.

shortages, particularly domestic pig production[135]. Droughts also reduce groundwater recharge, thinning the freshwater lens of groundwater catchments, and reducing the yield of swamp taro (pulaka) which is planted in excavated pulaka pits to access the water table[136].

Sea level rise and coastal inundation

Saline intrusion caused by sea level rise, coastal inundation and interannual sea variability has decreased the quality and availability of groundwater for domestic and agricultural use by increasing groundwater salinity and thinning freshwater lenses. Saltwater intrusion into drinking water sources has also been linked to a regional increase in the prevalence of hypertension[137].

Coastal inundation, especially during king tides and storm surge events, is also impacting Tuvalu's water infrastructure. Saline groundwater inundation of septic systems is causing pumped septic effluent from old design tanks to be discharged into adjacent properties and water catchments[138], increasing the spread of diseases including diarrhea[139]. Extreme sea level events and coastal inundation are also causing erosion which can damage low-lying water supply infrastructure, such as pipes, desalination plants and tanks, and cause sediment movement which block drains and pollutes water catchments.

Septic waste system in Tuvalu's Vaifou settlement during a flooding event. (Source: Economics of liquid waste management in Funafuti, Tuvalu (2006))

Tropical cyclones and extreme rainfall events

Surface water quality is impacted by extreme rainfall events and tropical cyclones, which can cause land-based pollution and septic effluent to enter water catchments and increase the risk of diarrhea[140]. Flooding and cyclone events can also damage water infrastructure by overwhelming Tuvalu's limited drainage systems, creating stormwater quality issues and causing septic overflow. Power outages during cyclone and flooding events can also disrupt desalination and water pump operations, with implications for disaster risk management, water quality, community health and economic activities.

Future exposure to hazards

This section discusses the future exposure of Tuvalu's water sector to key hazards.

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[135] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[136] Lloyd, G.G, Uesugi, A., and Gleadow, R.M. (2021). Effects of salinity on the growth and nutrition of taro: Implications for food security. Plants. 10:2319 doi.org/10.3390/plants10112319

[137] Talukder, M. R. R. et al. (2017). Drinking water salinity and risk of hypertension: A systematic review and meta-analysis. Archives of Environmental & Occupational Health, 72(3), 126–138. https://doi.org/10.1080/19338244.2016.1175413

[138] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[139] Lal, P. N., Saloa, K., and Uili, F. (2006). Economics of liquid waste management in Funafuti, Tuvalu. SPREP.

[140] Levy, K., et al. (2016). Untangling the impacts of climate change on waterborne diseases: a systematic review of relationships between diarrheal diseases and temperature, rainfall, flooding, and drought. Environmental science. 50(10): p. 4905-4922.

Extreme heat events

Increasingly severe extreme heat events will increase freshwater demand for both domestic and agricultural use. Desalination units will also be disrupted by power outages during more intense periods of extreme heat.

Drought

The overall impact of drought on future water security is uncertain. Projected reductions in drought duration and the frequency of *moderate* and *severe* droughts will reduce pressure on water supply and wastewater systems. However projected long-term increases in the frequency of *extreme* droughts and overall drought intensity will significantly increase stress on water resources and infrastructure (Figure 14)[141]. Future demand for water will be closely linked to changes in the population which is projected to increase from 11,478 (2024) to more than 14,000 by 2065[142], significantly increasing demand for fresh water.

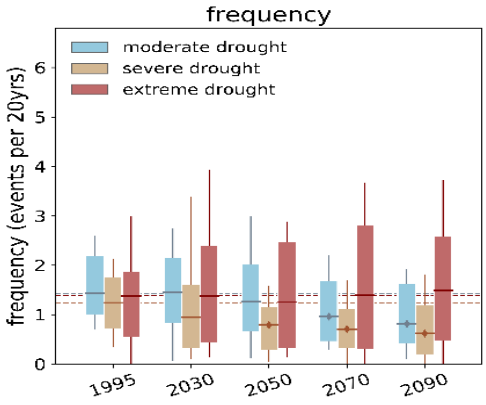


Figure 14: Projected frequency of moderate, severe and extreme droughts in Tuvalu. (Source: CSIRO, Federation University, Climate Comms. (2024))

Sea level rise and coastal inundation

Continued sea level rise and an increase in extreme sea level events will produce more frequent and widespread coastal inundation events, resulting in extensive saltwater intrusion into groundwater catchments and damage to water supply and wastewater infrastructure. The continued decline in groundwater quality and thinning of freshwater lenses will impact both crop production and human wellbeing, particularly in islands where groundwater is still relied on for pulaka cultivation and domestic use.

Low-lying water infrastructure will be increasingly exposed to groundwater flooding. Storm surge events will also increase in size with sea level rise and the projected increase in extreme windspeeds, resulting in worsening coastal erosion and more severe damage to drains, pipes, pumps, tanks and desalination plants.

Tropical cyclones and extreme rainfall events

Projected increases in extreme rainfall events will cause episodic flooding that will worsen water catchment pollution, septic overflow and drain and pipe blockages, resulting in significant infrastructure damage and an increased risk of diarrhea and other diseases. An increase in extreme rainfall events (and higher annual average rainfall) may increase water availability if sufficient capacity exists to harvest and store rainwater.

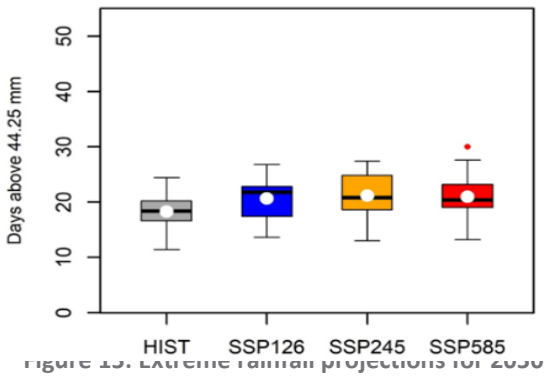


Figure 15: Extreme rainfall projections for 2050 in Funafuti. (Source: CSIRO, Federation University, Climate Comms. (2024))

While cyclone frequency is projected to decrease with low confidence, a projected increase in the intensity of cyclone

[141] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

[142] database.earth (2024). Population of Tuvalu. Accessed 2/5/2024. https://database.earth/population/tuvalu

windspeeds may reduce water security by causing ocean overtopping of barriers, resulting in further saltwater intrusion and reduced groundwater quality. There is also strong potential for storm surge and severe winds to damage water infrastructure placing additional pressures on remaining resources.

Vulnerability

This table presents sources of water security vulnerability to hazards in Tuvalu.

Hazard	Factor relevant for vulnerability
Average temperature and extreme temperature	• Water is prioritised for human health during extreme heat events, reducing water availability for livestock and crops. • Water demand is increasing with a growing population. • Reliance on energy grid to power desalination plants and sewage pumps increases vulnerability to power outages.
Drought	• Interdependence on rainwater catchments between domestic and agricultural use increases pressure on water resources and infrastructure during dry periods. • Limited storage capacity and limited land availability for storage tanks reduces water availability and water quality, especially during drought. • Maintenance of household rainwater tanks and gutters is a challenge because many homes do not have the adequate capacity to clean/maintain/flush out tanks and gutters. • Desalinated water is generally available for emergency use for people during drought but not for agriculture. • There is limited local capacity on the islands to maintain desalination units. • Sewage leakage from ageing septic tank systems on some islands compounds community health problems linked to water security issues during drought. • International aid support for disaster recovery cannot be accessed unless a State of Emergency is declared. • Poorer farmers and communities are least able to afford local water storage, irrigation infrastructure, and technologies for adaptation, increasing vulnerability of the disadvantaged. • Growing population increases demand for potable water, exacerbating the impacts of drought on water security.
Sea level rise, coastal inundation and storm surge	• Low elevation increases vulnerability of groundwater and low-lying infrastructure to saltwater intrusion. • Thin freshwater lens in groundwater catchments is sensitive to saltwater intrusion. • Old design (non-sealed) septic systems can overflow during king tides and storm surge. • Proximity of septic systems to the coast, property and water catchments increases community vulnerability to septic discharge during inundation events.
Extreme rainfall and cyclones	• Land-based pollution and sediment movement increases the vulnerability of water catchments and drains to flooding events.

	• Limited ability to capture and store rainwater reduces capacity to harvest increasing rainfall due to land availability and cost of purchasing and maintaining water tanks. • There are no specific monitoring bores to assess water quality. • There are no planned/structured communication materials pre- and post-cyclone system to raise awareness and provide informative material on maintenance of gutters.

Variations across the islands

Climate risks and impacts to water security vary according to a range of factors. These include geographical location, groundwater accessibility, water catchment and storage infrastructure, and wastewater facilities. The following water security issues have been identified for each of the nine islands:

Region	Vulnerability Issues
Funafuti	• Access to infrastructure such as water tanks has been found to be inequitable in the past[143]. • High social and economic costs of prolonged dry spells due to high population density, scarcity of land and contaminated groundwater. • Growing population will place significant pressure on water resources. • Desalination operations are reliant on the electricity grid, making the supply of desal water vulnerable to power outages during extreme heat and flooding events. • Discharge and overflow of septic effluent from non-sealed septic tanks into adjacent properties occurs because the bedrock layer is less than 1 meter below the surface and due to the close proximity of tanks to private property. This includes 'daily natural disasters' whereby groundwater inundation in and around Funafuti causes non-sealed septic tanks to flood and overflow. • Inadequate household water tank capacity. • Insufficient rainfall to meet community water security needs. • Leaky/faulty household water tanks and inability to pay for the operations/maintenance and upgrade of the household water system.
Nanumaga	• Inadequate household water tank capacity.

[143] Baarsch, F. and L.M.N. Berg. (2015). The Significance of contextual vulnerability in effective adaptation to Climate Change on Tuvalu. Climate Change in the Asia-Pacific Region. p. 301-317.

Nanumea	• According to a 2007 EU-SOPAC report[144], there is a history of comparatively reliable groundwater and more established use of wells than elsewhere in the country. • Inadequate household water tank capacity.
Niulakita	• Inadequate household water tank capacity. • Poor groundwater quality (not suitable for drinking). • Insufficient rainfall to meet community water security needs. • Scored as island with the lowest water security [145].
Niutao	• Pollution from wastewater. • Insufficient existing natural water sources to support water security needs. • Ongoing waste management and biosecurity issues, with no appropriate solutions identified.
Nukufetau	• According to a 2007 EU-SOPAC report[146], there is a history of comparatively reliable groundwater and more established use of wells than elsewhere in the country[147].
Nukulaelae	• Inadequate household water tank capacity. • Increasing groundwater salinity. • Insufficient rainfall to meet community water security needs.
Nui	• According to a 2007 EU-SOPAC report[148], there is a history groundwater and more established use of wells than elsewhere in the country[149]. • Inadequate household water tank capacity. • Inadequate communal water tank capacity.
Vaitupu	• Insufficient existing natural water sources to support water security needs.
Outer Islands	• Desalination plants are increasingly powered by solar with battery storage or generators, reducing vulnerability to mains power outages.

[144] Webb, A. (2007). Assessment of salinity of groundwater in swamp taro (Cyrtosperma chamissonis)"Pulaka" pits in Tuvalu. EU EDF8-SOPAC Project report Suva, Fiji, SOPAC, 75, 37.

[145] CSIRO (2024). Tuvalu Integrated Vulnerability Assessment Draft Report.

[146] Webb, A. (2007). Assessment of salinity of groundwater in swamp taro (Cyrtosperma chamissonis)"Pulaka" pits in Tuvalu. EU EDF8-SOPAC Project report Suva, Fiji, SOPAC, 75, 37.

[147] Webb, A. (2007). Assessment of salinity of groundwater in swamp taro (Cyrtosperma chamissonis)"Pulaka" pits in Tuvalu. EU EDF8-SOPAC Project report Suva, Fiji, SOPAC, 75, 37.

[148] Webb, A. (2007). Assessment of salinity of groundwater in swamp taro (Cyrtosperma chamissonis)"Pulaka" pits in Tuvalu. EU EDF8-SOPAC Project report Suva, Fiji, SOPAC, 75, 37.

[149] Webb, A. (2007). Assessment of salinity of groundwater in swamp taro (Cyrtosperma chamissonis)"Pulaka" pits in Tuvalu. EU EDF8-SOPAC Project report Suva, Fiji, SOPAC, 75, 37.

Complex risks

Water security risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Infrastructure:** Extreme heat events and tropical cyclones will increase demand for desalinated water, whilst also causing power outages that disrupt desalination plants.
- **Human health & well-being:** Droughts reduce water quality while also causing a decline in community hygiene and sanitation practices, leading to high disease and infection rates.
- **Agriculture:** Extreme heat events and droughts can significantly impact agriculture because water is prioritised for people during these events, whilst heat-stress harms and destroys livestock and crops.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R7 – Water availability	**Extreme drought** Drought-induced water scarcity causes major declines in community health, workforce productivity and agricultural yield.	**Major**	As a result of the interdependence on limited water storage infrastructure between domestic and agricultural water use, up to 70% of Tuvalu inhabitants still lack access to adequate catchment and storage capacity to face during historically long dry spells.
R7 – Water demand	**Extreme heat** Extreme heat events significantly increase demand for potable water.	**Moderate**	Extreme heat events are placing pressure on Tuvalu's limited supply of freshwater by significantly increasing freshwater demand for both domestic consumption and agricultural uses, such as stock watering and crop irrigation.
R7 – Water quality	**Saline intrusion due to sea level rise** Saltwater intrusion reduces groundwater quality and thins the freshwater lens supporting some crop production.	**Major**	Saltwater intrusion makes groundwater brackish and not suitable for drinking, reducing the cultivation of pulaka and other staple crops, and diminishing the availability of groundwater for domestic use in some communities.
R8 – Water infrastructure	**Coastal inundation from king tides and storm surge events** Water infrastructure is damaged through saline intrusion, erosion and sediment movement, and flooding.	**Major**	Coastal inundation from king tides and storm surge events damages water infrastructure through saline intrusion which causes water quality of reservoirs to decline, and flooding which causes septic tanks to overflow and pumps and drains to become blocked by sediment and pollution. This damage to

		water infrastructure is having major impacts on water security, community health and agricultural productivity in Tuvalu.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R7 – Water availability	**Extreme drought** Drought-induced water scarcity causes major declines in community health, workforce productivity and agricultural yield.	**Major**	Projected increase in the intensity of extreme droughts will cause periods of severe water stress. As a result, the drought-induced consequences for community health, economic activities and agricultural productivity in Tuvalu will be more extreme, particularly on islands without significant water infrastructure or reliable groundwater to support both domestic and agricultural water needs during prolonged dry periods.
R7 – Water demand	**Extreme heat** Extreme heat events significantly increase demand for potable water.	**Moderate**	Periods of extreme heat will compound the impacts of increasing average temperature by increasing water demand across sectors. The consequences will be most significant for the agriculture sector as water is prioritised for domestic use. Population growth may further increase water demand.
R7 – Water quality	**Saline intrusion due to sea level rise** Saltwater intrusion reduces groundwater quality and thins the freshwater lens supporting some crop production.	**Major**	Groundwater salinity will continue to increase as sea levels rise (9-17cm). Declining groundwater quality will cause pulaka cultivation to decline or cease on islands with limited groundwater reserves and reduce domestic water security on islands with a history of comparatively reliable groundwater and established use of wells, such as Nui, Nanumea and Nukufetau, affecting the water security, food security and livelihoods of island communities.

R8 – Water infrastructure	**Coastal inundation from king tides and storm surge events** Water infrastructure is damaged through saline intrusion, erosion and sediment movement, and flooding.	**Major**	More frequent coastal inundation events will continue to increase the salinity of groundwater reservoirs, as well as cause erosion and flooding that damages pumps, drains, treatment plants and wastewater infrastructure. As a result, the cultivation of groundwater-reliant crops will decline and the spread of infections and waterborne diseases including diarrhea will increase, particularly in communities with aging septic systems and limited desalination capabilities.

2050 High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R7 – Water availability	**Extreme drought** Drought-induced water scarcity causes major declines in community health, workforce productivity and agricultural yield.	**Extreme**	Despite the projected decrease in overall drought frequency and duration, the projected increase in extreme droughts and drought intensity will significantly reduce water availability, compounding the impacts of reduced groundwater quality and increasing water demand. Extreme droughts occurring in the high emissions scenario will place extreme pressure on already stressed water resources, with severe consequences for community health, economic activities and agricultural productivity in Tuvalu, including food shortages and spread of diseases. Development of desalination capabilities and projected increases in rainfall may provide greater resilience and increased water availability during periods of drought provided there exists adequate water catchment and storage infrastructure.
R7 – Water demand	**Extreme heat** Extreme heat events significantly increase demand for potable water.	**Major**	An annual-average increase of 140-331 days over 33°C will significantly increase water demand during extreme heat events with major consequences for human health, economic activities and agricultural productivity in Tuvalu. Population

			growth will further increase domestic water demand, exposing livestock to worsening heat stress
R7 – Water quality	**Saline intrusion due to sea level rise** Saltwater intrusion reduces groundwater quality and thins the freshwater lens supporting some crop production.	**Extreme**	Increasing sea level rise (19-37 cm) will cause widespread saline intrusion into groundwater catchments, continuing to affect the viability of subsistence crop production with significant impacts to the agriculture workforce. Food production will significantly decrease leading to food shortages and a loss of cultural practices tied to traditional agriculture practices such as pulaka pits. As the quality of groundwater catchments declines, increased pressure will be placed on surface water to meet domestic and agricultural demands. These compounding impacts will be more severe in the high emissions scenario given the greater pressure on water resources under these projections.
R8 – Water infrastructure	**Coastal inundation from king tides and storm surge events** Water infrastructure is damaged through saline intrusion, erosion and sediment movement, and flooding.	**Extreme**	Frequent and widespread coastal inundation caused by continued sea level rise (19-37 cm) will lead to saline intrusion of groundwater reservoirs that reduces the availability of groundwater for domestic and agricultural use. Coastal inundation caused by storm surges will be made more severe by the predicted increase in cyclone intensity, extreme rainfall events and sea levels, causing severe flooding and coastal erosion that may overwhelm wastewater infrastructure, treatment plants, drains and pumps. Flooding-induced power outages may impact the operation of desalination plants, with extreme consequences for community health.

2050 Low emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R7 – Water availability	**Extreme drought** Drought-induced water scarcity causes major declines in community health, workforce productivity and agricultural yield.	**Extreme**	Despite the projected decrease in overall drought frequency and duration, the projected increase in extreme droughts and drought intensity will significantly reduce water availability in Tuvalu, compounding the impacts of reduced groundwater quality and increasing water demand. Even in the low emissions scenario, extreme drought will place extreme pressure on water resources with severe consequences for community health, economic activities and agricultural productivity in Tuvalu, including reduced yield and increased infection rates. Development of desalination capabilities and projected increases in rainfall may provide greater resilience and increased water availability during periods of drought provided there exists adequate water catchment and storage infrastructure.
R7 – Water demand	**Extreme heat** Extreme heat events significantly increase demand for potable water.	**Major**	An annual-average increase of 140-331 days over 33°C will compound the impacts of population growth to increase water demand during extreme heat events, placing pressure on domestic and agricultural water security with major consequences for agricultural productivity in Tuvalu
R7 – Water quality	**Saline intrusion due to sea level rise** Saltwater intrusion reduces groundwater quality and thins the freshwater lens supporting some crop production.	**Major**	Sea level rise under a low emissions scenario is projected to be 17-29 cm. Saline intrusion due to sea level rise will continue to reduce groundwater-reliant crop production with major consequences for subsistence farming, impacting the livelihoods, cultural practices and food supply of the population, as well as causing a decline in economic output from the industry.
R8 – Water infrastructure	**Coastal inundation from king tides and storm surge events**	**Extreme**	Sea level rise under a low emissions scenario (17-29 cm) will produce more frequent extreme sea level events and combine with more intense tropical

	Water infrastructure is damaged through saline intrusion, erosion and sediment movement, and flooding.		cyclones to cause saltwater intrusion and storm surge flooding that may disrupt the capture, storage and treatment of potable water. Community access to clean water may be inhibited with extreme consequences for community health.

Confidence

Component	Hazard	Confidence score	Comments
Water demand	**Extreme heat**	**Medium**	• There is no projection data for extreme heat events in 2030. • The detailed quantitative relationship between extreme heat and water demand is unknown.
Water availability	**Drought**	**Medium**	• Although the current impact of drought on water security in Tuvalu is well-established, there is no 2050 low emissions scenario specific projection for drought intensity/frequency/duration. • Improvements to water catchment and desalination capabilities may reduce impact of extreme drought on water availability.
Water quality	**Sea level rise**	**Medium**	• Location of Tuvalu groundwater catchments is unknown, limiting the understanding of exposure to saline intrusion. • The relationship between sea level rise and saline intrusion was also not known.
Water infrastructure	**Coastal inundation from king tides and storm surge**	**Medium**	• Location of Tuvalu water infrastructure is not known across all islands, limiting the understanding of exposure to saline intrusion, erosion and flooding.

Knowledge Gaps

- Limited information regarding the exposure of Tuvalu's critical water infrastructure to saline intrusion and erosion.

5.6 Disaster risk management

Summary of this sector in Tuvalu

Tuvalu is one of the most vulnerable countries in the world to disasters and the impacts of climate change due to its isolation, small land area and average elevation of only 1.83 meters[150]. The National Disaster Management Office (NDMO) works in accordance with the Disaster Management Act (2007) and Department of Disaster Management (DDM) to coordinate Tuvalu's disaster mitigation, preparedness, response, and recovery activities. The National Disaster Committee (NDC) is the multiagency advisory and coordination body established to advise disaster management authorities.

Given its significant exposure and vulnerability to hazards, Tuvalu places emphasis on disaster risk awareness and preparedness, including early warning systems, public awareness campaigns and community training. Disaster readiness and reduction projects are particularly important because disaster protection infrastructure projects have generally been unable to provide sustained protection to infrastructure[151], especially during tropical cyclone and coastal inundation events. For example, the installation of desalination plants on all islands is a key disaster readiness capability designed to ensure communities can access emergency water resources during and immediately after disasters[152].

Early warning systems are also critical to reducing the impacts of disasters on community health and infrastructure. Currently, early warnings are provided to communities for cyclones, tsunamis and droughts[153]. No specific warnings are provided for heatwaves and king tides which are instead reported through daily weather bulletins. The NDMO notifies island councils of potential natural disasters using VHF radio, or Chatty Beetle for the Outer Islands, in addition to emails to key personnel and posts on official Facebook pages[154]. Island councils are expected to notify local communities of disasters, however communication breakdowns often occur, leaving communities unaware of potential hazards[155].

To protect vulnerable communities during disasters, Tuvalu has 48 designated evacuation centres that provide refuge and resources during cyclone, flooding and inundation events[156]. A variety of communal buildings are used as evacuation centres including schools, government buildings, community halls and purpose-built evacuation shelters. Although evacuation centres are primarily used during disasters (such as cyclones and flooding events), households which suffer significant damage during these events may stay at evacuation centres until their houses are reconstructed[157]. This can put pressure on evacuation centre resources, especially designated schools which do not have kitchen facilities. Accessibility to evacuation centres can also be a challenge for people with disabilities and the elderly due to the lack of ramps and air conditioning systems in many facilities. This reduces the effectiveness and useability of evacuation centres, particularly during extreme heat events[158].

[150] Tui, S., & Fakhruddin, B. (2022). Food for thought: Climate change risk and food (in) security in Tuvalu. Progress in Disaster Science, 16, 100255.

[151] Tuvalu's Second National Communication to the UNFCCC (2015)

[152] Tuvalu NAP Project-Mission (2024).

[153] Tuvalu NAP Project-Mission (2024).

[154] Tuvalu NAP Project-Mission (2024).

[155] Tuvalu NAP Project-Mission (2024).

[156] Tuvalu NAP Project-Mission (2024).

[157] Tuvalu NAP Project-Mission (2024).

[158] Tuvalu NAP Project-Mission (2024).

Disaster response activities in Tuvalu are supported by international partners who provide technical expertise, funding and resources. Following disasters, the Red Cross provides cash vouchers to affected households to purchase basic items as well as supplying other emergency needs such as blankets and tents[159]. The Red Cross does not maintain an emergency supply of food, medicine or medical equipment, with local health centres instead relied on for medical goods[160].

Gaining access to timely funding for disaster risk management can be a challenge because Tuvalu can only access support from the World Bank and Asian Development Bank (ADB) Disaster Response Fund when a State of Emergency is declared[161]. As a result, international funding generally supports disaster response activities, with a lack of support for disaster risk reduction initiatives. Even during disasters, uncertainty in weather predictions and a lack of clarity in emergency declaration criteria and thresholds can delay State of Emergency declarations. This can inhibit access to critical funding for emergency disaster response initiatives. For example, in 2022 Nanumea experienced a prolonged drought from January to November but a State of Emergency was only announced in June because there was uncertainty about how long the drought would persist[162].

The following risk statement (**R9**) has been developed through consultation during the Tuvalu NAP Project-Mission (2024). It discusses the risks that climate change present for disaster management that have been identified and analysed.

R9: Risks to Disaster Management

Chronic climate change and increased frequency and intensity of acute hazards will increase the frequency and intensity of climate-related natural disasters, including coastal inundation and flooding, TCs, drought and heatwaves. This will increase demand for systems and infrastructure to support citizens to prepare for, seek refuge and recover from such disasters. This includes enhanced early warning systems for droughts, cyclones and floods, and critical infrastructure such as communal air-conditioned refuges and evacuation centres and associated access routes, and myriad essential services across multiple public sector amenities and utilities. New and/or refitted/re-purposed infrastructure intended for disaster risk refuge/evacuation purposes will need to be built according to new climate resilient building codes and associated engineering design specifications. This will increase the demand for capital expenditure and dependence on international aid for disaster preparedness initiatives, disaster refuges/evacuation centres and post disaster impact assessments and recovery efforts, including compensation to affected households. Increased incidence and severity of climate-related natural disasters may also negatively impact community (physical and mental) health and psycho-social wellbeing.

Risk Summary

Disaster risk management in Tuvalu is at risk from climate change through chronic and acute climate change events including sea level rise, coastal inundation and storm surges, an increase in the severity of extreme heat and rainfall events, droughts, tropical cyclones and extreme windspeed. These events damage and destroy infrastructure and natural resources, impacting human health, livelihoods, food and water security, and economic activities. In addition to impacting energy, trade, housing, transport, health,

[159] Tuvalu NAP Project-Mission (2024).

[160] Tuvalu NAP Project-Mission (2024).

[161] Tuvalu NAP Project-Mission (2024).

[162] Tuvalu NAP Project-Mission (2024).

water and coastal infrastructure, climate change events also threaten the evacuation centres designed to keep people safe during disasters. As a result of the significant cross-sector/domain impacts of disasters in Tuvalu, there is substantial demand for capital expenditure, recovery funding and emergency services, especially early warning systems, evacuation centres, disaster risk reduction initiatives and impact assessments, to reduce the impact of disaster events.

Current exposure to hazards

This section discusses the exposure of Tuvalu's disaster risk management sector to key hazards.

Extreme heat events

Currently, there is approximately 1 death per month from heat stress in Funafuti[163]. This mortality rate is increasing with rising temperatures and extreme heat events driven by climate change[164]. As a result, extreme heat events drive demand for access to air-conditioned refuges and emergency water supplies to meet domestic needs and for agricultural purposes, such as stock watering and crop irrigation. In addition to impacting human health and agricultural productivity, extreme heat events can affect evacuation centres by damaging and disrupting the critical power and water infrastructure supporting the shelters.

Drought

Drought reduces water availability and reduces water quality. These factors can have significant impacts on agricultural productivity and on community health, wellbeing and livelihoods. As a result of these widespread impacts, droughts generate significant community demand for disaster response initiatives, such as emergency water supply from desalination plants, impact assessments and remedial action. Reduced water availability and quality during droughts also results in poor hygiene and sanitation practices across Tuvalu, generating demand for emergency health services during water shortages. As a result, the Department of Health carries out water quality testing and community WASH awareness activities.

Tropical cyclones and extreme rainfall

Tropical cyclones, and associated storm surges, extreme winds and flooding, are one of the biggest risk factors triggering natural disasters in Tuvalu, with an average of 12 cyclones per decade. Cyclones cause significant loss of property, damage to public and private infrastructure, and disruption to services. In 2015, Cyclone Pam struck Tuvalu causing damages that resulted in more than 25% of national GDP, including flooding damage to ancestral graves on Nui and damage to the Nukufetau seawall[165]. The extreme threat posed by cyclone-related winds, inundation and flooding drives demand for early warning systems, disaster reduction projects and evacuation centres to reduce the impact of cyclones, as well as post-disaster impact assessments and financial compensation for losses and damages to individual landowners and public entities.

Tropical cyclones and extreme rainfall events also damage evacuation centres and disrupt the critical infrastructure and essential services supporting evacuation shelters including power, roads, transport, telecommunications and water. Exposure of evacuation centres during tropical cyclones threatens community health and safety given the reliance on, and large gatherings within, evacuation centres for

[163] (Jan 2024). Tuvalu Mission Summary Report. Tuvalu_Inception Mission summary report

[164] (Jan 2024). Tuvalu Mission Summary Report. Tuvalu_Inception Mission summary report

[165] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

shelter and resources during these events. For example, during cyclone Tino in January 2020 hundreds of people on Funafuti evacuated from their homes and took shelter at designated evacuation centres including the hospital, the government building, and Nauti Primary School[166]. Even if evacuation centres are not directly exposed to disasters, flooding and road blockages can threaten human health by disrupting access to evacuation centres.

Sea level rise and coastal inundation

Sea level rise and coastal inundation (particularly during king tides and storm surge events) drives demand for emergency services by disrupting roads and infrastructure, increasing soil salinity, contaminating groundwater, and causing coastal erosion. King tides are occurring every year with increasing maximum wave heights, causing more widespread damage and increasing demand for early warnings, disaster risk reduction initiatives and post-disaster support. In Funafuti, emergency services are now responding to 'daily natural disasters' with groundwater inundation causing old (non-sealed) septic tanks to overflow into adjacent properties[167].

Coastal inundation is also the primary hazard threatening evacuation centres in Tuvalu. Currently, at least 21 of Tuvalu's 48 designated evacuation centres are exposed to a one-in-five-year coastal inundation event (noting exposure data is not available for 5 centres).

Future exposure to hazards

This section discusses the future exposure of Tuvalu's disaster risk management sector to key hazards.

Extreme heat events

Projected increases in extreme heat events will increase demand for early warning systems, communal air-conditioned refuges and emergency water resources to meet domestic and agricultural needs. It is broadly recognised that the National Building Code for Tuvalu needs to include engineering specifications for evacuation shelters to both reduce centre exposure to hazards and to ensure centres can provide vulnerable communities with refuge from increasingly severe heatwaves[168]. In addition to increasing the demand for evacuation shelters, increasingly severe extreme heat events will impact evacuation centres by increasing pressure on the power and water infrastructure that support evacuation centres.

Drought

Projected reductions in both drought duration and the frequency of *moderate* and *severe* droughts will reduce demand for emergency services. However, projected increases in drought intensity and extreme droughts will increase demand for early warning systems and emergency water resources to meet domestic and agricultural needs. Demand for funding and resourcing to support disaster response projects, impact assessments and remedial action will also likely increase.

[166] Tima, S. (2023). Coastal Inundation in Tuvalu (arcgis.com)

[167] (Jan 2024). Tuvalu Mission Summary Report. Tuvalu_Inception Mission summary report

[168] Tuvalu NAP Project-Mission (2024).

Tropical cyclones and extreme rainfall

Increasing extreme rainfall events and low confidence projections for more intense tropical cyclones will generate extreme windspeeds, widespread flooding, coastal erosion and inundation, freshwater contamination and risks to human safety. As a result, there will be increased demand for disaster risk management authorities to provide early warnings, shelter and post-disaster emergency services to protect increasingly exposed communities.

Increasing extreme rainfall events, and potentially more intense cyclones, will also increase the exposure of evacuation centres to damage from flooding and debris, challenging the climate-resilience of shelters as well as disrupting supporting infrastructure including power supply, water, food, transport, roads and telecommunication systems.

The increasingly extreme impact of these disasters is driving demand among communities for greater emphasis on disaster preparedness in future disaster risk management. Suggested measures to reduce the impact of increasingly severe cyclone and inundation events include a stricter National Building Code, more climate-resilient infrastructure and cutting down trees and branches that could pose a risk during extreme winds[169].

Sea level rise and coastal inundation

Rising sea levels will increase the frequency and severity of inundation events, leading to coastal erosion, saline intrusion, and increasingly severe risks to community safety. As a result there will be increased demand for emergency services to protect public and private infrastructure, maintain access to food, power and water resources, provide shelter during inundation events and to conduct post-disaster impact assessments.

More frequent and widespread extreme sea level events will also significantly increase the exposure of existing evacuation centres to coastal inundation. Under both medium and high emissions projections, more than 55% of existing evacuation centres will be exposed to a one-in-five-year inundation event by 2060 (Figure 16). The resulting impacts on community health and wellbeing will become more severe as community reliance on evacuation centres increases with more severe disasters.

[169] Tuvalu NAP Project-Mission (2024).

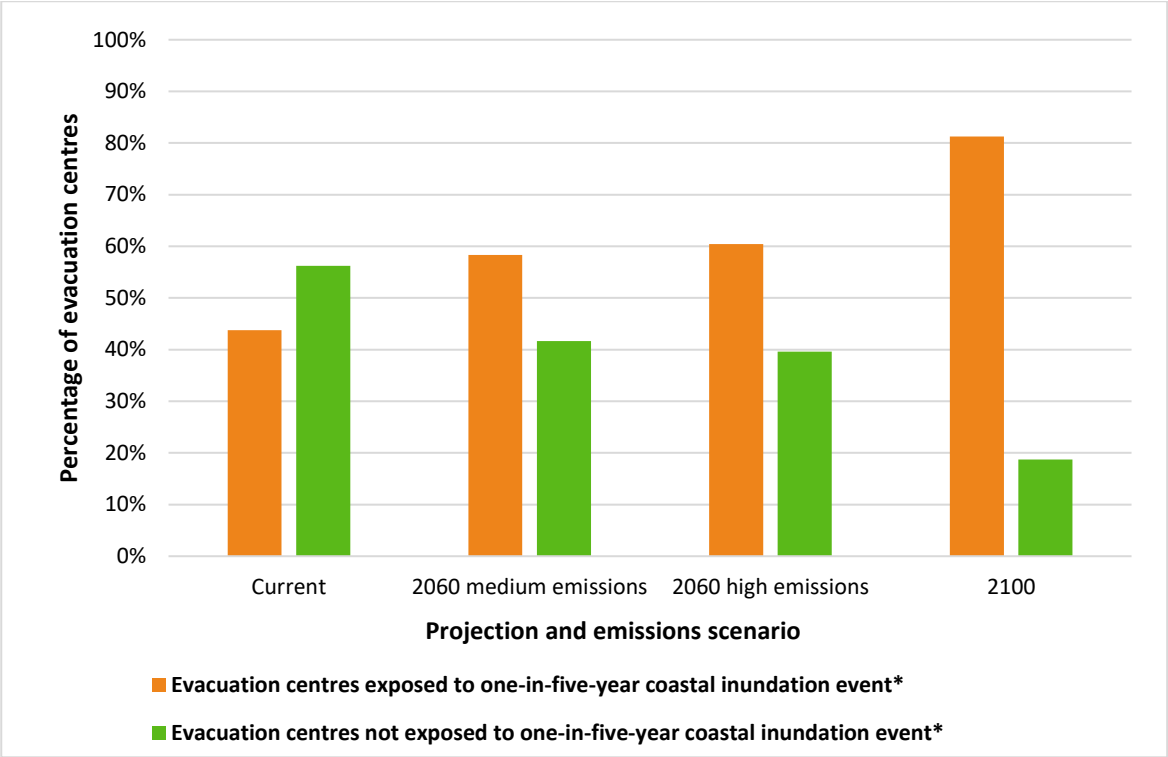


Figure 16: Exposure of evacuation centres to a one-in-five-year inundation event in different scenarios
***Exposure data not available for 5 evacuation centres**
(Data source: TCAP, WB climate change risk assessment of school buildings in Tuvalu, Tuvalu NAP Project-Mission (2024)).

Tuvalu is developing its disaster management capabilities through island-specific Strategic Plans (2021-24). This includes the recent construction of purpose-built evacuation centres on Nanumea and Niutao, and the introduction of new protocols on Funafuti to ensure proposed evacuation centres meet sufficient standards. As a result of this development, no evacuation centres on Nanumea, Niutao and Niulakita are projected to be exposed to one-in-five-year inundation events this century. Evacuation centres on all other islands will be increasingly exposed to inundation, with significant impacts on community health and wellbeing during disaster events.

Vulnerability

This table presents sources of disaster risk management vulnerability to hazards in Tuvalu.

Hazard	Factor relevant for vulnerability
Extreme heat	• Many evacuation centres do not have air conditioning. • Reliance on energy grid increases the impact of power outages on disaster response activities (e.g. air conditioning and food storage). • Vector-borne food safety issues occur at higher temperatures, increasing risk of community illness and demand for health and food resources during extreme heat events.
Drought	• Limited water storage capacity and interdependence on rainwater catchments between domestic and agricultural use reduces water

	availability and water quality during drought, increasing demand for emergency water supply. • Emergency water supply is generally reserved for human use, increasing vulnerability of agricultural sector. • Poor WASH/sanitation practices during water shortages increase the risk of community illness, thus increasing demand for emergency health services. • Limited ability on some islands to maintain desalination plants and provide emergency water. • Sewage leakage from ageing septic tank systems on some islands compounds community health problems linked to sanitation, water quality and water availability issues during drought.
Sea level rise and coastal inundation (king tides and storm surge)	• Low elevation increases vulnerability of communities and infrastructure, including evacuation centres, to inundation. • Old design (non-sealed) septic systems can overflow during king tides and storm surge, causing septic discharge that affects community health and water security increasing demand for emergency services. • Lack of clarity/consistency on the 'triggers' for natural disaster declarations as regional/national/sub-national jurisdictions for certain events (e.g. storm surge, king tides, extreme temperatures and drought).
Extreme rainfall and cyclones	• Tuvalu can only access funding from the World Bank & ADB Disaster Funds when a State of Emergency is declared, with a lack of support for disaster reduction initiatives. • There is often a communication breakdown in early warning systems with communities not adequately informed of potential hazards. • Post-disaster communication is also a challenge with island councils, it can take 1-2 weeks to receive feedback on disaster impact on the Outer Islands. • Accessibility to evacuation centres for people with disabilities and the elderly can be a challenge (e.g. no ramps, steps). • Community halls are often not equipped to meet requirements of an evacuation centre. • Schools used as evacuation centres lack kitchens for longer stays. • The 4G network is still being developed for Outer Islands and there is no integrated early warning system linked to Tuvalu telecom NextG network for (climate-related) natural disasters, increasing vulnerability to cyclone events. • There is no structured capacity building program to improve community gutter maintenance and reduce cyclone impacts. • Limited or no certified carpenters on some islands.

Variations across the islands

Climate risks and impacts to disaster risk management vary according to geographical location, disaster risk reduction infrastructure, warning systems and response capabilities. The following island-specific disaster risk management issues have been identified across Tuvalu:

Region	Vulnerability Issues
Funafuti	• Demand for emergency services is particularly high in Fongafale given the central portion of the densely populated islet is already below high spring tide level, resulting in regular saline flooding of low-lying areas. • Low resilience of shoreline protection structures to disasters.
Nanumaga	• Low resilience of health buildings and equipment to disasters (cyclone/storm/inundation and droughts). • Inadequate housing increases vulnerability to physical safety during cyclones, storms and other acute climate events.
Nanumea	• Presence of meteorological towers enables use of VHF radios, enhancing disaster communications and reducing vulnerability. • New purpose-built evacuation centre reduces vulnerability.
Niulakita	• Presence of meteorological towers enables use of VHF radios, enhancing disaster communications and reducing vulnerability. • Scored as most vulnerable island to disasters[170].
Niutao	• New purpose-built evacuation centre reduces vulnerability.
Nukufetau	• Inability to pay for medical response to disaster induced injuries/illnesses and health needs (water borne disease/malnutrition). • Inadequate housing and evacuation centre infrastructure increases vulnerability to cyclones, storms and other acute climate events.
Nui	• Presence of meteorological towers enables use of VHF radios, enhancing disaster communications and reducing vulnerability. • No purpose-built evacuation centre and inadequate housing increases vulnerability to cyclones, storms and other acute climate events.
Vaitupu	• Limited or no ability to pay for post-disaster housing reconstruction. • Inadequate evacuation centres increases vulnerability to cyclones, storms and other acute climate events.

[170] CSIRO (2024). Tuvalu Integrated Vulnerability Assessment Draft Report.

Outer Islands	• Chatty Beetles and other secondary forms of communication used to communicate disaster warnings are often inadequate to transfer messages. • Post-disaster communication can take 1-2 weeks to receive feedback on disaster impact, increasing the demand for emergency services to provide reliable disaster warning and response systems.

Complex risks

Risks to disaster risk management can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Infrastructure:** Extreme heat events increase demand for emergency water and air-conditioned refuges while also causing power outages and disruptions to infrastructure that inhibits desalination operations and the provision of cool shelters.
- Storm surge, cyclones and extreme sea level rise events increase demand for evacuation centres and expose shelters to damage, whilst also placing pressure on supporting infrastructure. This includes disruptions to transport and supply chains (leading to potential short-term food shortages), power supply, telecommunications and water infrastructure, affecting both vulnerable communities and the operation of evacuation centres.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R9 – Demand for emergency services	**Coastal inundation from king tides and tropical cyclone-induced storm surge** High community vulnerability to natural disasters places pressure on emergency services to protect human health, property, infrastructure and livelihoods, especially during inundation and flooding events.	**Moderate**	Coastal inundation, driven by king tides and storm surges, particularly during tropical cyclone events, produce massive flooding events that cause significant demand for emergency services including coastal protection infrastructure, early warning systems and evacuation centres to enhance preparedness and reduce the impact of coastal inundation, as well as demand for post-disaster recovery assistance to repair massive damage and provide compensation to affected communities.
R9 – Evacuation centres	**Coastal inundation from king tides and tropical cyclone-induced storm surge** Evacuation centres which have protected hundreds of people during two major tropical cyclones in the past decade are threatened by inundation and flooding.	**Major**	Coastal inundation from king tides and tropical cyclone-induced storm surge also threatens evacuation centres with 24 of 48 existing evacuation centres exposed to flooding from a one-in-five-year coastal inundation event. This threatens the health and safety of communities who do not have adequate disaster protection, particularly during tropical cyclones.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R9 – Demand for emergency services	**Coastal inundation from king tides and tropical cyclone-induced storm surge** High community vulnerability to natural disasters places pressure on emergency services to protect human health, property, infrastructure and livelihoods, especially during inundation and flooding events.	**Major**	Continued sea level rise (9-17cm) will drive coastal inundation events, threatening infrastructure, property, agriculture, human health and water security. There will be major demand for emergency services to prepare and manage the impacts of coastal inundation events.
R9 – Evacuation centres	**Coastal inundation from king tides and tropical cyclone-induced storm surge** Evacuation centres which have protected hundreds of people during two major tropical cyclones in the past decade are threatened by inundation and flooding.	**Major**	Inundation events will continue to increase in magnitude and frequency with continued sea level rise (9-17 cm), increasing the exposure and damage to evacuation centres. Resulting impacts on community health and wellbeing will increase in severity as community reliance on evacuation centres increases with more severe disasters.

2050 High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R9 – Demand for emergency services	**Coastal inundation from king tides and tropical cyclone-induced storm surge** High community vulnerability to natural disasters places pressure on emergency services to protect human health, property, infrastructure and livelihoods, especially during inundation and flooding events.	**Extreme**	Projected increase in the intensity of tropical cyclones and continued sea level rise (19-37 cm) will increase the severity and frequency of coastal inundation events by increasing the size of king tides and storm surge events. Demand for emergency services, especially early warning systems, risk reduction and disaster response activities, will also increase as the risk to infrastructure and human health becomes extreme. The development of disaster preparedness, warning, reduction, response and recovery capabilities will help meet the increased demand for emergency services during coast inundation events.
R9 – Evacuation centres	**Coastal inundation from king tides and tropical cyclone-induced storm surge** Evacuation centres which have protected hundreds of people during two major tropical cyclones in the past decade are threatened by inundation and flooding.	**Major**	Increasingly widespread and frequent coastal inundation, driven by sea level rise (19-37 cm) and an increase in cyclone intensity, will result in increasing exposure of evacuation centres to inundation. Every evacuation centre on Nukulaelae and Nukufetau will be exposed to inundation, whilst no evacuation centres on Nanumea, Niutao and Niulakita will be exposed. Communities without access to an adequate evacuation centre will be extremely vulnerable to worsening flooding, inundation, extreme heat and cyclone events with significant impacts on human health and wellbeing. An improvement in building standards and further development of evacuation shelters may reduce the effects of coastal inundation and cyclone events on evacuation centres.

2050 Low Emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R9 – Demand for emergency services	**Coastal inundation from king tides and tropical cyclone-induced storm surge** High community vulnerability to natural disasters places pressure on emergency services to protect human health, property, infrastructure and livelihoods, especially during inundation and flooding events.	**Extreme**	Projected sea level rise of 17-29 cm, as well as whilst low confidence projections for increased cyclone intensity, will increase the frequency and severity of coastal inundation and erosion in a low emissions scenario. The demand for emergency services will also increase as inundation causes widespread damage and destruction, impacting infrastructure, human health and agricultural activities.
R9 – Evacuation centres	**Coastal inundation from king tides and tropical cyclone-induced storm surge** Evacuation centres which have protected hundreds of people during two major tropical cyclones in the past decade are threatened by inundation and flooding.	**Major**	Projected increases in the intensity of tropical cyclones and continued sea level rise (17-29 cm) will increase the severity of coastal inundation events, increasing the extent of damage caused to evacuation centres and threatening community safety. The impact on community health and wellbeing will vary across islands, with every evacuation centre on Nukulaelae and Nukufetau projected to be exposed to inundation, whilst no evacuation centres on Nanumea, Niutao and Niulakita projected to be exposed. Improved building standards and purpose-built evacuation centres may reduce exposure of shelters, and thus lessen the impacts of increasingly severe disaster events on vulnerable communities by providing protection.

Confidence

Component	Hazard	Confidence score	Comments
Demand for emergency services	**Coastal inundation from king tides and storm surge**	**Medium**	• The disaster risk management-related impacts from past coastal inundation events are well established. • Low confidence in cyclone intensity projections reduces confidence from high to medium.
Evacuation centres	**Coastal inundation from king tides and storm surge**	**Medium**	• There is no coastal inundation exposure data for five evacuation centres. • Although 2060 exposure projections are detailed, the lack of coastal inundation exposure projections for 2030 and low confidence in cyclone intensity projections reduces the confidence score.

Knowledge Gaps

- Lack of information regarding local disaster response and impact assessment processes.

5.7 Coastal protection

Summary of this domain in Tuvalu

With the threat of rising sea levels and coastal inundation, coastal protection is a vital domain in Tuvalu helping to secure livelihood and economic prospects. Severe weather and coastal inundation events act to disrupt economic operations and cause harm to the people and their property as well as vital infrastructure (see section 5.8). There can also be permanent damages to the coastline.

Currently, there are sea walls which mitigate the effects of strong waves during tropical cyclones and high tide related events such as king tides. Land reclamation projects are also underway to reduce erosion, increase land availability and support coastal protection infrastructure.

Seawall in Tuvalu. (Source: Tuvalu NAP Project-Mission 2024.)

Protection is not limited to manmade structures, but also includes natural assets such as coral reefs and tree canopies. Reefs absorb wave energy and reduce coastal erosion, while tree canopies provide natural shade to communities during extreme heat events, they also reduce erosion through their root systems. Urbanisation and coastal erosion are reducing the space available for large trees in Tuvalu, exacerbating the health-related risks of extreme heat events on island communities.

The following risk statement (**R10**) has been developed through consultation during the Tuvalu NAP Project-Mission (2024). It discusses the risks that climate change present for coastal assets and flood defence structures that have been identified and analysed.

R10: Risks to coastal assets and flood defence structures:

Increasing chronic and acute climate hazards, including sea level rise and stronger tropical cyclones, will cause physical damage from storm-surge/inundation, water-logging/salinisation, erosion and salt-spray, and increase repair and maintenance costs for existing coastal and flood defence infrastructure (e.g., sea walls, levees, lagoon protection infrastructure, coral reefs etc.) and related public and private assets (homes, public buildings, roads, drainage systems, causeways, harbours and jetties, airport runways, septic tanks, water reticulation systems, energy distribution systems and telecommunications infrastructure etc)(see also R11). The damage to this coastal infrastructure, as well as the destruction of coral reefs that provide a natural barrier absorbing wave energy, can further expose coastal areas to the impacts of these hazards as well as compound the impacts on other priority sectors and systems. Natural shade from large tree canopies (e.g. bread fruit and ironwood) may also decrease due to clearing (e.g. for agricultural or urban development) and/or climate-related environmental damage (e.g. drought, soil salinisation, coastal erosion), thereby exacerbating extreme heat impacts on local communities.

Risk Summary

Tuvalu's coastal defence structures and natural coastal assets are critical for defence against tropical cyclones, extreme heat events and high tide related events. This is important as coastal communities in Tuvalu are highly exposed to sea level rise and coastal inundation. Despite ongoing land reclamation projects, every single resident lives within 1km of the coast, and infrastructure within 100m of the coast accounts for 66% of the total asset number and 62% of the total infrastructure replacement value. Failure of coastal defences and natural coastal assets due to tropical cyclones, extreme heat events, extreme sea level events and ocean warming will cause immense cascading impacts such as permanent relocation of residents and destruction of critical infrastructure, especially with changing of climate affecting likelihood and magnitude of hazards.

Current exposure to hazards

This section discusses the exposure of coastal protection structures to key hazards.

Sea level rise and coastal inundation

Sea level rise and coastal inundation changes the shoreline of the islands of Tuvalu which can impact coastal protection infrastructure. Researchers have found that between 2005 and 2015, there has been a decrease of 0.13% of net island area, with 13 islands decreasing in size[171]. Coinciding with Cyclone Pam were substantial losses in land area on islets of Fuageam, Tefala, and Vasafua. Destabilisation of the coastal area causes instability in existing man-made coastal defence infrastructure such as sea walls (Figure 17).

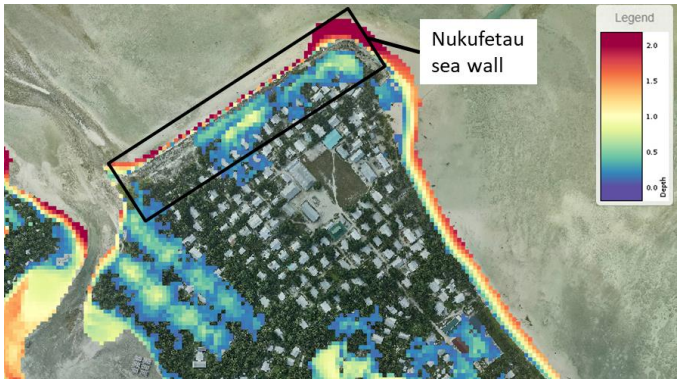


Figure 17: Current exposure of Nukufetau against 1 in 5-year coastal inundation events. (Source: Tuvalu Coastal Adaptation Project.)

Coastal inundation and resulting saline intrusion and erosion is also causing the loss of large tree canopies and mangrove forests in Tuvalu, reducing natural shade coverage. For mangroves, they are negatively affected around the atolls of Tuvalu, likely due to sea level rise and coastal inundation affecting sediment and wave energy conditions. This may also impact other types of trees around Tuvalu. Other impacts that affect trees include minimisation of root holding capacity by wind-wave forced erosion.

[171] Hisabayashi, M., Rogan, J. and Elmes, A. (2017). Quantifying shoreline change in Funafuti Atoll, Tuvalu using a time series of Quickbird, Worldview and Landsat data. GIScience & Remote Sensing. 55. 1-24..

Tropical cyclones

Extreme waves associated with tropical cyclones threaten the coastal protection infrastructure which safeguards Tuvaluan livelihood and economic stability, with past events causing catastrophic damage to coastal protection infrastructure. In 2015, Cyclone Pam destroyed a concrete block seawall of Nukufetau, resulting in increased vulnerability to coastal inundation and increased damage. Following this event, the United Nations Development Programme assisted in repair using geotextile sand containers filled with local sand to re-establish the seawall. Cyclones also damage and destroy coral reefs and tree canopies through wave erosion, flooding and extreme windspeeds.

Rebuild of seawall in Nukufetau. (Source: CSIRO, Federation University, Climate Comms (2024))

Ocean warming and acidification

Ocean warming and acidification are interrelated, as the ocean warms up, it is able to hold more carbon dioxide which causes it to become more acidic. This is in addition to the increase of carbon dioxide concentration in the atmosphere. Both hazards in conjunction causes bleaching of coral reefs and reduces their structural integrity. These act to reduce the ability of remaining reef material to disrupt wave energy resulting in the runup of waves to the islands themselves affecting coastal protection. This is important as offshore coral reefs act to break waves offshore and reduce the wave energy and wave height that reach the coast.

Future exposure to hazards

This section discusses the future exposure of coastal protection structures to the key hazards.

Sea level rise and coastal inundation

Sea level rise and coastal inundation (general exposure information as previously indicated) are projected to increase in height and reach further inland. This will put the defence structures at risk as wave energy increases, potentially destabilising the ground they are built on and causing direct damage to the structures. If those structures were to fail, consequence to the communities would be great with increased magnitude of flooding. (Figure 18). Natural coastal assets, such as trees and reefs, will also face further damage and destruction, exposing communities to heat stress and coastal erosion.

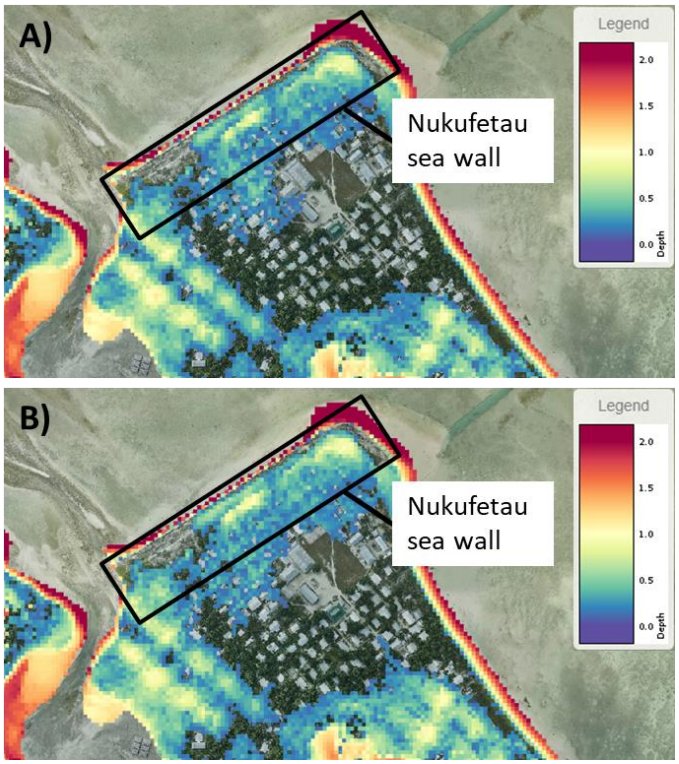


Figure 18 Exposure of Nukufetau against 1 in 5-year coastal inundation events by 2060. A) Under low emissions. B) Under high emissions. (Source: Tuvalu Coastal Adaptation Project.)

Tropical cyclones

Tropical cyclones are projected with low confidence to decrease in frequency in the Tuvalu EEZ. However, their intensity is projected to increase. Stronger winds and waves that result from more intense tropical cyclones will put coastal defence infrastructure, coastal biodiversity (such as coral reefs) and natural shade further at risk. Associated storm surge will be likely to cause greater erosion on shore and along the coast, including damaging trees and coastal vegetation[172]. All of these effects will be exacerbated over time by the influence of sea-level rise.

Ocean warming and acidification

Ocean temperature is projected to increase, which will cause more severe coral bleaching events. In conjunction with a more acidified ocean, coral reefs will experience a decrease in resilience and decrease in structural integrity. This will lead to an increase in the energy of the waves that affects the coastline, decreasing the amount of protection which the coral reefs provide.

Vulnerability

TIVA listed the following three items as the top three coastal protection related vulnerability factors, identified by communities across Tuvalu:

- Limited to no access to coastal stabilisation infrastructure.
- Limited or no means to pay for the development/maintenance or upgrade of coastal protection activities.

[172] Tamara Ticktin, Ashley McGuigan, Frazer Alo, Michael J. Balick, Andre Boraks, Chanel Sam, Thomas Doro, Presley Dovo, Thomas Ibanez, Alivereti Naikatini, Tom A. Ranker, Marika V. Tuiwawa, Jean-Pascal Wahe, Gregory M. Plunkett. High resilience of Pacific Island forests to a category- 5 cyclone. Science of The Total Environment, Volume 922. 2024. https://doi.org/10.1016/j.scitotenv.2024.170973.

- Low resilience of existing shoreline protection structures to disasters.

Six island communities have identified the three TIVA listed items above to be a top vulnerability affecting them (Table 7: 3Table 7).

Table 7: 3 Communities which identified any of the three coastal protection related vulnerability factor as being a top vulnerability to them.

Island	Men	Women	Youth
Nanumaga			Yes
Niutao	Yes		
Vaitupu	Yes		
Nukufetau			Yes
Funafuti			Yes
Nukulaelae	Yes		

In addition, coastal protection in Tuvalu is vulnerable to other factors.

Hazard	Factor relevant for vulnerability
Ocean warming, SST, Ocean acidification, Marine heatwaves	• Tuvalu's unique location in the Pacific Ocean predisposes them to rely on offshore coral reefs for coastal defence against strong waves. Inadequate marine conservation for coral and coastal protection will impact on natural coastal defences.
Sea level rise, Storms, cyclones	• Tuvalu does not have a domestic industry to produce coastal defence infrastructure and is reliant on aid, which may cause delays in responding to destroyed coastal defence infrastructure, or delays in improving current low resilience structures. Building coastal defences also bear significant economic cost, in which Tuvalu may fail to secure funding for. • With high exposure in low lying coastal areas, and limited coastal protection, shorelines are retreating due to coastal inundation and erosion (Nanumea and Nanumaga in particular). Exposure to salt water due to coastal inundation causes decline in shoreline vegetation health and cover.
Extreme heat events	• Land clearing for urbanisation and agriculture is reducing space available for large trees and reducing natural shade coverage.

Variations across the islands

The precise locations of coral reefs were not accessible for this report, but if an island is more reliant on offshore coral reefs to defend against strong waves, it would be more vulnerable as the climate changes.

The nature of rising sea surface temperatures and ocean acidity affect Tuvalu as a whole, the projection and hazard information is not enough to determine any variations across the islands.

Complex risks

Coastal defence structure risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Infrastructure/Human health & well-being:** Extreme heat events can cause trees to lose foliage, reducing the amount of natural shade available, whilst also causing power outages that limit access to air-conditioning and man-made sources of cooling. As a result, human health is threatened.
- **Coastal:** The loss of trees along the coastline decreases the resilience of the coast to erosion increasing the need for man-made protection and exposing vulnerable communities.

Consequence

Current

Risk Statement number	Component and hazard	Risk rating	Comments
R10 - Coastal and flood defence structures	**Tropical cyclone induced storm surge** Coastal inundation is not only triggered by tropical cyclones, but also high tide events such as king tides. This will cause damage and destruction of current coastal and flood defence structures.	**Major**	Through Cyclone Pam in early 2015, wind-waves caused considerable flooding and damaged seawalls across islands which resulted in further damaged homes and vulnerability to further coastal inundation. Coral reefs and large trees were also damaged, increasing exposure to coastal erosion and extreme heat.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions scenario	Comments
R10 - Coastal and flood defence structures	**Tropical cyclone induced storm surge** Coastal inundation is not only triggered by tropical cyclones, but also high tide events such as king tides. This will cause damage and destruction of current coastal and flood defence structures.	**Major**	Sea level rise around Tuvalu is projected to be 9-17 cm by 2030. This may exacerbate current impacts of storm surges to Tuvalu.

2050 High emissions scenario

Risk Statement number	Component and hazard	High emissions scenario	Comments
R10 - Coastal and flood defence structures	**Tropical cyclone induced storm surge** Coastal inundation is not only triggered by tropical cyclones, but also high tide events such as king tides. This will cause damage and destruction of current coastal and flood defence structures.	**Extreme**	By 2060, 60% of the population and 52% of building will be exposed to coastal inundation of a 5-year occurrence interval (based on a 2060 SLR scenario). This will cause permanent and irreversible consequences to coastal and flood defences, including natural assets.

2050 Low emissions scenario

Risk Statement number	Component and hazard	Low emissions scenario	Comments
R10 - Coastal and flood defence structures	**Tropical cyclone induced storm surge** Coastal inundation is not only triggered by tropical cyclones, but also high tide events such as king tides. This will cause damage and destruction of current coastal and flood defence structures.	**Extreme**	By 2060, 80% of the population and 69% of buildings will be exposed to coastal inundation of a 5-year recurrence interval (based on a 2060 SLR scenario). This will cause permanent and irreversible consequences to coastal and flood defences, including natural assets.

Confidence

Component	Hazard	Confidence score	Comments
Coastal and flood defence structures	**Tropical cyclone induced storm surge**	**Medium**	• There is low confidence in tropical cyclone projections, reducing confidence in the future impacts of tropical cyclone induced storm surges to coastal and flood defence structures.

		• However, sea level rise events have higher confidence and will likely cause damage to the point in which it will be too costly to consistently replace coastal defence structures.

Knowledge Gaps

- Detail on the location and past impacts to existing sea walls will allow a more detailed analysis of consequence to coastal defence.
- Details on the precise location of coral reefs will provide more island-specific exposure and vulnerability analysis.
- In addition, information regarding if there is an upper limit to the economic cost to replace the sea wall (too costly to replace) would support a more comprehensive analysis.

5.8 Infrastructure

Summary of this sector in Tuvalu

For the purposes of this climate risk assessment, Tuvalu's infrastructure sector has been divided into five sub sectors of internet and telecommunications, transport and supply chains, building and structures, energy security, and waste management. Each of these collectively act as scaffolding which serve Tuvalu's livelihoods.

Transport and supply chains are at the centre of all sectors significant to Tuvalu. The domestic and international transportation of people and goods revolve around boats, cars and motorbikes. Shipping delivers most food, all building materials and manufactured goods, as well as critical emergency relief goods following natural disasters. Inter-island vessels also provide vital transport links for secondary and tertiary students living on Outer Islands, as well as those requiring access to hospital services on Funafuti. This drives a heavy reliance on road infrastructure.

Tuvalu locals rely on motorbikes and cars to travel around Funafuti. (Source: Tuvalu NAP Project-Mission (2024))

There are significant weaknesses in Tuvalu's transportation infrastructure and services which can disrupt supply chains, impacting all other sectors. There is only one airport, located on Funafuti, that services all nine islands. The airport is central to providing travel needs, work opportunities and medical care that are not available on the islands. Outer islands receive imported goods every 2-3 weeks from three government-owned ships and a landing craft (Moeiteava). Only three Outer Islands (Vaitupu, Nanumea and Nukufetau) have docking facilities. The use of small workboats to transfer passengers within Tuvalu can also be very dangerous when the sea is rough, and the transport channels are often too shallow to use during low tides. Furthermore, the transport and supply chain sector of Tuvalu is heavily reliant on a workforce because there is no automation in container ship offloading or transportation of goods.

Boats are used for transport within and across islands. (Source: Tuvalu NAP Project-Mission (2024))

Buildings and structures form the foundation of all livelihoods in Tuvalu, with deeply ingrained culture in the ways of life in a Tuvaluan village. Each village is dominated by a Protestant Church and meeting hall, an open plaza or playing field, pastor's house and school. This makes up the tangible manifestation of the social, political and religious institutions that are shared and integrated across the islands[173]. In addition, crucial industrial buildings uphold the economy and provide refuge as evacuation shelters during disasters. This includes fishing shacks, schools and universities, supermarkets, government offices, power stations, ports and airstrips, and hospitals. For the Outer Islands of Tuvalu, nearly 70% of households now own their own land through their clan affiliations[174]. In contrast, in Funafuti, just over 30% of all households are on

[173] UNESCO. (2024). The Pacific atoll-island cultural landscape of Tuvalu.

[174] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

land for which they can claim ownership[175]. Most household buildings are generally wood frame or concrete masonry unit structures of one or two stories. All of the land on Funafuti is ultimately owned within the traditional land ownership system, with the possible exception of some church land which has been gifted in perpetuity[176]. All government land has been leased from the traditional owners[177].

Tuvalu has 12 schools comprised of 28 buildings[178]. The majority of school buildings have been constructed within the last 20 years and are in good condition with a reinforced concrete frame and masonry infill[179]. The main deficiency across most school buildings is the design and construction of roof structures, including the timber truss structures, structural connections and roof fixings[180]. Additionally, 2 out of the 12 schools have no sanitary facilities, and 1 timber building at Tutasi Primary School is in very poor condition despite being constructed relatively recently[181].

Tuvalu's energy system is critical for the provision of essential services, such as water, food, health care, lighting, evacuation centres, transport and temperature control. The power grid also supports the internet and telecommunications network which facilitates personal communications, business development, tourism, and disaster management[182]. Across Tuvalu, 98% of the population has access to electricity with refrigeration and air conditioning the primary uses[183]. In Funafuti, power is primarily sourced from 3 x 600kW diesel-powered generators with additional supply into the power grid from 735kW solar arrays[184]. The Funafuti power distribution network is underground, with upgrades required for cable size and ratings. The Outer Islands generally rely on diesel generation, apart from Niulakita which is dependent on small-scale solar power generation with backup generators[185]. An Asian Development Bank project is increasing energy system capacity in several Outer Islands by providing new generators, solar panels and batteries[186]. The energy sector is managed by the Department of Energy within the Ministry of Public Utilities[187], with an objective to be powered by 100% renewable energy by 2030, primarily relying on solar power[188].

However, the power grid is often under stress, and Tuvalu is considered one of the least connected countries in the Pacific region with limited internet and telecommunications services, particularly outside of Funafuti[189]. The islands are entirely dependent on satellites for international connectivity, whilst the underground copper network provides connection to fixed line and broadband services[190]. It is recognised that a sound and efficient telecommunications and ICT sector is a necessary precursor to sustainable and

[175] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[176] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[177] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[178] The World Bank (2021). Tuvalu School Infrastructure Risk Assessment. Technical Report | TUVALU-REP-001.

[179] The World Bank (2021). Tuvalu School Infrastructure Risk Assessment. Technical Report | TUVALU-REP-001.

[180] The World Bank (2021). Tuvalu School Infrastructure Risk Assessment. Technical Report | TUVALU-REP-001.

[181] The World Bank (2021). Tuvalu School Infrastructure Risk Assessment. Technical Report | TUVALU-REP-001.

[182] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[183] Government of Tuvalu (2012). "Fakafoou – To Make New" TUVALU INFRASTRUCTURE STRATEGY AND INVESTMENT PLAN.

[184] Tuvalu Inception Mission summary report

[185] Government of Tuvalu (2012). "Fakafoou – To Make New" TUVALU INFRASTRUCTURE STRATEGY AND INVESTMENT PLAN.

[186] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[187] Government of Tuvalu (2012). "Fakafoou – To Make New" TUVALU INFRASTRUCTURE STRATEGY AND INVESTMENT PLAN.

[188] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[189] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[190] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

effective national development, and potential international investment in the Tuvalu economy[191]. Tuvalu's ICT capabilities are currently being developed through the 2019 Tuvalu Telecommunications and ICT Development Project which is supported by a $29 million grant from the World Bank[192].

Tuvalu's energy system is chronically stressed, with limited inbuilt resilience due to aging energy infrastructure and the reliance on imported diesel for power generation. This vulnerability was demonstrated on November 22 2023 when the electricity grid on Funafuti failed completely and without warning for 12 hours due to long-term 'wear and tear' of a major transformer, exacerbated by extreme heat[193]. Due to the lack of back up transformers or switch gear to isolate individual transformers, a replacement transformer was required to be installed[194]. As a result, apart from critical services with back-up generators, there was no emergency electricity available during the outage. This left households without functioning air-conditioning, water pumps, refrigeration, internet or lighting, exposing locals to heat-stress and disrupting economic activities[195].

Waste management has long been a key issue in Tuvalu, particularly given the extremely limited land mass available to dispose of waste and the increasing consumption of waste-generating imported products[196]. Solid waste pollutes the coast, while septic leakage, landfill overflow and storm water run-off into the lagoon causes algal blooms, plastic pollution and water quality issues[197]. In addition to threatening human health, this pollution directly impacts fish stocks, reducing food security and impacting the livelihoods of vulnerable communities who are dependent on traditional reef fishing. Urbanisation and climate change are both causing worsening waste management issues, especially in Funafuti[198]. Storage and management of e-waste (such as lithium batteries and solar panels) and industrial waste (including old barges, excavators, pipes and fittings etc.) is expected to be an increasing problem into the future[199].

The Department of Waste manages waste including septic waste, landfill, e-waste and plastics[200]. Septic tanks are the predominant system of human waste disposal across Tuvalu, although pit latrines are more common in the Outer Islands[201]. Solid waste disposal systems vary across regions with the predominant mode being collection by the Kaupule (76% of households) in Funafuti, while in the Outer Islands, authorised collections sites are most common (58%)[202]. All the Outer Islands have a dumpsite and incinerator, enabling more diverse means of disposal, such as burning, which are less common in Funafuti (Figure 19)[203]. Recyclable waste is collected by the Department of Waste in Funafuti at the transfer station

[191] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[192] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[193] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[194] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[195] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[196] International Institute for Sustainable Development (2020). Report Evaluates Tuvalu's Progress towards Improving Waste Management. SDG Knowledge Hub.

[197] Tuvalu NAP Project-Mission (2024).

[198] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[199] Tuvalu NAP Project-Mission (2024).

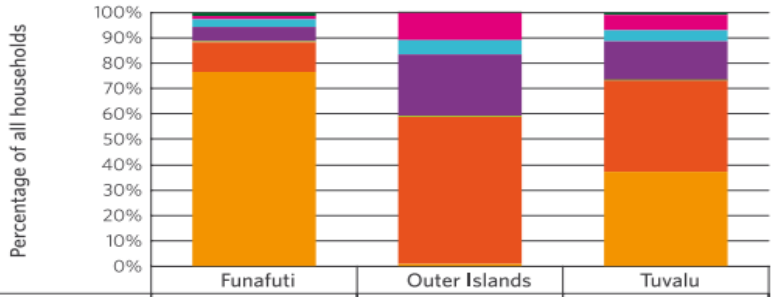
[200] Tuvalu NAP Project-Mission (2024).

[201] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[202] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

[203] United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.

while composting happens at the island scale[204]. Each Kaupule has a compost area and a shredder for all green waste[205].



	Funafuti	Outer Islands	Tuvalu
Other	13	3	16
Composting	12	98	110
Bury	25	52	77
Burn	47	222	269
Recycling	2	4	6
Authorised Collection sites	100	527	627
Collected by kaupule	646	10	656

Figure 19: Means of waste disposal across all Tuvalu, in Funafuti and in the Outer Islands.
(Source: United Nations Population Fund (2012). Migration, Urbanisation and Youth Monograph. Tuvalu National Population and Housing Census 2012.)

The 'Tuvalu Integrated Waste Policy and Action Plan 2017-2026' is the main national policy framework guiding the development of waste management[206]. This includes plans to strengthen engagement with the private sector to reduce the amount of disposable waste and ensure all recyclable waste is shipped overseas for treatment and processing[207]. Tuvalu is also actively engaged in the EU-funded Pacific Waste Management Programme (PacWastePlus), implemented by the Secretariat of the Pacific Regional Environment Programme (SPREP), to further support the country's waste management[208].

The following risk statements (**R11**, **R12**, **R13**, **R14**, **R15**) have been developed through consultation during the Tuvalu NAP Project-Mission (2024). They discuss the risks that climate change presents for infrastructure that have been identified and analysed.

The following risk statements discuss the key climate risks relevant to each of the five infrastructure sub-sectors which have been identified and analysed.

[204] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[205] Tuvalu Telecommunications and ICT Development Project (TvICT) Environmental and Social Management Plan (ESMP) Rev G October 2023

[206] International Institute for Sustainable Development (2020). Report Evaluates Tuvalu's Progress towards Improving Waste Management. SDG Knowledge Hub.

[207] International Institute for Sustainable Development (2020). Report Evaluates Tuvalu's Progress towards Improving Waste Management. SDG Knowledge Hub.

[208] International Institute for Sustainable Development (2020). Report Evaluates Tuvalu's Progress towards Improving Waste Management. SDG Knowledge Hub.

R11: Risks to Internet and Telecommunications

Increasing chronic and acute climate hazards, including coastal inundation, heatwaves and cyclones, impact critical internet and mobile phone infrastructure such as satellite connectivity, towers and underground copper cable distribution for landlines, and associated maintenance services. This will increase the frequency of telecommunication failure, including blackspots and overall reliability of services, with cascading and compounding impacts for other sectors, along with increased costs for maintenance, including for removal of salt spray for towers, and replacement of critical infrastructure, including upgrading of copper cable distribution network to fibre optic cable and emergency power generators for operation and air-conditioning of centralised data servers etc. The absence of a reliable telecommunications system has implications for multiple sectors including transport (in particular air and sea transport logistics), education, health and DRM; latter compounded by a lack of integrated SMS-based early warning system for climate-related disasters (see also R4, R9 and R12).

R12 Risks to Transport and Supply Chains

Increasing chronic and acute climate hazards, including SLR, cyclones, extreme rainfall and associated coastal inundation, groundwater upwelling and pluvial flooding impact transport infrastructure such as roads, causeways, ports and airports disrupting supply chains and logistics. This relates to transport and supply chains between Funafuti and outer islands as well as international connectivity for Tuvalu. Additionally, heatwaves affect workforce productivity for essential services using and maintaining this infrastructure. These impacts may result in a range of increased maintenance, repair, restoration and replacement costs, as well as periodic isolation of local communities and disruption to related support services, economic activity and direct/indirect health and wellbeing impacts on local communities.

R13: Risks to Buildings and Structures

Increasing chronic and acute climate hazards, including SLR, cyclones, extreme rainfall and associated coastal inundation, groundwater upwelling and pluvial flooding, will increase risks to buildings (private, government, commercial, education, industrial, traditional); particularly in absence of a climate change configured resilient building code for ensuring fit-for-purpose engineering design specifications for new and retro-fit applications. Increased temperatures and associated heatwaves will also impact on the intended functionality and utility of these buildings and structures, particularly in absence of sufficient shade, ventilation and air-conditioning where required. This will disrupt the services provided by activities undertaken within those buildings, resulting in reduction of their functionality and useful life and increased cost of maintenance and repair. Some may be completely destroyed and/or no longer fit-for-purpose, causing lost productivity/livelihoods and requiring major replacement and/or retrofit costs. Key buildings and structures include hospitals/health centres, schools, evacuation centres/refuges, petrol stations, supermarkets, churches, government offices, power stations, telecommunication towers and water treatment plants.

R14: Risks to Energy Security

Increasing chronic and acute climate hazards, including heatwaves and sea level rise, will likely increase energy demand (e.g. for air conditioning, desalination, telecommunications, health services etc), reduce reliability and serviceability of energy infrastructure, including existing diesel-powered gensets and also renewables (e.g. PV solar and battery storage) resulting in decreased energy security. Design specifications/ratings of existing energy infrastructure including generators, transformers and related distribution networks is likely to be increasingly inadequate and unreliable under future extreme climate conditions. This can increase the number and duration of blackouts which can impact other critical infrastructure (e.g., hospital, telecommunication, disaster management, water pumps and desal etc.) and increase the demand for back-up generators or batteries, placing additional demand on disaster management evacuation centres/refuges, and/or other suitable areas (shaded, ventilated, high ground etc) for communities to congregate when needed to seek relief from prevailing conditions.

R15: Risks to Waste Management

Increasing chronic and acute climate hazards, is likely to exacerbate the current waste management issues in Tuvalu. This includes run-off from stormwater and overflowing septic tanks into lagoons, land-fill management and run-off, e-waste disposal (including from increased use of renewables such as solar PV arrays and battery storage), industrial waste disposal (including surplus/redundant heavy machinery and associated lubricants, building/construction and associated packaging materials etc), and plastic waste as may enter the marine environment. Disruption to waste management services will cause contamination of toxic waste into Tuvalu's environment and cause knock on effects such as contaminated water sources, health impacts and decreased fertility of land, as well as contamination of the inshore marine environment with impacts on coastal fisheries, coral reefs and overall aquatic biodiversity.

Risk Summary

Infrastructure in Tuvalu is at risk from climate change through chronic and acute climate change events including sea level rise, coastal inundation and storm surge, an increase in the severity of extreme rainfall events, tropical cyclones and extreme windspeed. These events damage and destroy critical infrastructure including waste management systems, ICT, electricity distribution networks, hospitals, schools, petrol stations, supermarkets, industrial complexes, traditional buildings, churches, government offices, power stations, telecommunication towers, airports, ports, boats and roads. The loss and disruption of critical infrastructure will impact all other sectors/domains and threaten human health, livelihoods, food and water security, and economic activities. Population growth will compound these impacts by placing additional pressure on infrastructure.

Current exposure to hazards

This section discusses the exposure of the infrastructure sector to key hazards.

Increasing air temperature and extreme heat events

Buildings such as houses, schools and evacuation centres often have poor ventilation and cannot maintain comfortable temperatures during extreme heat events. Even buildings with air conditioning units can suffer power failures during heatwaves as energy demand is saturated, exposing vulnerable communities to heat stress. Extreme operating conditions compound high energy demand for air conditioning and refrigeration

to cause failure of the electricity grid, particularly as relates to generation and exceedance of operational ratings for conductors and related switching equipment. This affects all essential services such as hospitals, schools and emergency management. In addition, extreme heat events affect machinery necessary to upkeep the built environment by placing pressure on the power grid and causing overheating which ultimately damages machinery. This is exacerbated by Tuvalu's reliance on imported goods because damaged machinery cannot be replaced easily. Furthermore, the roads and the airstrip in Tuvalu are made of asphalt, with bitumen being an important component. Bitumen is sensitive to extreme temperatures, where it becomes more fluid and affects asphalt road surface performance[209], causing disruptions to transport services and the supply chain.

Heatwaves can also disrupt and damage internet and telecommunications infrastructure by causing power outages and overheating server equipment[210]. For example, following a 2023 power grid failure the ICT system required a full re-boot after power was restored[211]. Heatwaves can also disrupt connectivity by preventing critical maintenance of ICT infrastructure, such as salt removal from the Funafuti telecommunications tower[212]. More generally, the infrastructure sector is heavily reliant on a productive workforce. Increasing air temperature and extreme heat events puts this sector further at risk by reducing workforce productivity.

Sea level rise and coastal inundation

Extreme sea level events are causing inundation and salinization that damages critical infrastructure, threatening community safety, wellbeing and livelihoods. Infrastructure within 100m of the coast accounts for 66% of the total asset number and 62% of the total infrastructure replacement value. As a result, currently 1565 (30%) buildings are exposed to inundation every five years, with widespread impacts for both individuals and governments including an annual average cost of $42 million in inundation damage caused to buildings. School buildings are particularly exposed, with 10 out of 28 structures recording high or very high exposure to inundation (Figure 20). Current inundation exposure for critical infrastructure is shown in Figure 21 below.

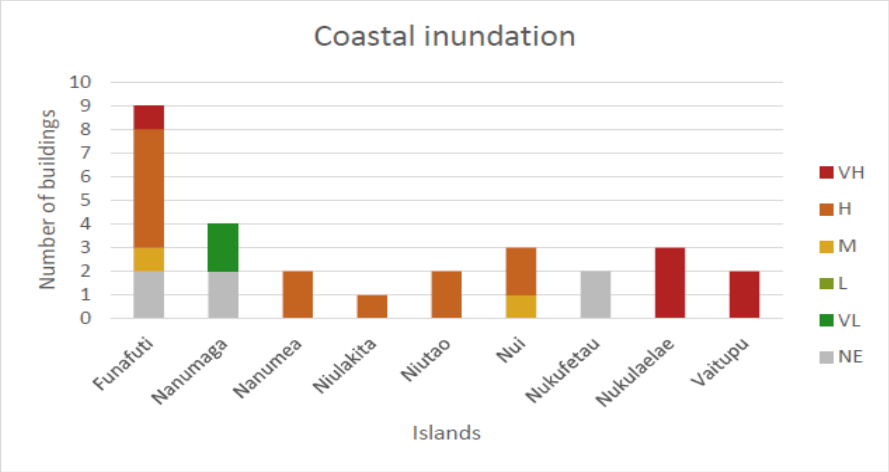


Figure 20: Exposure of school buildings to coastal inundation across different islands. (Source: The World Bank (2021). Tuvalu School Infrastructure Risk Assessment.)

[209] Almeida, A. and L. Picado-Santos, Asphalt Road Pavements to Address Climate Change Challenges—An Overview. *Applied Sciences,* 2022. 12(24): p. 12515.

[210] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[211] Tuvalu Inception Mission summary report_V1.1_11Jan24.

[212] CSIRO, Federation University and Climate Comms (2024). Assessment of climate hazards for Tuvalu under current and future conditions. Technical report prepared for SREP.

Waste management infrastructure, such as landfill and septic systems, is vulnerable to inundation and overflowing which pollutes the lagoon and coastal areas with plastic and sewage, affecting human health, water quality, land fertility and fisheries. Inundation-associated disruptions to ports can also prevent recycling transport and processing.

ICT infrastructure is impacted by extreme sea level events with significant impacts for disaster risk management and human health in Tuvalu. Underground copper wire infrastructure, including wiring and pits, are damaged by inundation and saline intrusion, disrupting fixed line and broadband services[213]. Low-lying surface-level ICT infrastructure is damaged by coastal erosion and inundation. Flooding of electricity infrastructure including underground wiring, junction boxes and inspection pits also causes loss of telecommunications and internet[214].

Sea level rise also causes saline intrusion that can corrode underground powerlines, as well as coastal inundation that floods low-lying power stations. Inundation of port infrastructure can also impact power supply given the reliance on imported diesel.

Roads and transport infrastructure can be made inaccessible or destroyed during extreme sea level events. Funafuti airport is also vulnerable to water table levels and sea tidal fluctuations that can cause sub-surface pressures that lift the pavement surface. Recent survey by LiDAR confirmed that the current runway is below the sea level and predicts it to be submerged in 100 years' time[215]. Figure 21 shows that the airport is already exposed to 1-in-10 year inundation events. The government plans land reclamation at the southern end of the island to enable the construction on a new international runway.

[213] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[214] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

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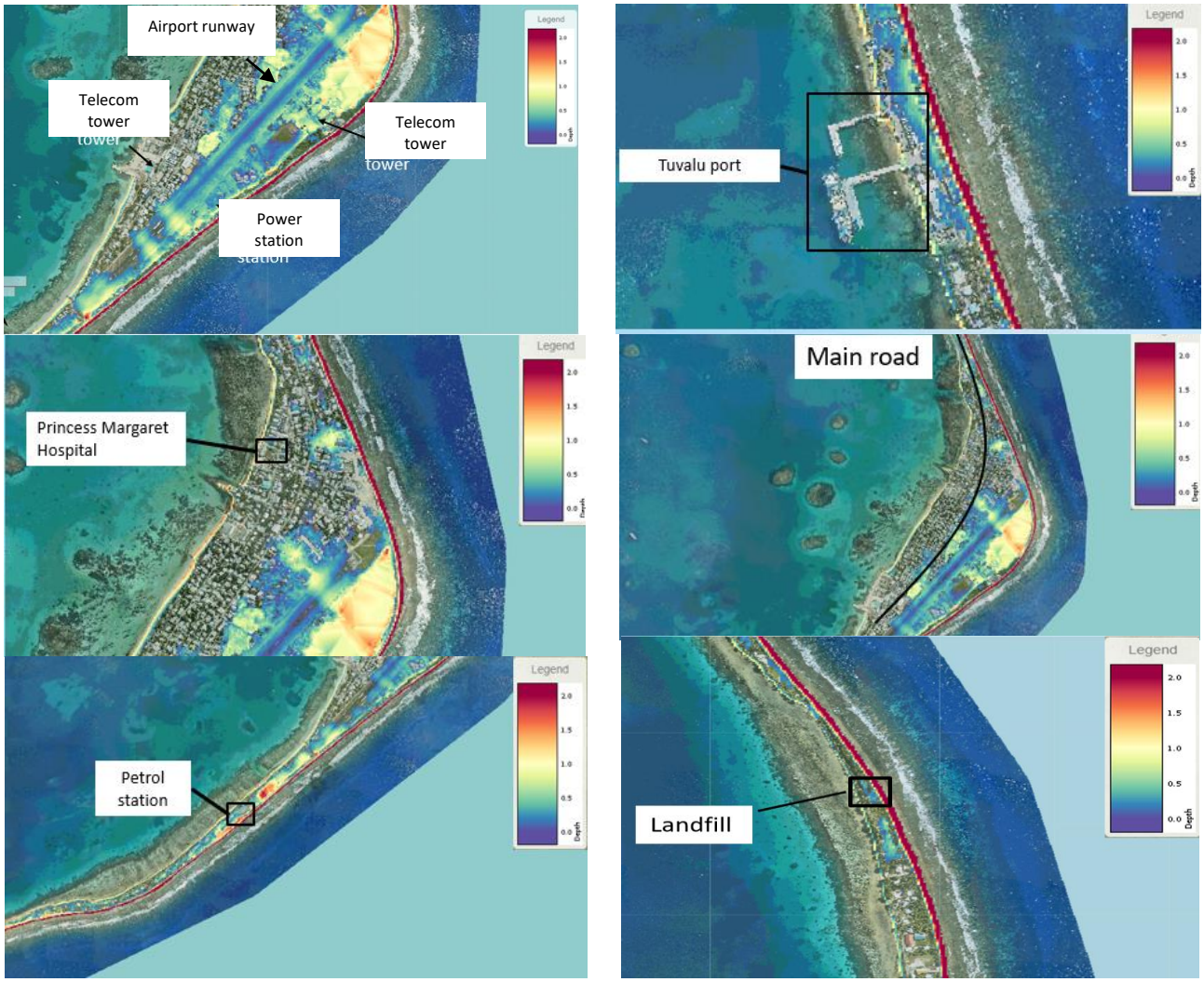


Figure 21: Current exposure of critical infrastructure in Tuvalu to one-in-ten-year coastal inundation events. (Source: Tuvalu Coastal Adaptation Plan.)

Tropical cyclone and extreme rainfall

Extreme winds, flooding and inundation can destroy and damage buildings and structures, including power stations, roads, hospitals, schools, houses, industrial complexes, traditional buildings, petrol stations, airports, ports, supermarkets, churches, government offices, power stations, telecommunication towers and water treatment plants, resulting in the loss of essential services and economic productivity, and threatening human safety. Damage to electricity and ICT infrastructure, including power stations, copper wiring and telecommunications towers, can cause power, internet and telecommunication blackouts[216] which inhibit disaster response initiatives, increase community vulnerability and cause psychological stress. Sea spray caused by

Telecommunications tower. (Source: Tuvalu NAP Project-Mission (2024))

[216] Tuvalu NAP Project-Mission (2024).

prevailing winds is also a growing problem for power stations and ICT infrastructure due to salt build up on diesel generators, telecommunications towers and tower-mounted antennae. For instance, the new telecommunications tower on the ocean side of Funafuti was severely impacted by thick build-up of salt on antennae after three months deployment, requiring frequent maintenance to clean and repair the damage[217].

Funafuti landfill. (Source: Tuvalu NAP Project-Mission (2024))

Extreme winds, rainfall and storm surge also impact waste management and results in water quality issues by causing landfill to overflow, leak and blow into the lagoon, and sewage to pollute surrounding areas and water catchments.

Maritime trade and transport infrastructure is particularly vulnerable to damage from cyclones. Both Cyclone Pam (2015) and Cyclone Tino (2020) caused severe flooding and erosion that damaged maritime infrastructure, such as ramps, in most of the Outer Islands, as well as blocking transportation channels with boulders and sand[218].

Future exposure to hazards

This section discusses the future exposure of the infrastructure sector to the key hazards.

Increasing air temperature and extreme heat events

Increasing severity of future heatwaves will damage buildings and roads, and disrupt power and ICT infrastructure through overheating and prevention of critical maintenance. There are plans to reduce the impacts of extreme heat on internet and telecommunications by reducing ICT reliance on the mains power grid and improving cloud-based server capabilities. As a result, storage and management of e-waste is expected to be an increasing problem, including for lithium batteries for solar backup[219]. Hotter temperatures in the future will also increase the discomfort of workers with potential health implications. This may disrupt infrastructure development and maintenance activities.

Sea level rise and coastal inundation

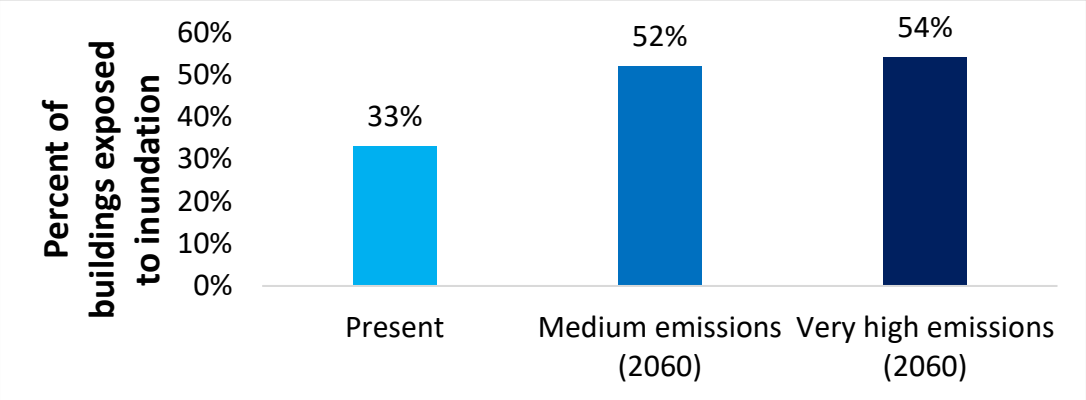
Continued sea level rise and increasingly severe extreme sea level events will result in worsening coastal erosion and inundation. There will be widespread impacts on infrastructure, including the power grid,

[217] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

[218] https://www.theprif.org/sites/default/files/documents/PRIF%20Tuvalu%20Infrastructure%20Plan%20FINAL%20pages_0.pdf

[219] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

roads, landfill, septic systems, airport runway, ports, telecommunication towers, petrol stations, roads, evacuation centres, schools, houses and industrial complexes. The annual average cost of damages to buildings from coastal inundation is projected to be $76 million (medium emissions) to $80 million (high emissions) by 2060, with more than 50% of buildings and structures in Tuvalu exposed to one-in-five-year inundation (Figure 22). Coastal erosion will also reduce the space available for critical infrastructure, including waste management systems. The majority of islands have identified the need for greater financial support from the national government to fund adaptation and resilience building initiatives[220].



Both low-lying and underground power and ICT infrastructure will be damaged by increasingly severe extreme sea level events, disrupting electricity, internet and telecommunications connectivity and inhibiting disaster response activities. The impacts of more frequent and widespread inundation on ICT infrastructure will be reduced by the upgrade of copper wire infrastructure to fibre-optic cable, but this will take time[221].Future inundation exposure of critical infrastructure is shown in Figure 23 below.

[220] CSIRO (2024). Tuvalu National Adaptation Plan: Climate Impact, Vulnerability & Risk Assessment.

[221] Tuvalu Inception Mission summary report_V1.1_11Jan24.docx (sharepoint.com)

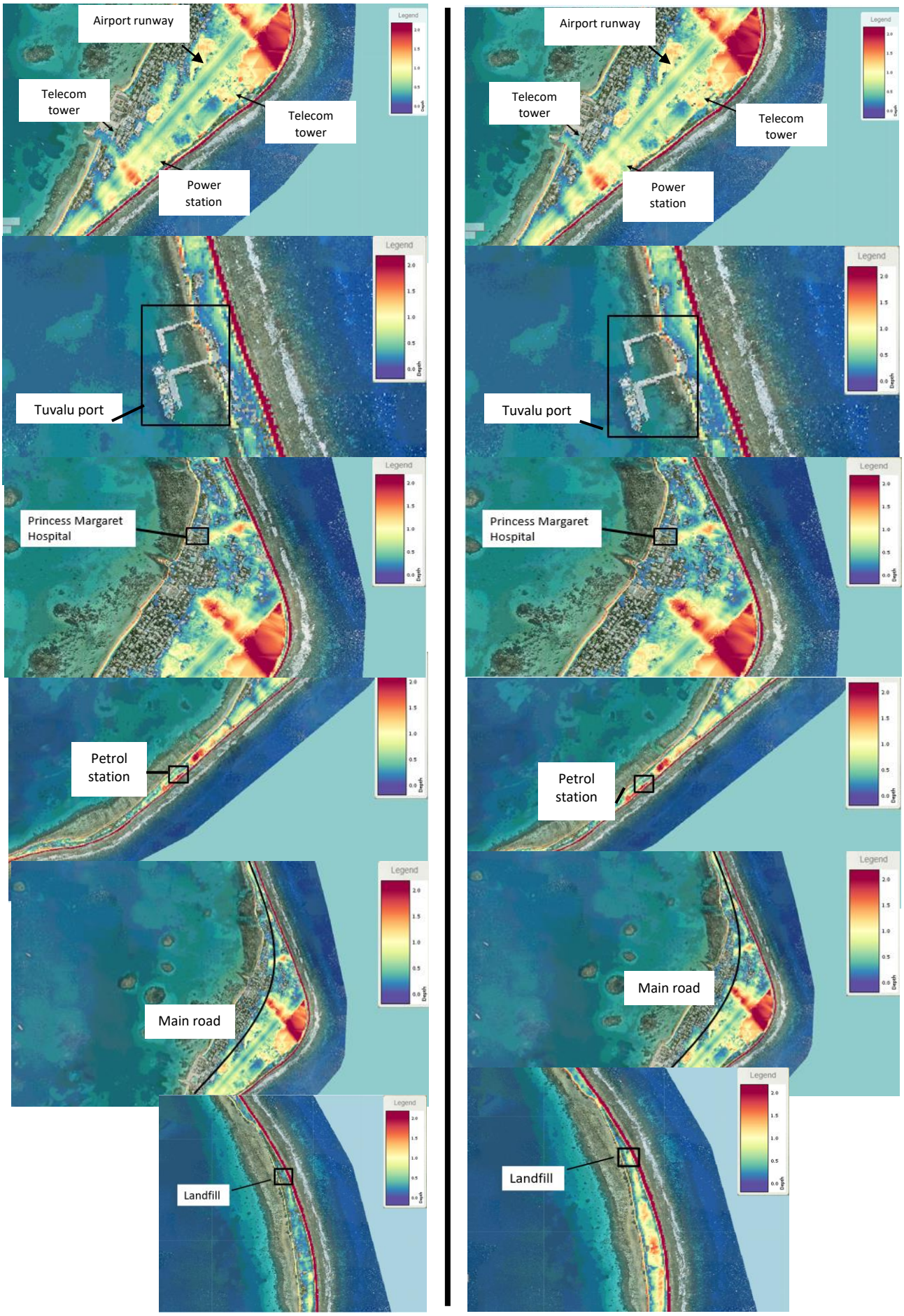


Figure 23: Exposure of critical infrastructure in Tuvalu to a one-in-five-year coastal inundation event in 2060 under medium (left) and high (right) emissions scenarios. (Source: Tuvalu Coastal Adaptation Plan.)

Tropical cyclone and extreme rainfall

Increasingly intense extreme rainfall events and low confidence projections for more intense tropical cyclones will cause increasingly severe damage to buildings and structures. The destruction of transport, education, housing, traditional and commercial infrastructure, including evacuation centres, industrial structures and schools, may have longer term impacts on human wellbeing and economic productivity in Tuvalu. ICT infrastructure, including towers, satellites and copper networks, will also be increasingly affected by cyclone and extreme rainfall events. In addition to the direct damage to internet and telecommunications infrastructure, flooding and inundation will also damage power stations and cause power outages, disrupting ICT connectivity and the provision of critical services. Increasing extreme windspeeds will also generate airborne debris and produce more sea spray, causing further salt build-up on power generation and ICT infrastructure, disrupting electricity supply, telecommunications and internet connectivity. Tropical cyclones and extreme rainfall will cause increasing damage to waste management infrastructure, increasing pollution from landfill and wastewater. The lagoon, coastal areas and water catchments may all be affected, impacting food security and human health.

Vulnerability

This table presents sources of infrastructure vulnerability to hazards in Tuvalu.

Hazards	Factor relevant for vulnerability
Extreme heat	• Reliance of internet and telecommunications infrastructure on the power grid with limited back up/solar power increases ITC services' vulnerability to power outages. • Funafuti hub houses all servers for Tuvalu with limited cloud-based capabilities, increasing risk of connectivity loss due to server overheating. • Aging energy infrastructure and lack of replacement parts increases vulnerability of power grid to overheating.
Tropical cyclones and rainfall	• Reliance on satellites for ICT services, with no current fibre-optic cable connection, increases vulnerability of telecommunication and internet connection to disasters. • Proximity to oceans makes telecommunications and power infrastructure vulnerable to sea spray and salt build up. • Underground transmission reduces the vulnerability of power supply to hazards such as cyclones. • Reliance on imported diesel and PV systems for power generation increases vulnerability to supply disruptions during and after disasters. • Lack of emergency power supply and spare parts increases power grid vulnerability to damage during disasters. • Use of small workboats to transfer passengers within Tuvalu is dangerous during disasters. • Poorly designed school roofs vulnerable to cyclones.

	• Limited access to post-disaster building reconstruction services, including shipping and transportation being affected by waves generated by remote severe cyclones.
Seal level rise and coastal inundation	• The power station is located next to a low-lying beach, making it vulnerable to inundation during extreme sea level events. • Reliance on the underground copper network that is exposed to inundation and flooding increases vulnerability of landline and broadband connections. • Reliance on electricity infrastructure that is exposed to inundation and flooding increases vulnerability of ICT services. • Proximity of critical infrastructure to the coast increases vulnerability to extreme sea level events and erosion e.g. pot holes in roads and runway • A single airport services the whole country and is vulnerable to rising sea levels. • Majority of islands do not have port infrastructure, increasing reliance on ports and small transport ships that are vulnerable to disruption during extreme sea level events. Reliance on low-lying roads prone to inundation for transportation.

Variations across the islands

Variation in internet, telecommunications, transport, supply chains, buildings, structures, waste management systems and power supply vulnerabilities across the islands:

Region	Vulnerability issues
Funafuti	• Both the new Funafuti telecommunications tower and the power station are located on the ocean side, increasing vulnerability to sea spray and salt build up from prevailing winds. • Reliance on imported diesel for power generation increases vulnerability to disasters that impact supply chains. • Access to infrastructure such as water tanks has been found to be inequitable in the past. • Desalination operations are reliant on the electricity grid, making the supply of desalinated water vulnerable to power outages during extreme heat and flooding events. • Leaky/faulty household water tanks and inability to pay for the operations/maintenance and upgrade of the household water system.
Nanumaga	• Coastal erosion encroaching housing and settlement. • Limited to no access to mobile and internet services from the island. • Limited access to cyclone-proof housing. • Low resilience of health buildings and equipment to disasters.

	• Inadequate housing increases vulnerability to physical safety during cyclones, storms and other acute climate events.
Nanumea	• Fisheries infrastructure/equipment and services badly affected by past cyclones. • New purpose-built evacuation centre reduces vulnerability to disasters.
Niulakita	• Limited ferry service or sea transportation.
Niutao	• Ongoing waste management and biosecurity issues, with no appropriate solutions identified. • Limited access to cyclone-proof housing. • Housing/settlement and migration concerns are not adequately addressed in the island development plan. • New purpose-built evacuation centre reduces vulnerability.
Nui	• Coastal erosion encroaching housing and settlement. • Limited access to cyclone-proof housing. • No purpose-built evacuation centre and inadequate housing increases vulnerability to cyclones, storms and other acute climate events.
Nukufetau	• Reliance on imported diesel for power generation with limited or faulty community backup energy system increases vulnerability to disasters that impact supply chains. • Limited to no access to telecommunications following disasters and extreme events. • Limited access to cyclone-proof housing. • Inadequate housing and evacuation centre infrastructure increases vulnerability to cyclones, storms and other acute climate events.
Nukulaelae	• Limited to no access to inter-island transportation to support access to markets. • Coastal erosion encroaching housing and settlement.
Vaitupu	• Reliance on imported diesel for power generation increases vulnerability to disasters that impact supply chains. • Inadequate evacuation centres increases vulnerability to cyclones, storms and other acute climate events.
Outer Islands	• Very limited 4G on Outer Islands with no integrated early warning system linked to Tuvalu Telecom's NextG network for natural disasters. Critical social services, such as education and healthcare, are also inhibited by the lack of connectivity.

Complex risks

Infrastructure risks can interact with and compound other risks with significant consequences for community health and livelihoods in Tuvalu.

- **Agriculture/Fisheries:** Extreme heat events can disrupt storage, cooling and transport infrastructure whilst also reducing agricultural and fisheries productivity, threatening food security in Tuvalu.
- Electricity disruption has cascading and compounding impacts on transport supply chains, telecommunications, waste management and water supply, with serious implications for service delivery and safety.

Consequence

Current

Risk Statement number	Component and hazard	Rating	Comments
R11 – Internet and telecommunications	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and power supply (blackout), impacting both internet and telecommunications infrastructure.	**Moderate**	Aging copper wire infrastructure is vulnerable to salinisation and inundation during king tides and storm surge. Power outages can also interrupt telecommunications and internet connectivity, threatening community safety and disaster response efforts.
R12 – Transport and supply chain	**Coastal inundation from king tides and tropical cyclone induced storm surges** Roads, bridges, maritime facilities, and airport may be damaged causing disruptions to supply chains and logistics.	**Moderate**	Airport is at risk from water table levels & tidal fluctuations that can cause lifting of the pavement surface. The current runway is below sea level. Transport infrastructure is also located adjacent to the coastline is exposed to inundation, undermining foundations such as pipes, wiring.
R13 – Building and structures	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding can damage and destroy private, government, commercial, education and industrial buildings. Service provision is disrupted and there are major costs for maintenance, repair and replacement of exposed buildings.	**Major**	Currently 1565 (30%) buildings exposed to inundation every five years. Annual average of $42 million damage caused to buildings by coastal inundation. Key affected buildings and structures include hospitals, schools, petrol stations, supermarkets, churches, government offices, power stations, telecommunication towers and water treatment plants

R14 – Electricity security	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and may cause instability in the power supply, causing blackouts.	**Moderate**	The Funafuti power station is already affected by coastal inundation. Aging copper wire infrastructure is also vulnerable to salinisation and inundation during king tides and storm surge.
R15 – Waste management	**Coastal inundation and flooding** Inundation from extreme sea level events and flooding can cause landfill and wastewater systems to overflow and leak into surrounding areas.	**Moderate**	Some landfills are already full, with the proximity to the coast of landfill sites and aging septic systems making waste management infrastructure highly vulnerable to inundation and flooding. Algal blooms and plastic pollution from waste overflow and leakage is affecting lagoon fisheries, water sources, land fertility and human health.

2030 Low and high emissions scenario

Risk Statement number	Component and hazard	Low and high emissions	Comments
R11 – Internet and telecommunications	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and power supply (blackout), impacting both internet and telecommunications infrastructure.	**Moderate**	Sea level rise is projected to be 9-17 cm by 2030. Inundation may cause damage to telecommunications and ITC infrastructure that affects community resilience during and immediately after disasters, especially cyclones.
R12 – Transport and supply chain	**Coastal inundation from king tides and tropical cyclone induced storm surges**	**Major**	Inundation and potential damage to the runway and maritime facilities will cause major disruptions to food, all building

	Roads, bridges, maritime facilities, and airport may be damaged causing disruptions to supply chains and logistics.		materials, manufactured foods, and critical emergency relief. Resealing & maintenance of Funafuti roads will be required.
R13 – Building and structures	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding can damage and destroy private, government, commercial, education and industrial buildings. Service provision is disrupted and there are major costs for maintenance, repair and replacement of exposed buildings.	**Major**	Rising sea levels and increasing cyclone intensity will cause significant inundation and flooding damage to commercial, industrial, government, private and community buildings and structures. Some buildings may be completely destroyed and/or no longer fit-for-purpose. Economic activities, education and development will be disrupted by damage and during repair efforts
R14 – Electricity security	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and may cause instability in the power supply, causing blackouts.	**Major**	Inundation and potential damage to the Funafuti power station may affect community resilience during and immediately after disasters, especially cyclones and heatwaves.
R15 – Waste management	**Coastal inundation and flooding** Inundation from extreme sea level events and flooding can cause landfill and wastewater systems to overflow and leak into surrounding areas.	**Major**	Continued sea level rise will lead to more frequent inundation of landfill and wastewater systems, whilst coastal erosion from inundation will reduce the space available for landfill sites. Given the amount of waste will also increase due to urbanisation, e-waste, reliance on imported goods and population growth, inundation and flooding events will result in increased pollution of the lagoon and coastal areas with worsening impacts on fisheries, water catchments, land fertility and human health.

2050 –High emissions scenario

Risk Statement number	Component and hazard	High emissions	Comments
R11 – Internet and telecommunications	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and power supply (blackout), impacting both internet and telecommunications infrastructure.	**Major**	The social, health, economic and governance consequences of coastal inundation-related impacts to telecommunications and ITC infrastructure will be more widespread, frequent and severe with projected 19-37m sea level rise and increasing cyclone intensity. Successful implementation of the Tuvalu Telecommunications and ICT Development Project may reduce impacts of inundation and salinisation
R12 – Transport and supply chain	**Coastal inundation from king tides and tropical cyclone induced storm surges** Roads, bridges, maritime facilities, and airport may be damaged causing disruptions to supply chains and logistics.	**Extreme**	Continued sea level rise (19-37 cm) and higher intensity of cyclones will cause destruction to maritime facilities, roads and the airport. This will have devastating flow-on effects to the population and economy
R13 – Building and structures	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding can damage and destroy private, government, commercial, education and industrial buildings. Service provision is disrupted and there are major costs for maintenance, repair and replacement of exposed buildings.	**Extreme**	Under a high emissions scenario, 2555 (54%) of buildings will be exposed to inundation every five years by 2060. Annual average of $80 million damage to buildings from coastal inundation Health, safety and housing of community members is significantly compromised across the region. Economic activities and service provision will also be disrupted by damage to commercial and industrial buildings.
R14 – Electricity security	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure	**Extreme**	The consequences of coastal inundation-related impacts to Tuvalu's power supply will be more widespread, frequent and severe with projected 19-37 cm sea level rise and increasing

	(salinisation) and may cause instability in the power supply, causing blackouts.		cyclone intensity will further damage energy infrastructure such as underground wires and solar panels on roofs.
R15 – Waste management	**Coastal inundation and flooding** Inundation from extreme sea level events and flooding can cause landfill and wastewater systems to overflow and leak into surrounding areas.	**Major**	Sea level rise of 19-37 cm and more severe extreme rainfall events will cause significant inundation and flooding of waste management systems and disrupt recycling transport. Overflowing and leakage of waste systems during inundation and flooding events will be made worse due to increased waste from imported goods and e-waste, and reduced land availability for landfill and septic systems due to coastal erosion and urbanisation. There will be significant consequences for food security and human health in Tuvalu as lagoon fisheries and water quality are significantly impacted.

2050 – Low emissions scenario

Risk Statement number	Component and hazard	Low emissions	Comments
R11 – Internet and telecommunications	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and power supply (blackout), impacting both internet and telecommunications infrastructure.	**Major**	Projected 17-29 cm sea level rise and increasing cyclone intensity will result in more significant impacts of inundation and salinisation on telecommunications and internet infrastructure. The effect on community safety and disaster response systems will depend on implementation of the Tuvalu Telecommunications and ICT Development Project
R12 – Transport and supply chain	**Coastal inundation from king tides and tropical cyclone induced storm surges**	**Extreme**	Inundation and damage to roads will have widespread flow-on effects to supply chains and movement & connectivity of people between islands. The current runway may be

	Roads, bridges, maritime facilities, and airport may be damaged causing disruptions to supply chains and logistics.		submerged for longer periods, causing damage to surface and disrupting supply chain and movement of people, making Tuvalu increasingly cut-off from the outside world
R13 – Building and structures	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding can damage and destroy private, government, commercial, education and industrial buildings. Service provision is disrupted and there are major costs for maintenance, repair and replacement of exposed buildings.	**Extreme**	In a medium emissions scenario, 2478 (52%) of buildings will be exposed to inundation every five years by 2060 with an annual average cost of $76 million from damage to buildings from coastal inundation. The health, safety and housing of community members will be significantly compromised across the region. Productivity and livelihoods will also be disrupted by damage to commercial and industrial buildings.
R14 – Electricity security	**Coastal inundation from king tides and tropical cyclone induced storm surges** Inundation and flooding during extreme sea level rise events affects underground wire infrastructure (salinisation) and may cause instability in the power supply, causing blackouts.	**Extreme**	Continued sea level rise (17-29 cm) and increasing cyclone intensity will result in more significant impacts of inundation and salinisation on energy infrastructure. The reliability of disaster response systems will depend on energy security.
R15 – Waste management	**Coastal inundation and flooding** Inundation from extreme sea level events and flooding can cause landfill and wastewater systems to overflow and leak into surrounding areas.	**Major**	Sea level rise of 17-29 cm and more severe extreme rainfall events will cause significant inundation and flooding of waste management systems, made worse with increasing waste and reduced land availability as a result of urbanisation, e-waste and coastal erosion. Pollution of fisheries, water catchments and coastal areas will significantly impact food security and human wellbeing. Flooding and inundation events may also cause major disruptions to recycling by impacting transport systems.

Confidence

Component	Hazard	Confidence score	Comments
R11 – Internet and telecommunications	Coastal inundation from king tides and tropical cyclone induced storm surges	**Medium**	• Detailed exposure of internet and telecommunications infrastructure requires further information regarding location and implementation of the Tuvalu Telecommunications and ICT Development Project.
R12 – Transport and supply chain	Coastal inundation from king tides and tropical cyclone induced storm surges	**Medium**	• Adaptation plans & investment in climate resilience are underway for airstrip, maritime facilities and roads. Limited information on these projects and risk reduction initiatives.
R13 – Building and structures	Coastal inundation from king tides and tropical cyclone induced storm surges	**Medium**	• No 2030-specific building and structure inundation exposure projection. • Development and infrastructure protection projects may reduce future exposure to inundation.
R14 – Electricity supply	Coastal inundation from king tides and tropical cyclone induced storm surges	**Medium**	• Detailed exposure of energy infrastructure requires further information regarding location and implementation of solar panels and underground wires.
R15 – Waste management	Inundation and flooding	**Medium**	• Detailed exposure of waste management infrastructure requires further information regarding location of waste management infrastructure across islands and the implementation of the 'Tuvalu Integrated Waste Policy and Action Plan 2017-2026'.

Knowledge Gaps

- Limited available information on the development of a proposed new National Building Code.

6 Appendices

Appendix 1:

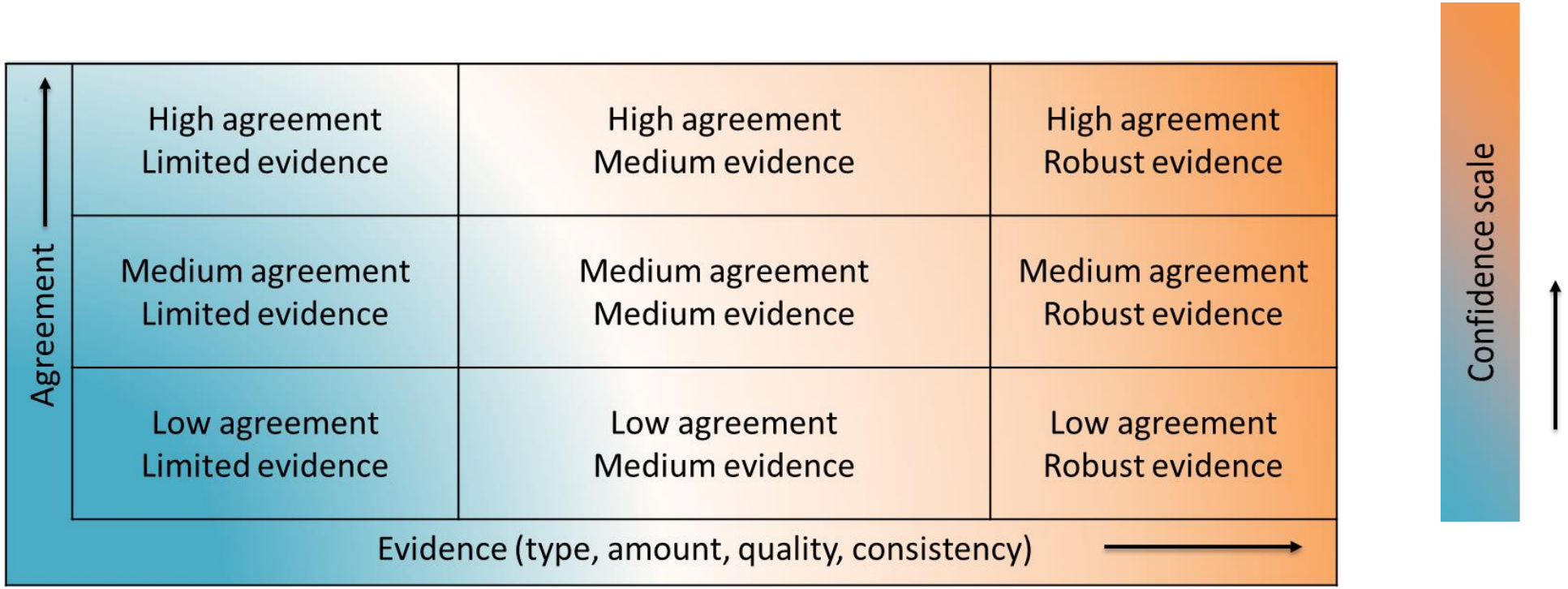
Magnitude of consequence rating criteria

Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
Very minor consequences which can be handled through business-as-usual processes; or some minor island-specific impacts requiring no specialised management or intervention.	Some minor consequences across multiple islands that could be addressed through local or regional management and adaptation processes. Consequences are short-term, not permanent and entirely reversible	Significant consequences to multiple islands (or major impacts to a single island), that may require intervention by the Tuvalu government. Consequences are moderate, but reversible with appropriate interventions.	Major consequences to multiple island (or extreme impacts to a single island), requiring intervention by the Tuvalu government. Consequences are long-term but reversible with significant intervention. May be of interest to Tuvalu's international partners.	Extreme consequences to multiple islands (or concentrated to a single island), that requires urgent intervention by the Tuvalu government. Consequences are permanent and irreversible. Consequences may completely compromise the system. May be of interest to Tuvalu's international partners.

Guidance of the application of the proposed magnitude of consequence scoring criteria

Negligible (1)	Minor (2)	Moderate (3)	Major (4)	Extreme (5)
• *Insignificant infrastructure disruption to utility services (i.e., water, electricity and telecommunication) and road infrastructure.* • *No discernible changes to health and wellbeing, including housing.* • *Indistinguishable impacts on quality and availability of water resources*	• *Isolated and short-term infrastructure service disruption to utility services (i.e., water, electricity and telecommunication) and road infrastructure.* • *Limited to no impact on health and wellbeing outcomes. Some minor restoration work required to commercial, health and residential buildings.* • *Short-term reductions in the productivity and profitability of agriculture and fisheries* • *Temporary localised or minor impacts on quality and availability of water resources.*	• *Many short-term infrastructure service disruptions; disruption recoverable by maintenance and minor repair.* • *Moderate lasting impacts to health and wellbeing outcomes; moderate disruption to education, employment and/or community services.* • *Sustained localised or shorter-term impacts on coastal areas.* • *Damage recoverable by maintenance and minor repair to commercial, health and residential buildings. Some buildings require immediate relocation and assessment.*	• *Widespread short-to-medium term disruptions to utility services (i.e., water, electricity and telecommunication) and road infrastructure.* • *Prolonged disruption to health, safety and wellbeing, social welfare and housing of community members.* • *Extensive infrastructure damage requiring major repair to commercial, health and residential buildings. Significant number of buildings need to be immediately relocated.* • *Regional/medium term reduction in the integrity/stability of most of coastal areas.*	• *Widespread, long-term service disruption; significant permanent damage and/or complete loss to utility services (i.e., water, electricity and telecommunication) and road infrastructure.* • *Health, safety and wellbeing, social welfare and housing of community members is significantly compromised across the region.* • *Prolonged disruption to education, employment and community services.*

Confidence scoring (Confidence) criteria



Appendix 2:

Summary of vulnerable sectors

In 2018-2021, Tuvalu completed an integrated vulnerability analysis (IVA) for all nine islands. The initial phase of the IVA was supported by the Global NAP Network via the International Institute for Sustainable Development. Drawing on the IVA framework for atoll islands, the Tuvalu IVA (TIVA) is based on a sustainable livelihoods approach that combines the assessment of vulnerability to both climate change and disasters. Vulnerability was identified and assessed across seven human security sectors and five livelihood assets, producing a total of 35 intersecting components.

The participants of the focus group discussions were asked to identify the most vulnerable sectors (out of a possible combination of 35 subsectors) by using a nominal scale (1=more vulnerable to 5= less vulnerable). The results were averaged to provide overall national scores for each sector. These national scores where then used to compare against the scores for each island/hamlet.

Based on the national average, the most vulnerable sectors, in order of highest to lowest vulnerability included:

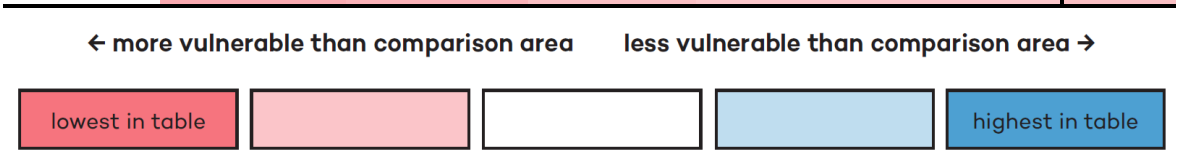
- Ecosystem health (average score of 1.6)
- Income security (average score of 1.9)
- Security of place (average score of 2.0)
- Energy security (average score of 2.0)
- Water security (average score of 2.2)
- Food security (average score of 2.3)
- Community health (average score of 2.4).

The national average scores for the sectors are shown in the table below.

Table 8: National average IVA vulnerability scores

Sector	Sub-sector					Total (avg.)
	Natural resources	Infrastructure & services	Finance	Human resources	Institutions & governance	
Ecosystem health	1.4	1.5	1.7	1.7	1.7	1.6
Water security	2.0	2.3	1.9	2.4	2.4	2.2
Security of place	1.4	1.6	2.0	2.7	2.4	2.0
Energy security	2.2	1.9	1.9	2.1	1.9	2.0

Income security	1.8	1.8	1.9	1.9	2.1	1.9
Community health	2.0	2.3	3.2	1.8	2.5	2.4
Food security	2.1	2.2	2.1	2.6	2.5	2.3
Total (Avg.)	**1.8**	**1.9**	**2.1**	**2.2**	**2.2**	**2.1**



Source: TIVA reports, 2021

Summary of results

Based on an assessment of climate hazards, exposure, vulnerability and related impacts currently experienced in Tuvalu, each hazard has been assigned a rating (Table 9). Currently, sea level and droughts are given a 'very high' impact rating, while the other climate hazards have a medium or high rating (Table 03). These may, or may not, change under projected climate conditions. For example, the projected decrease in droughts by 2050 is expected to reduce the impact rating from high to medium although the intensity of droughts is expected to increase. The projected increase in sea level by 2050 is likely to raise the impact rating from very high to extreme for low emissions and very extreme for high emissions. The impact ratings will also increase for marine heatwaves and floods, given projected increases in SST and extreme rainfall. The rating for cyclones does not change in future because the projected decrease in frequency and increase in intensity have high uncertainty and low confidence.

Table 9 Climate hazard ratings for Tuvalu, for current and future conditions (Table 131) (2030 and 2050 for low and high emissions pathways), noting current vulnerabilities and exposure based on the TVAR (T), Chapter 12 of this report (L), or in-country (IC) missions. Colours are aligned to the impact rating scale below. SST is sea surface temperature and MHW is marine heatwave.

Low	Medium	High	Very high	Extreme	Very Extreme	Unclear

Sector/Theme	Source	Current vulnerability and exposure	Current hazard ratings	Future hazard ratings		
				2030	2050	
				Low/high	Low	High
Fisheries: ocean	L	National revenue and household consumption is strongly dependent on offshore fish catches and licenses	SST			
Fisheries: coastal	T*, L	Household consumption is strongly dependent on inshore fisheries and aquaculture population size and diversity	SST			
	T	Invasive species affect marine food sources (e.g. Crown of thorns seastars).				
	L	Food and fish are vulnerable to spoiling on boats on very hot days due to lack of refrigeration	Extreme temperature			
	T	Invasive species affecting crabs etc. (e.g. yellow crazy ants)	Temperature			
	T, L	People can drift away and become lost at sea when weather / waves too rough	Wind speed			
	L	Fish being processed may spoil in the heat without refrigeration, affecting potential sale value and suitability for consumption	Extreme temperature			
	T	Declining health of coastal marine habitat such as coral reefs	MHW			
			Ocean acidification			
	T	Low drought resilience of marine food sources observed in past droughts	Drought			

		(Nukulaelae) maybe due to low water flushing through the lagoon				
	L, T	Nutrient runoff, pollution and wastewater degrades water quality	Extreme rainfall			
	L	Sea turtle gender affected by sand temperature (air temperature and SST)	Sand temperature			
	L	Sargassum polycystum due to high nutrient levels near densely populated areas (mainly in Funafuti lagoon)	Wind Rainfall			
Agriculture	T	High exposure in low lying coastal areas with reducing resilience to coastal inundation, declining or poor soil quality for farming with salt water intrusion and storm surge (Vaitupu in particular). Low resilience of crops to saltwater leading to declining or limited crop diversity (Niutao, Nui). Crops can become inundated with saline water from wave overtopping	Extreme sea level			
	T	Poor soil quality and exposure of crops to saltwater intrusion from below	Extreme sea level			
	L	Livestock (pigs) are vulnerable to heat stress	Extreme temperature			
	T, L	Crops have shown low resilience to droughts in the past	Drought			
	T	Crops have shown low resilience to floods causing recurrent crop failure	Extreme rainfall			
	T	Low resilience of crops to tropical cyclone winds and waves e.g. breadfruit dropping	Cyclones			
Coastal infrastructure and ecosystems	T*, L	With high exposure in low lying coastal areas, and limited coastal protection, shorelines are retreating due to coastal inundation and erosion (Nanumea and Nanumaga in particular). Exposure to salt water due to coastal inundation causes decline in shoreline vegetation health and cover.	Extreme sea level			

	L	Asphalt road surfaces/ airport runways are poorly maintained and exposed to coastal inundation/erosion, e.g. pot holes (Funafuti and Vaitupu)	Extreme sea level			
			Extreme rainfall			
			Extreme temperature			
	L, IC	Water, electricity and other infrastructure subject to flooding	Extreme rainfall			
	L	Inadequate marine conservation including coral / coast protection, also to waves generated by remote severe cyclones.	Ocean acidification			
			Marine heatwaves			
			Cyclones			
Health	L, IC	Heat stress occurs where there are buildings without cooling and at outdoor worksites without protection from the sun, and during power outages	Extreme temperature			
	L	Limited capacity to cope with heat related morbidity, diabetes, and heat related mental health issues				
	L	Food safety issues where refrigeration is not available				
	T	Lack of refrigeration and timely transportation of medical supplies				
	T	Changes to offshore fisheries may affect fresh food quality and quantity	SST			
	IC	Incidence of Cigateurra poisoning	SST			
	T	Exposure to vector borne disease (Chikungunya, dengue and lymphatic filariasis)	Temperature			
			Rainfall			
	T	Exposure to water borne diseases due to poor water quality and environmental health, especially during floods	Extreme rainfall			

	L	Flood related water borne disease and sanitation issues due to limited water treatment and sewage treatment plants				
	L	High exposure to inundation, loss and damage in low lying coastal areas, affecting mental health	Extreme sea level			
	T	Low resilience of health infrastructure to inundation				
	L	Communities affected by lack of access to water and reduced agricultural productivity, contributing to water/food stress and mental health issues	Drought			
Water infrastructure	L, IC	Water demand increases under extreme heat conditions	Extreme temperature			
	T	Saltwater intrusion affects ground water quality, affecting potable water supply	Extreme sea level			
	L, T	Increasing pressure on water resources occurs during drought due to limited access to water treatment equipment, inadequate household and communal water tank capacity, leaking or faulty household water tanks, and inadequate public water supply system and services	Drought			
	L	Drainage affected during flooding events leading to reduced water quality	Extreme rainfall			
	T*	Limited ability to capture water in household water tanks due to land availability and cost of purchasing and maintaining water tanks	Rainfall			
Disaster risk management	T	Lack of cyclone-proof and rain-proof housing, e.g., cyclone straps, poorly fixed roofing materials	Cyclones			
			Extreme rainfall			
	T	Limited access to post-disaster building reconstruction services, including shipping and transportation being affected by waves generated by remote severe cyclones.	Cyclones			
	T*		Cyclones			

		Limited or no access to adequately sized and located evacuation centres (Vaitupu, Nui and Nukufetau) (Top TIVA priority)	Extreme sea level			
	T, IC	High exposure to coastal inundation in low lying areas affects power supply and evacuation centres	Extreme sea level			
	L, IC	Inundation and damage to roads and airports affecting transport services	Extreme rainfall			

*denotes vulnerability issue with the highest

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Our work is performed on a sample basis; we cannot, in practice, examine every activity and procedure, nor can we be a substitute for management's responsibility to maintain adequate controls over all levels of operations and their responsibility to prevent and detect irregularities, including fraud.

We believe that the statements made in this report are accurate, but no warranty of completeness, accuracy, or reliability is given in relation to the statements and representations made by, and the information and documentation provided by CSIRO personnel and other sources. We have not attempted to verify these sources independently unless otherwise noted within the report.

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