Climate Risk Management in Water Sector in Tonga

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Abstract

Natural disasters have a significant impact in the Pacific Islands. Between 1950 and 2004, more than 200 disasters resulted in more than 1700 fatalities and losses amounting to USD 6.5 billion. Given their small populations and economies, such losses are traumatic to Pacific Island countries. Tonga, one of 52 Small Island Developing States (SIDS), is highly susceptible to the impacts of climate change and disasters due principally to its geographical, geological, and socio–economic characteristics. Climate change and natural disasters pose severe adverse threats on the environment, the people of Tonga, and their livelihoods. Scientific findings revealed that these impacts would be exacerbated by future climate change. The Government of Tonga has acknowledged these risks to the sustainable development of the country and has hence considered these issues as high priorities in its National Strategic Planning Framework. The United Nations Development Programme (UNDP) and the Australian Government Pacific Adaptation Climate Change (PACC) project have assisted to increase the resilience of the water resources management sector in Tonga and to enhance adaptive capacity of villages, communities and socio–economic activities to climate change and sea level rise (SLR). This paper, however, describes the impacts of water resources due to climate change rather than the PACC results.

Keywords: Small Island Developing States, Water Management, Sea Level Rise, Disaster Management

1. Introduction

The Small Island Developing States (SIDS) is a group of states that are not uniform and are differentiated (UNCTAD, 2004). Because the SIDS face challenges in coping with socio–economic and eco–environmental endeavors of their economy, strategies must be adopted to achieve sustainability and resilience and to reduce their vulnerability (Scheffer et al., 2003). Owing to their smaller and limited infrastructures, indigenous knowledge and utilization of scarce resources is complex (Armstrong and Read, 1998; Briguglio, 1995). It is essential to achieve sustainability for these SIDS (Robinson, 2004) as well as self-reliance by the proper utilization of available resources (Bertram, 1986). One technique is the replacement of traditional agriculture with cash-crop cultivation to increase the country's exports (Murray, 2001).

SIDS such as Tonga are susceptible to land loss due to sea level rise (SLR) even under the average Intergovernmental Panel on Climate Change (IPCC) scenarios of 2007 (Kelman and West, 2009). Various organizations including the Pacific Regional Environment Programme (SPREP), Pacific Islands Applied Geoscience Commission (SOPAC), and the International Global Change Institute (IGCI) have been working to support meteorological services in mitigating the effects of climate change and SLR for the SIDS in the Pacific region and to lessen the impacts on increased vulnerability and reduced sustainability (Shea, 2001; Feresi et al., 2000; Kouwenhoven and Cheatham, 2006).

Many researchers have shown that the global SLR will increase in the near future, which will adversely affect the SIDS (Granger, 1997; IPCC, 1998; Nicholls et al., 1999). Coastal land loss and widespread negative impacts of flooding and inundation are expected to affect island nations on a larger scale, disrupting the socio–economic and environmental sectors of their economies (Leatherman, 1997). It is estimated that an increase in mean SLR of 0.3 m to 1 m would result in land loss of 3.1 km^2 to 10.3 km^2 in addition to losses attributed to periodic inundation, flooding, and erosion (Fifita et al., 1992; Mimura, 1997).

According to the Global Climate Risk Index (2013), Tonga is ranked among the top 100 countries in the world most vulnerable to the adverse effects of climate change. It is a SIDS situated in the central South Pacific (United Nations, 2010) that lies between 15° and 23° 30' south and 173° and 177° west. Tonga, an archipelago of 172 named islands, has an area of 747 km^2, of which 36 islands are inhabited with an area of 649 km^2. It is composed of four clusters of islands extending over a north–south axis that include Tongatapu and Eua in the south, Ha'apai in the center, Vava'u in the north, and Niuafo'ou and Niua Toputapu in the far north. The capital, Nuku'alofa, is located in Tongatapu, the largest island, with an area of roughly 260 km^2. Between the two ridges is a 50-km-wide trough known as the Tofua Trough.

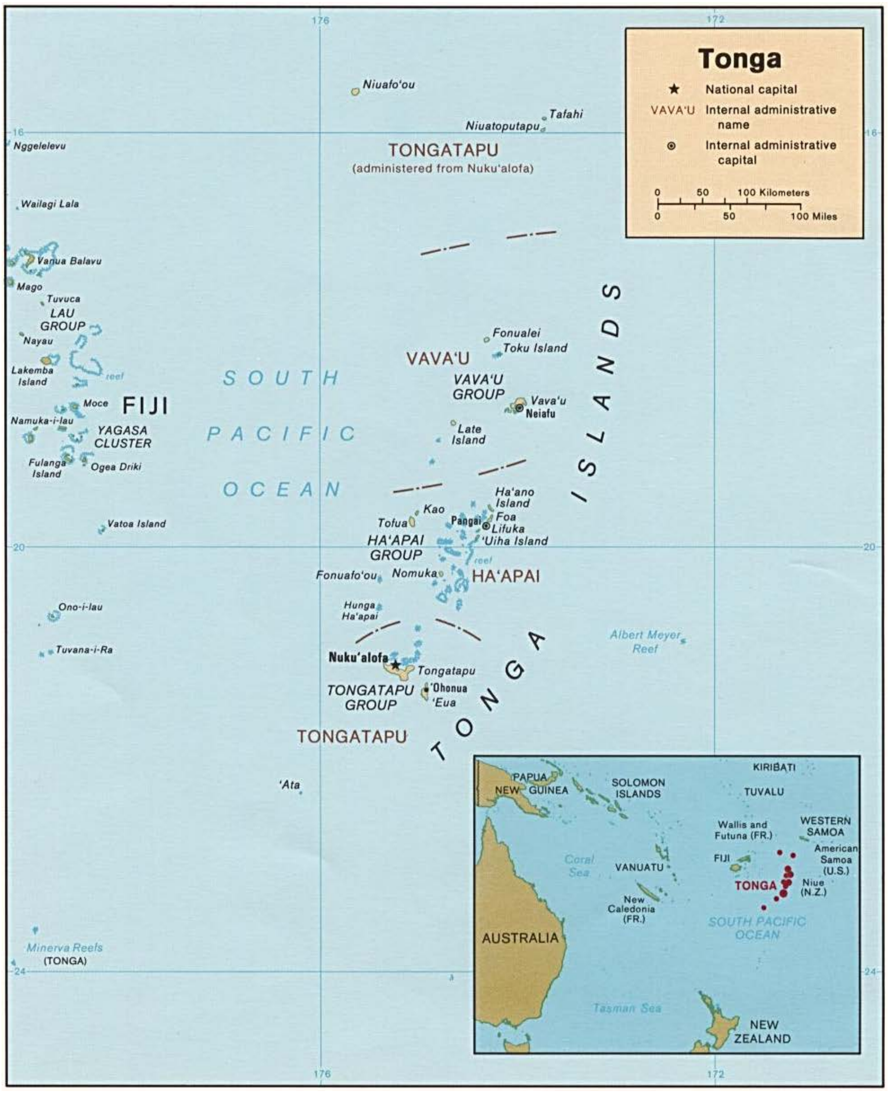

Figure 1: Map of the Tonga Islands (Source:

http://www.nationsonline.org/oneworld/tonga.htm),

Several volcanoes, some of which are still active, have formed along the western ridge, whereas many coral islands including low and raised types have formed along the eastern ridge. According to the 2006 census, the total population of Tonga was 101,991, which was distributed among 17,529 households. The Tongatapu Island Division had the largest population density (277 people/km^2). The population showed an increasing trend in the preliminary 2011 census report with total population of 103,036, including 52,001 males and 51,035 females. The gross domestic product (GDP) per capita in Tonga in 2009 was $2,891 with a GDP growth of 1.9 (IMF, 2009).

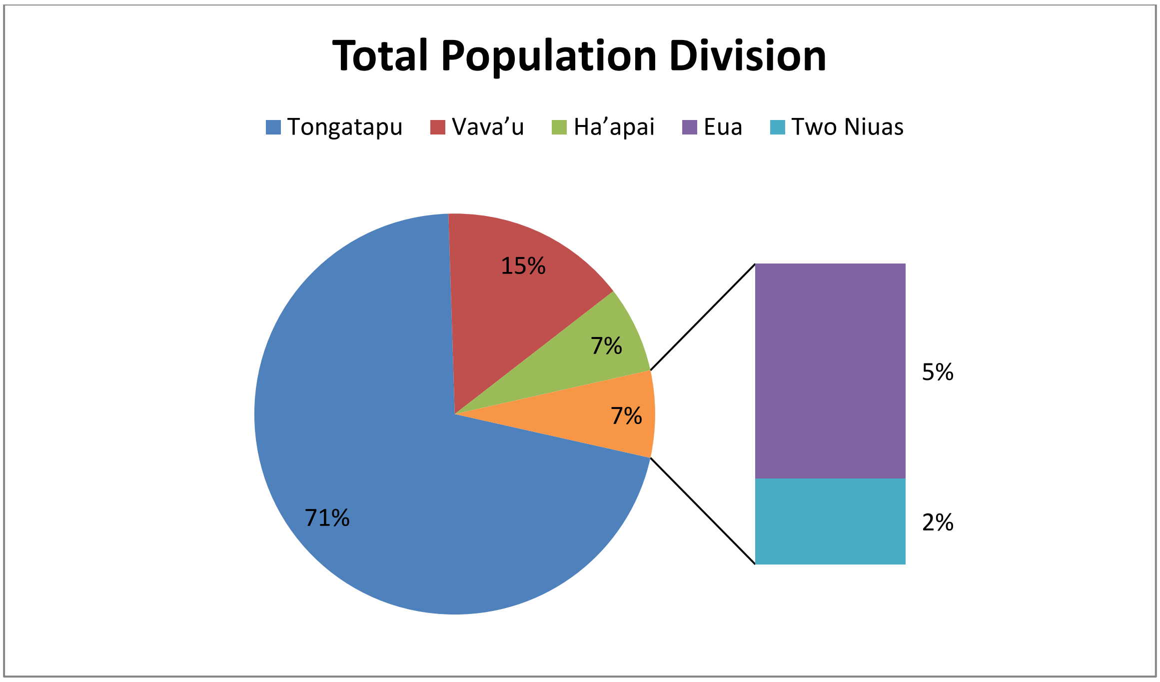

Figure 2: Total population division in Tonga in 2006 (Source: Census, 2006).

Tonga has been categorized as one of 52 SIDS that are vulnerable to exogenous shocks. The Economic Vulnerability Index (EVI) reflects the risk caused by these shocks to a country's development (SOPAC, Kaly et al., 2003). The EVI for Tonga is 48.48, and the threshold is 33. Gradual economic diversification will assist in strengthening the economic base, making Tonga more resilient to any future exogenous shocks.

Cyclones are the most frequently occurring disaster in Tonga (ESCAP, 2010). On average, 1.3 tropical cyclones affect Tonga per year. Figure 3 shows an increase in frequency to 1.7, particularly during El Niño years. Historical records of cyclone occurrences in the southwest Pacific have shown a decreasing trend, particularly during the past decade (1999–2008). However, there is not enough evidence to confidently predict that this trend is permanent and not an inter-decadal cycle. However, the years of increased tropical cyclone activity coincide with El Niño years, which are depicted in the figure by "E."

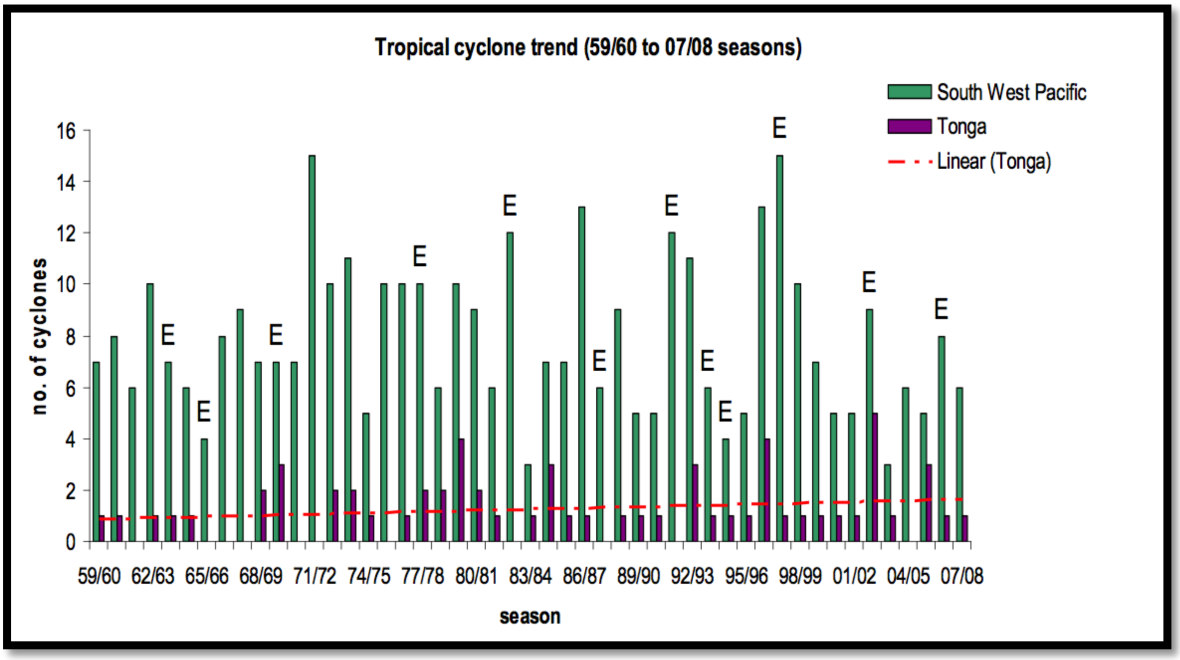

Figure 3: Tropical cyclone trend in Tonga (Source: TMS, Tonga 2008).

In February 2012, Cyclone Jasmine brought heavy rains and flooding to Tonga, which had been affected by Cyclone Cyril the prior week (AON Benfield, 2013). The worst cyclone disaster in the history of Tonga occurred in 1982, killing six people and affecting 146,512. In January 2014, Tropical Cyclone Ian tracked between Fiji and Tonga for several days before intensifying to a Category 5 system with winds of more than 200 k/h. This storm resulted in 1 fatality, 14 injuries, and extensive damage to homes, infrastructure, and agriculture. A total of 534 houses were destroyed, and 398 were damaged. Approximately 2,335 people sought shelter in 51 formal and informal shelters.

In addition to cyclones, natural hazards in Tonga include earthquakes and volcanic activity. Tonga lies in close proximity to the convergence of the Australian and Pacific tectonic plates, one of the most seismically active regions in the Pacific. The most recent major earthquake to affect the population occurred in May 2006, although no deaths or injuries were reported. The last major eruption of a volcano located in Niuafo’ou occurred in 1946 and caused total evacuation of the island.

Due to its seismic activity, Tonga is also vulnerable to tsunamis. The most recent significant tsunami hit Niuatoputapu in September 2009 (Fritz et al., 2011), in which nine people were killed when waves 6–17 m high affected areas 600 m inland and destroyed many villages. The total cost of damage estimated by the Tongan government was US $9.5 million.

Tonga’s climate pattern is highly vulnerable to the effects of El Niño, which generally occurs once every three to seven years and always coincides with drought incidence. The most recent three major droughts in Tonga occurred in 1983, 1998, and 2006 (JNAP, 2010) and were linked directly to El Niño events of May 1982–June 1983, May 1997–April 1998, and September 2006–January 2007. The average annual mean rainfall is 1,731 mm per year. Tongatapu received an average rainfall of 1,721 mm, whereas Vava’u, Ha’apai, Niua Fo’ou, and Niua Toputapu received 2,150 mm, 1,619 mm, 2,453 mm, and 2,374 mm, respectively (Figure 4).

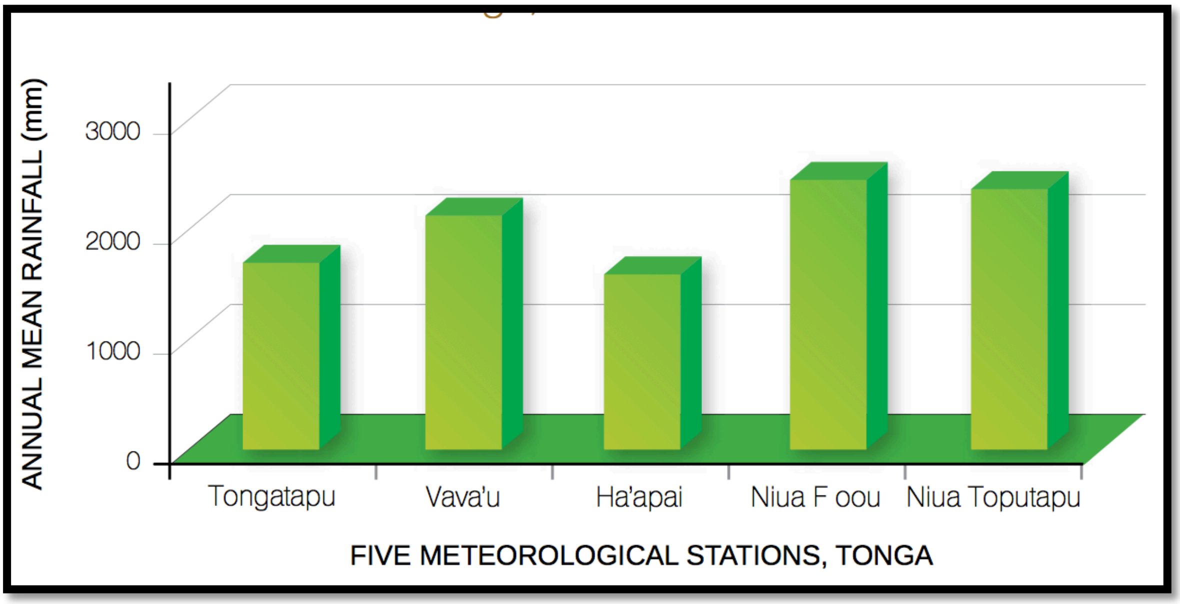

Figure 4: Annual mean rainfall for five meteorological stations in Tonga for 1971–2007 (Source: Joint National Action Plan (JNAP) report, Tonga, 2010).

Tonga has occasionally received heavy rainfall (Thompson, 1986), which recharges groundwater reserves (Furness and Helu, 1993). These events have caused flooding and prolonged ponding of water, which poses health risks through the outbreak of waterborne and vector diseases such as dengue fever. The agricultural sector has also been affected because some crops cannot tolerate such unfavorable climatic conditions. Heavy rainfall also increases surface runoff, which results in the pollution of nearby coastal areas and lagoons due to sediments and debris washing into these areas (Zann, 1994).

Despite the availability of substantial amounts of water, Tonga still faces drought situations. Severe droughts have led to significant reductions in the amount of water collected in water tanks. This decreases the recharge rate of underground water, hence reducing the availability of potable water.

Temperature variations throughout the kingdom show an increase in daily and seasonal variations with increasing latitude. Mean annual temperatures vary from 27 °C at Niuafo’ou and Niuatoputapu to 24 °C at Tongatapu. Diurnal and seasonal variations can reach as high as 6 °C throughout the island group. The average temperature range is 27–29 °C during the hot, wet season (November–April) and 20–24 °C during the dry, cool season (May–October).

Particularly in low-lying coastal areas, increased sea levels and storm surges during tropical cyclones permit the intrusion of salt water, hence contaminating the groundwater and affecting the quality and quantity of potable fresh water for drinking and other purposes. The sea level trend in Tonga suggests a general increase in sea level of 6.4 mm/year from 1993, when record-keeping began, to 2007. (TMS, Tonga, 2007). An increasing trend of electrical conductivity (salinity) during drought periods has been observed in some villages in Tonga. SLR, saltwater intrusion into aquifers, and over-pumping rates also contributed to such increases.

Coastal erosion is another critical environmental issue facing Tonga, partially as a result of SLR. Other contributing factors include low altitude, the increased denudation of mangroves and coastal trees, live coral removal, illegal mining of beach sands, and sand dredging of offshore sand dunes for construction purposes. The loss of land and infrastructure along the coast is a noticeable result of these activities and processes (Van der Velde et al., 2007).

Given the ongoing urgency for climate change adaptation in Pacific island countries, the Pacific Adaptation to Climate Change (PACC) has been developed to assist with the implementation of such measures in 11 countries of this region. The Kingdom of Tonga will participate in the PACC to implement adaptation measures for enhancing its resilience to the adverse impacts of climate change in the long term. The objective of the PACC project in Tonga is to increase the resilience of the water resources management sector and to enhance the adaptive capacity of villages/communities and socio–economic activities to climate change and SLR. This paper, however, describes the water resource impacts due to climate change rather than the results of PACC.

2. Materials and Methods

This study is based on existing literature and field surveys on the vulnerability of SIDS to climate change impacts. An extensive literature review has been analyzed, which includes research articles and government reports of Tonga in addition to the reports of various international organizations. The literature review indicated gaps in the cumbersome risk management process, particularly in the SIDS. The focus of the literature analysis was research related to enhancing the sustainability of SIDS, with special emphasis on Tonga. A field survey was conducted for gathering ground-level data to support the literature review.

3. Results and Discussion

The source of fresh water for Tonga is either rainwater harvesting or extraction from a thin freshwater lens within the highly porous limestone substrate. Groundwater is used domestically for cooking, bathing, food preparation, plants, animals, sewerage, and general cleaning and is also boiled and used for drinking if rainwater is unavailable. It is piped to homes, government buildings, businesses, industry, and tourist accommodations by the Tonga Water Board (TWB) in the urban centers of Nukualofa in Tongatapu, Neiafu in Va’vau, and Pangai-Hihifo in Ha’apai in addition to villages in ’Eua. Many villages outside of these centers have their own reticulated water system administered by water committees. The Tongan water supply is metered at each property; some villages are currently introducing individual meters. Each island within each group has varying water resource issues and concerns depending on population pressures, demand, the quality and quantity of the water supply, local geology, agricultural and sanitation practices, and extraction standards.

Water use for agricultural purposes is not documented, and water drawn from village water supply systems is not metered. The number of bores are operating in Tongatapu or in the other island groups is unknown, as is the extracted volume. Bores can requested for private homes, schools, churches, and villages.

Tonga does not have a centralized reticulated sewerage system. All wastewater is managed by on-site systems, with supervision by the Ministry of Health (MOH) when resources permit. In this respect, wastewater management is in the hands of the community. Poorly constructed or inappropriate sanitation systems are common, resulting in the potential for pathogen introduction into the surrounding environment, including the groundwater system. In addition, excess nutrient loads appear to be affecting the environmental health of the near-shore reef in the Nuku'alofa area and the lagoon, and algal growth can be seen in both areas. Because waterborne disease is common, the fish harvested in these areas, particularly shellfish, may be contaminated as well. Current sanitation practices also increase the potential for contamination of aquifers designated for TWB and village reticulated supplies; over-pumping can exacerbate this risk.

The threat of contamination in private hand-operated wells is also common, particularly in the outer islands. Efforts by the MOH to close these private wells, however, have met strong resistance because they are still considered as traditional and valued sources of free fresh water.

Dry sanitation options with non-waterborne, zero-discharge treatment such as composting toilets (CTs), have been introduced in Tonga during the past decade. Introducing new sewage technology is a challenge in any culture and requires long-term comprehensive attention to complex socio–cultural factors. During the recent past, recommendations have been made for a reticulated sewerage system in Nuku'alofa and other urban areas throughout Tonga. However, this measure is currently cost prohibitive and excessively complex, and its benefits may be limited by the numerous health and environmental risks.

No information database or data-exchange system on water resources is available for water resource assessment and monitoring, nor is a national hydrological network. Water resources are currently managed by a number of institutions, some of which deal with specific or general monitoring. There is a need for a collaborative approach to management that includes integrated planning, the introduction of buffer zones, management strategies, and comprehensive education to demonstrate the links between poor sanitation and waterborne disease and environmental degradation.

Disasters or emergencies that could affect water resources in Tonga include chemical pollution from pesticides, fertilizers, and oil and industrial components; biological pollution; and extreme weather events such as cyclones, earthquakes, drought, and flooding. Numerous significant health and economic threats have resulted from such emergencies. Overtopping by waves or inundation by SLR has led to seawater intrusion into freshwater lenses, hence reducing the availability of potable water. Beach mining for sand and aggregates (dead coral) have also increased the impact of storm surges on coastal areas. The economic impact of inundation has also affected town and tax allotments, resulting in the abandonment of homes and crops.

A national emergency management plan has been developed that builds on the 1987 national disaster plan. In addition, a National Emergency Management Committee (NEMC) has been formed, and a National Disaster Management Office (NEMO) has been established within the Ministry of Works (MOW). The Emergency Management Act (2006) is currently before the cabinet. Moreover, the Ministry of Land, Environment, Climate Change and Resources Management has been actively monitoring climate change in accordance with other ministries and bodies such as the Ministry of Infrastructure, Tonga’s meteorological service

(Lofa Talamatangi), and the Committee of Climate Change Cabinet Ministers. However, governmental bodies suffer from limited financial and human resources, policy implementation, and sustainability. The lack of awareness and risk-management initiatives to on adverse impacts of SLR and climate change leads to greater vulnerability of the region.

Demands for management measures, water supply augmentation, drought vulnerability assessment, and climate forecasting can all help toward greater disaster preparedness. Institutional and regulatory support is required to effectively prepare for and manage disasters and to reduce the impact of climate variability on freshwater resources. Legislation has been introduced that supports a sustainable approach, although it requires approval and funding allocations for implementation.

Wastewater management is almost entirely in the hands of the residents because all sanitation treatment in Tonga is on-site. With regard to water management, most households have rainwater tanks, and some have their own wells. The management of reticulated water is also dependent on the behavior and attitude of the consumer. Education is conducted through public meetings, school presentations, television programs, theater, and radio broadcasts. However, it is also necessary to actively engage residents and to provide them with the practical tools for sustaining their resources. There is a need to re-connect with traditional values regarding resource protection.

The village water supply committees require financial and technical assistance in addition to and on-the-job training to establish and maintain their systems. Numerous instances of poor maintenance, have been reported, which could affect quality. Moreover, extraction rates or quantities are not controlled.

Low-income families require financial assistance to establish and maintain rainwater-harvesting systems. All residents can benefit from technical training in system construction and maintenance. Institutions such as the MOH and the "the Ministry of Natural Resources and the Environment (MNRE) Hydrology Unit also require technical and financial assistance to adequately monitor biological and chemical pollution of water resources and extraction rates.

Unlike the electric energy utility, the TWB is not subsidized; however, it manages to cover its operational costs and contribute to consolidated revenue. Sources of revenue include water sales, contracts for services such as upgraded village water supplies, training of village water committees, and plumbing and fittings sales. Village water supply systems are installed or upgraded through grants from donor agencies, and operational costs are partially covered by minimal meter charges. Rainwater harvesting systems are funded by small grants from donor agencies administered through non-governmental organizations (NGOs), and revolving loans and fundraising are organized through women's groups. Nonetheless, insufficient funding is available for water conservation and management activities, in addition to a lack of financial support for water resource managers.

There is no comprehensive law in Tonga addressing issues of ownership, management, and protection of water resources despite the fact that the need for such legislation has been clearly highlighted in various documents, national consultations, and conferences since 1991. However, provisions have been made in a number of laws in relation to water pollution, which involves a range of government agencies.

Despite all of these factors, PACC was able to assist in the development of the National Water Policy and National Water Bill with Climate Change, which were mainstreamed to build support for confronting emerging climate risks in Tonga's water sector. Based on the stakeholder's discussions, the sensitivity of the water sector to climate stresses is summarized in Tables 1 and 2.

Table 1: Sensitivity of selected water components to both current and future climate change, sea level rise (SLR), and climate-related hazards.

Water sector component	Sea level rise and saltwater intrusion	Tropical cyclone and storm surge	Drought and increased temperature	Flooding	Erosion/ inundation (inland and coastal)
Water Quality	High	High	High	High	High
Water Quality	High	High	High	High	High

Table 2: Future impact of climate change in the water sector.

Climate Change	Impact
Decreased Rainfall (drought) Periods of low rainfall are likely to be accompanied by prolonged dry periods.	Prolonged dry periods will decrease water supplies for use in these communities. A reduction in groundwater recharge means a reduction in potable water supplies for use in these communities. Lack of availability of potable water will continue.
Increased Sea Level	Saltwater intrusion will reduce the quantity and quality of potable water.

As previously mentioned, SLR will not have a direct impact on groundwater lens thickness and volume, although it will increase the water lens proportional to the degree of SLR. However, if land is lost due to the SLR, the water lens will then shrink. SLR can also cause inundation of low-lying areas, which can increase the salinity of the thin water lenses in these areas.	Land loss will reduce the size of the freshwater lens, hence reducing the availability of potable water.
Increased Temperature The effects of projected temperature increase on water resources are mainly on evapotranspiration of water. Evapotranspiration can also be influenced by other factors such as solar radiation and wind speed. Increases in evapotranspiration would decrease the recharge to groundwater. Decreases in evapotranspiration, however, would tend to increase groundwater recharge.	Increased temperature will increase water consumption, hence reducing the groundwater supply. Increased water loss means lower recharge rates, hence a reduction in groundwater supply.
Increased Frequency and Intensity of Tropical Cyclones	Increased damage to water resources and water supply systems, hence increased

	water scarcity. Storm surge causes saltwater intrusion in groundwater aquifers, hence reducing the quality and quantity of potable water. Flooding, which is associated with cyclones and periods of heavy rainfall, will adversely affect water quality and quantity.

4. Conclusion

The Government of Tonga's commitments to addressing disaster risk management (DRM) are reflected in recently revised legislation and the development of the National Emergency Management Plan. Such commitments are reflected in national initiatives to improve risk management processes in Tonga through institutional strengthening and human resource development. This commitment is embodied in the Cyclone Emergency and Risk Management Project (CERMP, 2002) and other subsequent initiatives. Actions taken under the CERMP include the construction of 270 low-cost cyclone resistant homes for Cyclone Waka, the promulgation of the Emergency Management Act in September 2007, and a review of the National Emergency Management Plan.

A national disaster fund was established in June 2008 (Tongan Pa'anga exchange rate (TOP) $5 million) to facilitate the recovery process after Waka's impact, and the staff of the National Emergency Management Office was strengthened by three senior new posts in its 2007–08 financial year. Although this commitment is a milestone in the development of

DRM in Tonga, there is still room for improvement to enhance community preparedness and resilience to natural disasters.

PACC's support and development of the Joint National Action Plan (JNAP) for CCA and DRM is an important step toward strengthening Tonga's capacity to manage the challenges of climate change impacts and disaster risks. The timely and full implementation of this national action plan underscores Tonga's commitment to achieving the vision of the plan linked to its national strategic planning framework.

The World Risk Index (WRI), which analyzes the relationship between exposure to natural hazards in accordance with social vulnerability for calculating disaster risk for the globe, determined that Vauatu, Tonga, and the Philippines are among the top risk-prone countries (United Nations University, 2012). Multi-hazard risks include typhoons, tsunamis, earthquakes, and volcanoes. However, the government could reduce the vulnerability by more effective management of available resources and human settlements in addition to proper implementation of policies and procedures at the ground level.

This study shows the positive relationship between SLR and the vulnerability of the SIDS of Tonga. The depleted water resources are to be reinstated; with proper water management policies and mitigative measures, the risk could be reduced. Climate change impacts would be best addressed by the integration of indigenous measures as well as new technological knowledge and observations (Lewis, 1999; Mercer et al., 2007; Wisner, 1995; Wisner et al., 2004). The decisions for the utilization of available resources of SDIS by the inhabitants must be made deliberately to reduce the adverse impacts of climate change and SLR (UNFCC, 2005, 2009). It is hoped that this study will support and assist in enhancing the sustainability of Tonga from natural hazards and aid DRM at all community and government levels.

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