TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

EXECUTIVE SUMMARY

There has been a continuous global concern regarding the disastrous impacts of climate change, sea level rise and climate related hazards. Scientific findings revealed that the global climate system is being adversely affected due to the accumulation of Greenhouse Gases (GHGs) in the atmosphere. This has been scientifically proved to be caused by anthropogenic activities. The international response prompted the United Nations to adopt the United Nations Framework Convention on Climate Change (UNFCCC) in July 1992 during the Rio Earth Summit at Rio Janeiro, Brazil. The Kingdom Tonga acceded to the UNFCCC in July 20, 1998. The said convention sets out a framework of action to minimize the concentrations of GHGs and to facilitate adequate adaptation to the impacts of climate change, sea level rise and climate related hazards. Tonga, similar to the Pacific Island Countries (PICs) is extremely vulnerable to these impacts due to its geographical, geological and socio-economic features.

This Vulnerability Assessment Report (VAR) is a requirement of the Pacific Adaptation to Climate Change Project in Tonga. This is a regional project encompassing thirteen member countries in the Pacific Region. The PACC project is the first project in the region that solely addresses the urgent need for adaptation to climate change in the PICs including Tonga which will enable not only the implementation of adaptation measures in the PICs but also enhancing the resiliencies of these countries to the adverse impacts of climate change, sea level and climate related hazards in the longer term.

The PACC Project focusses on three thematic areas: ***water resource management, coastal management and infrastructure as well as food production and food security.*** Through consultative process with PACC communities, adaptation in the water resources sector was selected as Tonga's area of focus. The site for the PACC Project is the Western (Hihifo) District, Tongatapu, the main island. Six (6) vulnerable villages within this district were selected as pilot sites for the Tonga PACC Project. These included Fo'ui, Ha'avakatolo, Kolovai, 'Ahau, Kanokupolu and Ha'atafu villages.

This report is arranged as follows;

- National Circumstances
- Observed and Historical Climate Data
- Climate and Sea Level Projections
- Vulnerability Assessment
- Capacity Constraints
- Capacity Development

National Circumstances

The Kingdom of Tonga lies between latitudes,15^0 23^0 30' South and longitudes, 173 and 177^0 West. It is an archipelago of 172 coral and volcanic islands, of which 36 are inhabited with an area of 649km^2. The islands of Tonga are formed on the tops of two parallel submarine ridges stretching from Southwest to Northeast. Between the two ridges is the fifty-kilometer wide trough known as the Tofua trough. Several volcanoes, some of which are still active have formed along the western ridge, while many coral islands have formed along the eastern ridge. There are two types of coral islands in Tonga the low coral and the raised coral islands. The PACC pilot communities are situated in the raised coral island which had been tilted by earth pressures.

Fou'i, Ha'avakatolo, Kolovai, 'Ahau, Kanokupolu and Ha'atafu are located between latitude 20^{0}7'30'' South and longitude 175^{0}19'30'' West with a total land area of 8.23km^2. The width of these communities, from coastline to coastline ranges from 2-15km. Topographic elevation of the coast is below 2m above the mean sea level. These communities have been historically experienced coastal inundation and erosion due to their low topographical features. (Figure 2.2).

In accordance with the 2006 census, the total population for Tonga was 101,991 which distributed amongst 17,529 households. Tongatapu island division has the largest population density (277people/sqkm). Its total population recorded as 72,045 which accounted for seventy one percent (71%) of Tonga's total population.

The population of the six pilot communities totaled 2,353 that distributed amongst 401 households and which accounted for three percent (3%) of the total population of Tongatapu.

In the six PACC pilot communities, the main source of drinking water is from rainwater collected in the water tanks and from freshwater lens of the underground water aquifers. According to the 2006 Census, out of the 401 households, 369 household obtained their drinking water from water collected in water tanks; 19 households utilized piped water as source of drinking water, 5 households used bottled water; and 2 households used boiled water and other sources of drinking water.
Apart from drinking, water was also used for other purposes such as cooking, bathing, washing, toilet and others.

The economy of the country and the PACC communities is very much dependent on the agricultural, fisheries, forestry and tourism industries. Climate change. sea level rise and climate related hazards seriously affect productions in these industries and hence the economy.

Soils of Tonga consist of two main soil types: a clay soil (*kelekelefatu)* and a sandy soil (*tou'one*). The type of soil found at the PACC pilot communities is the Loam Soil, a combination of clay; sand and silt . With the exception of the areas that have been inundated by sea water intrusion , soils are more saline and less productive.

Observed and Historic Climate Data

The observed and historical climate data including temperature, rainfall, sea level and tropical cyclone were obtained. Rainfall trend indicates a general decrease from year 1949-2007. Trends for Temperature, Sea level and frequency and intensity of tropical cyclones show a general increase since 1949. Climate change, sea level rise and climate related hazards impacts on the water resource sector were assessed.

Climate and Sea Level Projections

Future climate and sea level projections were developed to assess their future impacts on the water resources in the PACC communities. Impacts will be exacerbated by future climate change. The time intervals selected for the scenario generation are, 2020, 2050 and 2100 respectively.

Vulnerability Assessment

Severe droughts seriously led to a reduction in the amount of water collected in the water tanks, a decrease in the recharge rate to underground water hence reducing the availability of water for consumption and other uses apart from drinking.
Tonga has occasionally received heavy rainfall. Despite of this availability of substantial amount of water, there is still lack of rainwater harvesting systems in these communities. In some households there are no gutterings in place for rainwater collection. Occasional heavy rainfall has caused flooding and prolonged ponding of water.
The narrowness and the low lying nature of the land in these communities permit the intrusion of seawater into the groundwater aquifer caused by sea level rise. These adversely affected the quality and quantity of potable freshwater for drinking and other purposes.
Salt water intrusion to groundwater aquifer caused by storm surges and overtopping of these communities by waves during Tropical Cylones affect the quality and quantity of potable freshwater not only for drinking but also other purposes.

Capacity Constraints

The capacity constraints identified in this report are; lack of policy/legislation/regulatory framework, institutional constraints, limited facilities/equipments, financial constraints, demand exceeds supply, poor infrastructures/infrastructural design, lack of awareness, education and training

Capacity development

Capacity developments recommended are; improved good governance for climate change adaptation, implementation of adaptation measures, awareness raising, training and education, strengthen institutional partnerships and ensure sustainable access to both internal and external resources

1 NATIONAL CIRCUMSTANCES

1.1. Introduction

There has been a continuous global concern regarding the disastrous impacts of climate change, sea level rise and climate related hazards. Scientific findings revealed that the global climate system is being adversely affected due to the accumulation of Greenhouse Gases (GHGs) in the atmosphere. This has been scientifically proved to be caused by anthropogenic activities. The international response prompted the United Nations to adopt the United Nations Framework Convention on Climate Change (UNFCCC) in July 1992 during the Rio Earth Summit at Rio Janeiro, Brazil. The Kingdom Tonga acceded to the UNFCCC in July 20, 1998.

Tonga, similar to the Pacific Island Countries (PICs) is highly susceptible to the impacts of climate change, sea level rise and climate related hazards. The geographical, geological and socio-economic features of Tonga thus determine its susceptibility to these detrimental impacts which seriously affect the environment, the people of Tonga and their livelihoods. In addition, these impacts also threaten the accomplishment of sustainable development and global, regional as well as national environmental goals in Tonga

Given the urgent need for adaptation to climate change in the Pacific island countries, a Pacific Adaptation to Climate Change (PACC) Project was developed. This project encompasses thirteen member countries in the Pacific region including Tonga. This is the first project in the region which solely addresses the urgent need for adaptation to climate change. It will enable, not only the implementation of adaptation measures in the PICs, but also enhancing the resiliencies of these countries to the adverse impacts of climate change, sea level and climate related hazards in the longer term.

The PACC Project in the Pacific region focuses on three thematic areas: ***water resource management, coastal management and infrastructure and food production and food security***. Through consultative processes with communities, adaptation in the water resources sector was selected as Tonga's area of focus. The site for the PACC Project is the Western (Hihifo) District, Tongatapu, the main island. Six (6) vulnerable villages (Fo'ui, Ha'avakatolo, Kolovai, 'Ahau, Kanokupolu & Ha'atafu) within this district were selected as pilot sites for the Tonga PACC Project.

This vulnerability assessment report is primarily focusing on the assessment of the adverse impacts of climate change, sea level rise and climate related hazards on the Water Resources in the aforementioned villages.

The assessment was undertaken by reviewing the national vulnerability assessment reports and conducting of a socio-economic and environmental survey. The identification of capacity constraints and recommendations for capacity development were both discussed in this report.

1.2. Geographical and Geological Setting

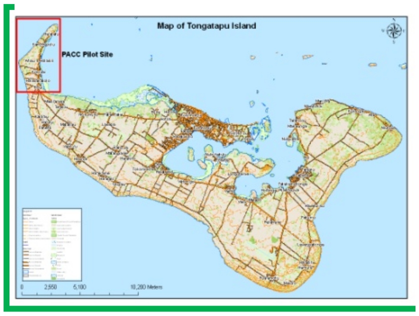
The Kingdom of Tonga lies between latitudes 15^0 23^0 30' South and longitudes 173 and 177^0 West. It is an archipelago of 172 coral and volcanic islands, of which 36 are inhabited with an area of $649km^2$.

The total area of Tonga's archipelago is $747km^2$. It is aggregated into four major island groups extended over a north-south axis: Tongatapu and 'Eua (347 km^2) in the south, Ha'apai (109 km^2) in the center, Vava'u (121 km^2) in the north and the two Niuas (72 km^2) in the far north. The largest island of these is Tongatapu ($260km^2$) on which Nuku'alofa, the capital is located.

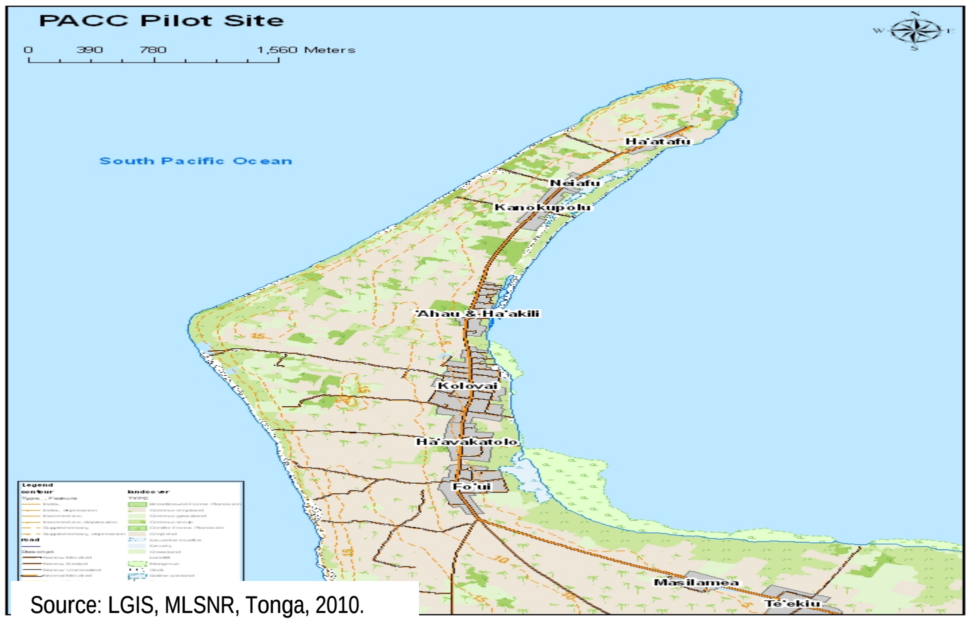
The islands of Tonga are formed on the tops of two parallel submarine ridges stretching from the Southwest to the Northeast. Between the two ridges is the fifty-kilometer wide trough known as the Tofua trough. Several volcanoes, some of which are still active have formed along the western ridge, while many coral islands have formed along the eastern ridge. There are two types of coral islands in Tonga, the low coral and the raised coral islands. ***The low coral islands***, as exemplified by the Ha'apai island groups are generally flat and undulated islands of sand which rise to 15 metres above sea level. These islands were formed on the coral reef platforms. ***The raised coral islands*** including Tongatapu, 'Eua and the Vava'u island groups which have been tilted by earth pressures showing a marked topography. The ocean to the west of the ridges is 3km deep whereas the ocean to the east is 8km deep. This deep water is called the Tonga Trench, the second deepest trench in the world.

Foui, Ha’avakatolo, Kolovai, ‘Ahau, Kanokupolu and Ha’atafu communities are located between latitude 20^{0}7’30’’ South and longitude 175^{0}19’30’’ West with a total land area of 8.23km^{2}. The distance from Fo’ui to Ha’atafu village is 6km and the width (from coastline to coastline) ranges between 1-2km.

Figure 1.1: Map of Tongatapu Island illustrating the geographical location of the PACC pilot communities



Source: LGIS, MLSNR, Tonga, 2010.



Source: LGIS, MLSNR, Tonga, 2010.

The topographic elevation of these villages ranges from 2-15m. Topographic height of the coast is below 2m above the mean sea level. These communities have been historically experienced coastal inundation and erosion due to their low topographical features. It is evident that the narrowest parts of Tongatapu fall into these villages (Figure 1.1).

1.3. Population

Tonga’s 2006 population census was its sixth decennial census. Tonga was divided into five island divisions; namely, Tongatapu, Vava’u, Ha’apai, ‘Eua and the Niuas. Within Tongatapu island division it was subdivided into seven districts, Kolofo’ou, Kolomotu’a, Vaini, Tatakamotonga, Lapaha, Nukunuku and Kolovai districts. Within Kolovai district, it was further subdivided into villages including the six PACC pilot villages, Fo’ui, Ha’avakatolo, Kolovai, ‘Ahau, Kanokupolu & Ha’atafu.

In accordance with the 2006 census, the total population of Tonga was 101,991 which distributed amongst 17,529 households. Tongatapu island division was the most populous. Its total population was 72,045 which constituted seventy one percent (71%) of Tonga’s total population. Its average population density was 277people/sqkm.

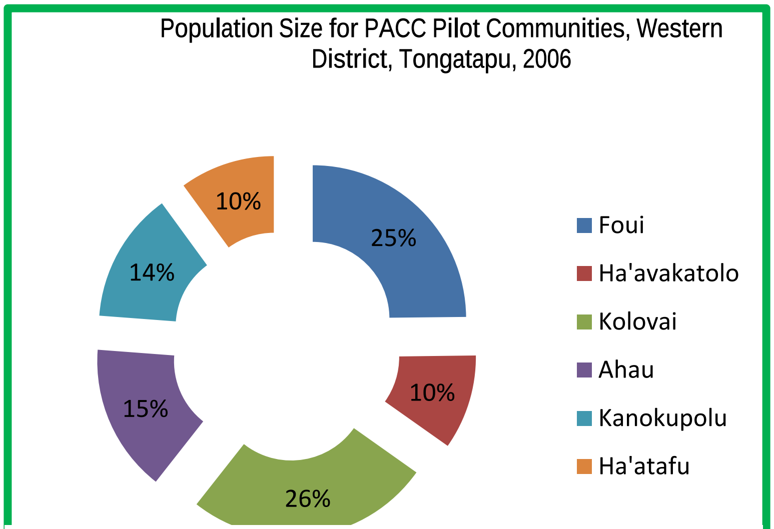


Figure 1.3 : Population Size for PACC Pilot Communities, 2006

The population of the six pilot communities totaled 2,353 that distributed amongst 401 households and which accounted for three percent (3%) of the total population of Tongatapu.

Additionally, for the six communities, twenty six percent (26%) lived in Kolovai, for Fo'ui (25%), 15% for 'Ahau, for Kanokupolu (14%) and 10% resided in both Ha'avakatolo and Ha'atafu. (Figure 1.3). The average population density was 286people/sqkm.

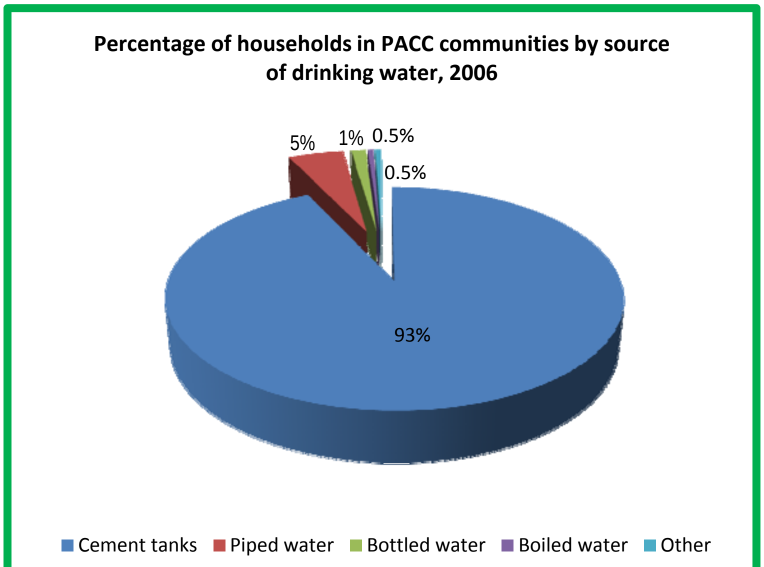
Out of the total population residing in these six villages, 1,190 (51%) were females and 1,163 (49%) were males.

1.4. Water Resources

Water is extremely valuable and an essential source of life. Humans, animals and plants critically depend on sufficient and sustainable supplies of water for their very existence, social, economic and environmental needs and development. This vital resource is limited in the island kingdom.

The two main sources of water in Tonga are from the rainwater collected and stored in the water tanks and also from the underground water aquifers.Tongatapu does not have surface water apart from that found in Eua and few salty lakes on the islands of Tofua and Niuafo'ou.

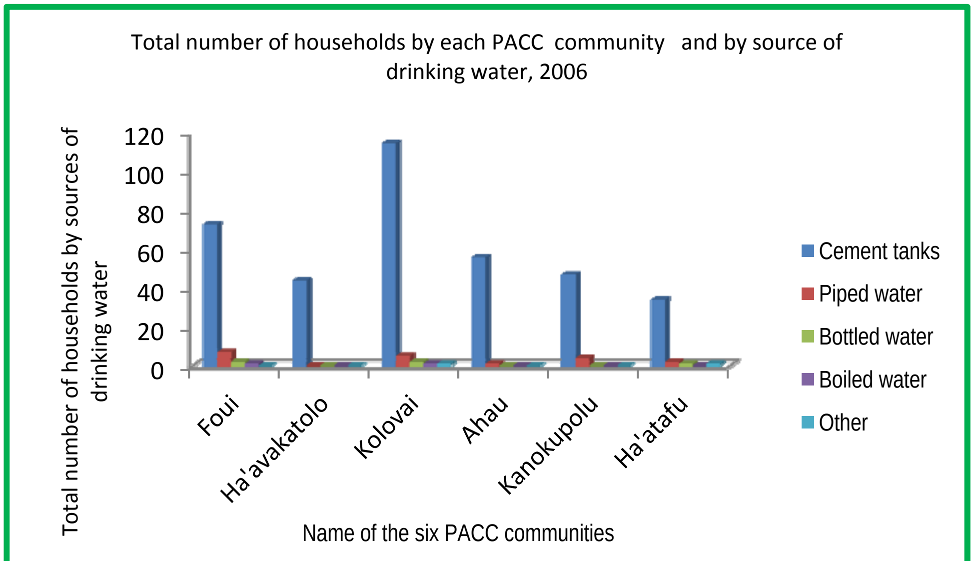
Figure 1.4: Percentage of households in the PACC Pilot Communities, by source of drinking water, 2006



Source: Statistics Department, Tonga, 2006.

In the six PACC pilot communities however, the main source of drinking water is from rainwater collected in the water tanks and from freshwater lens of the underground water aquifers. According to the 2006 Census, out of the 401 households of these communities, 93% (369 households) obtained their drinking water from water collected in water tanks; 5% (19 households) utilized piped water as source of drinking water, 1% (5 households) used bottled water; and 0.5% (2 households) used boiled water and other sources of drinking water (Figure 1.4).

Figure 1.5: Village name, number of households and sources of drinking water, Tongatapu, 2006

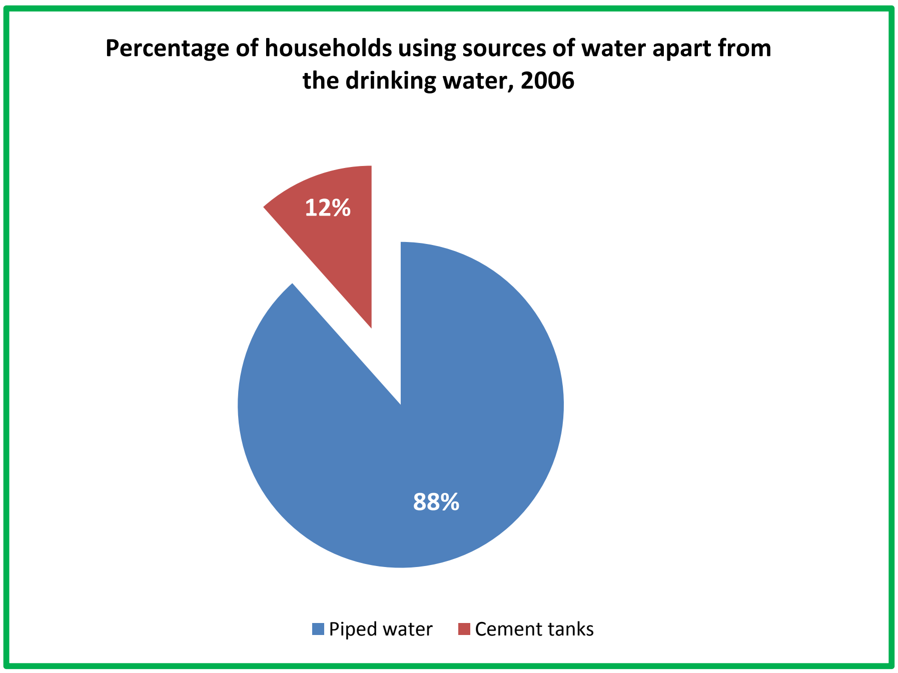


Source: Statistics Department, Tonga, 2006

Figure 1.5. depicts that for each PACC village, people are highly depending on water being collected in the cement tanks as their principal source of drinking water. The reliance on piped water and other sources for water consumption is very minimal.

Apart from drinking, water was also used for other purposes (cooking, bathing, washing, toilet and others). 88% of the total households from the six pilot communities had access to piped water whereas 12% had their own water tanks; no household was reported to have its own wells or had other sources of water supply (Figure 1.6).

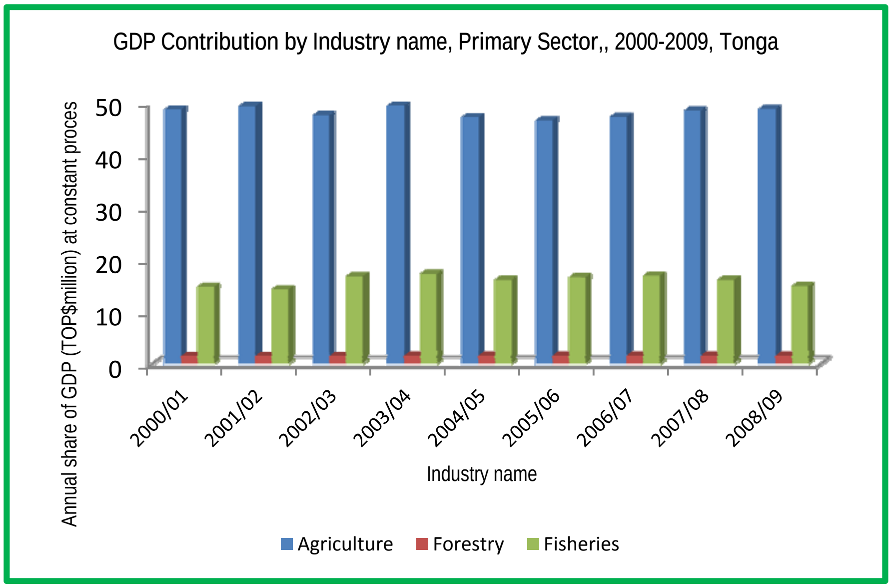
Figure 1.6: Percentage of households using sources of water apart from drinking water, 2006



Source: Statistics Department, Tonga, 2006

1.5. Economy

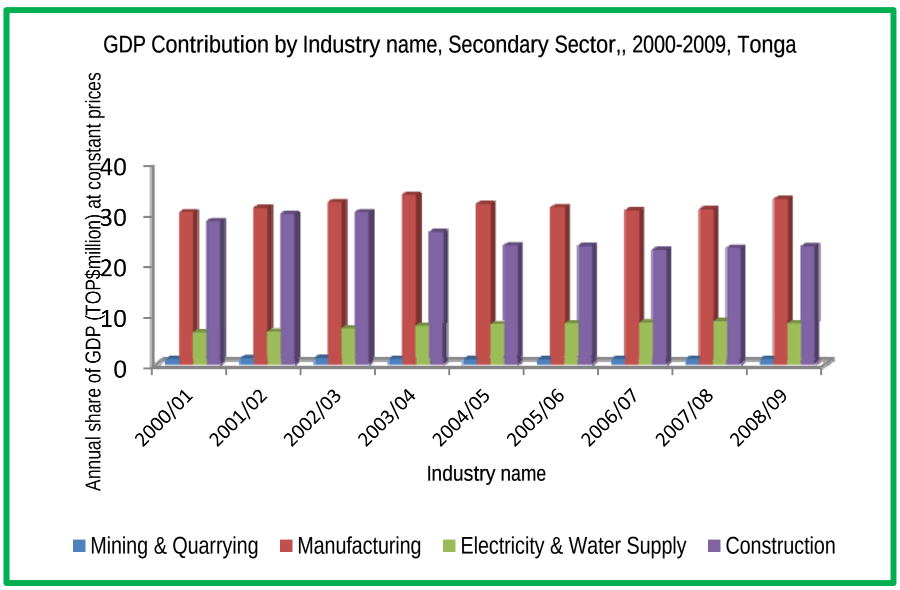
Figure 1.7: Industrial GDP contribution to the economy of Tonga, 2000-2009



Source: Statistics Department, Tonga, 2006.

Figures 1.7-1.10 illustrate name of each industry within the Primary, Secondary and Tertiary Sectors with its annual production and contribution to Gross Domestic Product of Tonga.

At the industry level, and from Years 2000-2009, the agricultural production remains the largest contributor to the economy of Tonga.

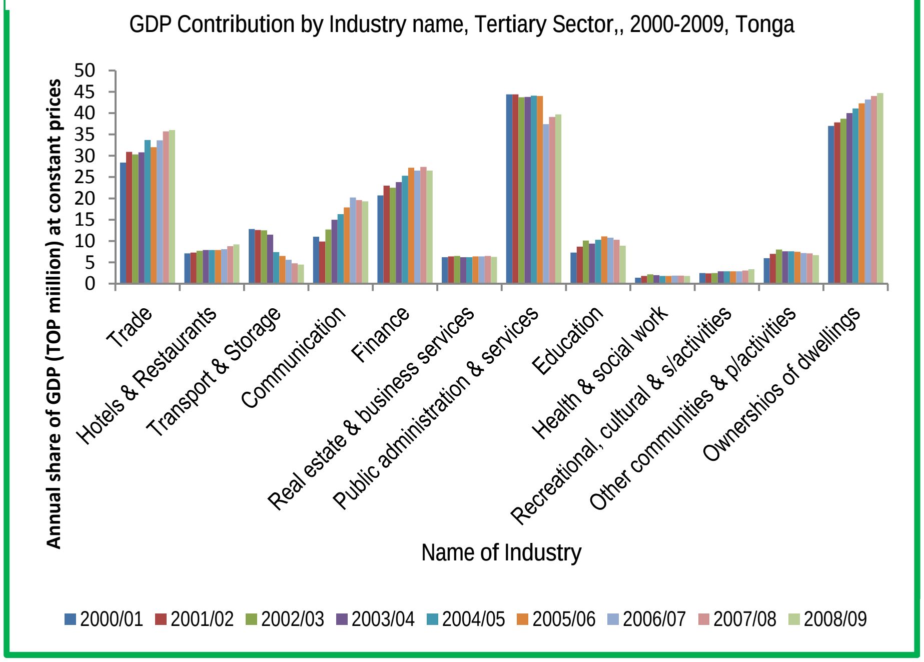


This is followed by the, Public services and administration, ownership of dwellings, manufacturing, trade and constructions.

At the sectoral level, the Tertiary/Services Sector recorded to be the largest contributor to the GDP.

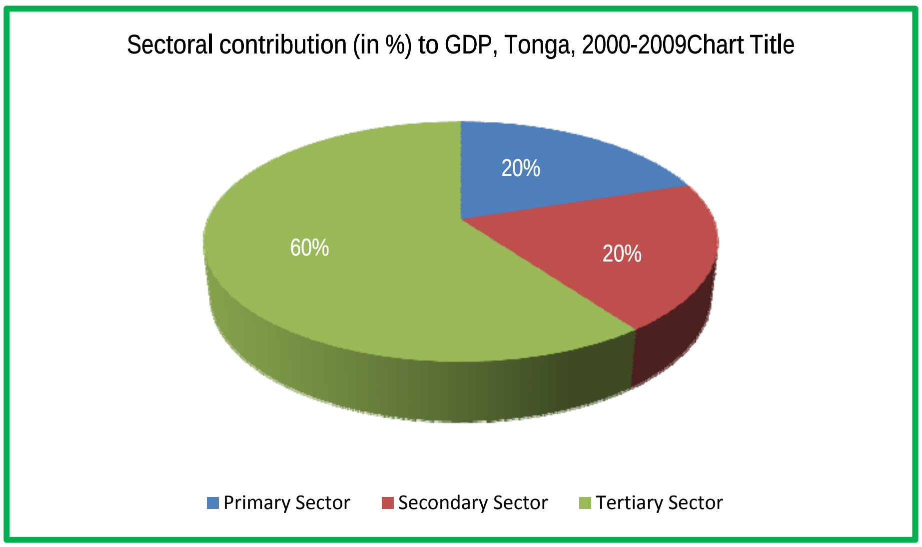
The contribution of the Primary sector (agriculture, forestry and fisheries) to the Gross Domestic Product was 20% while secondary and tertiary sectors contributed 20% and 60% respectively. Tourism is also a significant driver of Tonga's economy. Climate change, sea level rise and climate related hazards greatly affect these sectors which in turn affect the economy of the country.

Figure 1.9: Industry GDP contribution to the economy of Tonga, 2000-2009



Source: Statistics Department, Tonga, 2006.

Figure 1.10: Sectoral GDP contribution to the economy of Tonga, 2000-2009



Source: Statistics Department, Tonga, 2006.

1.6. Soils

Soils of Tonga consist of two main soil types: a clay soil (*kelekelefatu)* and a sandy soil (*tou'one*).

The clay soil varies in texture from light loams to heavy clays. It derives from weathered volcanic ash overlying coral bedrock. It is highly friable, fertile and generally permeable (Studien, 1983). It covers most of Tongatapu and Vava'u, and some parts of Ha'apai, often to a depth of two metres. These soils also have a moderate to high natural fertility due principally to the incomplete weathering of the volcanic ash.

The second main soil type is sandy soil which is predominantly made up of sands and it is less fertile soils. It is derived almost entirely from coral sand, and hence is mostly confined to the low coral island narrow strips along the coast. Sandy soil is particularly widespread in the low coral islands of the Ha'apai, where they occupy up to half of the area of some of the settled islands. Crops as cultivated on sandy soil generally has low yield production comparing to those grown on *kelekelefatu* and are more vulnerable to short-term droughts. Some coastal *tou'one* areas are subjected to flood by high tides or storms and so are too salty for general agriculture.

The type of soil found at the PACC pilot communities is the Loam Soil, a combination of clay, sand and silt The areas that have been been affected by sea water inundation are unfavourable and less productive.

2 OSERIVED AND HISTORICAL CLIMATE, TONGATAPU.

Climate is defined under the UNFCCC, as the "averaged weather," or more rigorously, as the statistical description of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is three decades/thirty years as defined by the World Meteorological Organization.
The climate of Tonga is tropical. Tonga is situated within the south-east trade wind zone of the South Pacific. The observed and historical trends of climatic parameters/quantities will be discussed are rainfall, temperature, sea level and tropical cyclone.

2.1. Rainfall

Rainfall in Tonga is categorized into two seasons, the Hot Wet and the Cool Dry seasons. The Hot Wet season is often known as the Cyclone season and it is noticeable from November – April whereas the Cool Dry season starts from May- October.

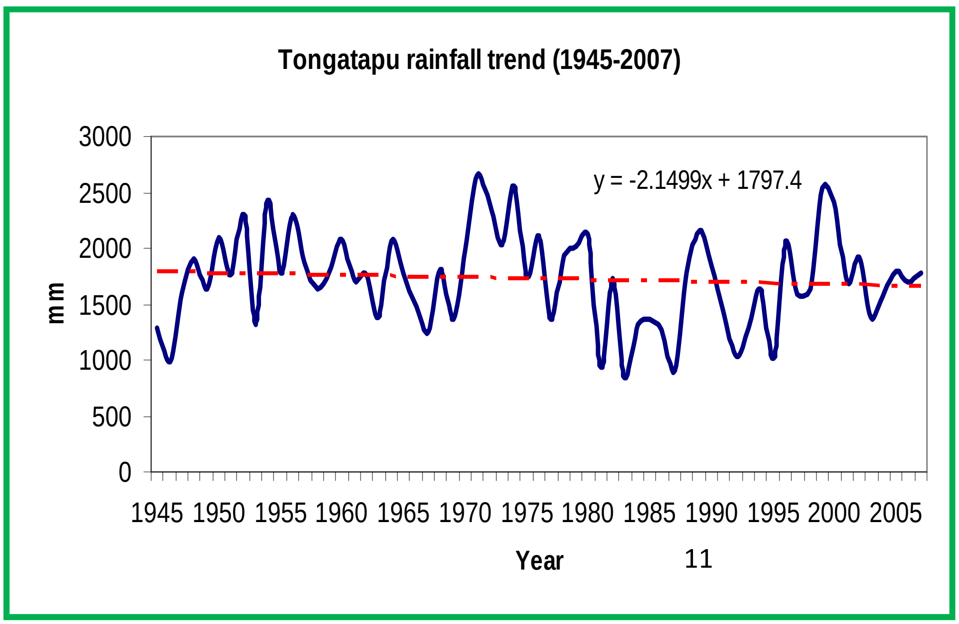
The annual mean rainfall for Tongatapu was calculated commencing from year 1945 -2007. Tongatapu received average rainfall of 1721mm. About 61% of the rain falls during the wet season and about 39% during the dry season (Table 2.1). Trends indicate a general decrease in rainfall since 1970s in Tongatapu (Figure 2.1).

Table 2.1: Annual mean rainfall, Tongatapu, 1971-2007

Location	Season (mm)		Annual mean (mm)	Percentage of Annual (%)	
	Wet	Dry		Wet	Dry
Tongatapu	1054	667	1721	61	39

Source: TMS, Tonga, 2008

Figure 2.1: Observed rainfall trend for Tongatapu, 1945-2007



2.2 Drought

The climate pattern of Tonga is very much affected by El Nino event which exists once in every 3 to 7 years. The eastward movement of the warm sea surface temperatures during El Nino event also caused the simultaneous eastward migration of moisture and water vapor required for cloud formation. This causes droughts in Tonga. In records, the last three major droughts incidence in Tonga were in 1983, 1998 and 2006. These have been directly linked to the May 1982-June 83, May 1997-April 98 and September 2006-January 07 El Nino events. The annual mean rainfall in Tongatapu is 1721mm per year. During the drought periods the average rainfall were as follows;

- 1983 – 70mm
- 1998 – 132mm
- 2006 – 142mm

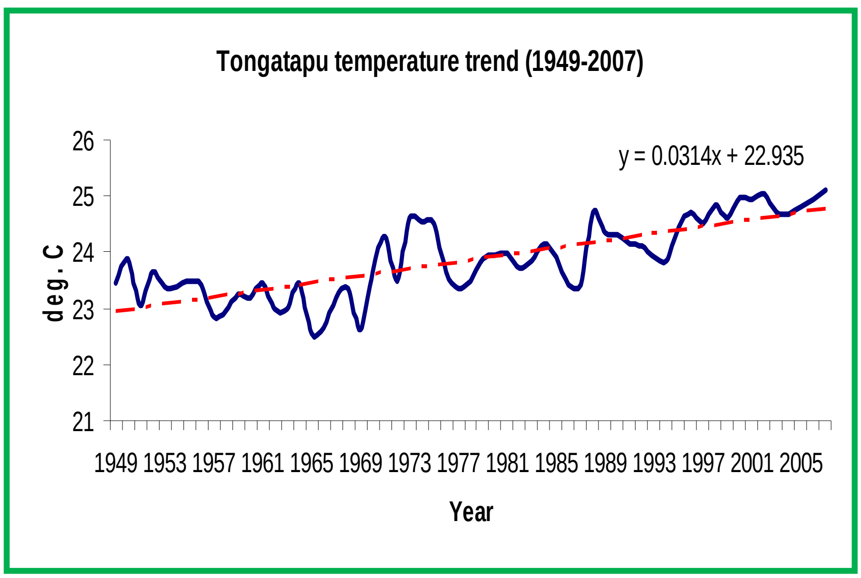
2.3. Temperature

Temperature variations throughout the Kingdom show an increase in daily and seasonal variations with increasing latitude. Mean annual temperatures vary from 27˚C to 24˚C on Tongatapu. Diurnal and seasonal variations can reach as high as 6°C throughout the island group.

During the Hot Wet Season, the average temperature ranges from 27-29⁰C whereas at Dry Cool Season, the average temperature ranges from 20-24⁰C.

Based on the historical climatic data records, there is a marked diurnal, seasonal and spatial variation in temperature for Tongatapu. Its average annual temperature rose by 1.8°C from 1949-2007.

Figure 2.2: Temperature trend for Tongatapu, 1949-2007

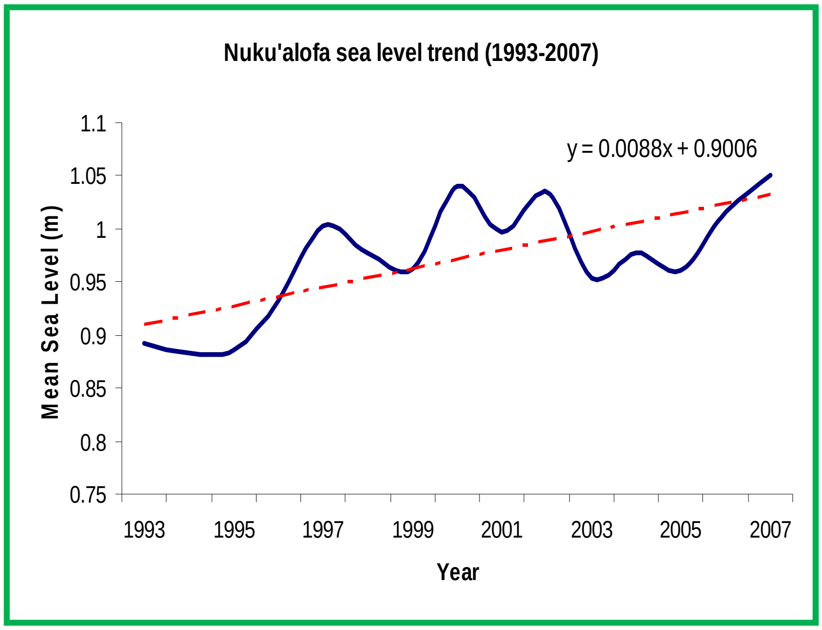


Source: TMS, Tonga, 2008

2.4. Sea level

The sea level trend in Tonga as Figure 2.3 shows that there is a general increase in sea level with a magnitude of 6.4mm/yr since records started in 1993 up to 2007. (TMS, Tonga, 2007).

Figure 2.3. Observed sea level in Tonga trend based on SEAFRAME data only from 1993 to 2007

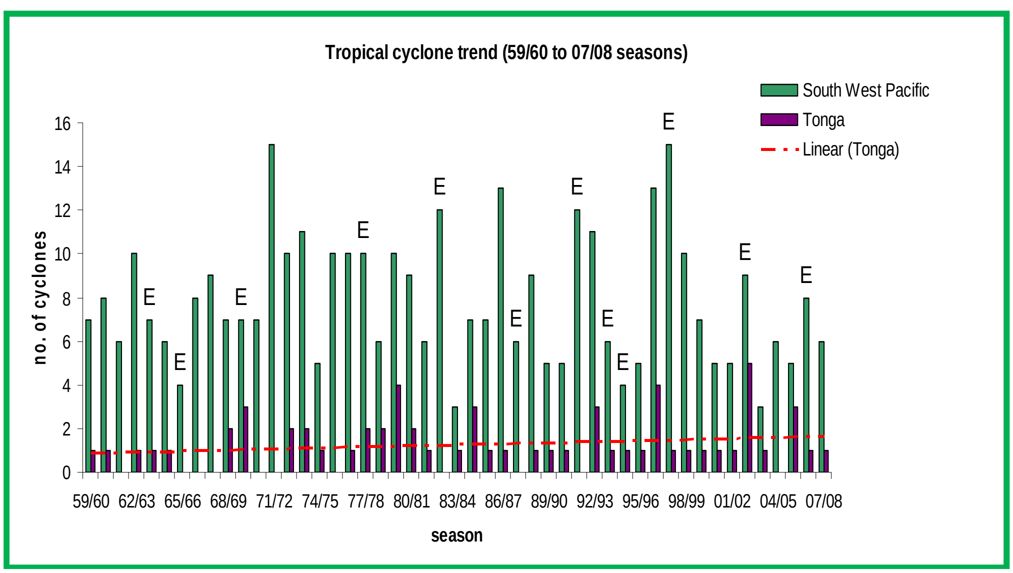


Source: TMS, Tonga, 2007

2.5. Tropical Cyclone

Tropical cyclones affect Tonga 1.3 times per year. Figure 2.4 shows the increase in frequency to 1.7 particularly during El Nino years. Historical records of cyclone occurrences in the South West Pacific have shown a decreasing trend particularly in the last decade (1999-2008), however there is not enough evidence to confidently predict that this trend is permanent and not an inter-decadal cycle. There is strong evidence however that years of increased tropical cyclone activity coincide with El Nino years. The letter “E” in Figure 2.4 depicts El Nino years.

Figure 2.4: Tropical cyclone trend, Tonga



Source: TMS, Tonga, 2008

In contrast to the South West Pacific trend, the tropical cyclone activity around Tonga shows an increased trend. as it is indicated by Figure 2.5. An explanation for the big jump in activity from the 60/69 decade could be attributed to improved recording of such events, improved technologies such as satellites to detect storms and changes to tropical cyclone definition.

Figure 2.5: Decadal occurrences of tropical cyclones in Tonga

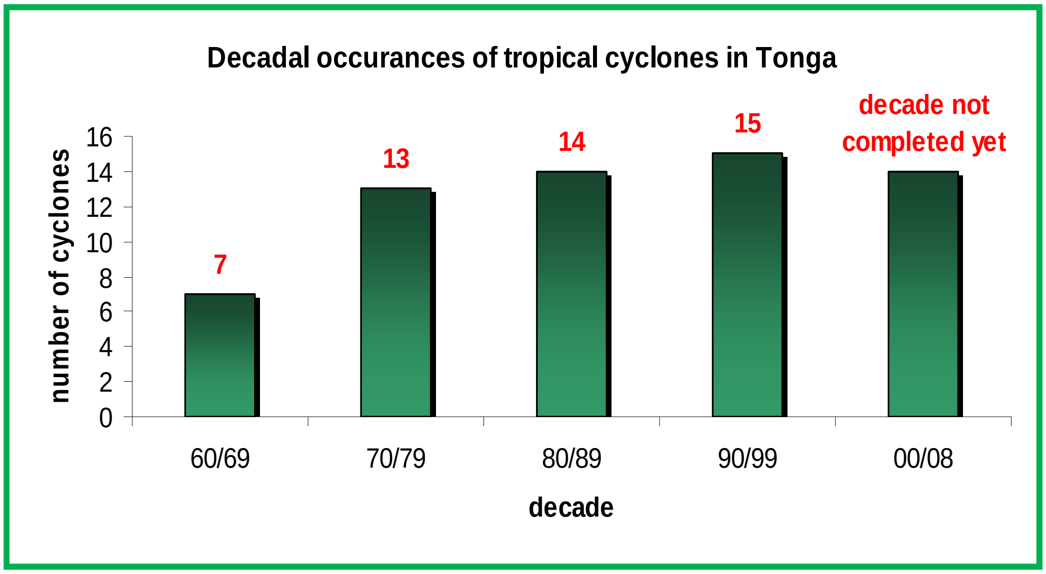
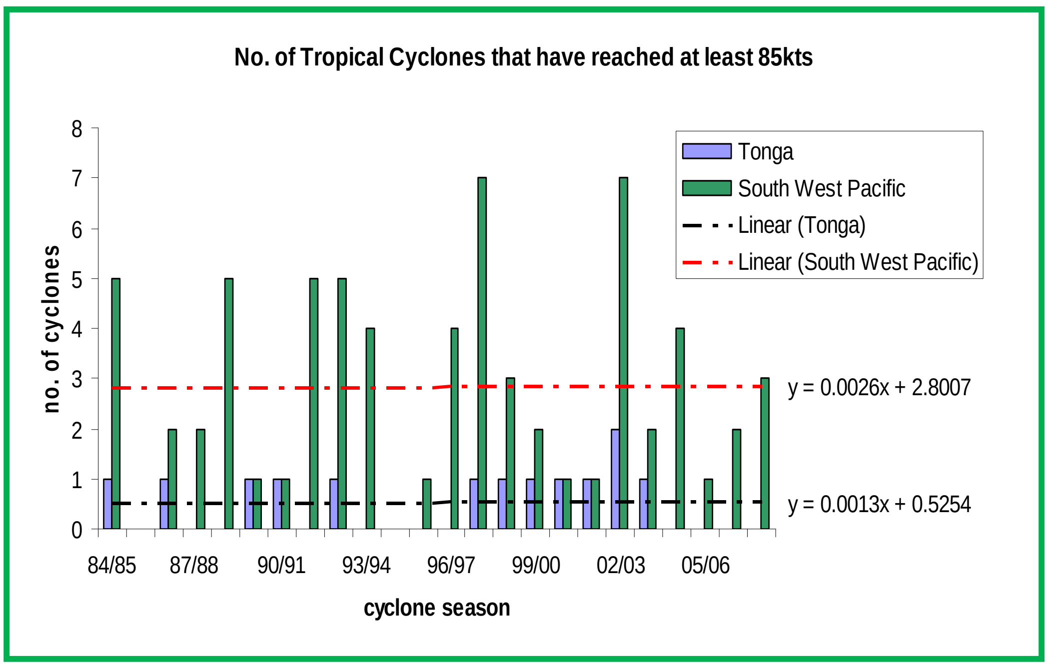


Figure 2.6: Observed trends of the occurrences of intense tropical cyclones.



Source: TMS, Tonga, 2008

There is also evidence that the occurrence of hurricane force intensity cyclones has increased since the 1980's in Tonga.

3. Climate Change and Sea Level Projections

The climatic data for climate change and sea level projections were developed by the Tonga Meteorological Service. The scenarios projected by the IPCC Special Report on Emission Scenarios (SRES) and a computer based modeling system for examining the effects of climate variability and change over time and space called SimCLIM were utilized to develop future climate and sea level projections.The time intervals selected for the scenario generation are, 2020, 2050 and 2100 respectively.

3.1. Rainfall

Tongatapu long term annual rainfall records also show that it has a negative but potentially manageable trend of 2mm per year. Tongatapu with its larger land mass holds a substantially large underground water reserve. Based on historical records, it is projected that there would be a 10% decrease in annual rainfall by the end of the century. The projected annual rainfall for Tongatapu is indicated in the table below.

Table 3.1: Rainfall projections for Tongatapu based on historic data trend.

Year	Annual rainfall projection based on linear growth trend (mm)	% change relative to mean
Normal	1721	0
2020	1693	-1.6%
2050	1629	-5.3%
2100	1521	-11.6%

Source: TMS, Tonga, 2008

3.2 Temperature

Based on the historical records, it is projected that the future average annual temperature for Tongatapu, would be as shown in the table below.

Table 3.2: Temperature projections for Tongatapu based on historic data trend.

Year	Annual temperature based on linear growth trend (°C)	% change relative to mean
Normal	24.1	0
2020	24.5	+1.7%
2050	25.5	+5.6%
2100	27.0	+12.1%

Source: TMS, Tonga, 2008

3.3. Sea level

Based on historical records, it is projected that the future sea level for Tonga would be as shown in the table below.

Table 3.3: Sea level rise projections for Tonga based on historic data trend from the Nuku'alofa tide gauge.

Year	Annual sea level rise projections based on the 2007 net relative sea level trend of +6.4mm/yr
2020	8.4cm rise
2050	27.5cm rise
2100	59.5cm rise

Source: TMS, Tonga, 2008

CHAPTER 4: VULNERABILITY ASSESSMENT

The six PACC pilot communities are extremely vulnerable to the impacts of climate change, sea level rise and climate change related hazards. These communities have experienced and continue to experience these detrimental effects. Scientific findings revealed that these impacts will be exacerbated by future climate change. Immediate adaptation actions be implemented to enable people and environment in these communities to reduce their vulnerabilities to the impacts of climate change and to mitigate disaster risks.

4.1. Methodologies

The methodologies that were used when conducting the Vulnerability Assessment (VA) exercise are as follows;

4.1.1. Historical and observed climatic data

The observed and the historical climatic data were provided by the Tonga Meteorological Service during the preparation of Tonga's Second National Communication on Climate Change Report. These data were obtained from the six meteorological stations in Tonga (Tongatapu, Vava'u, Ha'apai, Niuatoputapu, Niuafo'ou & Tide gauge, Tongatapu). These climatic data and trends were utilized to examine the impacts of climate change, sea level rise and climate related hazards on the water resources of the PACC pilot communities.

4.1.2. Climate change and sea level rise scenarios

The data for climate change and sea level projections were developed by the Tonga Meteorological Service during the preparation of Tonga's Second National Communication on Climate Change Report. The scenarios projected by the IPCC Special Report on Emission Scenarios (SRES) and a computer based modeling system for examining the effects of climate variability and change over time and space called SimCLIM were utilized to develop future climate and sea level projections. The time intervals selected for the scenario generation are, 2020, 2050 and 2100 respectively.These scenarios were generated to examine the future impacts of climate change and sea level rise on the water resource sector of the PACC pilot communities.

4.1.3. Literature Review

The following key relevant national assessment reports were reviewed. Some information from these reports was also used for the preparation of this VA report. The reviewed documentations are;

*the vulnerability and adaptation assessment on climate change for Tonga's national communication reports;

*the observed and historical climatic data from the Tonga's national communication reports;
*the national climate change policy, 2006;
*climate change under the National Assessment Report 2002;
*the Joint National Action Plan on Climate Change Adaptation & Disaster Risk Management 2010-2015;
* the Pacific Community Integrated Disaster Risk Reduction Plan 2010;
*the Tonga 2006 Census.

4.1.4 Socio-economic and environmental survey

A socio-economic and environmental questionnaire was developed by the TWG members of the PACC Project. This was closely followed when conducting the socio-economic and environmental survey for the six PACC pilot communities. Survey was carried out in November 2010. It was led by the TWG members of the PACC Project with the assistance from selected representatives from the pilot communities. Results of the survey were analyzed by the TWG members of the PACC Project. Consultations were held in February 2011 to present the findings of the survey to these communities. Inputs from these consultative meetings were recorded and subsequently used to prepare the final socio-economic and environmental survey report. Some relevant findings from this survey were extracted and used to prepare this VA report.

4.2: Observed Climate Change, Sea level rise and Climate Related Impacts and Sector Vulnerabilities

4.2.1. Drought/Reduced Rainfall

The annual mean rainfall for Tongatapu is 1721mm. During the drought periods in 1983, 1998 and 2006, the average rainfall were 70mm, 132mm and 142mm respectively.

According to the 2006 Census, 93% of the total households in the PACC pilot communities were heavily dependent on rainwater catchments as their principal source for drinking purposes. Severe droughts seriously led to a reduction in the amount of water collected in the water tanks, a decrease in the recharge rate to underground water hence reducing the availability of water for consumption and other uses apart from drinking.

Most of the traditional root crops such as yam, taro, cassava and sweet potatoes were seriously affected, their production rates subdued, and this in turn disastrously impacted food security, customary obligations, the standard of living in these communities and the economy of the country as a whole.

Droughts have potentially caused health and sanitation problems. Lack of water means the probability of exposing to dusts and contaminations from all sorts of sources are very high. This has caused diarrhoea, skin and respiratory diseases in these communities.

4.2.2. Occasional Heavy Rainfall

Tonga has occasionally received heavy rainfall. Despite of this availability of substantial amount of water, there is still lack of rainwater harvesting systems in these communities. In some households there are no gutterings in place for rainwater collection.

Occasional heavy rainfall has caused flooding to residential areas, schools, roads and prolonged ponding of water. This created favorable breeding sites for mosquitoes which posed health risks such as the outbreak of vector borne disease such as dengue fever. Some of the traditional root crops including yams are affected by this unfavourable weather condition. Heavy rainfall also increased surface runoffs from elevated areas. This has resulted in the deposition of sediments, debris being washed off especially to lower lying areas in these communities. Poor drainage system exacerbates erosional problems in these communities.

4.2.3. Sea level rise

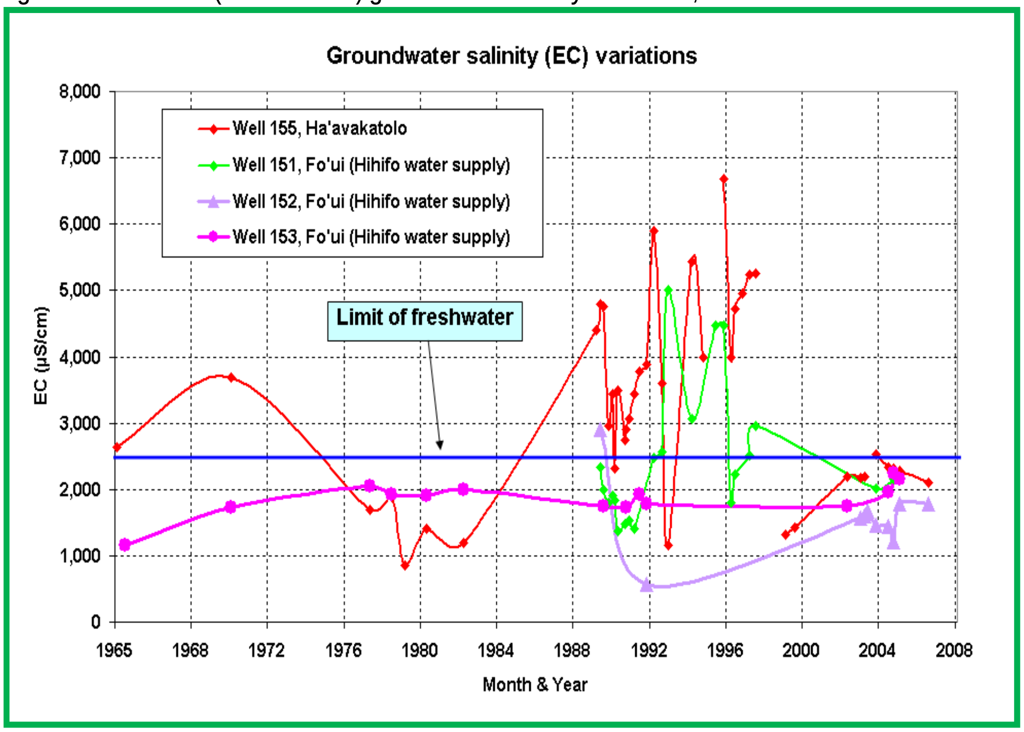
The narrowness and the low lying nature of the land in these communities permit the intrusion of seawater into the groundwater aquifer caused by sea level rise. These adversely affected the quality and quantity of potable freshwater for drinking and other purposes.

In measuring the salinity level, when it is below the limit for drinking water that is 2500uS/cm, it shows that freshwater lens is of reasonable thickness and it is safe for drinking. When salinity reaches or exceeds 2500uS/cm then it means the freshwater is generally thin and salinity level is high hence less freshwater is suitable for consumption.

There has been a record on the salinity levels in these pilot communities as exemplified by the wells located in Foui and Ha'avakatolo townships.

Well155 (Figure 4.1) at Ha'avakatolo has higher salinities than the other selected wells in the far west of the island due to the location of the well on the relatively narrow western 'hook' of the island. The salinity trend of this well is as follows: increasing from 1965 to 1971, decreasing from 1971 to 1980, generally increasing from 1980 to 1990 and then decreasing to 1991. Fluctuation in this trend is most probably caused by variations in recharge with an increase in salinity caused by a reduction in recharge and vice versa. The analysis of underground water recharge shows generally low recharge from 1965 to 1971, then higher than normal recharge in the 1970's followed by low recharge in the 1980's. The relatively high recharge in late 1990 and early 1991 correlates to the reduction in salinity from 1990 to early 1991.

Figure 4.1: Well 155 (Ha'avakatolo) groundwater salinity variations, 1965 to 2008



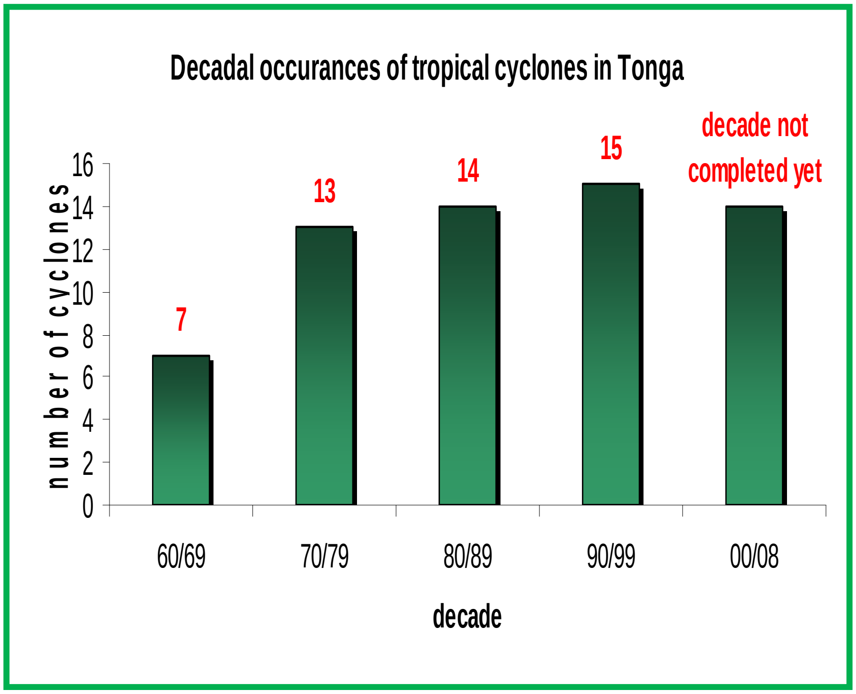
Source: TWB VA. 2008

Coastal erosion and inundation are critical environmental problems experiencing by these communities which partially due to sea level rise. These areas are tidally inundated and the worst times happen during spring tides. The increase denudation of mangroves and coastal trees exacerbate these impacts. A noticeable result of these activities and/or processes is the loss of residential, agricultural lands and infrastructures along the coast. Tax allotments are parcel of lands allocated for agricultural purposes. Loss of coastal allotments means finding alternate areas for residential, agricultural and infrastructural development purposes.

4.2.4. Impacts of Tropical Cyclone and Storm Surge

Figure 4.2 shows an increasing trend in the occurrences of tropical cyclones in Tonga on a decadal basis. There is also evidence that the intensity of cyclones has increased since the 1980's in Tonga.

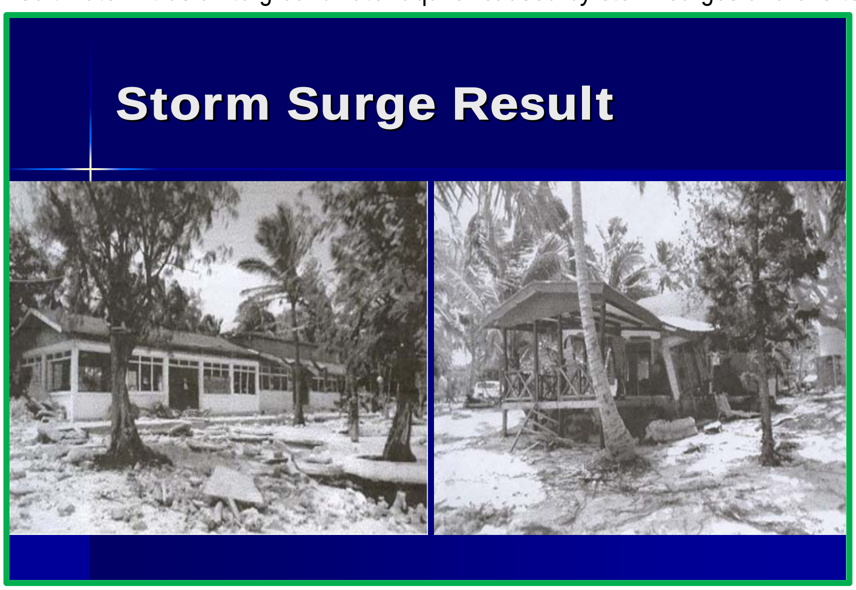
Figure 4.2 : Decadal occurrences of Tropical Cyclones in Tonga, 1960-2008



Since the 1960's 4 cyclones have severely affected Tonga. Cyclone Flora in March, 1961 Cyclone Isaac in March, 1982 Cyclone Waka in December, 2001 and Cyclone Renee in 2010. Amongst these four cyclones, Cyclone Isacc directly inflicted serious damages on Tongatapu. These PACC pilot communities were disastrously affected by Cyclone Isacc. It caused severe damages to water systems, crops and food supply, infrastructures, tourist resorts, the environment, buildings and disrupt essential services and the wellbeing of the people for a prolonged period of time. The total cost for the damage inflicted was T$18.7 million.

Storm Surge

Salt water intrusion to groundwater aquifer caused by storm surges and overtopping of these communities by waves during Tropical Cylones affect the quality and quantity of potable freshwater not only for drinking but also other purposes.



During Tropical Cyclone 'Eseta in 2003, storm surges inflicted serious damages to tourist resorts in Ha'atafu beach, Good Samaritan Inn resort in Kolovai (Photo on left), and the Princess Resort in Fo'ui

The Good Samaritan Inn at Kolovai was destroyed by this surge for it caused great damage costing around T$105,000.00.

4.3. Future Impacts of Climate Change and Sea Level Rise on the Water Resources, PACC pilot Communities, Tongatapu.

Table 4.3.1.: Summary of the future impacts of climate change, sea level rise and climate related hazards on the Water Resources PACC communities

CLIMATE CHANGE FACTOR	IMPLICATIONS
Decreased Rainfall (drought) *Periods of low rainfall are likely to be accompanied by prolonged dry periods.	*Prolonged dry periods will decrease water supply for uses in these communities *Reduction in recharge to groundwater means reduction in potable water supply for uses in these communities *Lack in the availability of potable freshwater for uses.
Increased Sea level As mentioned before, sea level rise will not directly have an impact on the groundwater lens thickness and volume but just raise the water lens proportional to the rising of sea level. However, if land is lost due to the rising in sea level, then water lens will shrink and reduce from its original size. Rising sea level can also cause inundation of low-lying areas, which can increase salinity of thin water lens of these areas.	*Salt-water intrusion will reduce the quantity and quality of potable freshwater. *Land loss will reduce the size of the freshwater lens hence reducing the availability of potable freshwater.
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. Increase in evapotranspiration would decrease the recharge to groundwater. The reverse would apply when there is a decrease in evapotranspiration would tend to increase groundwater recharge.	*Increased temperature will increase water consumption hence reducing the quantity of groundwater supply. *Increase water loss means low recharge rate hence reduction in groundwater quantity.
Increased frequency and intensity of Tropical Cyclone	*Increase damage to water resources and water supply systems hence increase water scarcity. *Storm surge caused saltwater intrusion to groundwater aquifers hence reducing the quality and quantity of potable freshwater. *Flooding, which is associated with cyclones and periods of heavy rainfall will adversely affect the water quality and quantity.

In summary , who or what are the vulnerable elements/groups in the Six (6) PACC communities.

Different groups are vulnerable in different ways to different climate change, sea level and climate related hazards based on their location/exposure, the type of hazards them faced/experienced, technology/resources available and their preparedness level. The following Risk Matrix (Y is "yes" and N is "no") indicates the elements that are at risk in these PACC communities.

Table 4.3.2: Risk Matrix of elements at risk to climate stresses

Elements at Risk	Tropical Cyclone	Flooding	Coastal Erosion	Drought	Sea level rise	Tidal Inundation	Sea Spray
Water supply	Y	Y	N	Y	Y	Y	Y
People	Y	Y	Y	Y	Y	Y- Coastal community	N
Agricultural crops/land	Y	Y	Y	Y	Y	Y	Y
Buildings (private, schools, churches)	Y	Y	Y	N	Y	Y	N
Livestock	N	Y	N	Y	Y	Y	N
Environment	Y	Y	Y	Y	Y	Y	Y
Power supply & Communication	Y	Y	N	N	N	Y	N
Coastal areas	Y		Y		Y	Y	
Tourist resorts,	Y	N	N	N	Y	N	N
Economy	Y	Y	Y	Y	Y	Y	Y
Cultural sites	Y	Y	N	N	Y	Y	N
Roads	Y	Y	Y	N	Y	Y	N

From this matrix it is very clear that these PACC pilot communities have a lot of vulnerable elements to climate change, sea level rise and climate related hazards. Generally speaking almost everything is exposed to the threats of these impacts from peoples lives and properties to infrastructures and economy.

Table 4.3.3 illustrates the sensitivity of identified key components of the water sector to climatic stresses. It is obvious that the two water sector components (water quality and quantity) in the PACC pilot communities are highly sensitive and vulnerable to these stresses.

Table 4.3.3: Sensitivity of selected water components to both current and future climate change, sea level rise and climate related hazards.

Water Sector Component	Sea level rise & salt water intrusion	Tropical Cyclone & Storm surge	Drought and increased temperature	Flooding	Erosion/inundation (inland & coastal)
Water Quality	high	high	high	high	high
Water Quantity	high	high	high	high	high

5. CAPACITY CONSTRAINTS

5.1. Lack of Policy/legislation/regulatory framework

*there is no national or community land use policy in place

*there is no regulatory, policy, planning framework on water resource management at national, sectoral and community level

*the water resource bill has not yet enacted

5.2. Institutional constraints

*the institutional framework for water management is often centered on the Village or District Water Committees who manage water supply (pumping and distribution) and maintenance. Each village also has a Town Officer and a District Officer. Despite of this there yet lack of coordination with national climate change committees.

*technical skills required for water resource management and monitoring are very limited.

5.3. Limited Facilities/equipments

* insufficient rainwater harvesting system in place

* cement tanks in some households do exist but with no gutterings

* water is being pumped for 15 hours only (6:00am -9:00pm) which is not sufficient to meet the communities demand. There is no pumping of water from the borehole 9:00pm to 6:00am every day

*there are four boreholes in the district but pumping of water is only done from two boreholes which cannot accommodate for the needs of these communities

5.4. Financial constraints

* limited access to funds (both internal and external resources) to sustainably manage and implement adaptation activities in these communities.

5.5. Demand exceeds supply.

*demand for water is likely to increase over the long term due to other developments. Currently there are five tourist motels/hotels, one health clinic and four primary schools who also need water. Any further development of tourism industry would put additional pressure on the water supply system.

.

5.6. Poor infrastructures/infrastructural design

* poor drainage system in place exacerbates erosional problems

* poor design of the existing coastal protection system in Kanokupolu. This system needs to be redesigned and climate proofed to adequately adapt to future salt water intrusion not only Kanolupolu but also adjacent villages.

5.7. Lack of awareness, education and training

*limited understanding and knowledge on climate change and its impacts on water resources

*lack of training on how to manage and monitor water resources in these communities

6. CAPACITY DEVELOPMENT

6.1. Improved good governance for climate change adaptation

6.1.1. Formulate regulatory and policy framework for these communities

6.1.2. Mainstream water resource issues into national, sectoral and local planning, programs, decision making and budgetary processes

6.1.3. Formulate water resource management plan

6.1.4. Water Resource Bill be enacted

6.2.Implementation of adaptation measures

6.2.1. Increase rainwater harvesting systems (private households, community water reserves)

6.2.2. Gutterings for every household

6.2.3. A 24-hour pump needs to be installed to cater the needs of the six villages.

6. 2.4. Optimally six pumps are needed to meet the demand for water uses of the six communities

6.2.5. Proper drainage systems to be installed to resolve erosional problems

6.2.6. Climate Proof the existing coastal protection system in Kanokupolu.

6.2.7. Build sea wall including the PACC pilot communities

6.3. Promote awareness raising, training and education

6.3.1.Conduct awareness and training programs in these communities in relation to climate change impacts on water resources

6.3.2. Conduct training to communities regarding ownership of the PACC Project.

6.4. Strengthen institutional partnerships

6.4.1.Enhance partnerships between the Hihifo village water committee with the people and between the Hihifo village committee with the Ministry of Environment and Climate Change and National Climate Change Committee

6.5. Ensure sustainable access to both internal and external resources

6.5.1. Prepare project proposal on climate adaptation by the communities and Ministry of Environment and Climate Change

REFERENCES

Department of Environment. National Assessment Report, 2004.

Department of Environment. Vulnerability and Adaptation Assessment on Tonga's Initial National Communication on Climate Change, 2005.

Fa'anunu, O. A report on climate and sea level trends and scenarios for climate change vulnerability assessment in Tonga, 2007, Tonga Meteorological Service, Tonga.

Fielea, K., Vulnerability Assessment Report on Water Resources, Tonga Water Board, Tonga.

Manu, V. T. (2000). Effects of cropping on soil Carbon and Nutrient availability, and the amelioration practices that enhances optimum and sustainable crop yields in Tonga. Ph. D. Thesis. University of New England, New South Wales, Australia.

Ministry of Environment and Climate Change. Vulnerability and Adaptation Assessment on Tonga's Second National Communication on Climate Change, 2010.

Ministry of Works. Community Integrated Disaster Risk Reduction Plan, 2010.

Trangmar, B. B. (1992). Chemistry, physics, and mineralogy of Tongan soils. Soil Fertility and Land Evaluation Workshop. 241p Nukuálofa, Kingdom of Tonga, (Ed B. B. Trangmar). (DSIR Land Resources, Lower Hutt.) 47-63.

Tuiafitu., L. et al., (2005). The Kingdom of Tonga's Initial National Communication in response to its commitments under the United Nations Framework Convention on Climate Change. Department of Environment, Tonga. GEF/UNDP. Published by the Climate Change Enabling Activity Project, P.O. Box 917, Nuku'alofa, Tonga.

Tuiafitu., L et al., (2010). Tonga's Joint National Action Plan on Climate Change Adaptation and Disaster Risk Management. Ministry of Environment and Climate Change, Tonga. GEF/UNDP, SOPAC. Published by Climate Change Enabling Project, P.O. Box 917, Nukualofa, Tonga and SOPAC, Suva, FIJI.