

Strengthening Adaptation Planning and Action to Climate-Related Health Impacts in Pacific Islands Countries: Tonga

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Abstract

A natural hazard and climate change vulnerability and adaptation tool was applied in Tonga to identify health and health system-related climate and natural hazards, and to create and prioritize adaptation strategies and opportunities. During a 2-day multi-sectoral workshop, expert stakeholders prioritized the most extreme health-related and health system risks and devised a series of adaptation strategies. A series of health and health system impacts were identified and related to: cyclones/severe storms, increased average and extreme temperatures, flooding (including landslides), drought, wildfire, tsunami, earthquakes and volcanic activity. The main adaptation strategies identified improving drinking water security; development of Government procedures for drought management; linking health and climate data; increasing food security; improvements in urban design; training health workers; increasing evacuation center resilience in villages; increased research into management responses and enforcing and updating the building code. Adaptation to the health and health system impacts explored during the workshop include many outside the scope of the health system. This paper highlights the importance of multi-stakeholder engagement and co-planning to anticipate and plan for natural hazard and climate-related health and health system impacts and; benefits of establishing and using expert knowledge to determine health adaptation connections, build bridges across sectors and prioritize strategies in the absence of climate and health attributable information.

Keywords: health, environmental health, climate change, natural hazards, adaptation, Pacific Island Countries, planning, cross-sectoral, vulnerability, Tonga

1. Introduction

1.1 Climate Change and Health in Tonga

The intergovernmental panel on climate change (IPCC) and the World Health Organization (WHO) have identified small island developing states (SIDS) as some of the most vulnerable to current and future climate-related drivers of risk (Nurse et al., 2014; World Health Organization, 2015a). The risks projected for the 21st century include increasing air and sea surface temperatures, changing rainfall patterns, storm surges and gale-force winds, sea level rise (SLR), coral bleaching, erosion and tropical and extratropical cyclones (The World Bank 2013; Nurse et al., 2014). These changes to climate can alter health risks associated with: water security and safety; vector borne disease (VBD); food security and safety; zoonoses and respiratory disease (World Health Organization, 2015a). Diffuse impacts are less known but may include disorders of mental/psychosocial health, non-communicable diseases (NCD) and nutrition, food safety and security, health system (as defined by WHO) and population pressures (Skinner et al., 2011; World Health Organization, 2015a; MEIDECC, 2018). There are also likely to be health impacts that are unknown or unpredictable.

When combined, the impacts of climate change and natural hazards from such events can increase direct physical risk to people and critical health infrastructure and facilities (World Health Organization, 2015a; MEIDECC, 2018).

Global climate model outputs for Tonga indicate that climate change and SLR will have serious effects on the biophysical systems and development sectors of the economy (GEF, 2007). The effects impact fresh water, which is projected to decrease by 10% overall by 2050, with a reduction in groundwater recharge by up to 30%. Seasonally dry periods are expected to become even drier and wet seasons wetter, and extreme years when the South Pacific Convergence Zone (SPCZ) moves north and merges with the Intertropical Convergence Zone (ITCZ) are projected to become more frequent with increases in ambient temperature (GEF, 2007; CSIRO, 2015). By 2100, rainfall projections are even lower, on average decreasing by 17.5% with a 32% reduction in recharge of the groundwater. In addition to the loss of this resource, SLR can affect groundwater through saltwater intrusion. Flooding associated with climate extremes such as storm surges will also erode land impacting on agricultural production and coastal infrastructure. The 2100 projections show a 1m rise in SLR at Tongatapu, part of the southernmost island group and home to the capital and largest city, Nuku'alofa, which accounts for 74% of the population. Land loss due to SLR equates to 10.3 km² of land or 37.3 km² of land associated with storm surges, or a total loss of 14% of land area of Tongatapu (GEF, 2007; MEIDECC 2018). Tropical cyclones are also projected to increase in severity, although potentially decreasing in frequency (The World Bank, 2017). Previous vulnerability and adaptation assessments in Tonga indicate that key development sectors will likely be affected by climate change. These sectors include water resources, forestry and agriculture, coastal areas and resources, fisheries and human health (GEF, 2007).

In 2015, the WHO identified the health impacts of extreme weather events, water security and safety, food security and safety, VBD and NCD as priority areas for Tonga (World Health Organization, 2015a). Tonga is also experiencing an epidemiological transition (Wahdan 1996) from infectious to NCD which are currently the main cause of morbidity and mortality in Tonga. Due to changing climate NCD are also projected to increase e.g. increased cardiovascular disease and diabetes complications due to increases in heat, air pollution, physical inactivity and dietary changes (Friel et al., 2011; International Diabetes Federation, 2012; Smith et al., 2014; Tonga Health Promotion Forum, 2016; McIver et al., 2016). Together, these pose challenges for the health sector and require sufficient and prioritized adaptation effort across multiple sectors.

1.2 Tonga Country Profile

The Kingdom of Tonga (Tonga) is a small developing Polynesian country in the Pacific region with a population of approximately 100,000 people (Tonga Statistics Department, 2016) (Figure 1). Tonga is an island chain, consisting of 176 islands, 52 that are inhabited with a total area of 290 square miles (748 km²) spread over 270,000 square miles in the southern Pacific Ocean.



Figure 1. Map of Tonga (Source: GCCA, 2013)

Compared to the rest of the Pacific, Tonga, is generally cooler, due to its southerly latitude (20-21°S). Depending on the latitude, annual maximum and minimum temperatures range from 28 °C to 15 °C respectively (Tonga Meteorological Service – Ministry of Civil Aviation). Rainfall is influenced by the position and strength of the SPCZ, a band of low-level (wind) convergence, cloudiness and precipitation, and the Pacific part of the ITCZ. Tonga's high exposure and susceptibility to natural disasters and climate change has contributed to its ranking as the second most vulnerable country in the world according to The World Risk Report 2018 (Heintze et al., 2018).

1.3 The Joint National Action Plan Approach

Planning and adapting for future risks relies on climate projections specific to Tonga but also, critically, on how that information is harnessed for decision making. Vulnerability and adaptation assessments, in-country consultations, and the Pacific joint national action plan for disaster risk management and climate change (JNAP), have provided useful information on the impacts of climate change in general (Tukutau, 2004; USP, 2012; World Health Organization, 2015a; SPC, 2016; MEIDECC, 2018).

The reality for many Pacific island countries (PICs) include pressure to recover from increasing intensities of extreme weather events. Recently, Tropical Cyclone Pam (March 2015), Tropical Cyclone Winston (February 2016) and Tropical Cyclone Gita (February 2018) have caused devastating damage. Historically such hazards are interspersed with natural disasters such as earthquakes, drought and tsunamis. Natural hazards adversely impact health and hinder development and economic opportunities. For example, Tropical Cyclone Evan in Samoa (2012) was estimated to have cost 30% of GDP estimated at USD \$103.3 million (The World Bank, 2018). Tropical Cyclone Gita impacted

Tonga at an estimated economic loss of USD \$164 million equivalent to 37.8% of nominal GDP (Government of Tonga, 2018). However, adaptation opportunities, when delivered in conjunction with other development goals, can generate larger benefits to small islands such as disaster risk reduction and community-based approaches to development (Nurse et al., 2014).

Tonga was one of the first Pacific island countries to develop a joint national action plan for climate change adaptation and disaster risk management. The JNAP is a strategic action framework to address Tonga's climate change and disaster risk management priorities. The first JNAP covered the period 2010-2015 and linked national, regional and international frameworks, policies, plans and agreements e.g. Tonga Climate Change Policy (at a national level), Pacific Disaster Risk Reduction and Disaster Management Framework for Action 2005-2015 (at a regional level), Paris Agreement (at an international level). In 2014 a new Ministry, MEIDECC (Ministry of Meteorology, Energy, Information, Disaster Management, Climate Change and Communications) was created with the mandate to "*ensure the protection and proper management of the environment and the promotion of sustainable development*". Both the Ministry of Environment and Climate Change (MECC) (within MEIDECC) and the national emergency management office (NEMO) co-developed the JNAP2 which covers the period from 2018 to 2028 (MEIDECC, 2018). A revised climate change policy was also endorsed at the cabinet level in 2016 with a strong resilience theme.

The Ministry of Health (MoH) are one of 13 agencies and sectors that link into the JNAP2 framework, which includes health related impacts from natural hazards and climate change. Other sectors involved in the JNAP2 framework also indirectly influence health. For example, agriculture is threatened by extreme events, SLR and drought, impacting on the availability of fresh and nutritionally dense food. Likewise, transport can decrease air quality, and impact respiratory health. Inadequate infrastructure can mean health centers are inaccessible, particularly during extreme events. These are examples of cross-sectorally linked health pathways and highlights the need for a systems thinking approach (Donald and Taghreed, 2009).

The health sector activities identified in the JNAP2 results framework include vulnerability assessments and priority sector resilience plans (MEIDECC, 2018). Specifically, the need for a systematic evaluation of all health facilities to determine their ability to withstand extreme weather events (e.g. cyclones) and to assess costs for developing secure and sustainable water supplies (roof water collection stored in ground tanks), energy independence (solar power systems) and climate proofing of buildings is mentioned in the chapter on health. A health sector plan, often referred to as a (climate change) and health adaptation action plan (HAAP or CCHAP) was also specified to be developed by 2018 although to date this has not occurred.

In 2017, a request from the Tonga MoH was made to the Institute of Environmental Science and Research, New Zealand, to assist in developing a health adaptation and action plan (HAAP). In July 2018 a team of environmental health scientists (AB and KK) and a health protection officer (JW) visited the MoH to pilot a vulnerability and adaptation assessment (V&A) that was led by the MoH. The main objective of the V&A was intended to provide information for the MoH, in collaboration with other health determining sectors e.g. environment, agriculture, non-Governmental organizations (NGOs), to develop a health action and adaptation plan for climate change, prioritize climate change and adaptation options (actions), and to identify areas requiring further research, information or capacity building. An additional objective was to create a dialogue between other Ministries and sectors to allow and enable engagement of climate change and health related information, and to co-develop solutions from a health perspective, but with the knowledge of key intersecting agencies.

2. Methodology

2.1 A Health Adaptation and Action Plan for Tonga

To achieve health resilience, a collaborative approach across all health-determining sectors was envisaged. This is important because areas associated with climate related health impacts are not always in the control of the health sector e.g. air pollution. However, the costs from those health determining sectors, without adequate adaptation/intervention will increase the health sector's ability to cope with such impacts. Inclusion of a wide range of sectors and actors that can influence or determine health can support the development and implementation of strategies to minimize the risks associated with climate related impacts on health. This additionally increases awareness of health-related impacts that may not have been given prior attention. Vulnerability assessments must therefore include all stakeholders, as the main benefits of adaptation occur when critical points across sectors of the population are identified and become the focus of adaptation measures (Spickett and Katscherian, 2014).

There are both quantitative and qualitative approaches to collecting climate, hazard and health information to provide

the evidence required to support and evaluate health resilience plans (e.g. health impact assessment, vulnerability and adaptation (V&A) assessments, indicators, surveillance data, hospital data etc.). The WHO recommends assessment processes that include inputs from academic experts, to ensure high quality evidence, as well as managerial and operational personnel to ensure relevance to policy and practice. It also states that the process should involve a range of stakeholders and use information from a variety of sources, including health and non-health scientific information, as well as community knowledge and feedback (World Health Organization, 2015b). The involvement of the public and the widest possible range of sectors in all stages of V&A should provide those with interests the opportunity to engage in the process and act collaboratively to make the best use of possible benefits as well as to minimize potential adverse effects. These recommendations were incorporated into the workshop as described in the following section.

2.2 Climate Change and Health Vulnerability and Adaptation Assessment: Workshop Process Overview

The health and action planning tool for Pacific island countries (HAAP-PIC) has been developed as a step-by-step guide to developing a country's Health Adaptation and Action Plan. In conjunction with other available resources (Brown et al., 2014; World Health Organization, 2014; United Nations, 2015; World Health Organization, 2015b) the tool has tried to simplify the process for the initial work required and allow work to continue in country. Unfortunately, poorly resourced and over-committed health staff seldom have the time to read and analyze the vast number of frameworks and policies that exist and provide information required. The HAAP-PIC tool aims to empower individual government health bodies (or equivalent) to develop (and in later years, revise) action plans at their own pace and provides guidance to carrying out the analysis. From a health perspective, the workshop is seen as the first step in a process that will contribute to a co-operative and health-focused approach to adaptation strategies for the sectors associated with natural hazards, climate change, health determining sectors and health sector resilience.

The Tonga workshop was conducted over two days in July 2018. A total of eighteen participants from health (n = 7) and non-health (n=11) sectors took part in the workshop and included public health inspectors, climate change technical officers, meteorological duty forecasters, JNAP2 officers, an education officer, environment/disaster division coordinator, and several project officers representing NGOs (Red Cross, Tonga Community Development Trust, Tonga National Youth Congress, Civil Society Forum of Tonga). The process used in-country expert and stakeholder views to identify the potential impacts that could arise due to climate change and natural hazards in health, health systems, and health-determining sectors.

Individuals were assigned to groups in one of five major areas based on their areas of expertise:

- (1) health; environment or ecology e.g. air quality experts, water experts, food
- (2) social; economists, lifestyle, housing, workforce, population displacement, psychosocial factors
- (3) community services and essential services
- (4) sustainable technologies and infrastructure; energy, transport, built environment, sanitation telecommunications, water, waste
- (5) "other"; community groups or NGOs.

At the beginning of day one, several presentations were given to the participants that covered climate change projections in Tonga and an update on JNAP II (MEIDECC); current and future impacts of climate change to health (MoH) and an introduction to health adaptation and action plan for climate change and disaster risks for Pacific Island countries (ESR). All the presentations were given in the context of the impact of environmental change on human health and well-being. The timeframe and climate change projections were also discussed. For example, the JNAP2 is designed to adapt to medium to long term changes in climate e.g. 2018-2028 and is a similar timeframe to the Sendai Framework for Disaster Risk Reduction (2015-2030) (United Nations, 2015). Most attendees decided to focus on a shorter timescale (10-20 years) in line with the JNAP2. It is noted that climate change (i.e. long-term changes to weather patterns is used here) but refers to current changes in weather patterns already being experienced in the Pacific, rather than those expected in the next 50-100 years. Following this discussion, each group, was asked to complete a series of tables to identify natural and climate related risks; the health and health system impacts which were split by biophysical, social and service/infrastructure factors and specific vulnerabilities. Vulnerability was described to the participants as the combination of exposure, sensitivity and adaptive capacity:

Vulnerability = Exposure + Sensitivity + Adaptive Capacity

Where Exposure = having no protection from something harmful

Sensitivity = dependence on the environment e.g. for work, food, shelter and medicine; lack of access to decision making and justice, geographical context, a range of intersecting inequalities including financial, socioeconomic, cultural and gender status

Adaptive capacity = assets (social, physical, financial, natural, human, and cultural) and resources (technological, knowledge and governance) which an individual, household or community may mobilize to build resilience to climate change impacts

Groups were asked to base their risk scores on the evidence available to make decisions where a score of 1 = good evidence and 5 = no evidence. Each group was asked to present a summary of their completed work which was opened for discussion.

The second day aimed to assess the potential health and health system impacts by examining and prioritizing the risks. Each of the participants joined in activities designed to consider, assess, and prioritize adaptation responses to the risks identified, to reduce the health impacts and health system for people in Tonga. The three groups were asked to select which of the hazards they would like to promote into the adaptation strategies section. Each group then co-created a table of adaptation strategies that were split into the following five categories below. Each category was explained in a power point presentation and examples were provided:

- Legislative or Regulatory
- Public Education and communication
- Technological or Engineering, Infrastructure Development and Ecosystem Intervention
- Health Intervention and Health Systems
- Research/Information/Surveillance/Monitoring

The adaptation strategies from each group were categorized by theme and displayed on a wall. Dot voting (a facilitation methodology) was used in this process. Each participant was given a selection of dots (red, orange and green). The red dots represented high priority, orange medium and green low. The participants were asked to stick 3 dots next to any adaptation option they considered a priority, and to rate the level of priority by the color of the dot (high, medium, low). The participants were able to use their 3 dots for the same adaptation option, or for any individual option or a mixture.

Finally, feedback form the workshop was collected, and a workshop report was sent to all participants that summarized the workshop process, information collected, key outcomes, knowledge gaps and next steps.

3. Results

3.1 Workshop Participants and Risk Ranking

The natural hazard or climate change related health risks that participants overall considered the highest risk (extreme) were related to extreme temperature and wildfire. These were followed by risks related to high to extreme events: cyclones/severe storms, increased average temperature, flooding, drought and tsunamis. Only volcanic activity was considered to present a low to high risk to health. Those risks were specific to the location and the projected direction of any ash fallout. Using the IPCC 1995 (Watson et al., 1995) for guidance, identified health effects were separated into direct impact (21%), and indirect (79%) (Appendix, Table 1).

3.2 Health and Health System Impacts

The health and health system related natural hazards and climate change related events identified during day one are summarized in Appendix, Table 1. These events are not new to Tonga but were considered requiring adaptation for the future. Other impacts worth noting are those caused by amplification of El Niño and La Niña events and seasonal changes or shifts in rainfall. The most frequently cited health impact was water security and safety (n = 19), followed by food security and safety (n = 10). The most frequently cited health system impacts were capacity of health systems (n = 7), infrastructure (n = 7) and healthcare worker access/ability to cope (n = 7).

3.3 Vulnerable Groups

For natural hazard related events, children, persons with disabilities and older people were identified as most vulnerable. In addition, gender, social equity (poorer people) and social conflict was also raised as an issue. People living in brick houses or living/working in high buildings were identified as vulnerable to earthquakes. The entire population of Tonga was considered vulnerable to drought and cyclones. For dengue fever, those living in swampy

areas were considered at higher risk.

For gradual (e.g. increases in ambient air temperature) climate-related events, children, persons with disabilities and older people were identified as more vulnerable. Areas of high population were considered more vulnerable to changes in temperature, as were poorer communities because of their lower adaptive capacity e.g. increases in food prices due to food security issues. Social conflict was also highlighted as an issue related to SLR, and vulnerable groups were identified related to gender (i.e. females were considered more vulnerable).

For extreme climate-related events, the impact of cyclones identified several vulnerable groups including health care staff and head of households. People with disabilities, older people and young women were identified as vulnerable to landslides, whereas the entire country was vulnerable to flooding.

The extent of vulnerability within the events considered, varied widely and was dependent on the specific health impact and other factors such as socio-economic, health, mental-health status, access to health care services and adaptive capacity.

3.4 Geographical Vulnerability

Geographical vulnerabilities can also occur in terms of exposure, sensitivity and adaptive capacity. The areas highlighted in terms of vulnerability show that impacts will not be experienced equally.

Communities in low-lying or in coastal areas, were identified as vulnerable to flooding, SLR, storms and sea-surges. In terms of sensitivity and adaptive capacity, regions with a high proportion of rural or isolated populations were identified at risk from specific hazards, for example landslides, extreme temperatures and drought leading to displacement and potentially relocation.

The main city, Nuku'alofa was identified as vulnerable to some impacts (temperature increase), in addition to additive effects such as urbanization, population density, traffic and air pollution.

Wildfires were more likely to impact on communities with bush allotments, those working in forestry, plantations or that kept (farm) animals. Those living near mosquito breeding habitats such as swampy areas were also more vulnerable to VBD.

3.5 Health System Vulnerability

Health system vulnerability may occur from direct physical damage to existing infrastructure. Other vulnerabilities include increases in demand such as the stress on human and resource capacity, lack of medical training, increases in hospital admissions, disruption to critical services and access to health care itself. Outer islands were identified as vulnerable from a health system perspective. Access to health centers, capacity of staff on outer islands and the difficulty of monitoring or support were common issues. Reduced access to essential services and a greater reliance on climatic factors for economic prosperity were identified as the potentially major contributors to vulnerability.

Infrastructure and service vulnerabilities were highlighted in remote areas and islands. Many of the participants mentioned that even basic health services were lacking, such as the availability of medical doctors on some islands.

3.6 Economic Vulnerability

Identification of economic vulnerabilities was much weaker compared to other vulnerabilities and probably reflects the lack of economic expertise at the workshop. However, the impacts considered include the increased need to prevent worsening of poverty. Impacts include increases in costs of food, water charges during times of shortage and the need to support communities that depend on the local environment such as farmers or subsistence growers that may suffer from health-related impacts via loss of income.

3.7 Specific Vulnerabilities

In addition to the vulnerabilities outlined above, some potential health impacts applied to specific vulnerable groups. People who spend large amounts of time outdoors, either through occupational or lifestyle activities were considered vulnerable to UV exposure and heat-related illnesses.

Other subtler social vulnerability was noted. During discussions related to evacuation centers and the impact on religious beliefs some participants expressed the view that evacuation centers that functioned normally as churches could influence religious beliefs. Other comments suggested that churches were not necessarily hazard proof and that the focus in the future should be on creating evacuation centers for every village.

General social comments also related to crime e.g. theft during natural disasters that resulted in a lack of evacuated

homes due to fear of burglary. On the other hand, there were serious mental health outcomes observed following natural disasters including homicide and domestic violence due to the stress or inability to deal with the stress (e.g. alcohol abuse).

3.8 Adaptation Responses

Participants agreed to focus on extreme hazards. The prioritized adaptation strategies presented in this section are not exhaustive. The strategies represent those from all the sectors who participated, and there is potential for this phase of the tool to be expanded (Appendix Tables 2-7).

Adaptation strategies were identified across five main categories:

- Legislative or regulatory
- Public education and communication
- Technological or engineering, infrastructure, development and ecosystem Intervention
- Health and health system intervention
- Research/information/surveillance/monitoring

The complete list of adaptation strategies (Appendix Table 8) was prioritized by participants (high, med, low) in terms of urgency. The scores (high, med, low) were used to assign weights to each of the options i.e. Each red dot has been given a score of 3, orange 2 and green 1. For example, if an adaptation option had 2 red, 1 orange and 1 green dot it would receive a score of $(2 \times 3) + (1 \times 2) + (1 \times 1) = 6 + 2 + 1 = 9$ but a total number of dots equaling 4.

The adaptation strategies with the highest scores (top 30% cumulative) relate to temperature increase whereas strategies with the second highest scores (next 20%), relate to drought, temperature and flooding (Table 2).

Table 2. Climate change and health adaptation strategies with the highest scores

Strategies with the highest scores (top 30%)	Strategies with the highest scores (top 40-50%)
Adequate drinking water supply (plus maintenance and security), especially on the outer islands (<i>increased temperature</i>)	Research – develop Government procedures for drought management (<i>drought</i>)
Linking health and climate data (e.g. hospital admissions) (<i>increased temperature</i>)	Enforcing current building codes (<i>flooding</i>)
Resilient crops (<i>drought</i>)	Improve food resilience (engineering, diverting, storage) (<i>flooding</i>)
Create more shade (co-benefit by planting edible foods e.g. coconuts) (<i>increased temperature</i>)	Update building code (ventilation) (<i>increased temperature</i>)
Training (personal hygiene, health impacts, water consumption, storage, management) (<i>drought</i>)	Future-proof reticulated waste water systems (<i>flooding</i>)
Ensure every village has an evacuation center (<i>flooding</i>)	

The results of this V&A have identified several health and health system related impacts and, importantly, prioritized adaptation activities. The next section discusses the relevant findings from Section 3, in order to develop a health adaptation and action plan.

4. Discussion

There is no one size fits all approach to V&A. In the Pacific, several other climate change vulnerability and adaptation assessments exist. Most are generic e.g. USP (2012) and include some health aspects, whereas other focus on a single issue e.g. SPC (2016). The assessments summarized in Table 1 draw upon several different methodologies. In Kiribati, a whole-of-island (WoI) approach to integrated vulnerability assessment (IVA) was used. This approach forms non-traditional linkages between the health sector and other actors, which enable more informed and efficient

adaptation planning. Other “types” of V&A include Community Vulnerability and Adaptation Assessment and Action (CV&A) which focus on collecting data from the community (elders, men, women, youths and children). Information collected includes experiences in relation to climate variability, change over time, and extreme events, current vulnerability to both climate and non-climate related factors, and on examining current adaptive capacity. Communities are asked to evaluate their perceived vulnerability to future climate related risks, leading to the formulation of adaptation policies to strengthen adaptive capacity. To support decision making, climate modelling and scenario generation and social science can be employed if available.

Table 1 summarizes selected V&A in Tonga, including those specifically centered on health adaptation. Analysis of these assessments identifies some limitations. There has been no monitoring of the identified health risks or trends. The same risks are being reported within decades of each other, but these are not quantified, so it is not possible to know how those risks have changed over time. Health infrastructure risks do not appear to have been covered well, although it is acknowledged that major assessments must have taken place (i.e. the relocation of the hospital at Ha'apai). The MoH assessment in 2004, identified socio-economic and demographic risks and recognized the economic costs to health, personal suffering and productivity which had knock-on effects nationally. However, this is an exception rather than the rule. Importantly, to date, except for the JNAP, there appears to have been no climate change and health adaptation discussion at a national and community level. The following sub-sections describe the change and health adaptation suggestions of the workshop.

4.1 Adequate drinking water supply

Drinking water supply, maintenance and security was a high adaptation priority. This was also identified by WHO (World Health Organization, 2015a) and SPREP (GEF, 2007). Improving infrastructure development in outer islands and rural areas, including climate change resilience is a policy area of the Government (GEF, 2007) and should be considered from a health lens. Resilience needs to reflect current and future water security sources, safety efforts to increase water supply and quality, and improved water use efficiency. A resilient water supply is strongly influenced by the ability to anticipate and prepare for threats to supply, and this requires bringing together datasets and expertise from a range of sectors. Led by the MoH, Tonga is progressing a national safe and secure drinking water and sanitation programme. Mainstreaming current policies is an important aspect to avoid duplication and create clear lines of governance. A lack of basic infrastructure in remote islands contributes to poor adaptive capacity and even greater vulnerability. Remote islands were viewed as particularly vulnerable to drought and extreme temperatures. Coupled with lack of basic healthcare these communities were perceived as requiring immediate adaptation; for example, ensuring that each village has an evacuation center (see 4.3) and an adequate water supply. In the past, some islands have depleted their drinking water sources and have relied on bottled water being shipped, at an expense and environmental cost (pers. comm. plastic water bottle pollution was noted as one of the environmental costs). In the past, donor agencies had provided portable desalination equipment, but because of their weight there was no suitable marine vessel to take these over to the islands (pers. comm.). Therefore, adaptation needs to consider improving communication and co-ordination between organisations during times of emergency to ensure critical resources reach vulnerable communities in times of need.

Table 1. Summary of selected vulnerability and adaptation assessments in Tonga. Note that not all of these were specifically focused on health but have been included due to their relevance to health

Vulnerability and Adaptation Assessment Report	Climate Related Health Risks Presented	Climate Related Health System Risks Presented	Adaptation Options Presented	Location	Comments	Reference
This study	Water and food safety, security, access and capacity	Infrastructure and healthcare worker resilience	Yes	National	Health risks are those prioritized	This paper
Climate change vulnerability assessments for communities in six Pacific Island countries: Fiji, Kiribati, Samoa, Solomon Islands, Tonga and Vanuatu (2016)	Increased food security Loss of forest cover Damage to trails and roads Water quality and quantity decline Emergence of water-borne diseases	No	Yes	Houma village ('Eua) Tefisi village (Vava'u) Kolonga village (Tongatapu)	Not specifically health focused but includes some health-related areas.	SPC 2016a
Results of Land Cover Type Mapping and Coconut Resource Field Inventory Using World View-2 Image Data, Tonga Vava'u Island (2016)	Coconut Resource Inventory		Limited	Vava'u Island		SPC 2016 b
Enhanced Climate Change Resilience of Food Production Systems for selected PICTs Tonga Vulnerability Analysis Report	Food security		Yes – as part of JNAP	Kolonga Village, Tongatapu Houma village, 'Eua Tefisi village, Vava'u		US Aid 2017
Rapid Vulnerability and Adaptation Assessments of six Communities in Tongatapu, Ha'apai, and	Water supply and security Water quality Water-borne and vector		Areas were prioritized but no adaptation. Recommendations to select pilot sites for further work.	Popua Village Sopu Tatakamotonga		USP 2012

Vava'u, Tonga (2012)	borne diseases Sanitation Food security Energy Disaster risk management Housing Determinants of health (income per household) and source of income.			Village Ha'afeva Island Tu'anekevile Village Ovaka Village		
Joint National Action Plan 2 (2018)	Vector-borne disease Drinking water security (drought) Drinking water quality (saltwater intrusion/Sea level rise)	Health facility vulnerability to climate change and disaster impacts (extreme weather events)		Some adaptation work undertaken: installation of water tanks in schools, churches and communities, climate proofing of schools and community halls, evacuation roads, relocation of hospital in Ha'apai. Includes sector resilience plan for health, water resources.	National	MEIDECC 2018
Human health and climate change in Pacific island countries (2015)	Water safety/security and diarrheal diseases Food safety/security Vector borne diseases (esp. dengue) Nutrition and its links with NCDs Injuries, deaths from extreme weather vents (tropical storms, floods and other climate-related disasters)	Damage to infrastructure from extreme weather vents (tropical storms, floods and other climate-related disasters)		Adaptation options focused on water and food safety and security.	National	WHO 2015b
Climate change project (2004)	Flooding (injuries) Water borne disease Food borne disease	Loss or damage to health infrastructure (SLR, extreme weather events)	Yes		National	This V&A was led. Tukatou 2004

Malnutrition (loss of food resources)	Loss of determinants of health (housing/resources)
Vector borne disease	Increased stress on healthcare system
Water shortage	
Skin infections	
Respiratory disease including allergic disorders (air pollution) and influenzas (following cyclonic activity)	
Socio-economic and demographic dislocation (overcrowding, decline in socio-economic development psychological disorders)	

4.2 Linking Health and Meteorological Data

Linking health and meteorological data (e.g. hospital admissions) and therefore historical changes was the second highest adaptation priority identified. Ascription of disease to meteorological conditions is challenging but can be used to provide evidence based on detection and attribution (Ebi KL, 2017). This allows health departments to prioritize the current, and plan for future climate change-related health burdens and derive evidence-based policies (Baicker and Chandra, 2017). This also supports actions to mitigate greenhouse gas emissions.

However, some challenges were identified. First, in order to gather appropriate correlations, historical data is required. This may or may not exist as some health records are manually recorded and would require large amounts of labor to digitize. To acquire the health data that is not already collected, digital health information systems need to be in place and capable staff (e.g. health and data analysts) will be needed or need to be trained. It is noted that SPC via the Fiji National University and ESRs Healthy Pacific Environments programme have developed training courses to support some of those needs.

The health sector needs to monitor the developing impacts of climate change, the effects on the population and the level of preparedness of its and other sector services, and communities. The relationship between health and climate can also be used from a modelling perspective to provide projections spatially and various climate scenarios. This information can be used to inform stakeholders where and what adaptation mechanisms will need to be resourced in the medium to long term.

Many countries are adopting centralized approaches to collecting climate, environmental, epidemiological and health related data e.g. The US Centre for Disease Control and the European E3 network (National Center for Environmental Health 2019; European Environment and Epidemiology Network E3 Geoport 2005-2019). Coordination and communication of climate and natural hazard related risks and opportunities could also be improved via the creation of an information platform that can be used across multiple sectors and countries.

The Environmental Public Health Tracking (EPHT) system under development in Tonga will bring together data sets critical to supporting adaptation planning. The EPHT system will link the impacts of environmental hazards, meteorological events and vector incursion, with community and national-level health outcomes. Data to support EPHT is drawn from several stakeholders which enables the development of a current, quality-assured and nationally coherent dataset, that can derive environmental health intelligence for adaptation planning. This avoids working in silos, holding back critical information and duplication. It also improves decision making, increases transparency across sectors and can be used to develop health early warning systems.

4.3 Planning Ahead: Evacuation Centers, Urban Design and Building Resilience

Provision of adequate evacuation centers and improving and enforcing the building code would lead to improved health outcomes, and particularly so in the event of natural disasters. Procedures to deal with drought such as water management, training, understanding the health impacts was another high priority area that is likely to be led outside of the health sector.

Many health adaptation strategies were cross-cutting (e.g. resilient crops, improving and enforcing building codes, creating more shade). Co-ordination across sectors is already included as part of the JNAP2. The health sector component could be strengthened by a health national adaptation and action plan that would support cross agency national planning. For example, resilient crops and improving food resilience are areas that should be led by agricultural departments but would also yield co-benefits to health. Integrated planning to create more shade (with edible plants) was another adaptation option that ideally would be led by urban and rural planners but alleviate heat impacts. Additionally, urban planners can support physical activity by creating spaces that encourage opportunities for light to moderate exercise and in turn support NCD initiatives. Community health is reliant on resilient infrastructure and services such as clean water, reliable energy, transport, communication, medical and other services. Strengthening those systems will form an important component of adaptation plans. Currently, cardiovascular and chronic respiratory diseases, diabetes and cancers account for more than 80 percent of deaths. Although the implementation of priority interventions for NCDs can prove challenging and have been considered the main obstacle in Pacific island countries and territories (Magnusson and Patterson, 2015; World Health Organization, 2015a), Tonga are already heading in the right direction by the provision of more recreational areas that encourage walking and cycling (pers. comm.).

4.4 Training and Research

Education (and communication) has a key role, including capacity building across the health sector, to improve preparedness of the health impacts currently and to come. The development of a research agenda (e.g. a climate change research action plan, further research into indirect impacts of climate change on non-communicable

diseases, successful implementation of adaptation in other PICs), to address knowledge gaps and monitor current and future health burdens is needed.

Alongside implementing adaptation strategies there needs to be an awareness of the current health care system. For example, previous work by Smith et al. (Smith and R. Sauerborn, 2014) identified issues with the number of doctors and medical specialists, the availability of medicine and aged medical equipment in the country. These issues are exacerbated in the outer islands that are low in infrastructure and staff capacity and have limited access to healthcare.

In terms of research gaps, updated V&A should include social care, gender equity and more information on the role of community, voluntary sector and NGO's. Aged groups were identified as vulnerable to a wide range of potential climate or natural hazard impacts, particularly temperature, cyclones and volcanic activity. Pre-existing medical conditions can also increase vulnerability to a range of health impacts (e.g. diabetes and asthma).

4.5 Resourcing

An unintended outcome of Tonga's JNAP process was the need for the MoH to develop its own climate change and health adaptation plan, which currently is not able to be resourced by the green climate fund (GCF). The WHO have recognized that the GCF has not typically funded health related adaptation projects in the Pacific, and it is noted that there are now efforts to understand the funding barriers for health-related projects and to address this need. It was also observed that there are several NGO's and civil society organizations working in this space who are critical to engage with.

4.6 Key Findings

The main objective of this V&A was to provide information for the MoH, in collaboration with other health determining sectors to develop a health action and adaptation plan for climate change, prioritize climate change and adaptation options (actions), and to identify areas requiring further research, information or capacity building. An additional objective was to create a dialogue between other Ministries and sectors to allow and enable engagement of climate change and health related information, and to co-develop solutions from a health perspective, but with the knowledge of key intersecting agencies.

The main health and health system impacts (rated high to extreme) identified were from the events: cyclones/severe storms, increased average and extreme temperatures, flooding (including landslides), drought, wildfire, tsunami, earthquakes and volcanic activity. However, the health impacts were not necessarily correlated. For example, wildfire was identified as an extreme natural hazard, but when all hazards were translated into health risks water and food safety, security and access; capacity; infrastructure and healthcare worker resilience were the most prioritized and relate to multiple climate and natural hazards. The main adaptation strategies included improving drinking water security by for example improving water management, development of Government procedures for drought management; linking health and climate data; increasing food security by research and use of more resilient crops; improvements in urban design; training health workers; increasing evacuation center resilience in villages; increased research into management responses and enforcing and updating regulation.

Pacific island nations have a unique advantage in their small size. In Tonga, the JNAP2 process has formalized inter-agency collaboration. Within Ministries, NGOs and communities exist strong informal networks. In the workshops open and frank discussions and a collegial approach to problem solving were observed, knowledge sharing and high degree of social capital. There is also a shared sense of urgency with climate change mitigation and adaptation shared across these networks, which was expressed by a need to continue the adaptation and action process into a costing and implementation stage.

4.7 Limitations

This paper forms the basis of a Health Adaptation and Action Plan for climate change and disaster risks (HAAP) for Tonga. There are however a few essential steps and limitations that need to be considered. The following list refers to identified limitations and participant feedback from the workshop.

- The approach used here was led and initiated by the MoH with a diverse range of participants from health and non-health sectors taking part in the workshop. It is acknowledged that adequate representation from all relevant sectors may not have occurred.
- The current management practice section was not completed on day 1 of the workshop due to time constraints. Although some of the adaptation options provided allude to management issues, it would be advantageous to cover this section in more detail to identify any current risks, priorities or gaps. This also agrees with the feedback from the workshop that suggest it is taken place over 3 days rather than 2 with

1st day organised around key sectors presenting on areas within climate change and disaster risks that they are working on.

- To consolidate all the inputs from relevant stakeholders, a 1-day consultation workshop of a draft HAAP will ensure a plan that is agreed at a national level.
- To draft cost estimates for adaptation options an economist with good knowledge of climate change will need to be engaged
- The HAAP-Tonga needs to be the health sector's plan (i.e. MoH) to meet JNAP2 requirements. It is anticipated that through the Department of Climate Change (MEIDECC) the MoH will be well placed to facilitate the financing requirements identified from various climate change funding mechanisms. This can be achieved through Green Climate Fund, Global Environment Facility (GEF) and other development partners and donors.
- The health sector needs to monitor the developing impacts of climate change, the effects on the population and the level of preparedness of services and communities.
- Further support should be given to embed climate change into local thinking and decision making, enhanced by a sound platform of information from nationally collated information and intelligence.
- Coordination and communication of climate and natural hazard related risks and opportunities could be improved.
- Future reports should include social care, particularly vulnerable populations and more information on the role of small providers, community, voluntary sector and NGO's. It was observed that there are several non-governmental organisations and civil society organisations (CSOs) working in this space who are critical to engage with.
- Attribution of disease, meteorology and climate change was considered one of the most important adaptation options, however to acquire these, health information systems need to be in place and staff considerations (e.g. health and data analysts) will need to be provided.
- The provision above can also be used to develop health early warning systems.
- Create a platform from which to centralise all the health-related data (e.g. information portal).
- The health sector should also consider its contribution of heat-trapping gases e.g. CO₂ and prepare in terms of mitigation.
- Compare previous health impacts and updated health impacts as a baseline data for health.
- Integrate previous research into the adaptation plan
- Further research into indirect impacts of climate change on non-communicable diseases need to be collated for the Pacific region and for Tonga.
- Sharing useful learnings from this workshop should similar workshops be carried out in other Pacific island countries.
- A pre-workshop for key health related sectors in-country to ensure enough time, planning and buy-in is made. This will allow further strengthening of ties with MoH and facilitate a stronger engagement and participation during the actual workshop.

5. Conclusions

Testing of a climate and natural hazard health V&A tool, across multiple stakeholders led by the MoH, identified several key health and health system impacts, and adaptation opportunities in Tonga.

A key insight is the need for multiple stakeholder co-development, including involvement in V&A assessments. This increases awareness of health in other policies and should lead to less exclusion of the health sector in adaptation planning and avoid critical actions to protect population health (World Health Organization, 2014). This will be aided by the development of functional and regionally interoperable environmental health, meteorological, and climate data-management and interpretation system. Such systems will be critical to supporting decision-making by providing quantitative/empirical evidence of where greatest vulnerabilities lie; support rapid dissemination and sharing of intelligence to support 'incident-response' activities and maintain effective monitoring and evaluation of health actions.

Another insight is that many health opportunities lie outside of the health sector. With that comes a potential

opportunity cost that would unequally fall on the health sector. On the flip side, opportunities that lie outside of the health care sector offer many co-benefits, such as improving food and water security, reducing other health burdens (e.g. NCDs) and encouraging personal and community resilience.

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Competing Interests Statement

The authors declare that there are no competing or potential conflicts of interest.

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Appendix

Table 1. Summary of the health and health system impacts related to natural hazards and climate related risks identified in the workshop. Health impacts with asterisks are those identified as indirect, as defined in IPCC, 1995

Natural hazard or climate related event	Health Impact	Health System Impact	Risk score	Evidence (1-5)
cyclones/severe storms (includes sea-level rise)	<ul style="list-style-type: none"> • Food safety and security (inc. nutrition) • Water contamination • Water security (SLR) • Vector-borne disease • Decreased wellbeing • Increased risk from VBD/vermin • Air pollution • Water pollution • Mental health • All water borne diseases • Death 	<ul style="list-style-type: none"> • Access to health care and emergency services 	High to Extreme	3-5
Increased average temperature	<ul style="list-style-type: none"> • Increase in morbidity and mortality • Decreased air quality - Increased respiratory disease 	<ul style="list-style-type: none"> • Capacity issues due to increased admissions infrastructure impact healthcare worker heat stress water availability energy availability 	High to Extreme	3-4

	<ul style="list-style-type: none"> • Decreased water quantity and quality • Decreased food production – impacts on diet • Mental health • Heat stress • Water borne disease • Skin disease • Skin cancer 	<ul style="list-style-type: none"> • Infrastructure of hospital coping with heat and health care workers 	
Extreme hot days	<ul style="list-style-type: none"> • Increase in morbidity and mortality • Decreased air quality - Increased respiratory disease • Decreased water quantity and quality • Decreased food production – impacts on diet • Mental health • Heat stress • Water borne disease • Skin disease • Skin cancer 	<ul style="list-style-type: none"> • Capacity issues due to increased admissions infrastructure impact healthcare worker heat stress water availability energy availability • Infrastructure of hospital coping with heat and health care workers 	Extreme 5
Flooding (inc. landslides)	<ul style="list-style-type: none"> • Death • Food security and safety • Water quality • Increased vector borne disease • Increase in NCD • Skin diseases • Water borne disease • Sanitation issues e.g. pit latrines • Community wellbeing • Psychosocial issues 	<ul style="list-style-type: none"> • Increased pressure and access to health services • Stress on human and resource capacity • Health centres affected by food security – quantity and quality 	High to Extreme 3-4
Drought	<ul style="list-style-type: none"> • Food security and nutrition • Water quality • Skin conditions • NCDs/mental health • Malnutrition • Air quality 	<ul style="list-style-type: none"> • Capacity issues • Stress on available/existing facilities and resources Availability of trained medical staff • Poor access to emergency services • Transport services e.g. airport, wharf, public transport 	High to Extreme 1-5

Wildfire	<ul style="list-style-type: none"> • Injury • Air pollution – respiratory impacts (asthma) • Food security 	<ul style="list-style-type: none"> • Destruction of health care service, capacity issues 	Extreme	3-5
Tsunami	<ul style="list-style-type: none"> • Death, injury 	<ul style="list-style-type: none"> • Access to hospital and health care due to tsunami, in Niuatopotapu only. • Damage to houses, roads, essential services 	High to Extreme	5
Earthquake	<ul style="list-style-type: none"> • Increases in mental health issues • Loss of life • Vulnerability to diseases e.g. communicable diseases, VBDs 	<ul style="list-style-type: none"> • Access to health care 	High	5
Volcanic activity, includes related earthquakes	<ul style="list-style-type: none"> • Volcanic ash fall – pollutes water, air • Food security • Water security • Community well-being • Mental health • Respiratory system issues • Increase in non-communicable diseases • Malnutrition • Water borne disease • Loss of life/Injury • Mental health issues • Communicable diseases • Vulnerable to other diseases e.g. dengue fever, Zika virus etc. 	<ul style="list-style-type: none"> • Access to hospital and health care due to volcanic activity - Niuafo'ou • Not enough medical supplies, skills, capacity, limitation 	High	5
Volcanic activity includes related earthquakes	<ul style="list-style-type: none"> • Volcanic ash fall – pollutes water, air • Food security • Water security • Community well-being • Mental health • Respiratory system issues • Increase in non-communicable diseases • Malnutrition • Water borne disease • Loss of life/Injury 	<ul style="list-style-type: none"> • access to hospital and health care due to volcanic activity – Tongatapu • Not enough medical supplies, skills, capacity, limitation 	Low	No rating

- Mental health issues
- Communicable diseases
- Vulnerable to other diseases
e.g. dengue fever, Zika virus
etc.

Table 2. Health and health system impacts of prioritized natural hazards: Tsunami

Adaptation strategies (investments)	Rating of adaptation strategy	What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
1. Legislative or Regulatory				
National tsunami plan National emergency act – 2007 Meteorology Act 2017 SOP for tsunami (MET) Communication Act – 2000 Community Emergency Plan	A	Legislations and regulations in place	Integrate all relevant acts and policies. Incorporate gender equality into policies	Meteorology MEIDECC Geology Department All clusters
2. Public Education & Communication				
Improve public awareness of risks of tsunami Conduct regular tsunami drills	I	There is public awareness, information and drills but needs more. Recruit qualified people to manage and coordinate drills and simulation exercises	Publish more awareness materials for people in the community	NEMO Meteorology MEIDECC All clusters
3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention				
Improve dissemination system	I	Dissemination system in place but not effective	Install more sirens for tsunami 100% radio coverage Uptime internet, access 100% Install automated dissemination system	MEIDECC TCC Digicel Communication Cluster

4. Health Intervention and Health Systems

Endorse MoH Disaster Management Plan	D	There is a disaster management plan but needs endorsement	Get MoH DMP endorsed.	MoH
Establish Emergency Medical Team	D			WHO
Establish training programs for tsunami	N	Health plans are not incorporated into some of the response and emergency plans	Ensure a well-trained EMT	NEMO
Involve health workers in tsunami drills and simulation exercise.	I			
Incorporate health plan into all response plan	N			

5. Research/Information/Surveillance/Monitoring

Improve health information management system	D	Systems in place but not adequate and needs improvement	Ensure Health Information System digitization	MoH
Improve monitoring weather system	I		Install radars	

Table 3. Health and health system impacts of prioritized natural hazards: Tropical Cyclone

	Rating of adaptation strategy	What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
Adaptation strategies (investments)	A – Adequate I – Inadequate D – Developing N – Not in place			
1. Legislative or Regulatory				
Climate Change Policy			Need better coordination between government organizations and agencies.	Water Health MEIDECC
- Community Emergency Plans				All cluster members
- Communications Act 2000				
Environment Management Act 2010		In general systems are in place	Need integrated/multi-hazard early warning system	National Emergency Management Act 2007
Regional TC Operating Plan	A			MET Act 2017
Tropical Cyclone Standard Plan (TCSP)				
Follow up with other ministries to see if they have emergency policies in place.				

2. Public Education & Communication

Awareness program

Awareness week (MEIDECC)

Improve school syllabus by including traditional knowledge about weather and climate D

MEIDECC

Public awareness to be more regular

Ministry of Education

E.g. TV program, radio program, social media (Facebook), workshops and trainings I

3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention

Improve TC early warning system

Need more sirens

Army

Disseminating system for example sirens.

Uptime internet access 100%

MOI

Improve internet access I

Some system in place but need improvement

Need better radio coverage.

TPL

Enhance emergency management e.g. training, volunteer

Upgrade power supply system.

TCC/Digicel
All government and non-government organizations

4. Health Intervention and Health Systems

Ensure that the Health Disaster Plan is endorsed, circulated among ministry staff and well implemented. D

Improve storage for medical supplies

Identify the committee that can revise the Health Disaster Management Plan, request endorsement from CEO for Health

MEIDECC

Ensure there is an emergency medical team that can be deployed in times of tropical cyclones to affected areas. D

Some system in place but still need a lot of improvements

Identify focal points in every ward for emergency coordination.

NEMO

MOH
Health Cluster members (e.g. Red Cross)

Conduct trainings for healthcare workers on emergency management N

Develop training programs on disaster management (ongoing training course)

5. Research/Information/Surveillance/Monitoring

Improve health information management system D

Health information system is moving towards digitization.

Improve monitoring weather system I

Monitoring weather system in place but not adequate.

Install radars

MOH

Table 4. Health and health system impacts of prioritized natural hazards: Flooding

Adaptation strategies (investments)	Rating of adaptation strategy	What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
1. Legislative or Regulatory				
Enforcing current building codes (soon to be passed).	D			MIA/MoH NEMO Red Cross CBDRM
Not to build in certain areas, height of foundations				
Need to consider impact of building up infrastructure e.g. roads on runoff and impact building houses up has on neighbors	I			
Every village has an evacuation center and trained first aiders				
2. Public Education & Communication				
More social media	A	Public health radio and TV Communication (not swimming/move to evacuation centers, remove vulnerable population.	Keep doing this Security issues needs addressing (Theft)	Some churches are at risk Not all villages have evacuation centers MoH Media Evacuation
Evacuation centers in all villages (besides churches) Some churches are at risk	I			
3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention				
Reticulated wastewater systems				
Drainage to sea – more creative solutions needed	I	Storage pond - Tiliapia	Public are not swimming and playing in storm water	
Hai pai – culverts joining two islands – bad design				
Crops – engineering prevent flooding				
4. Health Intervention and Health Systems				
More first aid training		Army/Police	More staff	Ministry of Health
Red Cross could train community based first aiders to take the pressure off health systems especially in outer islands				
Training at evacuation centers				

<p>5. Research/Information/Surveillance/Monitoring</p> <p>Crops – research crops that can stand flooding</p> <p>Drainage – find solutions</p> <p>Tongan traditional medicines – their role/efficiency</p> <p>Traditional knowledge</p>	<p>MEIDECC are MEIDECC gathering information on how to use traditional knowledge for biodiversity conservation.</p> <p>How to “mainstream responses”?</p>
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Table 5. Health and health system impacts of prioritized climate related (gradual): increases in temperature

Adaptation strategies (investments)	Rating of adaptation strategy		What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
	A – Adequate	I – Inadequate			
1. Legislative or Regulatory					
Regulating maximum temperatures for working, schools etc.					
Triggers					Government
Air conditioning in government buildings			JNAP 2		NGOs
Building code – adequate ventilation					
Meteorological data predicting temperature increases					
2. Public Education & Communication					
Employers			MIA – community		Radio for older MIA
Schools			Climate change week		NGOs
Mass media – MIA			13 th Oct – Disaster Day		MEIDECC – EU GIZ
Preparation – adequate supplies, water			Self-sufficient programs – Amataki Loa (TCDT)		Mangrove planting
Long term planning			Coconuts		Coastal planting – ridge to reef people
Coastal planting					
3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention					
Early warning systems			Early warning system for tsunami	Weather forecasts unique to each country.	Communication and Information department

Radio/social media of daily forecasting Security of water supplies	Careful that information is not too detailed. Visual – easier to understand		
4. Health Intervention and Health Systems Improved training programmes and information on emergency management	EMT role and development of a team ready to deploy in emergencies (under development)	Training for food vendors, health inspectors and storage in times of heat, outbreaks.	Health WHO
5. Research/Information/Surveillance/Monitoring Linking health data (more presentations to health centers and hospitals) when high temperature events occur Priorities water security in Outer Islands – Ha’apai Strengthen rainwater collection on outer islands		Child centered climate change programs (TCDT) Working in schools MEIDECC – CRSP Climate Resilient Sector Project Climate resilient building – Ha’apai Hospital Tonga water board	

Table 6. Health and health system impacts of prioritized climate related (extreme): Cyclones

Adaptation strategies (investments)	Rating of adaptation strategy	What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
1. Legislative or Regulatory Building code Strengthen existing process to enforce/incorporate code in construction Government should review building legislation to address community housing	A – Adequate I – Inadequate D – Developing N – Not in place		It is possible to review/amend legislation Review/amend legislation Enforce bill	Statistics on buildings destroyed (TC Gita Feb 2018). Infrastructure (MOI) Finance Health MIA (Internal Affairs) NGOs

<p>2. Public Education & Communication</p> <p>Needs to be ongoing/sustainable</p> <p>Strengthen network partnership with relevant sectors, groups e.g. NGOs, government</p> <p>Fully integrate CCA and DRM (syllabus)</p>	<p>A</p>	<p>Systems are in place but need strengthening</p> <p>Public awareness (TV, radio, Facebook)</p> <p>School visits</p> <p>Better coordination to avoid duplication</p> <p>HR sufficient</p> <p>Technical resources (lacking)</p> <p>Early warning systems</p> <p>Telecom</p> <p>Upgrade existing warning system</p> <p>Conduct community training on cyclone response</p>	<p>Documentation (Reports, clips, videos)</p> <p>Meteorology</p> <p>Education</p> <p>NEMO</p> <p>Climate Change (MEIDECC)</p> <p>Radio/TV</p> <p>TCC</p> <p>Telecom</p> <p>NGOs – Private Sector</p>
<p>3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention</p> <p>More mangrove replant</p> <p>Introduce mangrove protection bill</p>	<p>I</p> <p>D</p>	<p>Technological system to be developed. Ecosystem in development.</p> <p>Direct assistance to most vulnerable communities e.g. CCTF – Water tanks</p>	<p>MEIDECC</p> <p>MOI</p> <p>MAFF</p> <p>Lands and Survey</p> <p>NGOs</p>
<p>4. Health Intervention and Health Systems</p> <p>Public Health Act Increase budget allocation to public health division to meet needs of staff, relating to capacity training, ER training, resources</p> <p>Capacity building (training and upskilling)</p> <p>Climate proofing of health centers/facilities</p> <p>Community involvement in best health practices</p>	<p>I</p> <p>I</p>	<p>We need champions in health and MPs</p> <p>More funding</p> <p>Increased awareness (public)</p> <p>Upskill service providers (health officers)</p> <p>Increase budget/funding</p> <p>Make services more accessible to locals.</p> <p>Localize language</p>	<p>Health Statistics reports</p> <p>Data from health center</p> <p>Tonga Health</p> <p>NGOs</p> <p>All of above-mentioned sectors</p>

5.	Research/Information/Surveillance/Monitoring	There needs to be an “established system” to manage and control surveying across government. Clear procedures for all government sectors to adhere to avoid duplication; in accuracy data.	Research – we have ‘local expertise’ to conduct research	Establish a data system	Statistics Health NEMO MEIDECC
		Data needs to be collected and managed better, and also needs to be shared.	Data collection, storing, management is weak.	Train staff in data collection, analysis	All sectors private and NGOs ESR All government sectors Public
		Information gaps need to be addressed.			Donors (Regional/International) SPC

Table 7. Health and health system impacts of prioritized climate related (extreme): Drought

Adaptation strategies (investments)	Rating of adaptation strategy	What is our capacity – In general and for vulnerable regions and groups?	How can we improve resilience? (implementation, upgrading, mitigation)	Sectors involved and/or supporting evidence (including champions, Government)
1. Legislative or Regulatory	A – Adequate I – Inadequate D – Developing N – Not in place			
We cannot decide on legislations as we do not know if drought is included – as it is a rare incident. If ‘yes’ then it needs to be circulated/shared with relevant ministries.			Strengthen research into drought to provide more reliable data.	
2. Public Education & Communication		Human resources are adequate to conduct training Network is strong (between relevant groups) to coordinate training, resources	Strengthen working relationship between government, NGOs, all sectors involved to work on ‘trust’.	Meteorology MEIDECC All Government NGOs private and faith based sectors donors
Public education and awareness on: Water management Preparatory measures/practices Incorporate education curriculum	Indecisive			

3. Technological or Engineering, Infrastructure Development and Ecosystem Intervention

WASTE Management Act 2016 Tree planting/mangroves
 Review Waste Management Act and amend
 Encourage recycle/reuse

I

Review/enforce existing systems

Conduct training on waste management (household level).
 Include marine pollution in waste management
 Waste Authority
 Health
 MEIDECC
 Environment
 Tourism
 MOI
 NGOs

4. Health Intervention and Health Systems

Training on personal hygiene, water consumption, water management/storage
 Health impacts on drought (counselling, mental health)
 Local knowledge (utilize)
 Build capacity (training and upskilling)
 In some areas desalination of seawater may be an option (already some desalination plants on outer islands) in emergency situations there are smaller ones that can be shipped across but there have been issues finding a suitable vessel to transport this heavy equipment

Indecisive based on insufficient data

Systems in place but need to put more emphasis on drought in training
 Capacity needs improving, especially service providers that respond to drought

Change mind set and behavior of public through more trainings and awareness programs
 Statistics
 Health
 NEMO
 METEOROLOGY
 MEIDECC
 FINANCE
 Government
 NGOs
 Private
 Faith based organizations
 Donors

5. Research/Information/Surveillance/Monitoring

There needs to be an “established system” to manage and control surveying across government
 Clear procedures for all government sectors to adhere to avoid duplication; in accuracy data.
 Resilient crops that cope in dry periods

I

Research – we have ‘local expertise’ to conduct research
 Data collection, storing, management is weak.

Establish a data system
 Train staff in data collection, analysis
 Statistics
 Health
 NEMO
 MEIDECC
 All sectors private and NGOs
 Health
 ESR
 All government sectors
 Public
 Donors (Regional/International)
 SPC

Table 8. Adaptation strategies for each hazard by the level of priority (highest at the top)

Hazard	Adaptation Option	L			Ove rall	Weighte d Total
		Hi gh	M ed	o w		
Cyclone/						
Tsunami	Endorse health disaster management plan	3			3	9
	Improve monitoring weather system	3			3	9
	Improve health information management system	1	3		4	9
	Mainstream other emergency policies and include surveying data	2			2	6
	Strengthen enforcement of building code	2			2	6
	Create emergency/medical management teams	2			2	6
	Create/enhance emergency management training/capacity e.g. volunteers	1	1		2	5
	Improve school syllabus including traditional knowledge and weather and climate	1		1	2	4
	Training in emergency management for healthcare workers		1	1	2	3
	Renew building code especially community housing			2	2	2
	Increase public awareness (TV, radio, partnership with relevant networks, social media)			1	1	1
	More eco-system adaptation (mangroves)				0	0
	Avoid duplication				0	0
Drought						
Drought	Resilient crops	1	4	1	6	12
	Training (personal hygiene, health impacts, water consumption, storage, management)	3	1		4	11
	Research - Develop Government procedures for drought management	3		1	4	10
	Include more legislation for drought	1	1	3	5	8
	Public education (water management, and curriculum)	1	2	1	4	8
	New rain water storage tanks to have volume indicators	2		2	4	8
	Legislation of water tank size (minimum size)	1	1		2	5
	tree planting	1		1	2	4
	Encourage recycling/reuse	1			1	3
	Review and amend waste management act		1		1	2
	Use local knowledge				0	0
Flooding						
Flooding	Ensure every village has an evacuation center	2	1	3	6	11
	Enforcing current building codes	3		1	4	10
	Improve food resilience (engineering, diverting, storage)	3		1	4	10
	Future-proof reticulated waste water systems	3			3	9
	Increase first aid training	1	3		4	9
	Improve drainage to the sea e.g. culverts	2	1		3	8
	Restricting building or building foundation heights	2		1	3	7
	Crops research (able to withstand flood events)	1	2		3	7
	Mainstream traditional knowledge systems e.g. Tongan medicine to increase resilience/understanding weather patterns/birds/animals	1	1		2	5
	Create new opportunities (new crops, freshwater aquaculture)		1		1	2

Temperature increase	Adequate drinking water supply (plus maintenance and security), especially on the outer islands	6	1	7	19
	Linking health and climate data (e.g. hospital admissions)	2	6	1	9
	Create more shade (e.g. coconuts and you can drink them)	4		4	12
	Update building code - ventilation	1	3	1	5
	Increased air conditioning in Government buildings (refuge in emergency)			3	3
	Regulate/guidance on outdoor exposure (schools, walking)			1	1
	Ecosystem based adaptation (all systems)			0	0

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